Joint Ocean Ice Study /
Beaufort Gyre Exploration Project
2019 Cruise Report

Photo by Gary Morgan

Report on the oceanographic research conducted aboard the *CCGS Louis S. St-Laurent,* September 12 to October 4, 2019 IOS Cruise ID 2019-87

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1. OVERVIEW

The Joint Ocean Ice Study (JOIS) in 2019 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 lead). The scientists from WHOI lead the Beaufort Gyre Exploration Project (BGEP, **http://www.whoi.edu/beaufortgyre/**) which maintains the Beaufort Gyre Observing System (BGOS) as part of the Arctic Observing Network (AON).

The 2019 program includes collaborations with researchers from:

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

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

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

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

Table 1. Project websites

Project	Website Address
Beaufort Gyre Observing System	www.whoi.edu/beaufortgyre
Beaufort Gyre Observing System dispatches	https://www.whoi.edu/page.do?pid=165036
Ice-Tethered Profiler buoys	www.whoi.edu/itp
Ice Mass Balance buoys	http://imb-crrel-dartmouth.org/
JOIS website from DFO	https://dfo-mpo.gc.ca/science/atsea-enmer/missions/2018/jois-eng.html

2. CRUISE SUMMARY

The JOIS science program onboard the *CCGS Louis S. St-Laurent* began September 12th and finished October 4th, 2019. The research was conducted in the Canada Basin from the Beaufort Slope in the south to 81°N by a research team of 27 people from 9 institutions from 3 countries. Of the 27 people, 11 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 conducted. Zooplankton net tows, phytoplankton and bacteria measurements were collected to examine distributions of the lower trophic levels. Underway measurements were made of the surface water. Daily dispatches were posted to the web. The location of science stations, the primary sampling at each station, and the total number of each type of station, are shown in Figure 1 below.

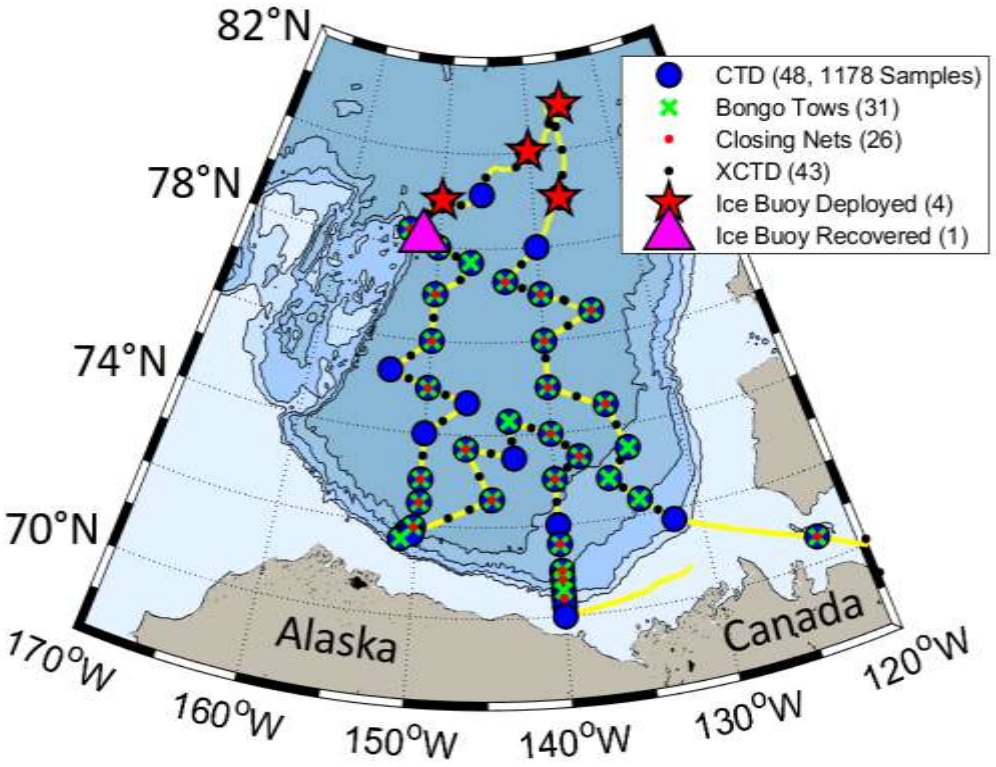

Figure 1.The JOIS-2019 cruise track showing the location of science stations.

Prior to the JOIS program, opportunistic sampling was conducted with the Canadian Hydrographic Service deploying 2 XCTD in northern Baffin Bay for the Institute of

Ocean Sciences. These XCTDs will be listed in the appendix but are not included in the JOIS report below.

Figure 2. Opportunistic sampling performed prior to the JOIS program. Sampling is not described in the report but locations of stations are given in the appendix.

2.1 Program Components

Measurements:

- At CTD/Rosette Stations:
  - 52 CTD/Rosette Casts at 48 Stations (DFO) with 1178 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, U Victoria, KIT).
  - Water samples taken:
    - At all full depth stations: Salinity, dissolved O_2 gas, Nutrients (NO_3, PO_4, SiO_4), Barium, ^{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 ^{137}Cs.
  - Mounted on the CTD/Rosette frame was an upward and downward looking ADCP to measure ocean currents and a fiber-optic gyro to determine accurate instrument heading for the ADCPs (WHOI).

- Zooplankton Vertical Net ("Bongo") Casts at 32 CTD/Rosette stations with one cast to 100m. The two nets per cast have a mesh size of 150 µm and 236 µm. (DFO).
- Zooplankton Closing Vertical Net (NORPAC net) Casts at 26 of the CTD/Rosette stations with multiple casts per station to capture depth specific layers of pteropods.

- 41 XCTD (expendable temperature, salinity and depth profiler) Casts typically to 1100m depth. 4 of these were short casts due to wire breaking on ice and were redone. 2 more XCTDs were launched in northern Baffin Bay (pre JOIS) (DFO, JAMSTEC, WHOI)

- Buoy operations
  - 1 Ship-based deployment in open water with:
    1 Ice-Tethered Profiler (ITP119, WHOI)
  - 1 Ice-Station with:
    1 Ice-Tethered Profiler w/ SAMI-CO2 (ITP117, WHOI)
    1 Seasonal Ice Mass Balance Buoy (SIMBB, CRREL)
    1 Tethered Ocean Profiler (TOP01, WHOI)
  - 1 Ice-Station with:
    1 Ice-Tethered Profiler w/ SAMI-CO2 (ITP118, WHOI)
  - 1 Ice-Station with:
    1 Ice-Tethered Profiler (ITP112, WHOI)
  - Ice-Tethered Profiler Recovery
    ITP w/ SAMI-CO2+Mcat (ITP107, WHOI)

- There were no mooring operations this year.

- Ice Observations (KIT/OSU)
  - Hourly visual ice observations from bridge with more frequent periodic photographs taken from cameras: 1 mounted on Monkey's Island looking down on the EM31, the other mounted in the bridge window looking forward..
  - Underway ice thickness measurements from an electromagnetic inductive sensor (EM31-ICE).
  - On-ice measurements at the ice-stations including:
    - Drill-hole ice thickness transects
    - Ice-cores for temperature, salinity and structure profiles
    - Ice-cores for microdiversity
    - Snow pit

- 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, UMontana). Water samples (66) were collected from the underway seawater loop for salinity and chlorophyll (DFO), DIC and Alkalinity (DFO, TUMSAT), FDOM (SherbrookeU), microbial diversity (Concordia).

- Daily dispatches to the web (WHOI)

2.2 Comments on Operation

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We were delayed reaching the ship for the start of the program but with good conditions for science operation during the cruise were able to finish in time and finish the program on our scheduled day. Delays began with a typhoon shutting down Tokyo affecting the Japanese travelers and then with fog in Kugluktuk. Instead of joining the ship Sep 10th, we were all onboard by Sep 12th and departed that evening.
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). We continued farther north than usual, up to 81N, to find suitable ice with enough distance between other buoy deployments. We then traveled back south along 150W taking measurements at our standard western stations, mostly in open water. We did not complete the 5 stations within 60nm of Barrow due to whaling season. The Alaska Eskimo Whaling Commission requested ships not to come w/in 60nm to avoid disruption of the whale migration. From 150W we turned east, finishing with the southern leg of stations along the 140W line, ending on the Canadian Beaufort Shelf. We considered recovering a beached ITP during the steam back to Kugluktuk but due to timing and weather this was not done.

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. .

See the figures below for details of the ice cover during the expedition. Figures are from the Canadian Ice Service showing Western Region Ice Concentration and Stage (source: https://iceweb1.cis.ec.gc.ca/Archive/page1.xhtml) and the National Snow and Ice Data Center showing Arctic-wide sea-ice extent (source: http://nsidc.org/arcticseaicenews/2019/09/)

Again this year we had an ice specialists from the Canadian Ice Service on board. His 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 while we were in open water from the south up to 77N. 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.

Three of the four buoys deployed were done by parking the ship within an ice floe ~1.5m thick, lowering the ladder for people to walk out to the ice. The ship's crane transferred gear. This method worked well. It got multiple science teams working quickly once the ladder was down and gave easy access to the ship for workers on the ice.

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

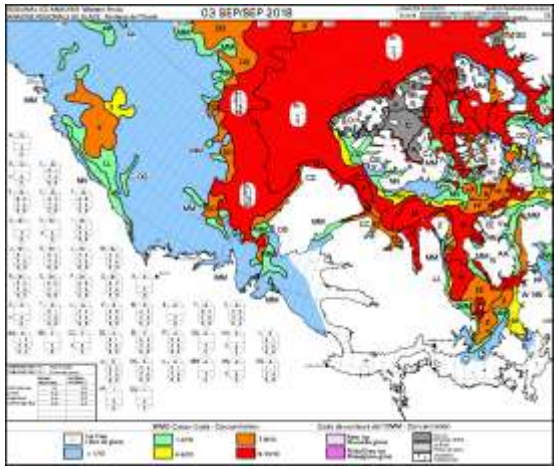


Figure 3. Sep 3, 2018 Ice Concentration

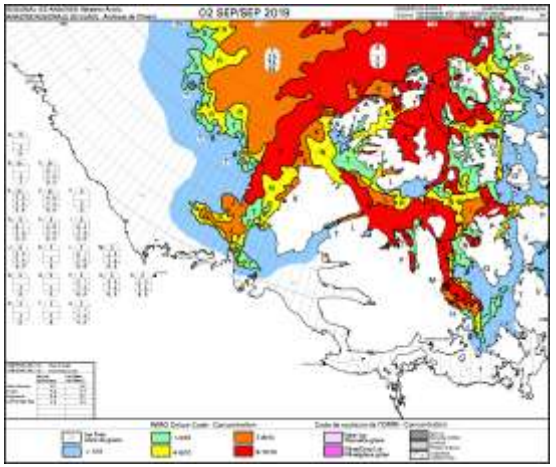


Figure 4. Sep 2, 2019 Ice Concentration

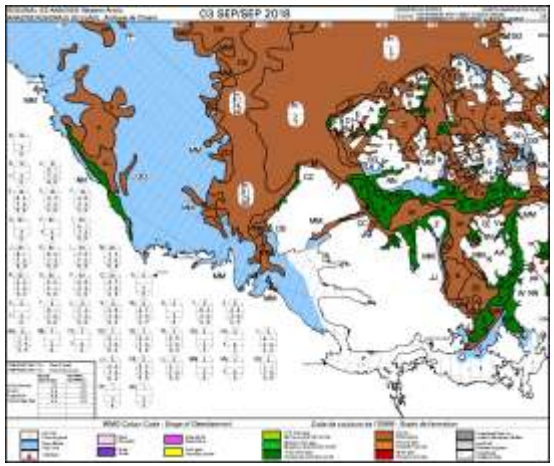


Figure 4. Sep 3, 2018 Ice Stage

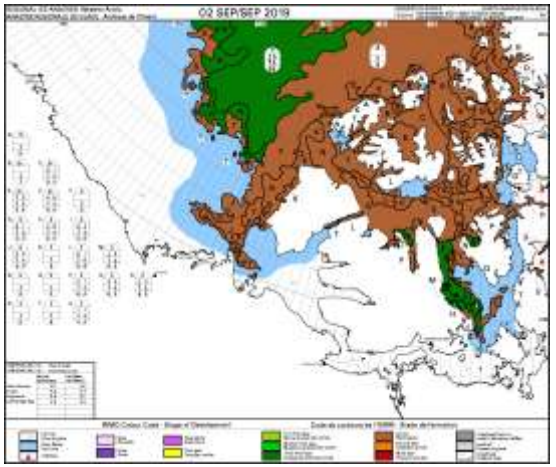


Figure 5. Sep 2, 2019 Ice Stage

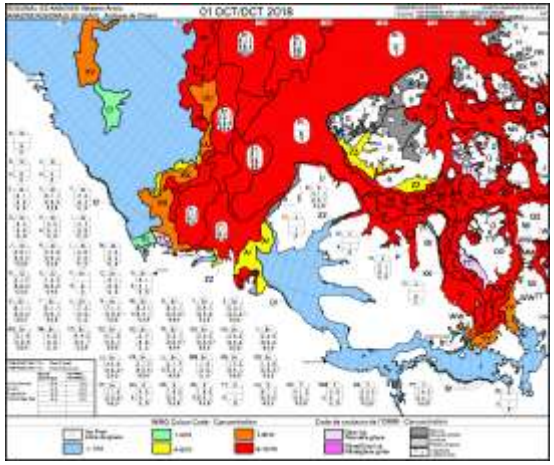


Figure 7. Oct 1, 2018 Ice Concentration

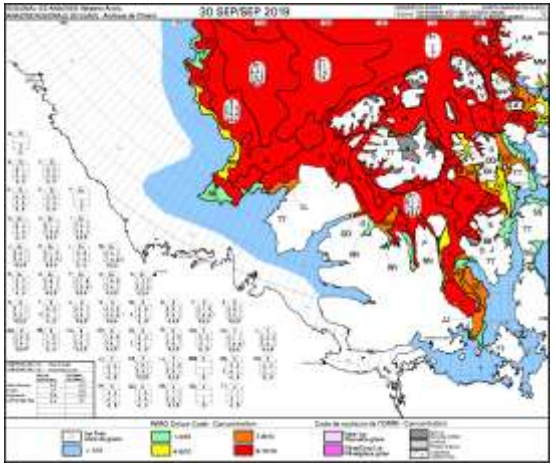


Figure 3. Sep 30, 2019 Ice Concentration

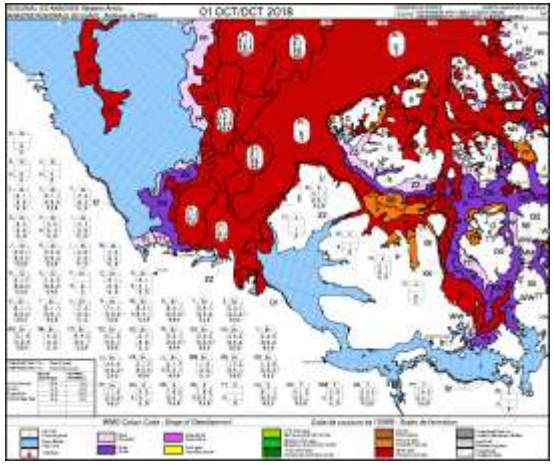


Figure8. Oct 1, 2018 Ice Stage

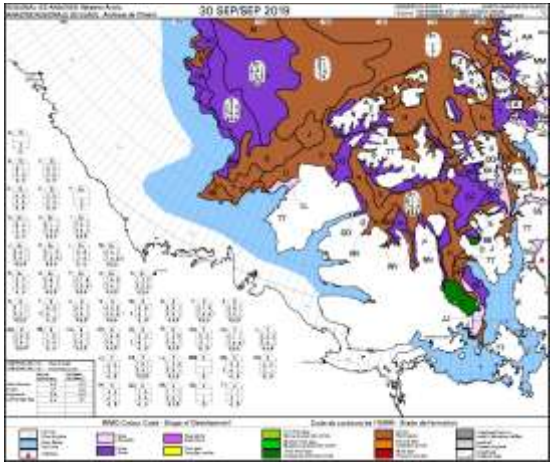


Figure 4. Sep 30, 2019 Ice Stage

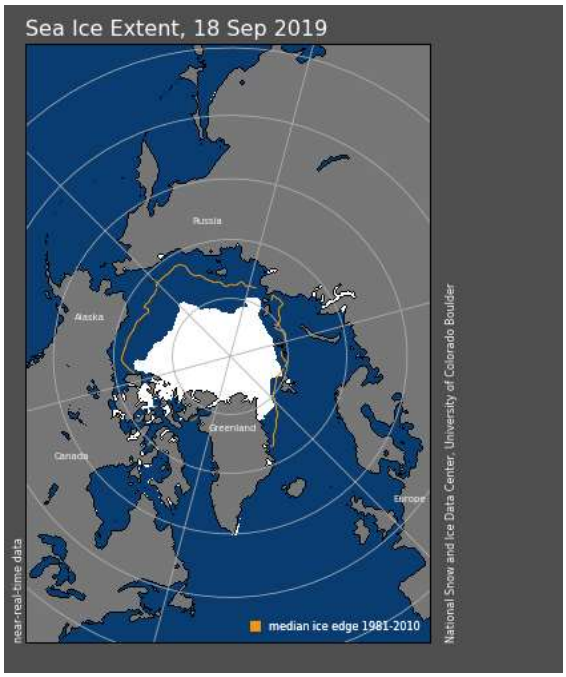


Figure 5. Sea Ice Extent mid-way through the cruise, from the National Snow and Ice Data Center

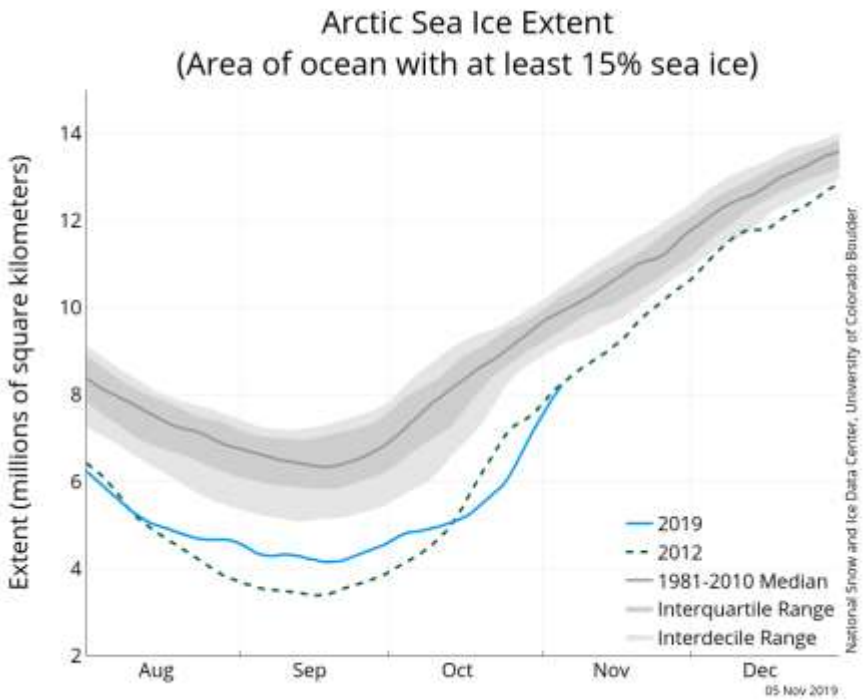


Figure 6. Sea Ice Extent from National Snow & Ice Data Center (source: http://nsidc.org/arcticseaicenews/)

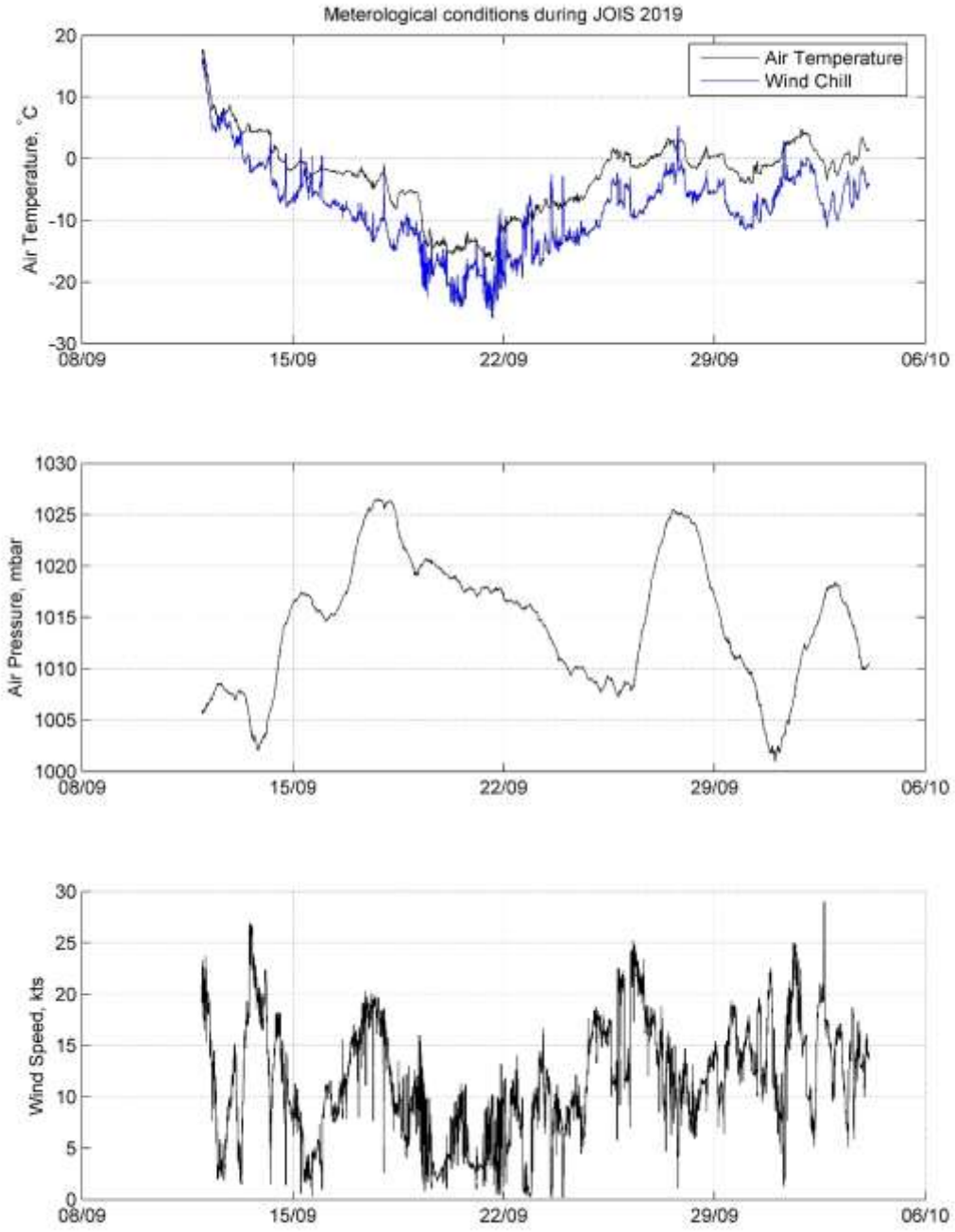


Figure 7. Temperature, air pressure and wind speed for the duration of the expedition from the AVOS weather station above the bridge of the CCGS Louis S. St-Laurent.

Completion of planned activities:

Our primary goals were met during this successful program due to efficient use of time by science and the ship, and the unflagging support from the officers and crew. We lost time with a delayed start of the program but without any further weather or equipment delays were able to complete all the planned stations. Due to whaling season sailing restrictions near Barrow we missed 5 shelf-slope stations, but used that extra time to help fill in under-sampled areas, gaining more information in the area of the Beaufort Gyre's maximum fresh-water storage, a key component of the program.

3. ACKNOWLEDGMENTS

The science team would like to thank Captains Roy Lockyer, 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. As usual, there were a lot of new faces on-board and we appreciate the effort everyone took to accommodate us and our science. Autumn 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 from the Canadian Ice Service gave daily briefings that were much appreciated. It was a pleasure to work with the helicopter pilot and mechanic and we would like to 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. We'd also like to acknowledge this year's funding participation from the Kitami Institute of Technology.

This was the program's 17th consecutive year and the exciting and valuable results are a direct result of working with such experienced, well trained and professional crews.

Figure 8. After finishing the ice station science. Photo by Gary Morgan

Figure 9. All crew and science on board. Poster made by Cassie DeFrancesco and Catherine Buschhaus.

4. PROGRAM COMPONENT DESCRIPTIONS

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

4.1 Rosette/CTD Casts

PI: Bill Williams (DFO-IOS)
Chris Clarke (DFO-IOS) Stephen Page (DFO-IOS), Peter Van Buren (DFO-IOS)

4.1.1 Overview

A Seabird 9/11 CTD system was used with SBE9 s/n 756 used 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.

Our rosette frame has also been substantially modified since JOIS 2017 to accommodate extra instrumentation added by Woods Hole Oceanographic Institute (WHOI). The added instrumentation included upward looking RDI WHS300 LADCP, downward facing RDI WHS150 LADCP, a fibre optic gyro (FOG), and a DSPL Sea Battery.

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 was mounted beside the other SPAR unit to be used to periodically to provide 1hz data. These 1-minute averaged data are reported with the underway suite of sensors.

During a typical station there would be a CTD cast to 10 m off the seafloor. While in the water, at most stations, one or more zooplankton vertical net hauls (bongo nets and closing NORPAC nets) would occur from the foredeck. On a few occasions, repeat CTD casts were carried out to 1000m or less for specialty large volume water sampling (microbial diversity, Cs isotope). Repeat casts were also done at some BGOS mooring sites for calibration of the SAMI and WQM instruments installed on the moorings. . During JOIS 2019, there were a total of 52 CTD/Rosette casts.

Prior to JOIS cruise 2019, the SBE3plus temperature and SBE4c conductivity on the primary SBE 9 were returned for re-calibration by the factories in November 2018. The SBE43 oxygen sensor on the primary SBE 9 was calibrated by Seabird in August 2019. The altimeter was new in 2016. In addition, other sensors were checked for functionality and the plumbing tubing renewed and checked for functionality.

Figure 10. The rosette showing the addition of LADCPs and orange battery back and FOG logger. The CTD is hidden behind the Niskin bottles.

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. Most Niskin bottles were normally closed during the upcast without a stop. For surface bottles, calibration casts, and some shorter high volume casts, 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 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.

It is noted that the WHOI instrumentation, specifically the gyro, was not tied into our SBE9 connections this year. In 2017 and 2018, the gyro was tied into our secondary SBE3plus temperature and SBE4c conductivity sensors via y-cables in order to receive this data, but was not required this year.

4.1.3 Performance notes

Assembly - Niskins

Due to the added instrumentation on the rosette, we had to cock some of the Niskins bottom end caps to the side rather than straight back. In addition, we re-routed the lanyard on Niskin 13 to cock the bottle outward due to the positioning of WHOI's LADCP. This was something to double check each deployment, as there were more ways to catch the Niskin's lanyard than usual.

Assembly – Sensors

The CDOM sensor, altimeter, and transmissometer were mounted in the same positions as 2017 to allow space for LADCP installation.

Assembly – Prototype CTD

Jeff O'Brien (WHOI) intended to install a prototype CTD and underwater battery on the rosette this year, but due to issues with the oil-filled sensor leaking, it was not installed.. Mounting holes were drilled in the lower frame, and can be used in the future if needed.

Assembly – CTD

We used SBE9plus s/n 756 as our main CTD for JOIS 2019. SBE9plus s/n 724 was going to be our main CTD for JOIS 2019, but during the initial setup and testing of the rosette, the seacable power was plugged into the wrong bulkhead connector (JB6 bottom contact switch instead of JT1 power) on the CTD. The SBE 11 deck unit (s/n 680) did not recognize or power the CTD, and after a few minutes of trying to determine the issue, the deck unit started its warning signal. Deck unit power was turned off immediately following warning signal. Deck unit fuses were checked, and the 0.5A fuse was blown. This fuse was replaced, and when powered on again, the warning signal persisted and power was turned off immediately. It was then determined the sea cable was plugged into the wrong bulkhead connector (JB6). Seacable was unplugged and replugged into correct bulkhead connector (JT1). When powering on the deck unit, warning signal persists and power is turned off. The spare SBE11 deck unit (s/n 649) is swapped in, and when powered on, the warning signal comes on immediately and deck unit is powered down. We then tried the cheater deck cable instead of the sea cable, and both deck units have the same result. Decide to try spare CTD SBE9plus s/n 756, and the system works immediately with main deck unit s/n 680 and seacable.

It was determined after talking with Seabird and Mike Dempsey that it is likely that one of the three boards on the bottom end of SBE9plus s/n 724 is damaged, and the CTD will need to be returned to Seabird for repair.

SBE9plus s/n 756 performed well throughout the cruise, and there were no further issues with the CTD.

Pylon/ Water Sampler

Generally the system performed well. A new 24 position pylon (s/n 1231) was installed and performed near flawlessly. In comparison to previous years, the trigger mechanism did not need to be removed to be cleaned nearly as often. The trigger mechanism was removed and cleaned once prior to ITP1 ROS14 for posterity.

WHOI Instruments

The LADCP, Sea Battery and Fibre Optic Gyro (FOG) were installed for the entirety of the JOIS 2019 cruise.

Niskin configuration

Replaced Niskin 8 spigot, vent, and o-rings after CB16 ROS13 due to leaking spigot.
Replaced Niskin 8 entirely after CB11 ROS19, as the leaking issue had not resolved. Suspect a cracked mount.
Replaced Niskin 19 due to persistent leaking.
Replaced Niskin 15 after CB21 ROS42 due to persistent leaking.
Niskin lanyard lengths were modified through cruise to maintain consistent top and bottom cap openings.

Seacable re-termination

The wire on the main winch was first noticed to have developed a proud strand prior to BL8 ROS33 when the wire started to spin up on deck before cast. This is likely due to the high winds and reasonably large swell from the previous few days. Strand did not seem like a safety concern and did not affect CTD data, so it was decided to be used for the BL line, and to be re-terminated on the 12+ hr transit to STN-A. We did four casts (BL8/BL7/BL6/BL7a-Cs; ROS33-ROS36) with the proud strand. We pulled off 400m of wire (proud strand had migrated ~350m up wire, took off an extra ~50m to be safe) and re-terminated. First station after re-termination (STN-A ROS37) wire worked well and data looks good. Termination locked in after ~1/8" slide down wire wraps.

Seasave and CTD data

Seasave crashed during upcast of CB22 ROS43 at ~215m. Seasave was rebooted at ~187m, and bottle 15 was not fired due to this discrepancy. It is suspected that Seasave had been left open too long, and the computer's RAM memory was full or perhaps a second copy of Seasave was also open in the background. Other issues that point to a problem in RAM was a significant lag when firing bottles, as well as IOS label program

running extremely slow. After this point, Seasave was not left open for more than a couple casts at a time.

Transmissometer

Transmissometer was thought to be a bit noisy, and seemed to be getting a bit worse through the cruise. After re-terminating prior to STN-A ROS37, as well as cleaning the windows with soap prior to CB21 ROS42, noisiness seemed to be reduced.

Altimeter

Altimeter s/n 72144 performed fairly well throughout cruise. Most stations had it kicking in around 70m from bottom. Some stations it picked up the bottom at 100m, and others it would kick in around 30m. We did not have any total failures of the altimeter. It should be noted that due to interference with the ADCP installed on the rosette, there were frequent false positives throughout the water column.

Conductivity cell

On CB15 ROS11, Sarah noticed an offset in the secondary conductivity cell when compared to the primary. This offset did not persist in further casts. It was quite cold out, so it is possible that fresh DMQ water froze in the cell on deck. Procedure was reiterated to watchkeepers to not take the rosette out of the rosette shack until completely ready to go overboard, especially in sub-zero temperatures.

Bottom contact

On CB10 ROS20, the rosette touched bottom due to being on a steep slope and the ship drifting upslope. The CTD operator failed to see the reducing altimeter readings, and the winch operator was assisting the person standing watch to put on the ice chummy. Once realizing the rosette had touched bottom, it was raised off the bottom slowly and the altimeter kicked in at 1-2m almost immediately. After retrieval, a small amount of mud was seen in the bottommost ring of the rosette under Niskins 18-20. No sensors touched bottom (confirmed by Sarah/data). It was determined that there was no wire damage.

Winch and Conducting Cable

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 2014 and ~6500 remained on the drum in 2018. We were unable to find the most recent logbook of wire terminations prior to JOIS 2019, so after cutting off 400m during JOIS 2019 cruise for re-termination, it is suspected that ~6000m of wire remains on the winch.

The winch was returned to IOS after JOIS 2018 for service on the hydraulics and braking system. The winch performed quite well throughout the cruise, and we had no issues with the hydraulics leaking or the hydraulic brake function, however, around CB40 ROS7, the winch developed a loud squeal during upcast from the brake pad/hydraulic brake. It was determined that something had likely fallen into the open space behind the

hydraulic adjustment wheel, been sucked up into the brake, and gotten lodged between the brake pad and the clamping mechanism. A small groove developed (~1cm across) in the brake pad. This did not affect brake function and as we did not have a replacement brake pad, it was determined after talking with the senior engineer that it was not worth pulling the winch apart to dislodge the obstruction unless the obstruction migrated and the groove widened, as the damage had already been done. After a few casts, the squealing lessened and the groove did not widen or move.

Figure. Brooke Ocean Technology IMS winch display
Figure. Operation of the Hawbolt oceanographic winch. Photos from prior years similar to 2019.

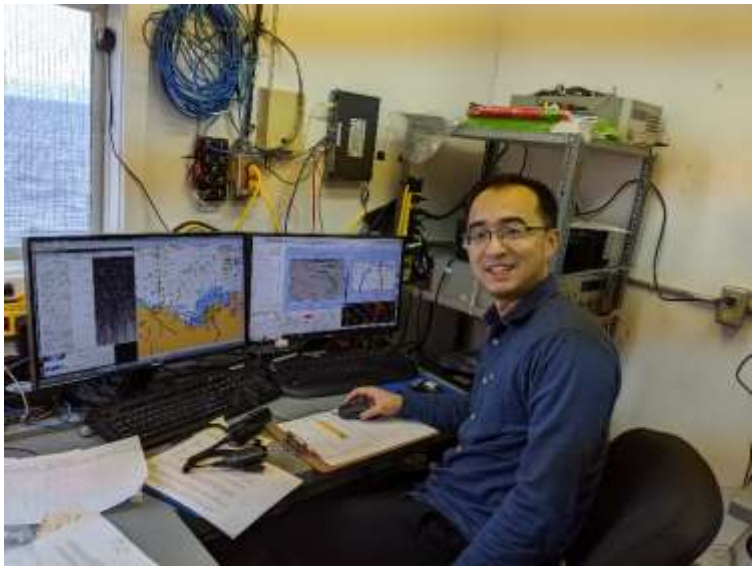


Figure 11. CTD data acquisition carried out by Bingkun Luo.

See appendix for CTD sensor configuration and calibration information.

4.2 Lowered ADCP, FOGLogger Report

P.I. Daniel J. Torres for LADCP and FOGLogger (WHOI)
Marshall Swartz (at –sea lead), Jasmine (Jian) Zhu (WHOI)

Figure 1. CTD Rosette with LADCP and FOGLogger

LADCP/FOGLogger System

On JOIS 2019, the IOS CTD rosette was outfitted with a Lowered ADCP (LADCP) system provided by Woods Hole Oceanographic Institution (WHOI.) The instruments provided LADCP observations on 48 of the 52 CTD rosette stations occupied during the cruise.

The LADCPs are designed to acoustically measure currents to determine absolute velocity current profiles during a rosette cast. The LADCP system installed on this rosette

consisted of an upward facing Teledyne RDI 300 kHz ADCP, a downward facing 150 kHz ADCP, and an external 48 V 20 Amp-hr rechargeable pressure-compensated AGM lead-acid battery pack. Additionally, a combined fiber-optic gyrocompass and ADCP data logger (FOGLogger) was installed to permit more accurate ADCP headings at high latitudes and enable faster data off-loads from the ADCP measurements at the end of a station.

The FOGLogger is a WHOI-developed rosette-mounted gyrocompass and data logger system housed within a 6000m rated pressure case. The core of the instrument is a KVH model 1775 3-axis fiber-optic inertial navigation system (INS) gyrocompass with a 3-axis magnetometer and a 3-axis accelerometer. An on-board PC104-based Linux computer running Ubuntu 16.05 Server Edition with a 1 TB SSD drive acquires and stores the KVH INS and ADCP data streams. A data acquisition program running on the PC104 logs the incoming gyro data at 5 kHz and the two incoming ADCP data streams at 1 Hz. Each sample is uniquely time stamped with a clock from the PC104 computer that has been time- synchronized prior to each cast with the shipboard Linux downloading computer.

The FOGLogger is powered by a Deep Sea Power and Light (DSPL) rechargeable 48 volt 18 amp-hour AGM battery sealed inside a pressure-balanced oil-filled polyethylene case (model SB48-20). This battery has sufficient capacity to operate the two ADCPs and the FOGLogger for at least 8 hours before discharging to 50% capacity. When on deck and still connected to the FOGLogger, the battery is charged by a charger located in the CTD control shack using separate cable provided for this purpose. The charge cable is normally dummied off at the rosette, but while in charge mode, the charging cable is attached to a charge lead cable on the FOGLogger. The FOGLogger and ADCPs thus stay continuously powered up (in standby mode on deck) for normal operations over many stations, or the entire cruise in some cases. The charger is an American Reliance LPS-305 power supply used in constant voltage mode set to 54.0V.

The download Linux computer is a Slimpro Mini-PC running Ubuntu Linux 16.30. SSH is used to communicate with the PC104 Linux operating system on the FOGLogger. The download computer stores all transferred files on an internal drive. It is not connected to an external network so it will not be affected by other network traffic.

While the rosette is in the hangar, the FOGLogger communicates over a wired Gigabit Ethernet with the download and control computer located in the CTD control shack. This Linux computer is used to configure the FOGlogger and ADCPs before each station, and to off-load the acquired ADCP and FOGLogger data after recovery of the rosette. A weatherproof Cat-6 Ethernet extension cable runs from the download computer inside the CTD control shack, under the deployment platform and into the rosette hangar. At the rosette, the Ethernet and the charge cables are attached to the data transfer and charge line pigtails plugged in to the FOGLogger endcap between stations.

Summary of rosette-mounted equipment:

Instrument	Function	When used
RDI WHM300-1-SP s/n 1412	Upward ADCP	All stations.
RDI WHS-150 s/n 14643	Downward ADCP	All stations.
WHOI FOGLogger s/n 1	INS gyro and logging	All stations.
DSPL SeaBattery 48-18 s/n SB-010009 (#2)	Rechargeable underwater battery	All stations.

Figure 2. Clockwise from top left. (a) 150 kHz down-facing ADCP; (b) 300 kHz upward-facing ADCP; (c) top view of the FOGLogger; (d) Bottles removed to show the FOGLogger installed into the rosette beside the 48-volt battery.

Deployment and Recovery Procedures

While the rosette is in the hangar, the FOGLogger communicates over a wired Gigabit Ethernet with the download and control computer located in the CTD control shack. This Linux computer is used to configure the FOGlogger and ADCPs before each station, and to off-load the acquired ADCP and FOGLogger data after recovery of the rosette. A weatherproof Cat-6 Ethernet extension cable runs from the download computer inside the CTD control shack, under the deployment platform and into the rosette hangar. At the rosette, the Ethernet and the charge cables are attached to the data transfer and charge line pigtails plugged in to the FOGLogger endcap between stations.

Preparing for a station, the operator in the CTD control shack starts a script on the download Linux computer to initiate communications with the FOGLogger and ADCPs. The scripts provide for custom setup of the ADCPs, time synchronization and testing, and start the ADCPs and FOGlogger data logging programs.

When the operator confirms the system is ready to deploy, at the rosette hangar the Ethernet and charge cables are disconnected and replaced with dummy plugs just prior to deployment. At this point the LADCP and FOGlogger gyro data are logging continuously during the cast on the FOGLogger PC104 computer until recovery, or when the battery runs out.

Upon rosette recovery, the Ethernet transfer and battery charge cables are re-connected at the rosette inside the hangar. In the CTD control shack, on the download Linux computer, the PC104 logging programs are gracefully ended by the operator. A program based on the Linux utility rsync is used to transfer data from the FOGLogger PC104 to the data acquisition computer in the CTD shack. The LADCP/FOGLogger

collects approximately 10.6 GB data per 1 hour of cast time, with a typical 3500m cast collecting approximately 32 GB data. Data are transferred using Ethernet data rate of approximately 1.5 GB/ Minute. A 35 GB station takes approximately 23 minutes to download. A final rsync script serves to back up and verify the downloaded data from the Linux computer's internal drive onto three separate external 4TB hard drives to complete the process and verify archival data.

Data Collected

A total of 48 LADCP/FOGLogger station datasets were collected on the 2019 JOIS cruise during the 52 CTD rosette stations occupied. Two stations were not sampled (ROS-01 and ROS-02 at AG5) due to insufficient time to complete setup on joining the ship, and two were purposely not sampled (ROS-27 and ROS-41 at CB4-DNA and CB21-DNA, respectively) as they were shallow casts taken immediately prior to a deep station at the same location. The station time and location data come from the CTD station data record and are not duplicated here.

ADCP and FOGlogger data were backed up immediately after each station onto three separate external hard drives for return to WHOI, along with pertinent metadata acquired during each station from the CTD processed datafiles and the ship's navigation data (NMEA-formatted GPS strings for position and heading.)

All data are being returned to WHOI for processing and quality control, merging the ADCP and the FOGLogger heading data and producing the final dataset.

Issues

The internal clocks of both the FOGLogger PC104 and the shack-based Linux computer required frequent adjustment for small slewing errors, and when a shipboard power failure shut down the download Linux computer in the CTD shack.

The first 300 kHz ADCP (s/n 4896) installed onto the rosette in the upward position failed to respond to commands during preparation testing, despite having been tested and verified ok prior to shipment from WHOI. There was no visible damage. This was exchanged for a spare identical unit. It is expected this instrument will return to RDI for inspection and repair.

4.3 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 for Main CTD/Rosette

Parameter	Canada Basin Casts	Depths (m)	n (dup, trip)	Analyzed	Investigator
Dissolved Oxygen	*All	Full depth	1016 (114, 18)	Onboard	Bill Williams (IOS)
DIC/alkalinity	2-7, 10, 12, 14-15, 19-22, 27, 29-30, 32-36, 38-41, 43, 46, 48-50	5-450			
	8-9, 11, 13, 17, 22, 28, 31, 37, 42, 44-45, 47, 51-52	Full depth	741 (58)	Onboard	Bill Williams (IOS)
CDOM	*All	5-500, 1000, 2000, 2500, Bot-10	379	Onboard	Celine Gueguen (USherbrooke)
Chl-*a*	*All	5-250			
	15	5-400	344 (204)	Shore lab	Bill Williams (IOS)
Bacteria	*All	Full depth	1010	Shore lab	Connie Lovejoy (Ulaval)
Nutrients	*All	Full depth	1030 (127)	Onboard and Shore lab	Bill Williams (IOS)
Salinity	All	Full depth	1175 (117)	Onboard	Bill Williams (IOS)
$\delta^{18}O$	2-7, 10, 14-15, 18-21, 23-26, 29-35, 38-40, 43, 46, 48-50	5-450			
	8-9, 11, 13, 17, 22, 28, 37, 42, 44, 45, 47	Full depth	740 (62)	Shore lab	Bill Williams (IOS)
Barium	*All	5-430	487 (34)	Shore lab	Billl Williams or Christopher Guay (PMST)
DOM	15, 17-19	425, 1000, 2000, Bot-10	20	Shore lab	Celine Gueguen (USherbrooke)
DNA/RNA	1, 16, 27, 41	5-1000, Bot-10	**86	Shore lab	Connie Lovejoy (Ulaval)

	4, 6-7, 9-11, 13-14, 19-20, 22, 25, 30-31, 33, 37, 44, 47	Full depth			
^{129}I	10-12, 20, 23, 37	Full depth		Shore lab	John Smith (DFO-BIO)
^{134}Cs	36	5, 100, 180		Shore lab	John Smith (DFO-BIO)

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

4.3.1 Iodine-129, Cesium-134

Sampling by CTD Watch
P.I.: John Smith (DFO-BIO)

Sampling was performed for two radionuclides ^{129}I and ^{134}Cs 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.

Measurements for ^{134}Cs in the upper water column of one station near the entry of Pacific derived waters to the Canada Basin will indicate if any water from near the Fukashima nuclear reactor spill of 2011 has entered the Arctic.

Samples for ^{129}I were collected into 500mL Nalgene bottles with lids taped shut to prevent leaks. Ideally two bottles should have been filled per sample for a total of 1L but this was not done. Samples for ^{134}Cs were taken at 3 depths, 60L per sample and collected into 20L plastic bottles. Salinity samples were taken from each Niskin to compare with CTD salinity to confirm the bottle trip location. Isotope samples were stored between 4C and room temperature until analysis on shore at Bedford Institute of Oceanography (DFO).

4.3.2 Chromophoric Dissolved Organic Matter Sampling

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

4.3.2.1 *Summary*

Chromophoric Dissolved Organic Matter (CDOM) samples were collected for Celine Guéguen (USherbrooke), following the protocol given below. A total of 402 samples were collected at 44 stations and 41 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 2019.

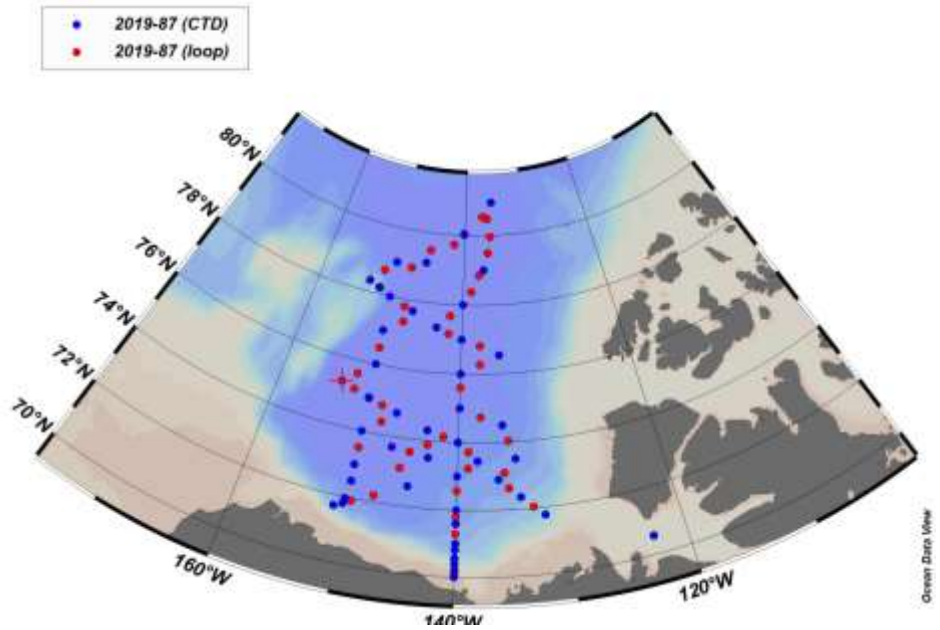


Figure 1: Map of the Arctic Ocean representing the sampling sites of the CTD stations (blue) and the loop samples (red).

4.3.2.2 *Rosette Casts Samples*

Samples > 200m

The bottom spigot of Niskin was opened to allow stream of seawater to flush the 40 mL amber glass vial used for CDOM 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 CBN1, NE-1, CBN3, CB11 and CB10. The samples were solid phase extracted immediately after collection.

20L water samples were collected for lignin phenol analysis at loop depth (~7m) between CB11 and CB10, at RN7, between CB4 and CB6, and between CB6 and CB3 . The samples were solid phase extracted immediately after collection.

Samples <200m

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

4.3.2.3 *Underway Samples*

Forty one CDOM samples were collected from the underway system while the ship was steaming, at a frequency of approximately 2-3X per day. Seawater from the TSG outlet was used to flush the 40 mL amber glass vial used for CDOM sampling. Vials and caps were rinsed 3X with sample before collecting the actual sample. Upon collection of each sample from the underway system, CDOM sensor reading (volts), latitude, longitude, UTC time, sample ID etc. was noted.

4.3.2.4 *Storage and Analysis*

After collection, CDOM samples were immediately transported to the 4°C walk-in walk-in fridge where they were stored in the dark in a tote until analysis. The CAA samples from Casts 2 to 14 were analysed on the Aqualog spectrofluorometer on September 07-09, 2018. The Canada Basin samples were analysed onboard within 12h of collection. The 5-m and chlorophyll maximum samples at the BL and MK stations were also analysed on a portable fluorometer. The results will be compared to those obtained using the Aqualog spectrofluorometer.

The DOM extracts were stored in the -20°C freezer and transferred to Trent University for analysis.

After collection, CDOM samples were immediately transported to the 4°C walk-in fridge where they were stored in the dark until analysis. The Canada Basin samples were analysed onboard within 12h of collection.

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

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

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

Oxygen isotopes, ^{16}O and ^{18}O, are two common, naturally occurring oxygen isotopes. Through the meteoric water cycle of evaporation and precipitation, the lighter weight ^{16}O is selected preferentially during evaporation, resulting in a larger fraction of ^{16}O in

meteoric water than in the source water (i.e. seawater). Sea-ice formation and melt on the other hand, only changes the source water's $^{18}O/^{16}O$ ratio (noted as $\delta^{18}O$) slightly. River water is fed from meteoric sources and thus the $\delta^{18}O$ is a valuable tool used in the Arctic Ocean to distinguish between fresh water from river (meteoric) sources and from sea-ice melt.

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

4.3.4 Dissoved Inorganic Carbon

Cassie DeFrancesco (DFO-IOS), Marty Davelaar (DFO, IOS)
P.I.: Bill Williams (DFO-IOS)

Samples for DIC and Alkalinity analysis were collected into 250 mL glass bottles. The bottle was filled smoothly from the bottom (tubing touching the bottom of the bottle) and the bottle overflowed by two times its volume. One percent of the stoppered sample volume was removed to leave a headspace (about 1 % of the bottle volume - i.e., 2.5 mL for a 250 mL bottle) by inserting a nylon plug into the bottle Since most of the samples on this cruise were analyzed within 2 days, mercuric chloride (HgCl2) and grease were not used to help preserve the samples. Instead a Teflon stopper was used to seal the bottle. Samples were stored at 4°C until analysis. DIC, then alkalinity were measured from the same sample.

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

At the start of each day, seawater was run through the system to condition the cell. Next a system blank is started. If the blank is below 0.90 □g Carbon or approximately 360 counts in a ten minute period a Dickson CRM sample is analyzed to confirm the system is working properly. For each analysis (standard or sample) a peristaltic pump is used to pull the sample out of the bottle and into the water-jacketed calibrated pipette. The water from the pipette is then forced into a scrubber compartment with UHP nitrogen to which approximately 0.5 mL of 8.5 % ortho-phosphoric acid had been added. UHP nitrogen is

then pushed through a bottom mounted frit, the nitrogen pushes the CO2 which has been stripped from the sample by the acid through a Peltier cooler and an Orbo-53 tube which are used to keep water vapor and impurities from entering the cell where the CO2 is titrated The coulometer was operated in the counts mode. The software then uses the counts total along with the pipette's temperature, the salinity of the water and other constants to calculate the □mol/kg value of each sample.

At the start of each sample or standard, the system is rinsed twice with the sample being analyzed and a system clear check is performed to ensure there is no CO2 in the system. The final concentrations are calibrated with the daily measured Dickson CRM where:

corrected value = (raw value * certified CRM value)
(Daily CRM measured value)

When runs were taking longer than the average eight minutes and the system was having difficulty finding the endpoints, the Orbotube would be changed to allow for better gas flow into the sample.

Precision, Standards, and Blanks

Chemistry Sample	Precision (s_p)	Units	Number of Replicates (n)	Outliers removed	Minimum Range	Maximum Range	Accuracy (%recovery)
DIC	2.54	µmol/kg	55	0	1816.228	2234.157	100.008

4.3.5 Alkalinity

P.I.: Michiyo Yamamoto-Kawai (TUMSAT, michiyo@kaiyodai.ac.jp)
Yuanxin Zhang (TUMSAT, yxzhang930803@gmail.com)

4.3.5.1 ***Sampling***

During the 2019 JOIS cruise, seawater samples were collected for DIC/alkalinity analysis from 0-350m of the water column at most of CTD/R stations into 250 ml glass bottles. At selected stations, deeper samples (0-bottom) were also taken. Since all of the samples on this cruise were analyzed within two days, mercuric chloride was not used to help preserve the samples, instead a Teflon stopper was used to seal the bottle. A total 798 samples were collected from Niskin bottles, 2 were lost. Of these, 57 samples were taken in duplicate.

4.3.5.2 ***Analysis***

Samples were analyzed for DIC first, and then seawater left in the bottle was analyzed for alkalinity on board. Samples were put in water bath (25 °C) at least 20 minutes before being analyzed. The total alkalinity was determined by potentiometric titration using 0.1N HCl using an open cell system named ATT-05 based on DOE (1994). Alkalinity values are reported in units of µmol/kg.

At the start of each batch, seawater was run through the system to condition the instruments. Once the system appeared to be working well, certified reference material (CRM) was run to confirm proper operation. The concentration of acid was chosen to give the assigned alkalinity values for CRM. 70mL of seawater was transferred from the sample bottle to a glass beaker by using a glass syringe equipped with a stopper to take a same volume of sample water every time. An initial amount (ranged from 1.5 to 1.7 mL) of the HCl was added to the seawater and then 0.05 ml aliquots of acid were added to the seawater until a pH of below 3.6 was obtained. The sample was then stirred for 600 seconds to degas CO2, the reading of pH (EMF) and addition of 0.05 mL of acid were repeated until a final pH of below 2.995 was reached.

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

4.3.5.3 ***Precision and Standards***

Table Water Sample Precision

Chemistry Sample	Precision (s_p)	Units	Number of Replicates (n)	Minimum Range	Maximum Range
Alkalinity (from DIC sample)	2.80	µmol/kg	57	1880.0	2308.7

The accuracy of the alkalinity analysis was assured by daily analysis of certified reference material (batch #178, concentration of S=33.782, alkalinity=2216.53 µmol/kg; DOE 1994; Dickson 2001; Dickson et al. 2003) supplied by Andrew Dickson (Scripps Institute of Oceanography, San Diego, USA). Precision is given by the pooled standard deviation (s_p) of sample duplicates and was 2.80µmol/kg, where n = 57 pairs.

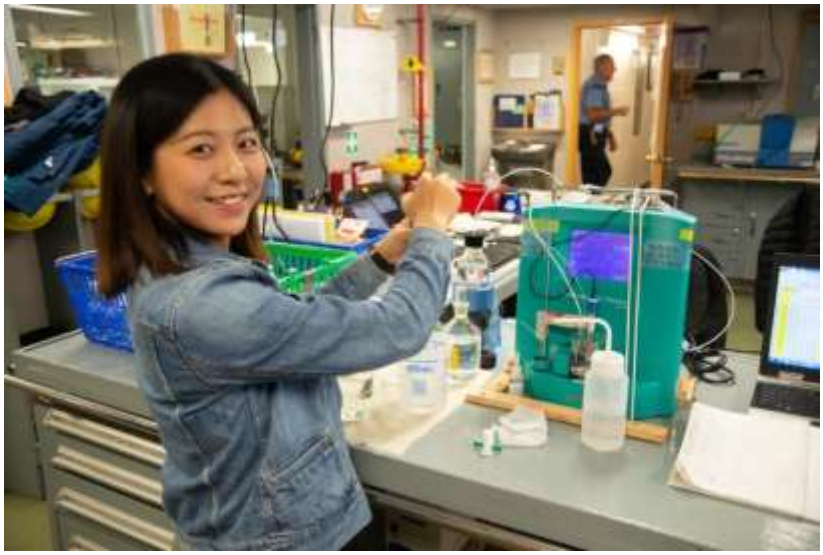


Figure 12. Alkalinity analysis. Photo by Fred Marin.

4.3.5.4 ***References***

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

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

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

4.3.6 Nutrients

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

Nutrient samples (nitrate plus nitrite, silicate and orthophosphate) were collected into 15 mL polystyrene test tubes. One set of samples were analysed onboard, while the other complete set was frozen at -20°C for checks on shore if needed. Ideally, the first set was analyzed within 12-24 hours from collection. Samples were analysed using a three channel Auto-Analyzer 3 (Seal Analytical, AA3), following the methods described by the manufacturer.

Silicate and Nitrate Analysis: It seems like the silicate and nitrate primary standard prepared at IOS were bad, as the Kanso CRM was reading lower than when tested at IOS.

I prepared a fresh batch on board with pre-weighted dried Na2SiF6 and KNO3 on 8 September 2019.

Figure 13. Nutrients analysis on the AA3. Photo by Fred Marin.

4.3.7 Dissolved Oxygen

Kenny Scozzafava (DFO-IOS)
P.I.: Bill Williams (DFO-IOS)

Oxygen samples were collected in 125 mL calibrated ground glass stoppered iodine flasks. Samples were analyzed on board within 48 hours using an automated Scripps Institution of Oceanography (SIO) Winkler-based UV titration system, consisting of: laptop with LVO2 software, 2 Brinkmann 665 Dosimats, a pencil UV lamp, a UV100BQ photodiode detector, a mini stirrer with a water bath sample holder mounted on top, 2 Platinum Resistance Thermometers (PRT) to monitor solution temperatures, and an analogue to digital converter to convert voltages from the detector and the 2 PRTs, to a digital signal. The methodology followed was as described in the SIO Oxygen Titration Manual Version 10-Apr-2003.

Figure 14. Oxygen sampling from the rosette. Photo by Fred Marin.

4.3.8 Salinity

Peter Van Buren, Chris Clarke, and Stephen Page (DFO-IOS)
Marshall Swartz (WHOI)
P.I.: Bill Williams (DFO-IOS)

Salinity samples were collected in 200 mL type II glass bottles with screw caps and disposable plastic inserts. 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.

Standby number instability: There were a few occasions where the standby number had a significant change and required adjustments to the potentiometer. Temperature fluctuation in the lab was the likely cause for the standby number to change but in general, the standby number would always return to a value close to 24+6038 where it began at the start of the field trip.

Conductivity ratio instability: Occasional random spiking of the conductivity reading was observed whereby the reading would jump upwards by an order of magnitude or more. The cause of this could not be determined but a thorough cleaning of the conductivity cell using CLR at full strength followed by ethanol seemed to help reduce the number of times this phenomenon occurred. It may be coincidental that this tended to happen after a prolonged analysis period.

Bath temperature logging bug: On a few occasions, the salinometer software logged 3°C in the bath temperature column regardless of the bath temperature setting (24°C). Analysts suspected it was perhaps a power supply related issue and seemed to have no ill effect on the accuracy of the measurement. The problem was seemingly random.

Copepod inside conductivity cell: A copepod ended up inside the cell and would not evacuate even with numerous flushes of the conductivity cell. Analysts suspected that the copepod was eventually reduced to a white particle that flowed in and out of coil arm 1. It did not seem to pose a problem and readings remained relatively stable regardless of its presence.

4.3.9 Chlorophyll-a

Edmand Fok (DFO-IOS), Bingkun Luo (University of Miami)
P.I.: Bill Williams (DFO-IOS)
Total Chlorophyll-a (>0.7um) samples were collected into brown 1-L polyethylene bottles. 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 at IOS.

A total of 577 samples from 52 stations were collected, of which 438 were in duplicates. For 12 of these samples, the samples were thrown because of running dry. For 3 of these samples, the result may inaccurate because of leaking. Problems maintaining a rapid drainage rate were intermittently experienced causing much slower-than-average filtration times (2-3 hours in some cases).

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.

4.3.10 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. 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 (TrentU) and Cassie DeFrancesco (TrentU).

Samples were initially collected into 10mL scintillation vials . 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: For the first few stations, Ros1 to Ros11, AG5 to CB15, 100 uL of paraformaldehyde was added to 1.8 mL of sea water in the cryogenic vial instead of 200uL. The pipet was not working properly.

4.4 Moorings and Buoys

Jeff O'Brien (WHOI-Lead at sea), Fred Marin (WHOI), Cory Beatty (U Montana), Peter Van Buren (IOS)(SIMB) and Stephen Page (IOS)(SIMB)
P.I.s not in attendance: Andrey Proshutinsky, Rick Krishfield, John Toole (WHOI) and Mary-Louise Timmermanns (Yale U)

4.4.1 Summary

Moorings were not serviced this year. Four Ice-Tethered Profiler (ITP) buoys and one Tethered-Ocean Profiler (TOP) buoy were deployed: three ITPs and the TOP were deployed on ice floes with one Seasonal Ice Mass Balance Buoy (SIMB), and one ITP was deployed over the side of the ship in open water.

Table 3. Ice-Based Observatory buoy deployment summary.

IBO	ITP / Buoy System	Date /Time UTC	Location
1	ITP119 (open water)	18-Sep	79° 00.3' N
		19:00	137° 04.3' W
2	ITP117 w/ SAMI-CO2, TOP01, SIMB	19-Sep	80° 55.01' N
		20:00	135° 31.91' W
3	ITP118 w/ SAMI-CO2	20-Sep	80° 02.46' N
		23:30	140° 10.20' W
4	ITP112	22-Sep	78° 59.69' N
		20:00	150° 08.43' W
5	ITP107 w/ SAMI-CO2+Mcat (recovery)	23-Sep	78° 11.09' N
		17:30	151° 45.28' W

4.4.2 Moorings

There were no mooring operations this year.

4.4.3 Buoys

The existing moorings only extend up to about 30 m from the ice surface in order to prevent collision with ice keels, so automated ice-tethered buoys are used to sample the upper ocean. On this cruise, we deployed four Ice-Tethered Profiler buoys (or ITPs), one Tethered Ocean Profiler (TOP) and one 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. While the TOP measures temperature and salinity from just under the ice down to 200 m and also broadcasts 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 12 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. Indeed, ITP data have contributed to a variety of research studies by researchers and students worldwide.

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

Table 4. Project websites

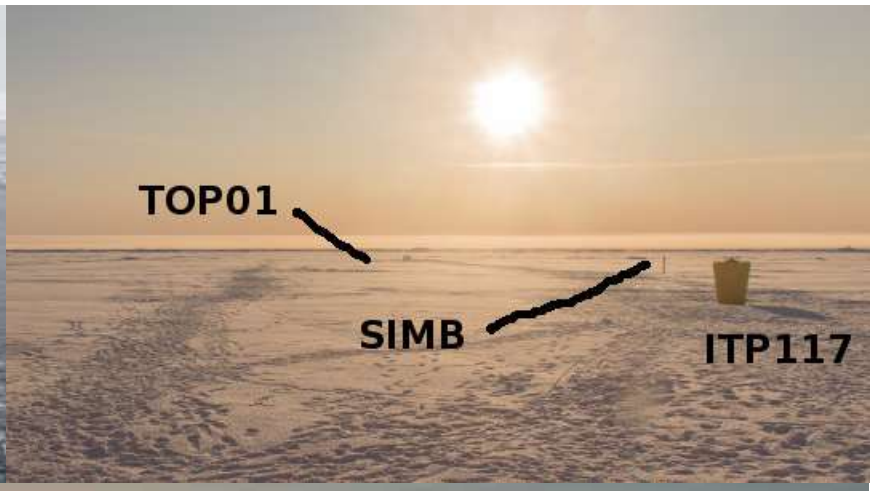
Project	Website Address
Beaufort Gyre Observing System	www.whoi.edu/beaufortgyre
Beaufort Gyre Observing System dispatches	www.whoi.edu/page.do?pid=165036
Ice-Tethered Profiler buoys	www.whoi.edu/itp
Ice Mass Balance buoys	http://imb-crrel-dartmouth.org/

4.4.4 Operations

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). Due to weather and ice conditions, the helicopter was not used for ice floe reconnaissance, but

instead floes were selected visually from the bridge and surveyed by lowering 2 scientists over the side of the ship in the man basket to drill the potential site to determine thickness. After it was determined that the floe was adequate, the ship's gangway was lowered onto the ice for access by personnel and equipment was lowered using the ship's crane. ITP119 was deployed over the side of the ship in open water using the ship's bow A-frame on the way up to the first ice station. The first ice floe selected for deployment of ITP117, TOP01 and SIMB was 1.25 meters thick, and the second for deployment of ITP118 was 1 meter. A third floe was selected for ITP112 and was 0.7 meters. Ice analyses were also performed by others in the science party while the IBO deployment operations took place.

Figure 15. ITP deployed.



(Figures Left to Right)
Figure 1. ITP119 Open Water
Figure 2. IBO-1 ITP117, TOP01, SIMB

Figure 3. ITP118

Figure 4. ITP112
Figure 5. ITP107 Recovery

4.4.5 Outreach

Dispatches documenting all aspects of the expedition were composed by Fred Marin (WHOI) and posted in near real time on the WHOI website.

4.5 Underway and Moored pCO2 and pH Measurements

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

4.5.1 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.

Figure 16. SAMI-CO_2 w/ dissolved Oxygen and PAR deployed on ITP 117 during the first on-ice ITP deployment.

4.5.2 Cruise Objectives

1. Deploy 1 SAMI-CO_2, 1 Aanderaa DO and 1 LiCor PAR sensor on 2 of the WHOI ITPs (ITP117 & ITP118).
2. Conduct underway pCO_2 measurements to provide data quality assurance for the ITP-based sensors and to map the spatial distribution of pCO_2 in the Beaufort Sea and surrounding margins.
3. Assist with other shipboard research activities and to interact with ocean scientists from other institutions.

4.5.3 Cruise Accomplishments

We deployed a SAMI-CO_2 equipped with a dissolved Oxygen sensor and PAR sensor on 2 of the ITPs (ITP117 & ITP118). We collected underway pCO_2 data using an infrared equilibrator-based system (SUPER-CO2, Sunburst Sensors). The instrument was connected to the Louis seawater line manifold located in the main lab. The sensor data collection is summarized in Table 1 below.

During the cruise, we were also able to recover ITP107. ITP107 included SAMI C180 and a Seabird ODO Microcat which were deployed during the 2018 BGOS field campaign.

Table 5. pCO_2 sensor data collection summary

Measurement system	Instrument IDs	Location	Duration
Underway infrared-equilibrator pCO_2	SUPER (Sunburst Sensors)	Entire cruise track (see IOS report in this document)	9/10/2019 - 10/2/2019
ITP SAMI-CO_2 w/ DO and PAR sensors	WHOI ITP 117, SAMI-CO2 (C9u)	First ITP ice deployment, CO2 ~ 4.5 m depth (see WHOI cruise report in this document)	9/19/2019 - present
ITP SAMI-CO_2 w/ DO and PAR sensors	WHOI ITP 118, SAMI-CO2 (C207)	Second ITP ice deployment, CO2 ~ 4.5 m depth (see WHOI cruise report in this document)	9/20/2019 - present

4.6 XCTD Profiles

Operators: Kazu Tateyama, Masahiro Saito, Hiromi Kimura, Kohei Sato, Yurika Watanabe (KIT)
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.

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 to measure the vertical profiles of water temperature and salinity. Two types of probes were used, with differing maximum depth and ship speed ratings.

Probe Type	Max Depth (m)	Max Ship Speed (Kts)
XCTD-1	1100	12
XCTD-2	1850	3.5

The data is 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.
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)

The GPS connection was lost intermittently causing the XCTD software to hang onto a prior latitude and longitude. Four XCTD files had incorrect position and the *.EDF files have been updated with corrected position taken from the TSG file based on UTC time. The UTC time in the XCTD file is correct.

There were a couple of complete fails with no data files, likely due to procedural errors and four probes with incomplete casts due to wire breakage with the sea-ice. If the probe did not reach 350m, another probe was launched.

See Appendix for table of stations.

4.7 Vertical Net Tows

Peter Van Buren, Chris Clarke, Stephan Page (DFO-IOS)
Masataka Seo, Michiyo Yamamoto-Kawal, Yuanxin Zhang (TUMSAT),
Bingkun Luo, University of Miami
P.I.: John Nelson (DFO-IOS),), Michiyo Yamamoto-Kawal (TUMSAT)

4.7.1.1 ***Sampling***

Zooplankton sampling and preservation were conducted on board by Peter Van Buren, Stephane Page and Bingkun Luo of the day watch as well as Chris Clarke, Masataka Seo, Michiyo Yamamoto-Kawal of the night watch with additional lab support by Yuanxin Zhang. A standard bongo net system was used, carrying on the 17 year time-series on zooplankton collection on the JOIS program. The frame had a fitted 150μm net on one side and a fitted 236μm net on the other. 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. New this year, a NORPAC closing net was supplied by the TUMSAT researchers and used to target Pteropods (*Limacina helicina*) at three depth ranges.

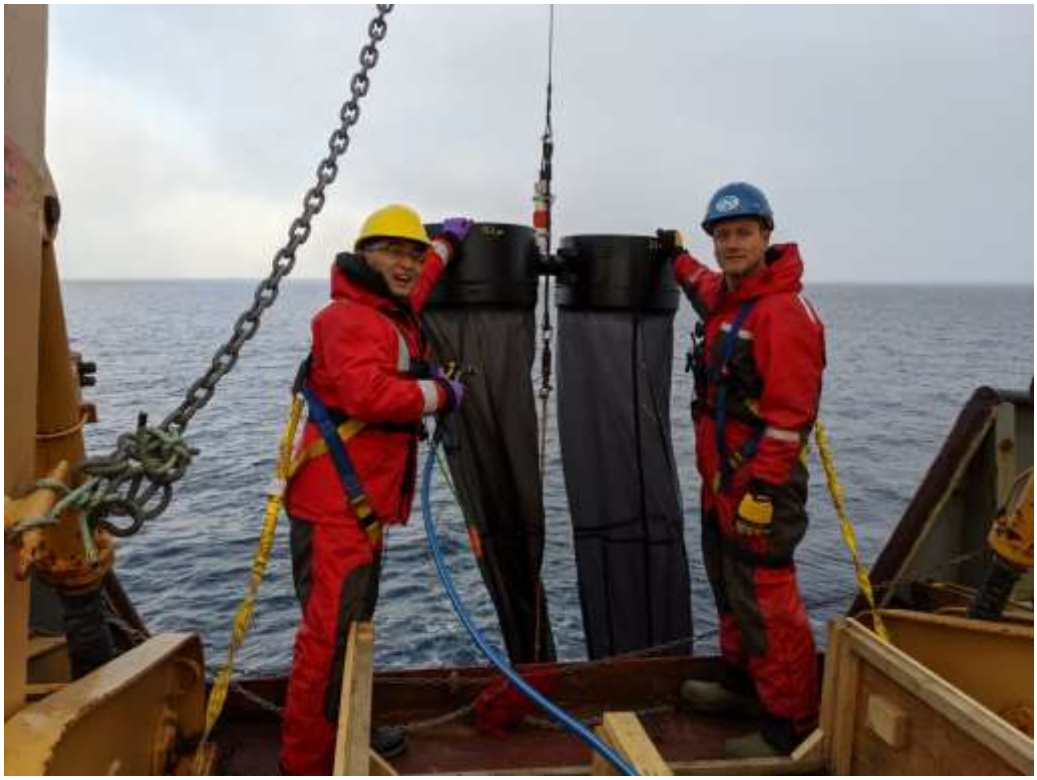


Figure 17. Bingkun Luo and Peter Van Buren rinsing the bongo nets after a cast during JOIS 2019

A total of 32 bongo vertical net hauls were completed at 32 stations. In addition 78 NORPAC closing net vertical hauls we completed at 29 of these 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, the sampling procedure was to begin with three NORPAC casts targeting the depth ranges of 50m-surface,100m-50m and 200m-100m the latter two depth ranges we collected through the use of the closing net feature by sending a brass messenger down the winch cable. Following the NORPAC casts a single 100m bongo vertical net haul was completed. The bongo was performed last to allow for the timely preservation of the samples. A total of five samples were collected at a standard station, three from the NORPAC and two from the bongo.

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

Figure 18. NORPAC closing net. Photo by Yuanxin Zhang.

The pteropods in the NORPAC samples where preserved in buffered ethanol for transportation and later imaging and analysis in Japan. The bongo samples collected from the 236µm mesh nets were preserved in 95% ethanol, and those collected from the 150µm were preserved using formalin with a final sample concentration of 3.7% formaldehyde. The formalin samples will be examined for species identification and the ethanol samples for DNA sequence analysis at DFO-IOS.

With one winch and two net systems a fair amount of time was spent each cast transferring the winch wire and pressure sensor from system to system. This required undoing shackles in cold weather which could have been greatly improved by using a suitably weight rated stainless steel locking carabiner.

The ship moved within three times zones on the cruise. September 10th-14th UTC -7, September 15th-17th UTC-8, September 17th-29th UTC-9, September 30th-Oct 2nd UTC - 8. Use this time change information to determine local time from UTC in the Zooplankton Log.

4.7.1.2 *Issues and solutions*

With one winch and two net systems a fair amount of time was spent each cast transferring the winch wire and pressure sensor from system to system. This required undoing shackles in cold weather which could have made more efficient by using a suitably weight rated stainless steel locking carabiner.

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.

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.

It was very useful to have a third set of cod ends packed, and it is recommended to continue doing so. In additional it is recommended that itemized packing lists be included with each box as well as "keep frozen" labels and copies of the MSDS sheets for the chemicals used in preparation for the shipment home. A brass hose nozzle was packed and used on the foredeck; this was a great choice as it is much more durable than plastic nozzles that often brake at cold temperatures.

VHF communication between the CTD lab and the foredeck is poor for recording station information. Zooplankton depth,positions and times where then recorded on the bridge. Consider installing and deck mounted VHF in the CTD acquisition lab so that position and times can be directly recorded in the Daily log during a rosette cast.

A plastic 53 micron mesh made of a double PVC rings was packed for use in preparing the samples in the lab. This was extremely helpful in preparing samples and a back-up should be considered.

One three occasions the NORPAC net was damaged. Twice during recovery in high seas the release mechanism let go in air and put strain on the net causing the cod end connection to tear away from the net. To repair this net was cut back slightly and the "new" bottom of the net was affixed to the cod end. The final time the NORPAC was damaged occurred when the release mechanism was driven into the A-frame block causing it to release and tear vertically just above the cod end.

Fortunately the Bongo net did not suffer any damages, however it's recommended that a repair product Tear-Aid Type B be packed from repairs where stitching and sealing are not preferred.

The counter on the foredeck winch was often unreliable. The reset bottom became less functional throughout the cruise and blacked-out twice. Salt build up was found within the display box. This should be repaired before returning to the field.

The 'date' field on the paper labels and in the plankton log book should be updated to specify UTC date format. The digital log spreadsheet asks for UTC date, but the paper log and labels don't specify, yet ask for both local and UTC time. This caused confusion, and the result was local time being entered in most cases which then had to be converted when entering the data on the digital log. In addition the paper log should have

a field for sample number if individual sample numbers are preferred for later log keeping and analysis.

The RBR's pressure sensor 30 pin connector was damaged on September 17th. Fortunately, this did not impede it's ability to be downloaded. There was a problem with the internal clock not being consistent throughout the cruise, see Figure 2. Thanks to Stephane Page we were able to decipher the casts and complete the log information. The sensor is being hand carried back to IOS and should be repaired before next cruise.

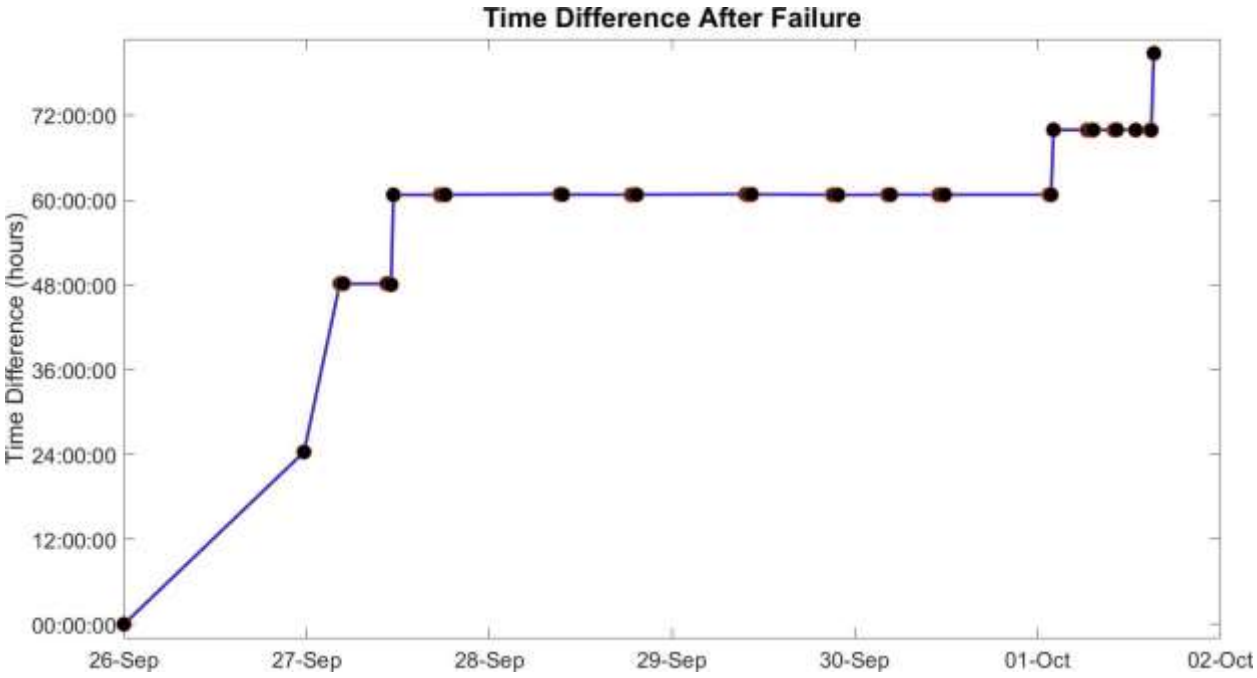


Figure 2. Pressure Sensor time Difference after failure JOIS 2019

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

Thomas Grevesse (ConcordiaU) and Loïc Jacquemot (ULaval)
P.I.: Connie Lovejoy (ULaval) and David Walsh (ConcordiaU)

4.8.1 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). This physical stratification impacts the vertical structure of microbial communities. 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 (Trent 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. 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.

4.8.2 Methodology

Water column samples were collected at 22 stations (Figure 1) to cover a range of previously visited stations (in 2012-2018). 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 from the bottom. At four designated stations, NE1, CB4, CB21, we

also sampled for proteins at these sites for the CBOmics collaborative study between the Lovejoy, Walsh, and Guéguen. samples for population cell sorting preserved in glyTE buffer (LiveFCM), microscopy samples (DAPI, FISH).

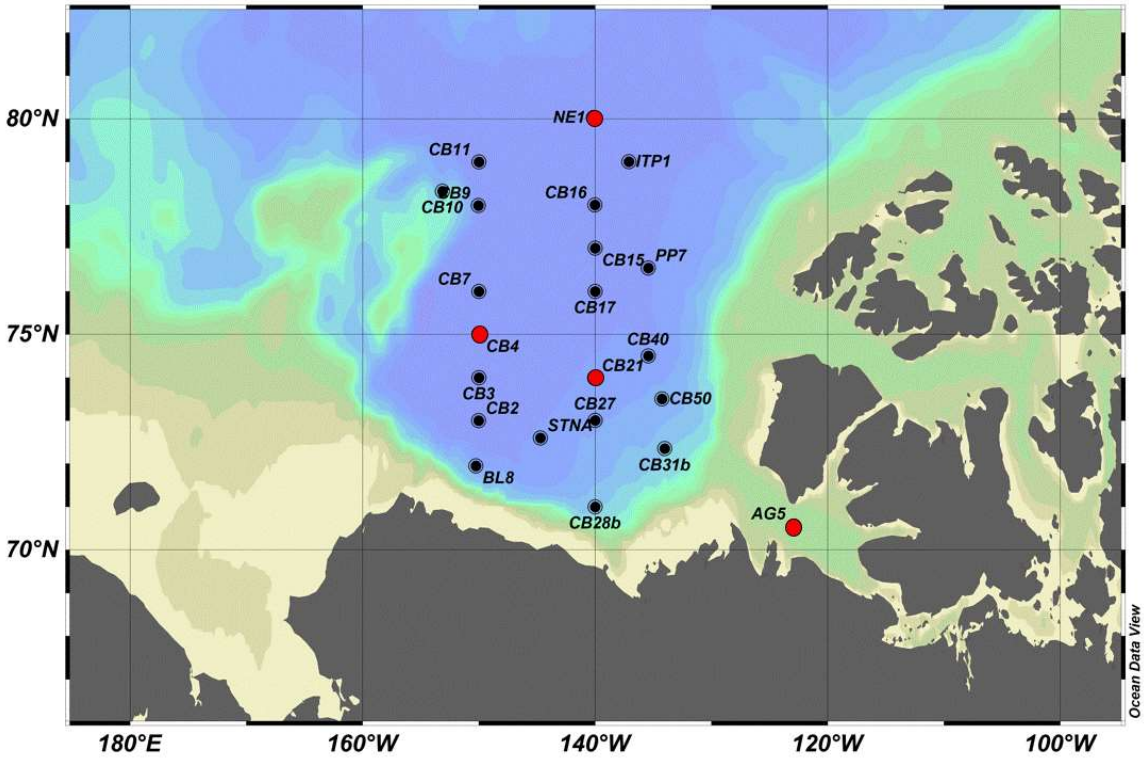


Figure 19. Microbial diversity sample locations.

Red circles demonstrate super stations for DNA/RNA sampling (FICUS project) and black circles demonstrates 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.

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.

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).

Fluorescent in situ Hybridization (FISH)

FISH is a technique that uses fluorescent-labelled nucleic acid probes to identify specific phylogenetic groups under the microscope. Samples for FISH were collected at some of the CBOmics stations and depths. Seawater was fixed with 3.7% (final concentration) formaldehyde (Sigma-Adrich) and processed within 6-12 hours after sampling. For eukaryotic organisms, 150 mL of fixed sample was filtered onto a 0.8 µm polycarbonate filters (AMDM) and for bacteria, duplicate 50 mL aliquots were filtered onto 0.2 µm polycarbonate filters (AMDM). Filters were air-dried and stored at -20ºC to be analysed onshore, following probe development and selection.

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.

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 flash frozen in liquid nitrogen before being finally 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.

4.8.3 Summary

A total of 169 depths at **22** 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.

4.8.4 Comments

As with JOIS 2015 and 2016, the RNA/DNA group was provided with 2 dedicated bottles primarily for collecting in the DCM and near the surface during full casts and 8 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.

Figure 20. Microbial Team. Photo by Fred Marin.

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4.9 Experimental simulations of the fate of microbial communities under climate-change induced environmental modifications

Thomas Grevesse (onboard, ConcordiaU)
P.I.: David Walsh (ConcordiaU)

4.9.1 Introduction and objectives

One of the most striking feature of the Arcitc ocean is the amount of fresh water it receives comparatively to other oceans. Making only ~1% of the total world oceans volume, its watershed collects and pours ~11% of the total fresh water runoff. It has as a consequence, that the Arctic ocean receives a significantly higher proportion of carbon from terrestrial sources, making the Arctic ocean physico-chemistry unique. As mentioned above in this report, these conditions provide a unique environment that drove the emergence of uniquely adapted microbial species and communities. As microbial communities represent ~50% of the ocean biomass, are primary producers and at the base of the food chain, in addition of cycling and recycling organic matter, they have a huge impact on the Arctic ocean ecosystems.
The Arctic ocean is changing at an alarming rate due to climate change-induced modification in the physico-chemistry of the water column. In addition of an obvious loss of sea ice, the Arctic land regions are warming too. The regions forming the watershed of the Arctic ocean are widely covered by the permafrost. With increasing temperatures, permafrost is melting and releasing its long-stored carbon sources into running water that will end in the Arctic ocean, after some transformations by land and fresh water microbial communities. Forecasts predict that the carbon from terrestrial sources will dramatically increase in the Arctic ocean, with the ongoing temperatures increase. As microbial communities have adapted to the unique conditions of the Arctic ocean, this new input of dissolved organic matter (DOM) may strongly modify and alter the dynamics and composition of microbial communities of the Arctic. These modifications could cascade up the food chain and alter the whole ecosystem.

The goal of these experiments is to simulate an increase in DOM from terrestrial sources on the composition of the Arctic ocean microbial communities. By using DNA sequencing, we hope to make some predictions on how microbial communities will be impacted by increased amounts of DOM from terrestrial sources in the next 20-30 years. This could allow to take preventive actions to limit the damage done to the Arctic ocean ecosystems due to drastic modification of microbial communities

4.9.2 Methodology

Before the cruise, we prepared a solution of concentrated organic matter. Soil fron the active layer of the permafrost was collected at Peninsula point, in the region of the MacKenzie river delta. This soil was incubated with water collected from lake Tuk (Inuvik area) for 3 weeks in the dark at 4^0C to mimic the natural transformation of DOM from terrestrial sources (tDOM) before reaching the Arctic ocean. Before the cruise, we filtered ~300 mL of this solution through GF/F filters and measure the total dissovled organic carbon.

During the cruise, water was collected at the surface of two sites through the pump located under the boat: one over the continental shelf (AG5 station) and one over the Canada basin (CB18 station). For each station, 6 L were colected and separated in 6 bottles of one liter, each receiving 950 mL of seawater. In 2 bottles, we filtered the water through a 0.2 μm filter and added 45 mL of MilliQ water (Filtered control). Two bottles received unfiltered seawater and 45 mL of MilliQ water (control). The last two bottles received seawater and 45 mL of the concentrated tDOM solution. The concentratio of tDOM was chosen to exceed the highest concentration observed in annual measurements around the Mackenzie river delta. The 12 bottles constituting our 12 microcosms were wrapped in aluminium foil and kept in the dark at 4^0C for the duration of the experiments (18 days for the continental shelf microcosms, 16 days for the basin microcosms). We took salinity, temperature (CTD provided by Prof. Kazutaka Tateyam) and O_2 measurements (optode provided by the IOS team) at the beginning of the experiments, every 6 hours for the first 48 hours and daily until the end of the cruise. Samples for DNA (5 mL of seawater filtered on a 0.2 μm filter), fluorescent DOM measurement (5 mL filtrate) and flow cytometry were collected at the same time points as the salinity/temperature/ O_2. Samples for total carbon measurements (30 mL) were collected at the beginning of the experiments, after 3 and 10 days, and at the end of the experiment (corresponding with the end of science work on the cruise).

DNA

DNA samples were collected by filtering 5 mL of seawater at room temperature, through a 0.2 μm polycarbonate filter. The filters were placed in 2 mL microfuge tubes and

immersed in RNAlater solution (Ambio) and left for at least 15 minutes at room temperature before being stored at -80°C.

Target metagenomics (LiveFCM)

For potential cell population metagenomics, 200 μL of GlyTE solution was added to 1.8 mL of water sample in 2 ml cryovials. Samples were left 10-20 minutes at 4ºC before being stored placed into the -80°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.

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. Samples used for theses measurements will be the same that have been collected for targeted metagenomics.

Fluorescent DOM measurements

The 5 mL filtrate that was obtained after filtration for DNA collection was kept in 5 mL cryovials at 4^0C until measurement on boat by Prof. Céline Gueguen with a . The samples that were not measured on boat were kept at 4^0C until measurement back on shore.

Total dissolved organic carbon

At the beginning of the experiments, as well as at day 3, day 10, and the end of the experiment, 30 mL of water were collected and filtered through GF/F filters and kepts in combusted glass vials. 300 μL of HCL 37% were added to the vials. On shore, they will be used to measure total dissolved organic carbon with the team of Prof. Yves Gélinas (Concordia University, Montreal, Canada)

4.9.3 Summary

A total of 21 time points were sampled for these experiments. For each time point, we collected 12 (corresponding to the 12 microcosms bottles) samples of each kind (DNA,

FCM, Fluorescent DOM) and measured salinity/temperature/O_2. For 4 time points we collected 12 samples fot total organic carbon measurements.

4.9.4 Comments

These experiments were planned in a short notice before the start of the cruise. The support from the Chief scientist and her team greatly helped the setup of the experiments and the collection of data. We warmly 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.

4.10 Underway measurements

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

Measurements were made for:

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

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

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

a. GPS from the ship's Marine Star GPS, using NMEA strings $GPGGA, $GPVTG, and $GPZDA. Giving position, time, date and course and speed over ground. This is the same GPS string being accessed by CTD, XCTD and TSG systems.
b. Backup GPS from the ship's Furuno GPS, using NMEA strings $GPRMC, $GPGGA, $GPVTG, and $GPZDA. Giving position, time, date and course and speed over ground.
c. AVOS weather observations of air temperature, humidity, wind speed and direction, and barometric pressure ($AVRTE)
d. Heading from the ship's Gyro ($HEHDT)
e. Sounder depth and the applied ship's draft and sound speed ($SDDBT)
f. Surface Photosynthetically Active Radiation (PAR)
g. Time-stamped logging of the above listed TSG (item 1a), and the inlet sea surface temperature from the SBE38 that is also given in the TSG data stream.

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, equipment and instruments, and issues are given in the Appendix.

4.11 Ice Watch Cruise Report

Kazu Tateyama (onboard P.I.), Masahiro Saito, Hiromi Kimura, Kohei Sato and Yurika Watanabe (KITAMI)
P.I.: Jennifer Hutchings (OSU), Kazu Tateyama (KIT),

As in previous years, the ice observations recorded during the Louis S. St-Laurent 2019-87 cruise will provide detailed information for the interpretation of satellite imagery of the ice pack.

4.11.1 Observations from the Bridge: Methodology

We split the ice and XCTD watch into 12 hour shifts throughout the cruise and operated Ice Watch every 1hour. The observations thus start and end around the time period of our traverse through the ice pack. Ice conditions were noted within 1nm about the ship, when visibility allowed, along the ships track during the observation period from 16th to 24th September.

We follow 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 include melt pond characteristics, sediment on ice and an additional ice type – second year ice.

4.11.2 Result

Observation has started after CB17 on 16th September. The young white/gray ices less than 30cm and second-year ice around 120 cm were observed. After CB16, we observed highly packed sea ice area which consists of second-year ice, young ice and nilas. During 18th and 23rd September, we encountered packed thicker second-year ice area around 100-120cm in the area ranged from 78N to 81N. Three ice stations were established in this area. After 23rd September, ship proceeded toward south along ice edge. Ice watch was finished at CB8.

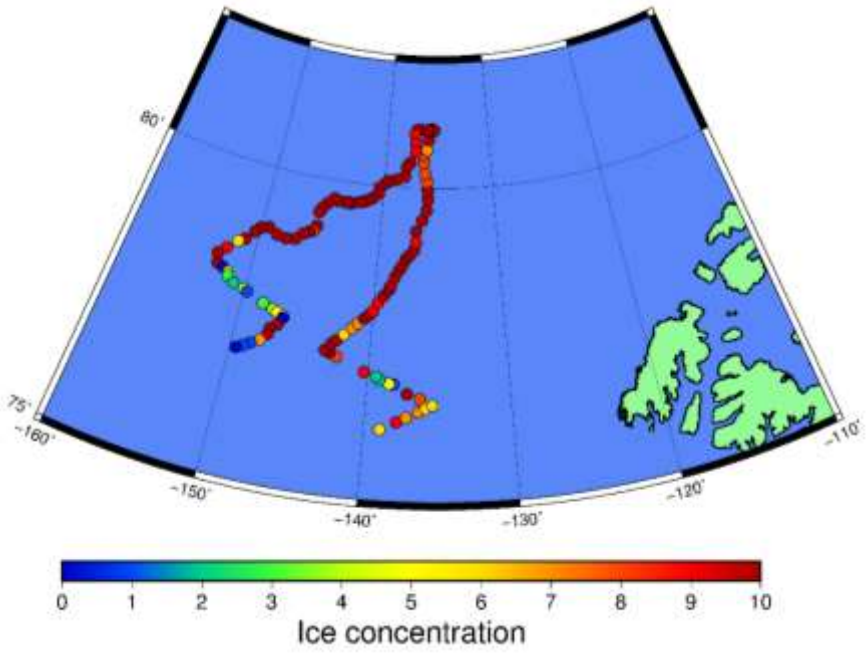


Figure 1. Total ice concentration in tenth.

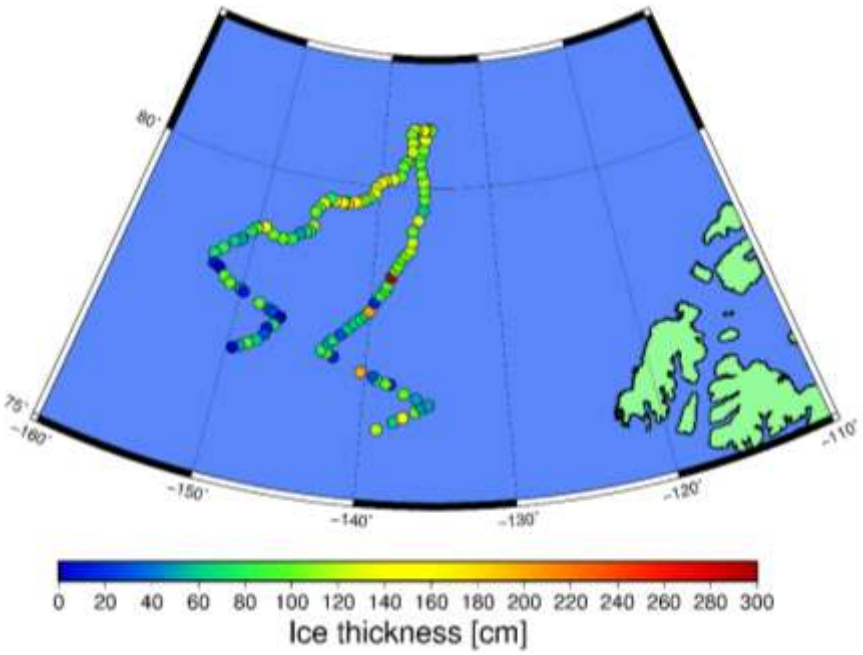


Figure 2. Ice thickness for primary ice

4.11.3 WebCams

As in previous years, two Netcams were installed on the monkey island. Netcam imagery has been collected since 2007. One facing towards the bow recording images every minute. The other camera looking down over port side recording images every 10seconds. The imagery was saved in real-time onto the ScienceNet server.
Please note: in 2019 the bow camera stopped after accidental black out at 15th September. It seems to be some problem on the black-colored LAN/power cable, not on the camera. Backup forward camera was installed in the bridge.

4.12 EM ice observation Cruise Report

Kazu Tateyama, Masahiro Saito, Hiromi Kimura, Kohei Sato and Yurika Watanabe (KITAMI)
P.I.: Kazu Tateyama (KITAMI), Jennifer Hutchings (OSU)

4.12.1 Methodology

An Electro-Magnetic induction device EM31/ICE (EM) and a laser altimeter LD90-3100HS were used for indirect sea-ice thickness measurement continuously, installed at foredeck's crane on the portside. EM and laser instruments were covered by a yellow-orange color waterproof fiber reinforced plastic case and hanged at 4.5m height above sea surface and in more than 7m separation from ship due to avoid hitting ice and the effect from ship hull as shown Fig.3.

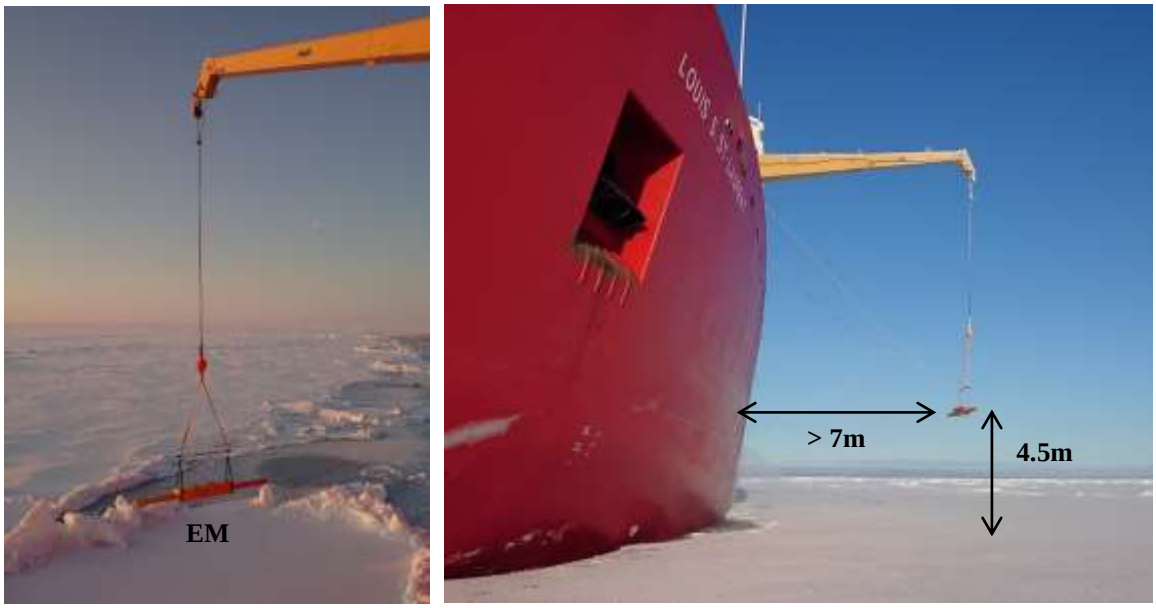


Figure 3. Photos of EM sensor

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

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

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

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

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

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

4.12.2 Calibrations

EM sensor was calibrated twice over open water at the beginning (17th September) and the end (23rd September) of EM observation. Empirical equations (1) and (2) for estimating total thickness were derived from these calibrations as shown in fig.4.

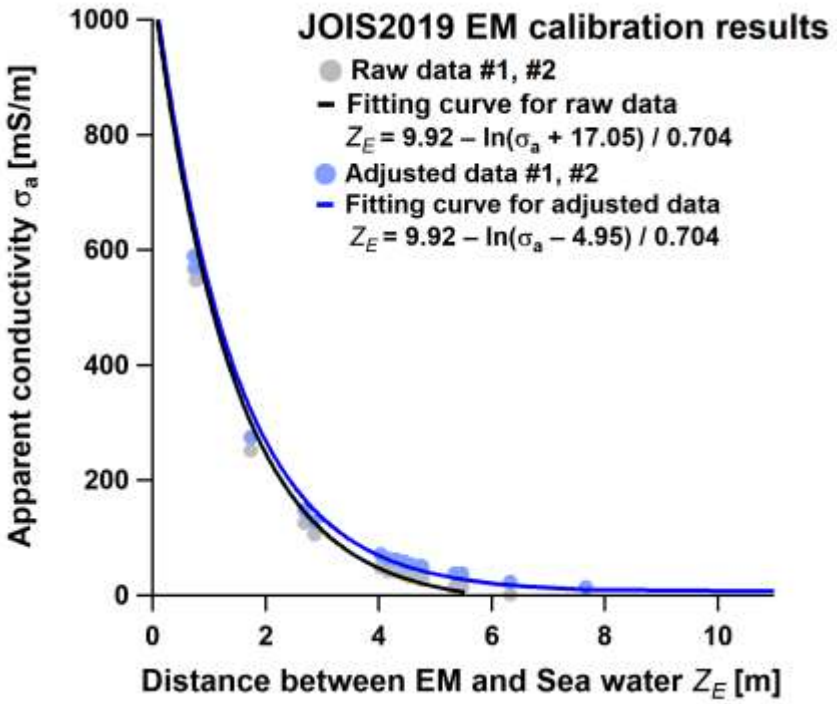


Figure 4. EM calibrations over open water at 17th and 23rd September.

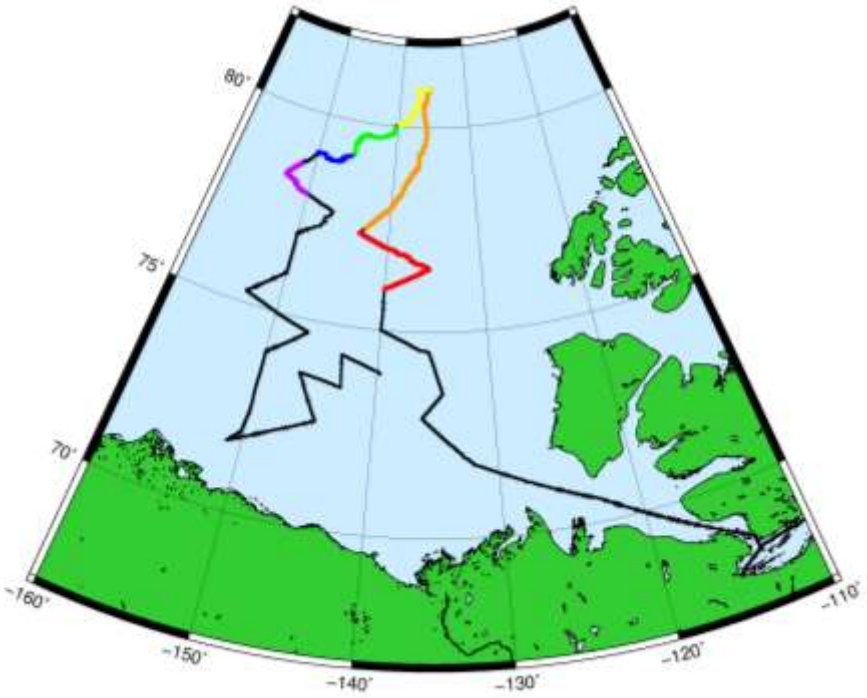


Figure 5. EM survey lines along ship track during September 16-23.
Ship track is drawn by black line. EM survey lines are shown by red, orange, yellow, green blue and purple corresponding to Profile No.1-6 in Table 1.

4.12.3 Total thickness profiles

EM observations were carried out from 16th to 23rd September along ship track as summarized in Table 1, Figure 6 and 7.

Table 6. Summary of EM sea-ice observation

Profile Number	Start		End		Length of profile [km]	Average Ice concentration [%]	Average total thickness [m]
	Time (UTC)	Position	Time (UTC)	Position			
1	2019/9/16 17:05:42	76.00102 N 140.00667 W	2019/9/17 22:16:26	77.30187 N 143.31939 W	366.9	10.7	0.34

2	2019/9/18 01:33:32	77.41852 N 142.81098 W	2019/9/19 22:16:26	80.91887 N 135.45526 W	509.2	22.7	0.42
3	2019/9/20 03:23:25	80.93544 N 135.63370 W	2019/9/21 01:35:56	80.03968 N 140.18762 W	189.6	45.4	0.53
4	2019/9/21 09:06:00	79.96351 N 140.35819 W	2019/9/22 02:49:39	89.13969 N 145.68006 W	215.1	47.3	0.57
5	2019/9/22 02:49:48	79.136969 N 145.68008 W	2019/9/22 17:17:41	78.99369 N 150.08523 W	131.6	10.7	0.53
6	2019/9/23 00:49:50	78.693365 N 151.58275 W	2019/9/23 21:50:18	77.989971 N 150.04181 W	163.9	6.6	0.26

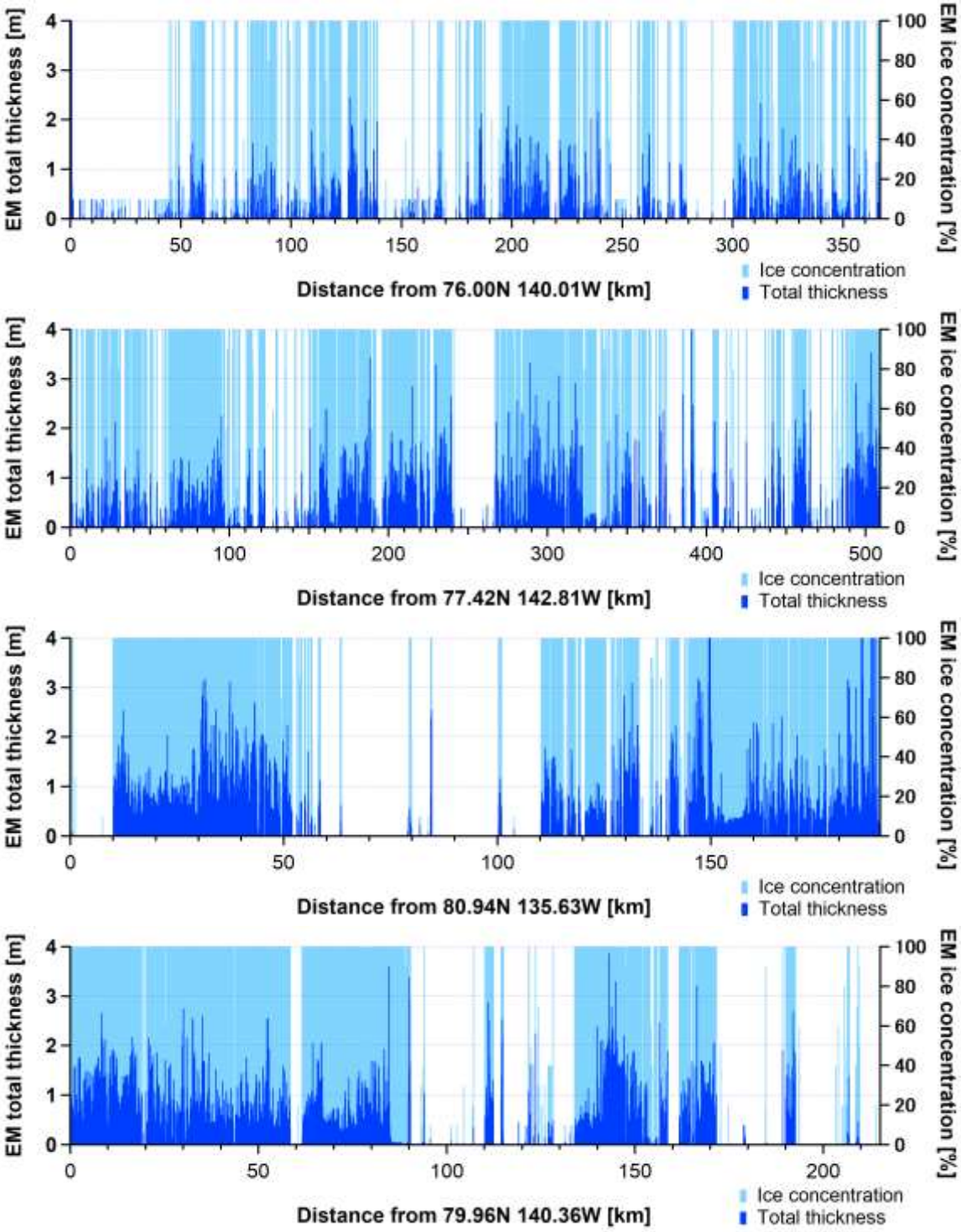


Figure 6. Profiles of total thickness for Profile No.1-4 measured by EM.

Profiles of ice thickness (left hand side y axis, dark blue dots) and ice concentration (right hand-sde y-axis, pale blue).

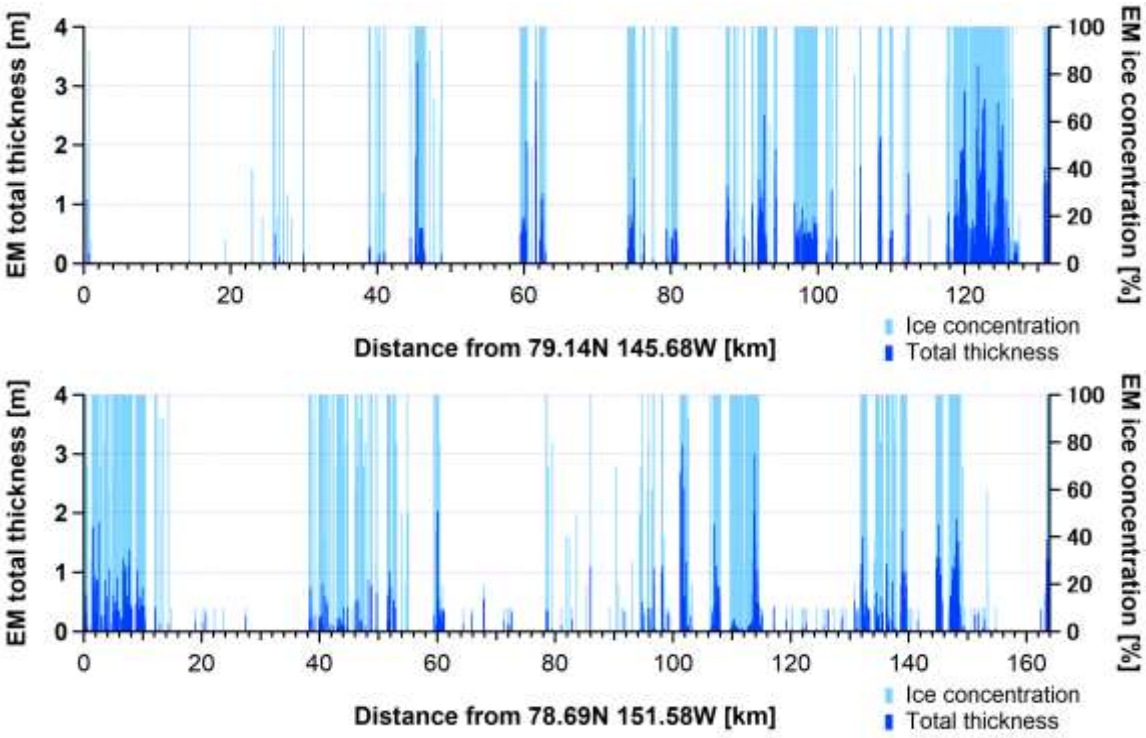


Figure 7. Profiles of total thickness for Profile No.5-6 measured by EM.

4.13 Ice Station Observation Cruise Report

Kazu Tateyama, Masahiro Saito, Hiromi Kimura, Kohei Sato
and Yurika Watanabe (KIT) ,
Masataka Seo, Yuanxin Zhang (TUMSAT),
Nicolas Sylvestre (Sherbrooke), Thomas Grevesse (Concordia),
Loïc Jacquemot (U Laval), Bingkun Luo (U Miami)
P.I.: Jennifer Hutchings (OSU), Kazu Tateyama (KIT)

4.13.1 Methodology

Cores, transects and snow pits were taken at the 3 ice stations to characterize the sea-ice floe where deployed WHOI's buoys. We followed the following standard JOIS protocol of collecting snow depth, ice thickness and freeboard data along transects and collecting ice cores at each ice station. In addition, profiles of snow type, size, temperature, density and salinity were also measured.

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

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

4.13.2 Overviews of ice stations

Ice Station 1
Drilling: Kazu Tateyama, Yurika Watanabe, Masataka Seo, Loïc Jacquemot, Bingkun Luo, Yuanxin Zhang
Coring: Masahiro Saito, Nicolas Sylvestre, Loïc Jacquemot
Snow: Hiromi Kimura, Kohei Sato

Ice was accessed from gangway of starboard side. Three 300m-long transects (300m X 3) were set as shown in Fig.8. Ice cores were collected at three sites (0, 50, 100m) along the transect #1 line. Thickness of 0m, 50m and 100m sites were 0.94m, 1.03m and 0.81m, respectively.

Ice Station 2
Drilling: Kazu Tateyama, Yurika Watanabe, Masataka Seo
Coring: Masahiro Saito, Nicolas Sylvestre, Loïc Jacquemot,
Snow: Hiromi Kimura, Kohei Sato

Ice was accessed from gangway of starboard side. A 300m-long transect was established as shown in Fig.8. Ice cores were collected at three sites (0, 50, 100m) along the transect line. Thickness of 0m, 50m and 100m sites were 0.93m, 0.67m and 1.00 m, respectively.

Ice Station 3
Drilling: Kazu Tateyama, Yurika Watanabe, Masataka Seo
Coring: Masahiro Saito, Nicolas Sylvestre, Loïc Jacquemot,
Snow: Hiromi Kimura, Kohei Sato

Ice was accessed from gangway of starboard side. Crossed 100m-long transects were established as shown in Fig.8. Ice cores were collected at two sites (0, 50m) along the transect #1 line and at two sites (0, 100m) along the transect #2. Thickness of #1-0m, #1-50m, #2-0m and #2-100m sites were 0.65cm, 0.79cm, 0.80cm and 0.82m, respectively.

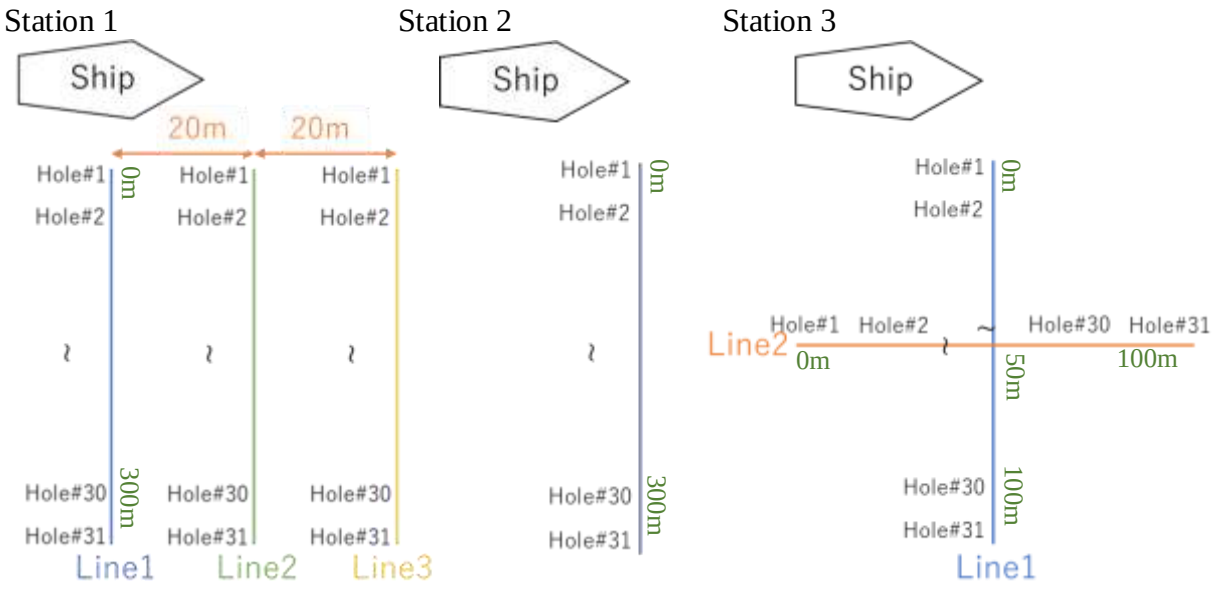
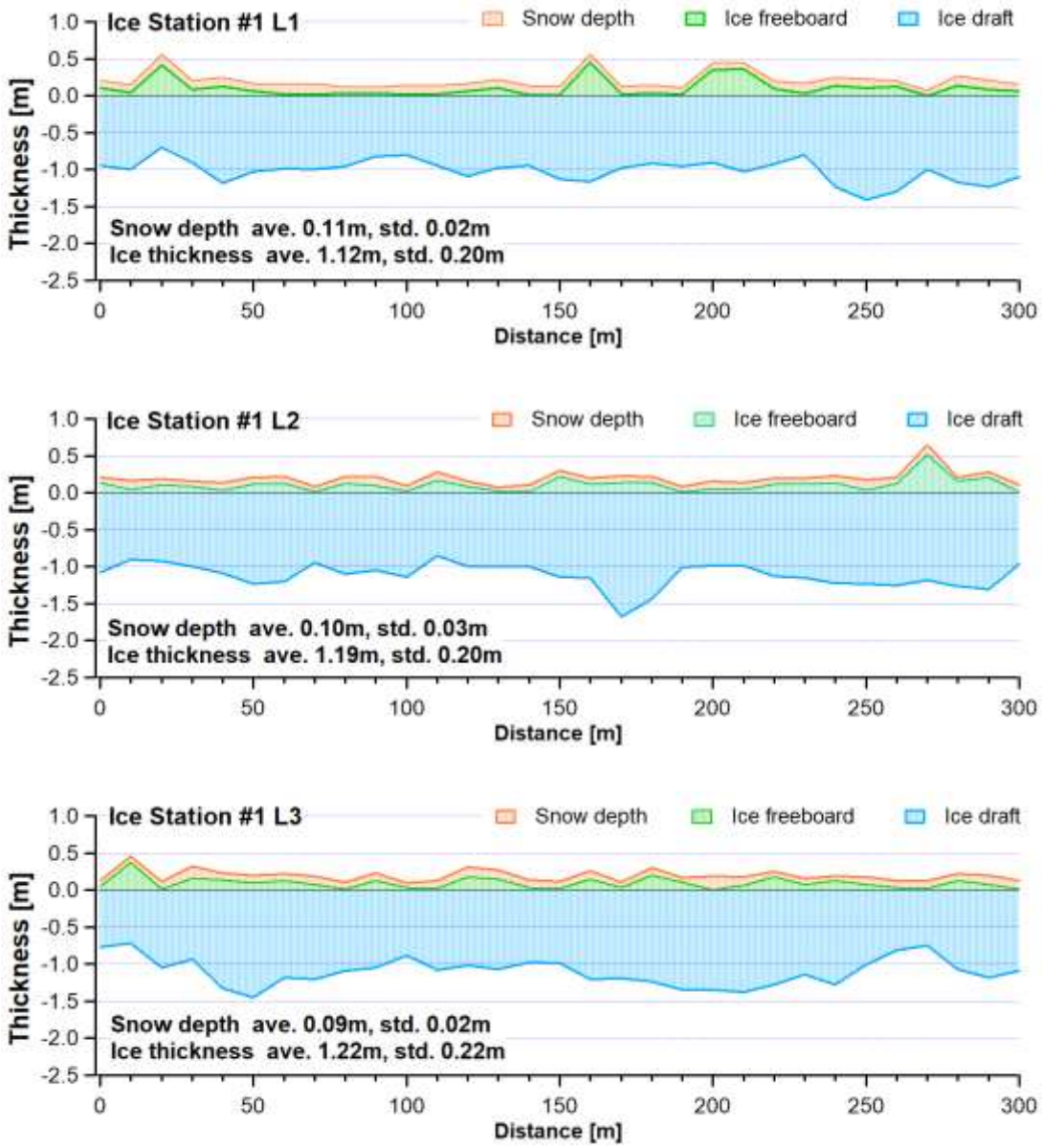


Figure 8. Schismatic of transects on each ice stations.
Station 1, 2 and 3 consist of parallel 3 transects, single transect and cross 2 transects, respectively.

4.13.3 Ice thickness transects

We settled for 300 m transects with snow depth, thickness and freeboard of sea ice measurements every 10m along transects as shown in Fig.8. Ice thickness and freeboard

were measured directly with the use of a drill and tape measure. Snow depth was measured by a steel scale.



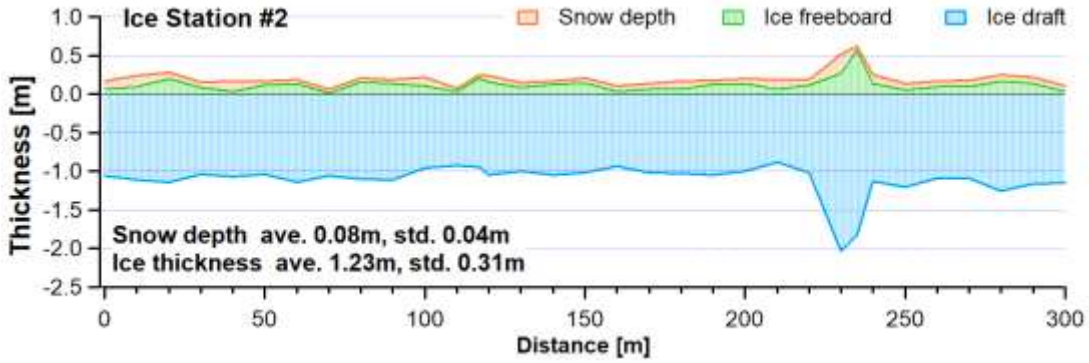


Figure 9. Snow depth, ice thickness and freeboard measurements at ice station 1 and 2.

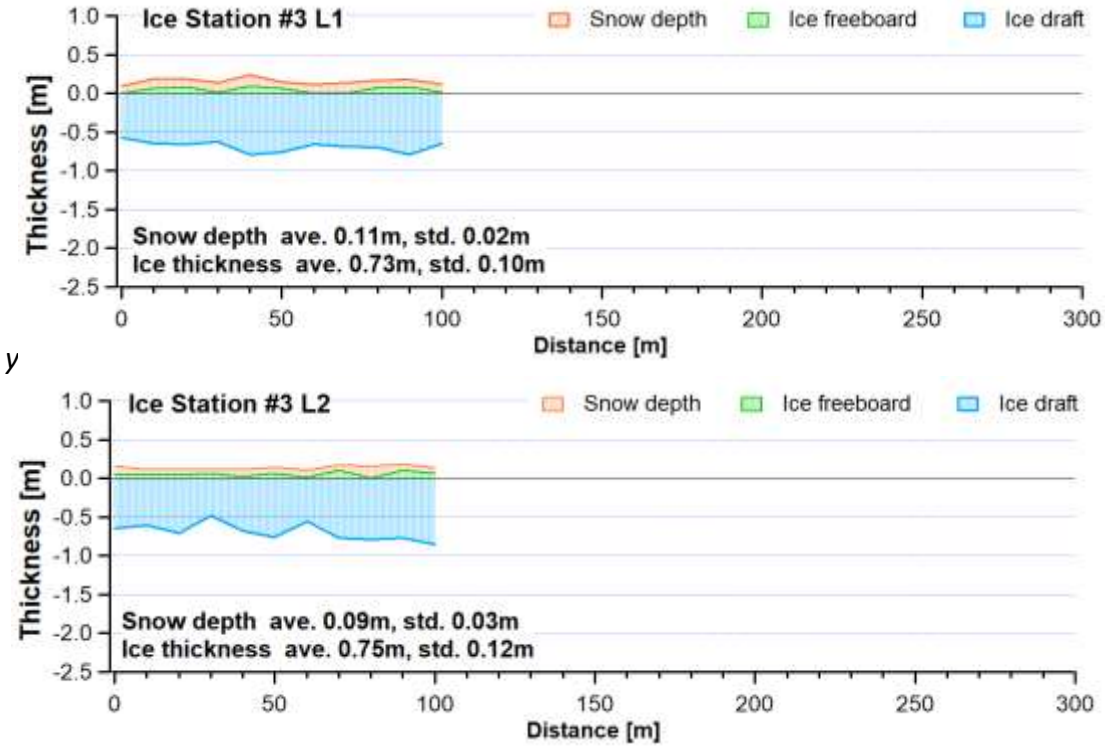


Figure 10. Snow depth, ice thickness and freeboard measurements at ice station 3.

4.13.4 Ice Cores

Table 1 shows the summary of collected ice core samples. 11 physics cores and 3 DNA cores were taken.

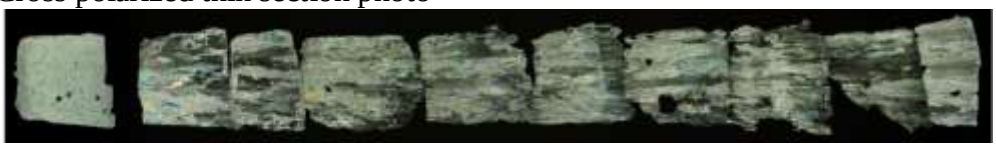
Table 1 summary of collected ice core samples

Ice Station	Site	Length [m]	Purpose	PI
1	#1-0m	0.94	Physics	Tateyama
	#1-50m	1.03	Physics	Tateyama
	#1-100m	0.81	Physics	Tateyama
2	0m	0.93	Physics	Tateyama
			DNA	Saito
	50m	0.67	Physics	Tateyama
			DNA	Saito
	100m	1.00	Physics	Tateyama
			DNA	Saito
3	#1-0m	0.65	Physics	Tateyama
	#1-50m	0.79	Physics	Tateyama
	#2-0m	0.80	Physics	Tateyama
	#2-100m	0.82	Physics	Tateyama

Station 1-#1-0m

Ice core photo

Cross polarized thin section photo

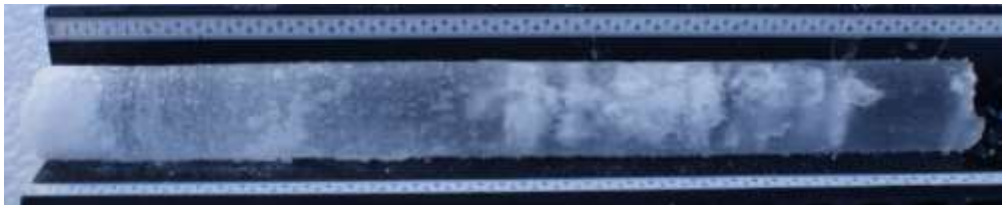


Station 1-#1-50m ice core photo

Station 1-#1-100m ice core photo

Station 2-0m

Ice core photo



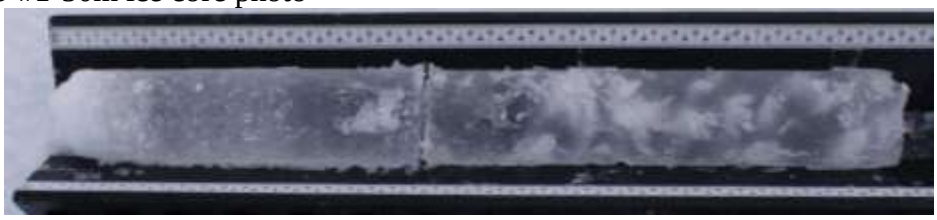
Cross polarized thin section photo

Station 2-50m

Figure 11. Pictures of ice core sample and cross polarized thin section photo from Ice station 1 and 2.

Station 3-#1-0m ice core photo

Station 3-#1-50m ice core photo



Station 3-#2-0m cross polarized thin section photo

Station 3-#2-100m ice core photo

Figure 12. Pictures of ice core sample and cross polarized thin section photo from Ice station 3.

From ice core photos and cross polarized thin section photo, information of ice core structure can be derived. Bottom layer of refrozen melt ponds shows white sparse ice layer and apeared in the upper or middle part of ice cores from station 1-#1-50m, station 1-#1-100m, station 2-50m and station 3-#1-0m.

Temperature, Salinity and Density Profiles

Temperature, salinity and density profiles were measured at each core site. Thick and thin section analysis were also carried out. Ice cores from station 1 shows salinity maximum in top and bottom layers. On the other hand, Ice cores indicate salinity minimum in top layer. The existence of surface fresh layer suggests formed by refreezing melt pond.

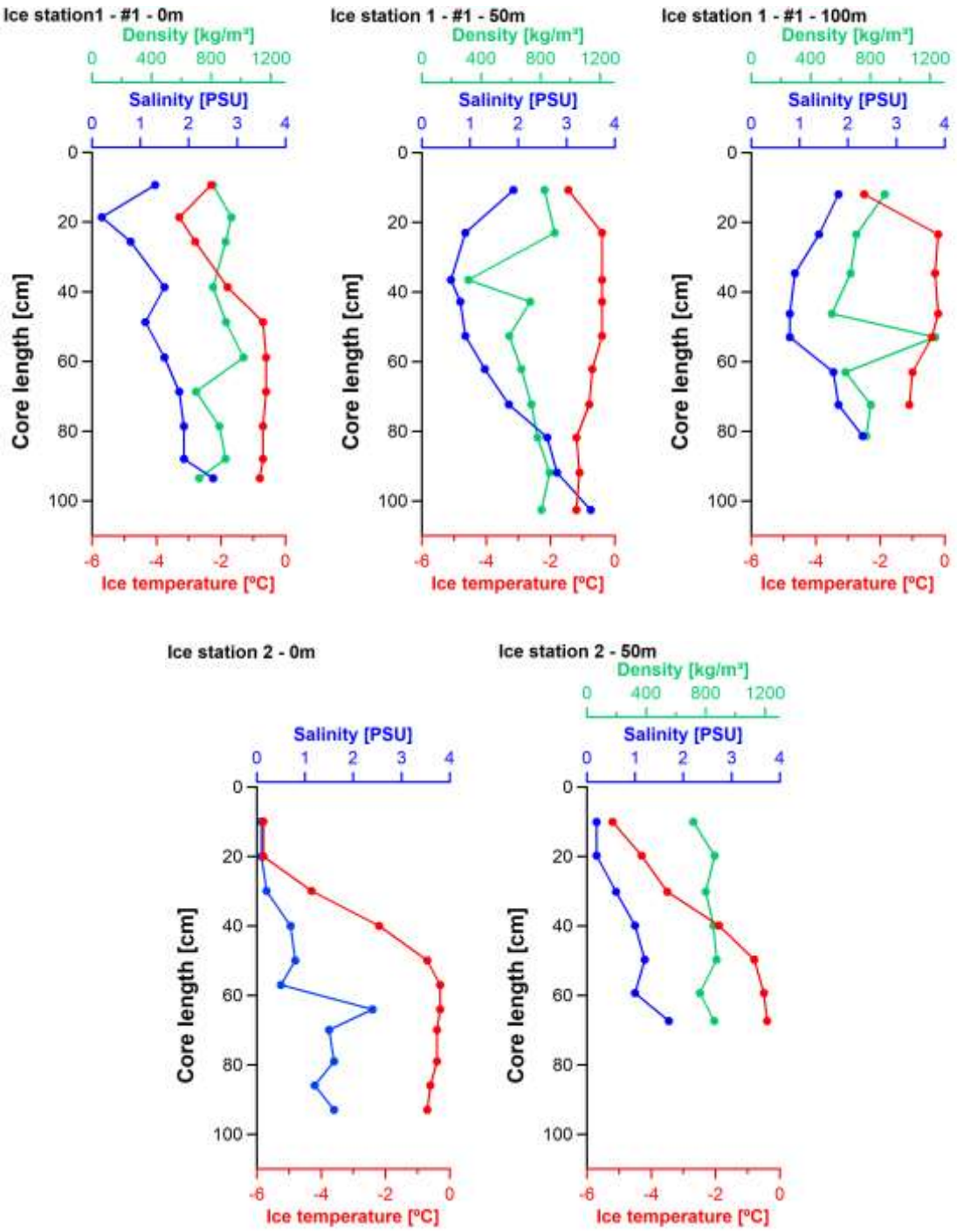


Figure 13. Temperature, salinity and density profiles of ice core samples from Ice station 1 and 3.

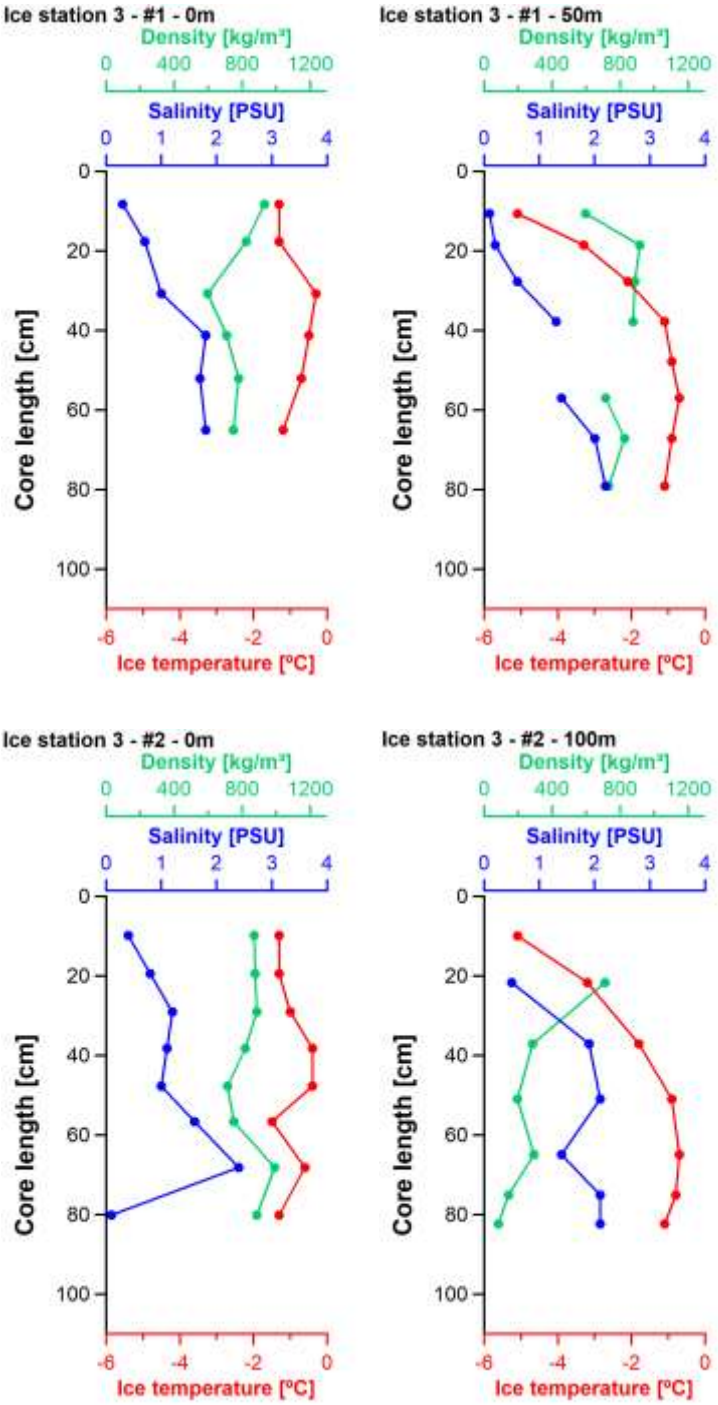


Figure 14. Ice core profiles from Ice Station 3

4.13.5 Incubating Microorganism of Arctic Water and Sea Ice

Filtered arctic sea water and melted sea ice were incubated by using the touch filtrated filter on Yeast-Malt medium (YM medium) and MRS medium (medium for Lactic acid bacterium) at room temperature.

Antibiotic to YM medium was added due to reduce risk of contamination. Some colonies appeared on 33 plates (in all 77 plates). We will investigate DNA data and condition of cultivate these species.

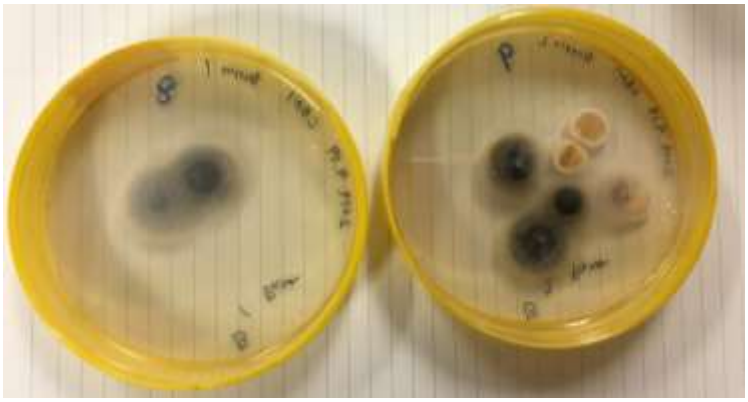


Figure 15. Ice core profiles from Ice Station 3.

Figure 16. Colony of sea ice at ice Station 2.

4.13.6 Snow pit observations

We measured snow properties with snow pits at ice stations. Profiles of temperature, salinity and density of snow, water content of snow and structure of snow layer were collected.

Figure 17 and 18 show results of snow pit observations from all ice station. Snow layer structures showed the rimed wind pack snow on the surface layer except station 2. Depth hoar and solid type depth hoar were observed in lower layer to bottom. A water content of snow on the sea ice indicate completely dry (0%).

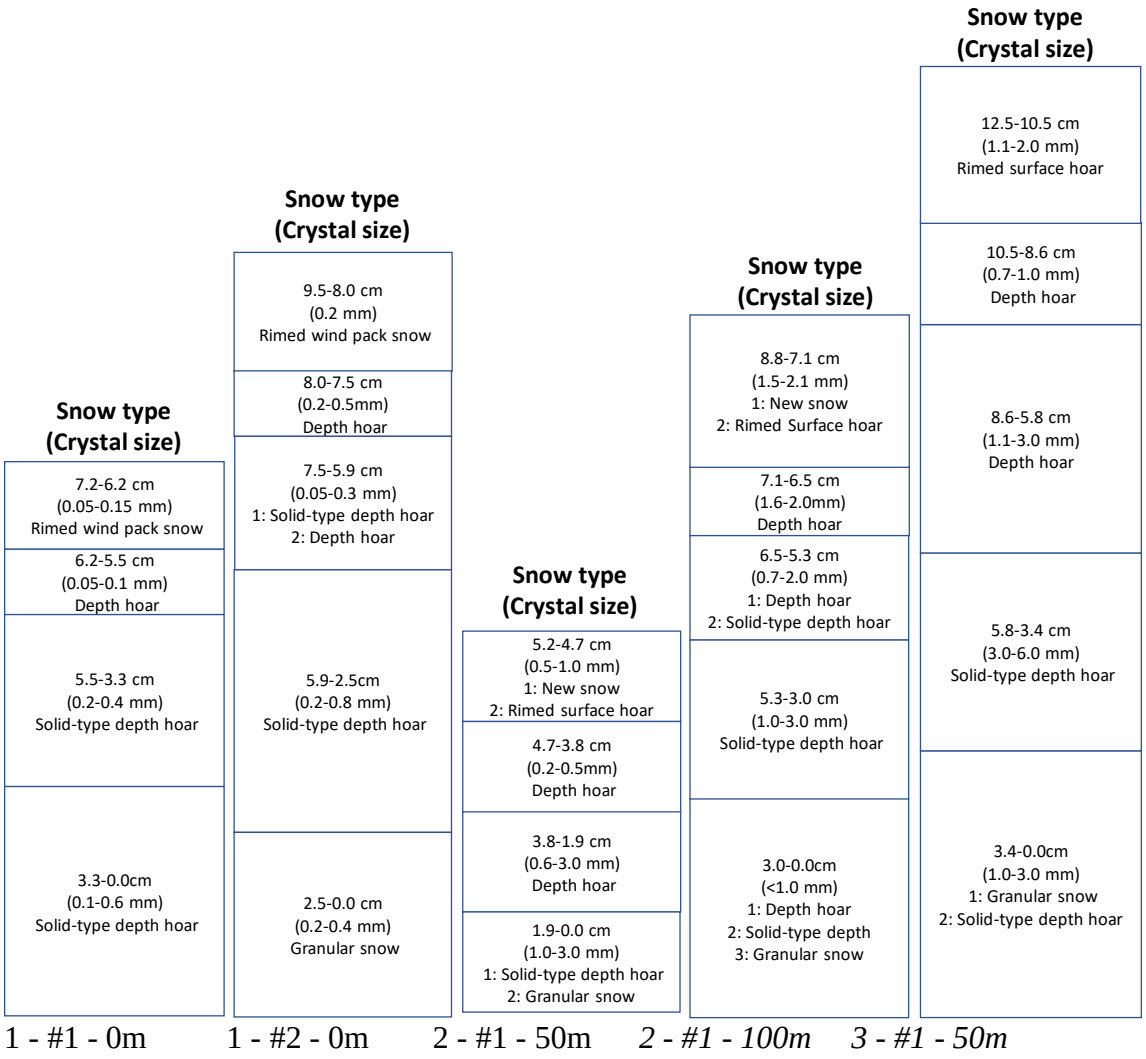


Figure 17. Results of snow structure observations from all ice stations.

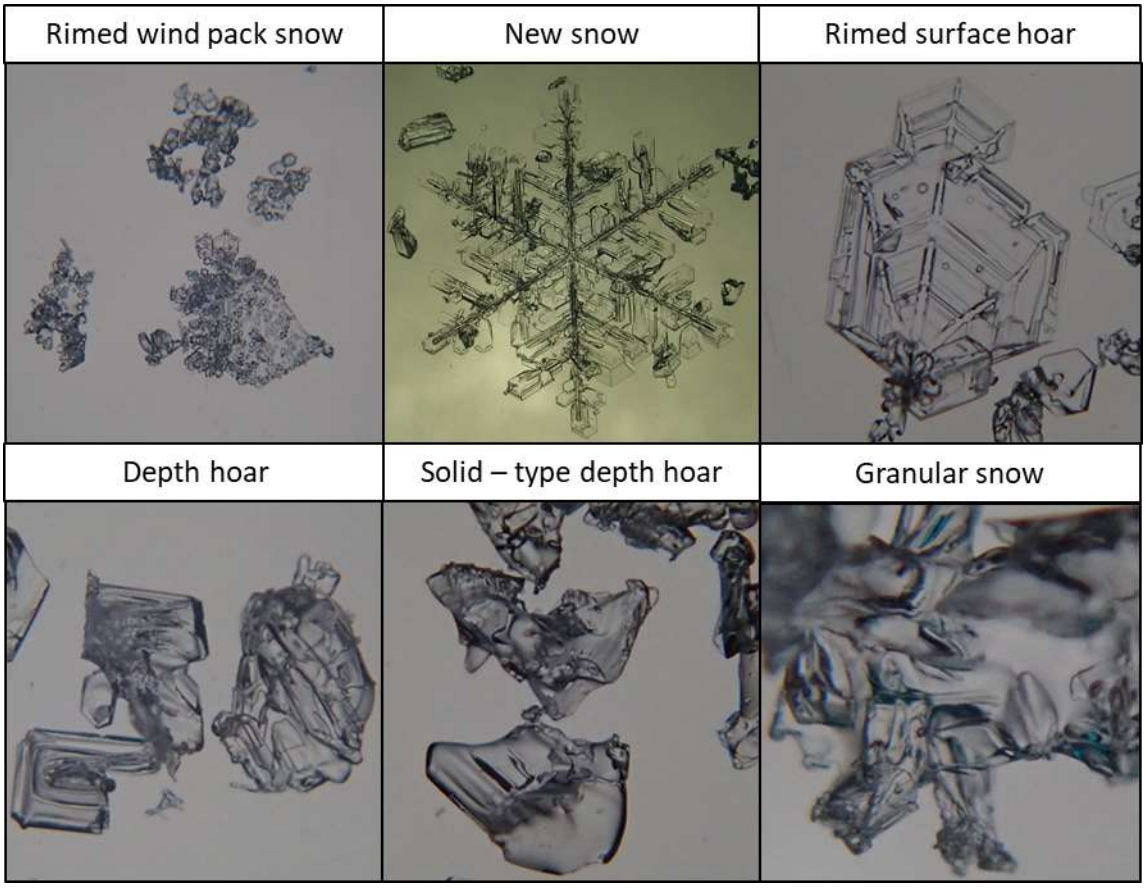


Figure 18. Pictures of observed snow type in ice stations.

4.13.7 Location of All Ice-Related Data

lsloaa::sciencenet/2019-87-JOIS/Data/

- /Ice_Stations/Ice_and_snow_survey/
  JOIS2019_summary_of_ice_stations.xlsx
  /Ice_Core_Photos/
  /Snow_Pit_Photos/

- /Ice_Watch/
  JOIS2019_ice_watch.xlsx
  /Ice_Watch_Photos/

- /Shipborne_EM/
  JOIS2019_EM_0916_1607-0917_2118_1sec.xlsx

JOIS2019_EM_0918_0133-0919_1726_1sec.xlsx
JOIS2019_EM_0920_0323-0921_0135_1sec.xlsx
JOIS2019_EM_0921_0905-0922_0249_1sec.xlsx
JOIS2019_EM_0922_0249-0922_1717_1sec.xlsx
JOIS2019_EM_0923_0049-0923_2150_1sec.xlsx

Many Thanks to all those that helped during the Ice Stations.

4.13.8 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. Student ice team. Photo by Kazu Tateyama.

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Figure 22. Photo by Kazu Tateyama.

5. APPENDIX

5.1 SCIENCE PARTICIPANTS 2019-87

Table 7. Onboard Science Team pre-program from Aug 29th to Sep 11th.

Name	Affiliation	Role
Sarah Ann Quesnel	DFO-IOS	Nutrient Setup and Analysis
Edmand Fok	DFO-IOS	TSG/SCS/Computer Setup

Table 8. Onboard Science Participants for 2019-87

Name	Affiliation	Role
Sarah Zimmermann	DFO-IOS	Chief Scientist
Kenny Scozzafava	DFO-IOS	Dissolved oxygen analysis
Marty Davelaar	DFO-IOS	DIC/Alkalinity analysis
Cassandra DeFrancesco	DFO-IOS	DIC assist / spreadsheets
Sarah-Ann Quesnel	DFO-IOS	Nutrients analysis, lab supervisor
Chris Clarke	DFO-IOS	Watchleader, salinity analysis
Stephen Page	DFO-IOS	Watchleader, salinity analysis
Edmand Fok	DFO-IOS	Watchstander, CTD, IT
Peter Van Buren	DFO-IOS	Watchstander, zoops, salts
Bingkun Luo	U Miami	Watchstander
Celine Gueguen	Sherbrooke	Watchstander, CDOM
Nicolas Sylvestre	Sherbrooke	Watchstander, CDOM
Masahiro Saito	KIT	Watchstander, ice observation
Hiromi Kimura	KIT	Watchstander, ice observation
Kohei Sato	KIT	Watchstander, ice observation
Yurika Watanabe	KIT	Watchstander, ice observation
Masataka Seo	TUMSAT	Pteropod net, Watchstander
Yuanxin Zhang	TUMSAT	Alkalinity analysis
Michiyo Yamamoto-Kawai	TUMSAT	Alkalinity analysis
Thomas Grevesse	Concordia	DNA/RNA sampling
Loïc Jacquemot	ULaval	DNA/RNA sampling
Jeff O'Brien	WHOI	ITPs, buoys
Fred Marin	WHOI	ITPs, buoys, dispatches
Cory Beatty	UMontana	pCO2 on buoys, moorings and underway
Marshall Swartz	WHOI	LADCP, dispatches
Jasmine (Jian) Zhu	WHOI	LADCP

Table 9. Principal Investigators Onshore for 2019-87

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
Mike DeGrandpre	U Montana	pCO2, pH, Underway system, Buoy, Mooring
Motoyo Itoh	JAMSTEC	CTD/Rosette / XCTD
Shigeto Nishino	JAMSTEC	CTD/Rosette
Takashi Kikuchi	JAMSTEC	CTD/Rosette
John Toole	WHOI	ITP Buoys
Mary-Louise Timmermans	YaleU	Moorings / ITP buoys
Don Perovich	CRREL	Ice Mass-Balance Buoy
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
Jennifer Hutchings	OSU	Ice Observations
Dan Torres	WHOI	Rosette: LADCP / Fiber Optic Gyro

Table 10. Affiliation Abbreviations.

Abbreviation	Definition
BIO	Bedford Institute of Oceanography, DFO, Dartmouth, NS, Canada
ConcordiaU	Concordia University, Montreal, Qc, Canada
CRREL	Cold Regions Research Laboratory, New Hampshire, USA
DFO	Department of Fisheries and Oceans, Canada
IOS	Institute of Ocean Sciences, DFO, Sidney, BC, Canada
JAMSTEC	Japan Agency for Marine-Earth Science Technology, Japan
KIT	Kitami Institute of Technology, Kitami, Hokkaido Prefecture, Japan
OSU	Oregon State University, Corvallis, Oregan, USA
USherbrooke	University of Sherbrooke, Quebec, Canada
TUMSAT	Tokyo University of Marine Science and Technology, Tokyo, Japan
UBC	University of British-Columbia, Vancouver, BC, Canada
ULaval	University of Laval, Quebec City, Quebec, Canada

UMontana	University of Montana, Missoula, Montana, USA
UVic	University of Victoria, Victoria, British Columbia, Canada
WHOI	Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA
YaleU	Yale University, New Haven, Connecticut, USA

Table 112. 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=165036
Ice-Tethered Profiler buoys	www.whoi.edu/itp
Ice Mass Balance buoys	http://imb-crrel-dartmouth.org/
JOIS website from DFO	https://dfo-mpo.gc.ca/science/atsea-enmer/missions/2018/jois-eng.html

5.2 LOCATION OF SCIENCE STATIONS

The scientific crew boarded the *CCGS Louis S. St-Laurent* icebreaker in Kugluktuk, NU, on 11 /12 September 2019 and returned to Kugluktuk, NU on 4 October 2019. 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 12. CTD/Rosette cast locations for 2019-78.

Cast #	Station	CAST START DATE and Time (UTC)	Latitude (°N)	Longitute (°W)	Water Depth (m)	Cast Depth (m)	Sample Numbers	Comments
1	AG5wDNA	9/13/2019 12:27	70.5532	122.9072	644	634	1-24	yo-yo each niskin: stop - 30 sec , up 1m , down 2m , up 1m, 30 sec , trip. Niskin 8 : leaky niskin - vent was loose Niskin 13-15 where tripped out of depth order - deeper than originally planned.
2	AG-5	9/13/2019 15:03	70.5513	122.8962	644	629	25-44	
3	CB1	9/14/2019 17:00	71.7730	131.8785	1100	1110	45-68	Sample 52: loose vent Sample 60: niskin 16 empty -> no sample
4	CB31b	9/14/2019 23:58	72.3493	134.0015	2075	2055	69-92	Sample 76: niskin 8 tripped out of order because target property T_{max} was deeper than niskin 7 -> firing order = 5,6,8,7,9
5	CB23a	9/15/2019 6:20	72.8975	135.9992	2748	2739	93-116	Samples 100 and 116: niskins had loose vents. CTD Operator Switched during cast from Stephan Page to Edmand Fok.
6	CB50	9/15/2019 13:07	73.5018	134.2492	2886	2874	117-140	Sample 130: bottle closure command sent with no response until it closed at 208m.
7	CB40	9/15/2019 21:14	74.4993	135.4313	3260	3242	141-164	Sample 141: had water collected in carboy for nutrients in-house reference sample. CDOM collection shifted to sample # 123 to draw from T_{max}
8	CB18	9/16/2019 7:09	74.9992	139.9948	3607	3616	165-188	Sample 172: Spiggot was leaking.
9	CB17	9/16/2019 15:59	76.0002	139.9982	3680	3688	189-212	Sample 196: niskin 8 leaking from spiggot left over water from bottle number 1 Sample 189 put in carbouy for Deep water Reference

10	PP7	9/17/2019 1:53	76.5393	135.4358	3554	3561	213-236	With 2 microbial diversity (DNA/RNA) allocated niskins
11	CB15	9/17/2019 12:53	77.0000	140.0030	3707	3719	237-259	Sample 260: niskin 24 did not close and no record in seabird file.
12	CB13	9/17/2019 21:34	77.3017	143.3070	3761	3774	261-284	Sample 268: niskin 8 vent left open. Rosette stopped at 50m to remove chummy and do yo-yo.
13	CB16	9/18/2019 8:15	78.0038	140.0075	3732	3743	285-308	Sample 289: bottle 5 oxygene redraw Sample 292: bottle 8 leaky spiggot Samples 295-297 Barium collection added
14	ITP1	9/18/2019 23:32	79.0070	137.0957	3708	601	309-332	Samples 321,323 and 331 have had duplicate nutrient samples added. Samples 324-328 filtered for pteropods (after salt collection)
15	CBN1	9/20/2019 2:38	80.9360	135.6242	3686	3697	333-356	Samples: 333,336,338 and 342 added DOM sample collection. Sample 354 : closed early, at approximetly 390m.
16	NE-1 DNA/RNA	9/21/2019 2:41	80.0317	140.1378	3745	1002	357-380	Up stop mix for each depth.
17	NE-1	9/21/2019 4:50	80.0302	140.1580	3746	3757	381-404	
18	CBN-3	9/22/2019 2:23	79.1403	145.6732	3786	3800	405-428	
19	CB11	9/22/2019 11:44	79.0013	149.9905	3805	3808	429-452	Sample 436: bottle 8 Leaky spiggot (full bottle replaced-CC) Sample 431: bottle 3 redraw oxygene sample
20	CB10	9/23/2019 4:23	78.3252	153.1412	2648	2645	453-476	Note: This cast has Iodine collection

21	RN7	9/23/2019 9:53	78.1817	151.6395	3806	3814	477-500	Sample 497 : niskin 20 yo-yo at chl_{max} Sample 500: niskin 24 yo-yo and will compare with SAMI on ITP (5m bottle) Station is at ITP107 location prior to recovery
22	CB9	9/23/2019 20:36	77.9952	150.0362	3827	3814	501-524	Sample 501, 519,520, 523,524 were all USM. Altimeter kicked in at 50m
23	CB12	9/24/2019 5:03	77.7028	146.6717	3812	3802	525-548	
24	CB8	9/24/2019 16:39	76.9997	149.9982	3826	3817	549-572	Sample 567: niskin 18 closure was USM, leaking from bottom cap.
25	CB7	9/25/2019 2:10	75.9987	149.9937	3832	3820	573-596	
26	CB5	9/25/2019 10:59	75.2995	153.3032	3847	3832	597-620	Stopped at 50m on downcast for cups ; stopped at 51m on upcast for cups (nightwatch)
27	CB4 DNA	9/25/2019 18:57	74.9983	149.9970	3827	1000	621-644	yo-yo at all depths. Sample 642 to 644 (surface niskins 22-24): weather too rough so change to 10m closures. Sample 636-638 (niskins 15-17) selected for comparison against SAMI on mooring.
28	CB4	9/25/2019 21:09	74.9863	149.9940	3825	3817	645-668	Note: niskins fired out of order, 17, 18,22,19,20,21,23,24 (around 155m to catch eddy) Sample 660: niskin 15 collected water for Si Depolymerization Test. Sample 652: bottle 8 leaky bottom.
29	CB6	9/26/2019 4:57	74.6985	146.6985	3784	3771		Changed surface niskin closure to 10m from 5 due to large swells.
30	CB3	9/26/2019 13:46	74.0002	149.9947	3818	3815		Sample 700 : niskin 8 leaky bottom. Samples 712-713: niskin 19-20 were USM. Samples 715 and 716: niskin 22-23 no USM because too much swell.

31	CB2	9/26/2019 22:17	72.9992	150.0185	3690	3740		Niskin 21: depth changed to 3100m and as 2nd niskin closed. Niskin 23: removed request for DIC chl-a, $\delta^{18}O$, Ba Niskins fired out of order: 1-21-2-3-....
32	CB2A	9/27/2019 4:04	72.4995	149.9947	3731	3714		Niskins fired out of order: 19-21-22-23-20-24
33	BL8	9/27/2019 10:04	71.9497	150.2668	2200	2960		Niskins fired out of order: 18-21-22-19-20-23-24
34	BL7	9/27/2019 13:37	71.8207	150.7677	2500	2561		
35	BL6	9/27/2019 17:12	71.6790	151.1298	2000	2073		
36	BL7a-Cs	9/27/2019 21:18	71.7987	150.3565	2560	501		Sample 631: niskin 19's bottom cap was leaking, 3 sets of USM closures.
37	STN-A	9/28/2019 8:57	72.6002	144.7018	3432	3420		Niskin 8: bottom cap was leaky. Niskin 15:single replicate chl-a sample. Niskin 18: duplicate chl-a samples. Niskin 2,4,6,7: have bacteria samples.
38	CB6s	9/28/2019 18:10	73.6980	146.6978	3739	3726		Niskin 8: bottom cap was leaking.
39	CBS-2	9/29/2019 3:01	73.4997	142.9967	3634	1103		~1000m cast due to time constraint.
40	CB19	9/29/2019 9:21	74.2992	143.3052	3702	3689		Niskin 9: one salinity sample 10: duplicate salinity samples. Bottle top dispenser tips of oxygen reagents were left open since last station, so pumped twice before application.
41	CB21-DNA	9/29/2019 17:18	73.9908	140.0430	3523	1002		Niskin 16-18 : slow firing response, see bottle summary for actual depth; SAMI calibration on BGOS-D @30 35 40. Niskin 20: bottom cap leak.
42	CB21	9/29/2019 20:28	73.9928	140.0610	3523	3510		Altimeter clicked in at 100m hotstuff
43	CB22	9/30/2019 3:51	73.4498	138.0108	3132	3112		Niskin 15: didn't trip as computer crashed.

44	CB27	9/30/2019 10:37	73.0037	140.0055	3230	3208		Sample 1017: niskin 18 dissolved oxygen was re-drawn.
45	CB29	9/30/2019 20:08	72.0005	140.0185	2685	2684		Niskin 8: change to 90m fired out of order:1 2 3…7 9 10 11…20 8 21 22 23 24 Sample 1030: bottle 7 oxygen redraw
46	MK6	10/1/2019 1:09	71.5848	140.0000	2500	2475		Altimeter kicked in at 50m; niskins fired out of order:19-22-20-21-23-24.
47	CB28b	10/1/2019 6:19	71.0010	139.9963	2000	2072		Niskins fired out of order: 1, 2, 3, 4, 5, 7, 18, 6, 19, 24. Sample 1077: niskin 5, DIC was sampled last as it was missed at the beginning. Sounder was not working.
48	MK4	10/1/2019 9:44	70.8090	139.9988	1514	1503		
49	MK3	10/1/2019 12:25	70.5673	140.0025	774	757		
50	MK2	10/1/2019 14:24	70.3980	139.9982	500	490		30 kHz sounder utilized.
51	MK1	10/1/2019 16:51	70.2262	139.9957	200	219		Changed niskin firing order to capture a chl feature at 60m instead of 100m: niskin 7,9,10,8,11
52	CB28aa	10/1/2019 20:04	70.0020	139.9975	60	52		Niskin fired out of order 11-17 . Bottle 1-7 was not collected due to bottle 1-4 dumped Sample 1177: niskin 16 CDOM sample not collected. Niskins 1-10 and 18-24 not used on this cast. Samples collected only from niskin 11-17.

5.2.2 XCTD

Table 13. XCTD cast deployment locations for 2019-78.

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 (°E)	S/N	Probe Type	Cast Depth (m)	Comments
C3_00049.EDF	9/14/2019 21:07	72.0471	-132.8846	16017096	XCTD-1	1100	Deployed after CB-1
C3_00050.EDF	9/15/2019 4:02	72.6505	-135.0865	15105316	XCTD-1	1100	
NA	9/15/2019 10:48			15105315			Probe misfired, will deploy another probe.
C3_00051.EDF	9/15/2019 10:55	73.2443	-134.9956	15105314	XCTD-1	1100	
C3_00052.EDF	9/15/2019 18:22	74.0217	-134.8531	15105313	XCTD-1	1100	
C3_00053.EDF	9/16/2019 3:13	74.7438	-137.7007	16027293	XCTD-1	1100	Ice floating around
C3_00054.EDF	9/16/2019 13:34	75.6249	-139.9793	16027294	XCTD-1	1100	
C3_00055.EDF	9/16/2019 22:14	76.2738	-137.7205	16027295	XCTD-1	1100	
C3_00056.EDF	9/17/2019 8:55	76.8108	-137.7301	16027296	XCTD-1	183	Data stopped logging at ~182m - probe misfired
C3_00057.EDF	9/17/2019 9:03	76.8188	-137.7961	16027297	XCTD-1	229	Breaking through ice, wire broke.
C3_00058.EDF	9/17/2019 9:12	76.8342	-137.8669	16027298	XCTD-1	1028	
C3_00059.EDF	9/17/2019 18:14	77.1518	-141.6953	16027299	XCTD-1	1100	
C3_00002a.EDF	9/18/2019 3:41	77.6609	-141.6382	16027300	XCTD-1	1100	
NA	9/18/2019 14:56		132.8548	16027313			System not functionning well - data is erronous
C3_00062.EDF	9/18/2019 19:19	78.8734	-137.5786	16027314	XCTD-1	1056	Ship stopped due to due heavier ice
C3_00063.EDF	9/19/2019 3:11	79.4620	-136.4234	16027315	XCTD-1	1045	
C3_00064.EDF	9/19/2019 6:14	79.9852	-136.0366	16027316	XCTD-1	1100	
C3_00066.EDF	9/19/2019 9:32	80.4682	-136.4685	16027389	XCTD-1	100	Small ice flow broke the wire shortly after deployment

C3_00067.EDF	9/19/2019 9:44	80.4862	-136.4229	16027390	XCTD-1	979	
C3_00068.EDF	9/20/2019 12:05	80.5678	-137.1891	16027391	XCTD-1	285	Ship slowed, we deployed between mid and aft of ship
NA				16029392			Failed - XCTD wasn't being recognized by system
C3_00069.EDF	9/20/2019 12:13	80.5541	-137.2142	16027394	XCTD-1	1100	
C3_00070.EDF	9/21/2019 12:51	79.7187	-141.6794	16027393	XCTD-1	1100	Ship stopped due to due heavier ice
C3_00071.EDF	9/21/2019 23:15	79.5096	-145.2345	16027395	XCTD-1	1100	System was rebooted
C3_00073.EDF	9/22/2019 8:14	78.9208	-147.9529	16027396	XCTD-1	896	
C3_00074.EDF	9/23/2019 0:48	78.6963	-151.5694	16027397	XCTD-1	1100	
C3_00075.EDF	9/24/2019 2:21	77.8273	-148.2060	16027398	XCTD-1	1100	
C3_00076.EDF	9/24/2019 11:16	77.3414	-147.6651	16027399	XCTD-1	1100	
C3_00077.EDF	9/24/2019 22:30	76.4908	-149.9759	16027400	XCTD-1	1100	
C3_00078.EDF	9/25/2019 7:54	75.6416	-151.6966	16027377	XCTD-1	1100	
C3_00079.EDF	9/25/2019 16:06	75.1542	-151.6910	16027378	XCTD-1	1100	
C3_00080.EDF	9/26/2019 2:03	74.8579	-148.5012	16027379	XCTD-1	1100	
C3_00081.EDF	9/26/2019 11:09	74.2886	-148.6146	16027380	XCTD-1	1100	
C4_00082.EDF	9/26/2019 19:07	73.5173	-149.9826	15115715	XCTD-2	1850	
C4_00083.EDF	9/27/2019 23:35	71.9111	-149.6448	15115714	XCTD-2	1850	
C3_00084.EDF	9/28/2019 3:01	72.1903	-147.8117	16027381	XCTD-1	1081	
C3_00085.EDF	9/28/2019 5:35	72.3932	-146.3056	16027383	XCTD-1	1092	
C3_00086.EDF	9/28/2019 14:27	73.1233	-145.6449	16027382	XCTD-1	1100	
C3_00087.EDF	9/28/2019 23:43	73.6157	-144.7722	16027384	XCTD-1	1100	
C3_00088.EDF	9/29/2019 6:13	73.8723	-143.1354	16027385	XCTD-1	1100	
C3_00089.EDF	9/29/2019 14:33	74.1423	-141.5664	16027386	XCTD-1	1100	
C3_00091.EDF	9/30/2019 1:30	73.7240	-138.9816	16027387	XCTD-1	1097	Skipped file name C3_0090
C3_00092.EDF	9/30/2019 8:08	73.2370	-138.9892	16027388	XCTD-1	1100	
C3_00093.EDF	9/30/2019 15:44	72.5006	-140.0088	17025043	XCTD-1	1100	

5.2.3 Zooplankton – Vertical Bongo Net Hauls

Table 14. Zooplankton vertical bongo net hauls.

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

Net Event #	CTD cast #	Date	Time (UTC)	Latitude (°N)	Longitude (°W)	Net Mesh (um)	Bottom Depth (m)	Wire angle (°)	RBR depth (m)
1	ROS-1	13/Sep/19	21:34	70.5508	122.8933	150 236	633	<5	131.5
2	ROS-4	15/Sep/19	0:34	72.3497	122.9995	150 236	2065	0	98.9
3	ROS-5	15/Sep/19	6:49	72.8950	122.0033	150 236	2738	0	98.5
4	ROS-6	15/Sep/19	13:34	73.5000	122.0033	150 236	2884	5	103.3
5	ROS-7	15/Sep/19	21:36	74.5000	122.4333	150 236	3260	0	99.1
6	ROS-8	16/Sep/19	9:02	74.1617	122.9000	150 236	3615	0	98.0
7	ROS-9	16/Sep/19	17:15	76.0017	122.9833	150 236	3679	0	98.7
8	ROS-10	17/Sep/19	3:46	76.5367	122.4583	150 236	3554	0	101.1
9	ROS-11	17/Sep/19	14:23	77.0350	122.0030	150 236	3707	0	99.9
10	ROS-12	17/Sep/19	22:30	77.3024	122.3083	150 236	3762	0	103.6
11	ROS-15	20/19/2019	4:09	80.9333	122.6383	150 236	3696	0	100.8
12	ROS-21	23/Sep/19	4:48	79.3248	122.6383	150 236	2640	0	100.8
13	ROS-22	23/Sep/19	21:55	77.9897	122.0418	150 236	3827	0	102.4
14	ROS-23	24/Sep/19	5:30	77.7037	122.6746	150 236	3812	0	99.9
15	ROS-24	24/Sep/19	17:34	76.9997	122.9976	150 236	3826	0	100.3

16	ROS-25	25/Sep/19	3:18	75.9987	122.0004	150 236	3832	0	110.0
17	ROS-26	25/Sep/19	12:14	75.2978	122.3089	150 236	3847	0	99.7
18	ROS-28	25/Sep/19	22:36	74.9850	122.0083	150 236	3823	20	90.6
19	ROS-31	26/Sep/19	23:44	72.9953	122.0135	150 236	3750	5-10	85.2
20	ROS-32	27/Sep/19	4:55	72.4983	122.9950	150 236	3725	0	106.6
21	ROS-33	27/Sep/19	21:41	71.6783	122.1250	150 150 236	2970	30	140.9
22	ROS-35	27/Sep/19	17:14	71.6789	122.1300	150 236	2082	20	96.7
23	ROS-37	28/Sep/19	9:38	72.6000	122.7000	150 236	3432	0	99.5
24	ROS-38	28/Sep/19	19:20	73.7017	122.6917	150 236	3739	10	98.9
25	ROS-40	29/Sep/19	10:27	74.2983	122.2567	150 236	3702	0	98.9
26	ROS-42	29/Sep/19	21:50	73.9917	122.0617	150 236	3534	10	94.7
27	ROS-43	29/Sep/19	4:45	73.4483	122.0000	150 236	3132	20	86.4
28	ROS-44	30/Sep/18	11:48	73.0033	122.0083	150 236	3226	10	98.5
29	ROS-46	1/Oct/19	2:08	71.5848	122.0057	150 236	2500	10	99.6
30	ROS-47	1/Oct/19	7:19	71.0000	122.9967	150 236	2000	0	106.9
31	ROS-48	1/Oct/19	10:23	71.8092	122.9983	150 236	1511	0	140.4
32	ROS-49	1/Oct/19	12:53	70.5683	122.0017	150 236	775	0	96.6

5.2.4 Zooplankton – Vertical NORPAC Closing Net Hauls

Net	CTD	Date	Time (UTC)	Lat N	Lon W	Bottom Depth (m)	Attempted Depth (m)	Flow before	Flow after	note
1	ROS2	13/09/2019	21:04	70.5505	122.8983	659	50-100	0	740	
2	ROS7	15/09/2019	22:01	74.5017	135.4327	3242	0-50	0	402	
3			22:08	74.5133	135.4328	3243	50-100	0	482	
4			22:27	74.5017	135.4350	3248	100-200	0	781	
5	ROS8	16/09/2019	7:38	74.9983	139.9817	3607	0-50	0	332	
6			7:48	74.9983	140.0000	3607	50-100	0	1821	wire miss
7			8:21	74.9983	140.0050	3609	100-200	0	281	
8	ROS9	16/09/2019	16:41	76.0000	140.0333	3679	0-50	0	370	
9			16:51	76.0000	140.0333	3679	50-100	0	382	
10	ROS10	17/09/2019	2:24	76.5383	135.4433	3554	0-50	?	560	
11			2:54	76.5383	135.4483	3554	50-100	560	760	
12			3:13	77.2667	135.4517	3554	100-200	0	345	
13	ROS11	17/09/2019	13:28	77.0017	140.0183	3707	0-50	0	135	
14			13:38	77.0033	140.0200	3707	50-100	0	230	
15			13:51	77.0050	140.0300	3707	100-200	0	787	
16	ROS12	17/09/2019	21:59	77.3017	143.3142	3762	0-50	0	448	
17			22:08	77.3017	143.3188	3762	50-100	0	447	
18	ROS13	18/09/2019	8:18	78.0035	140.0073	3732	0-50	0	296	1cast only
19	ROS15	20/09/2019	3:08	80.9360	135.6247	3696	0-50	0	340	
20			3:17	80.9360	135.6333	3696	50-100	0	370	
21			3:31	80.9350	135.6333	3696	100-200	370	682	
22	ROS19	22/09/2019	12:21	79.0000	150.0067	3805	0-50	0	274	
23			12:28	79.0000	150.0100	3805	50-100	0	281	
24			12:42	79.0000	150.0117	3805	100-200	0	543	
25	ROS20	23/09/2019	5:02	78.3250	153.1417	2640	0-50	0	?	
26			5:11	78.3238	153.1450	2640	50-100	?	360	
27			5:27	78.3238	153.1450	2640	100-200	0	400	
28	ROS22	23/09/2019	21:00	77.9932	150.0400	3827	0-50	0	185	
29			21:13	77.9917	150.0383	3827	50-100	0	303	
30			21:28	77.9912	150.0400	3827	100-200	0	468	
31	ROS24	24/09/2019	17:00	76.9997	149.9975	3826	0-50	0	422	
32			17:08	76.9997	149.9975	3826	50-100	0	407	
33	ROS25	25/09/2019	2:32	75.9997	150.0012	3832	0-50	0	168	
34			2:38	75.9997	150.0012	3832	50-100	0	270	
35			2:48	75.9997	150.0012	3832	100-200	0	610	
36	ROS26	25/09/2019	11:40	75.2967	153.3083	3828	0-50	0	340	
37			11:47	75.2967	153.3083	3828	50-100	0	382	

38	ROS28	25/09/2019	21:42	74.9867	149.9938	3823	0-50	0	415	
39			21:52	74.9857	149.9913	3823	50-100	0	715	
40			22:06	74.9850	149.9967	3823	100-200	0	1295	
41	ROS29	26/09/2019	5:21	74.6987	146.7000	3784	0-50			net was broken
42	ROS31	26/09/2019	22:45	72.9988	150.0158	3750	0-50	0	818	big waves flowmeter reading may vary significant
43			22:54	72.9983	150.0148	3750	50-100	0	1280	
44			23:09	72.9970	150.0130	3750	100-200	0	558	
45	ROS32	27/09/2019	4:22	72.4982	149.9943	3725	0-50	0	791	
46			4:30	72.4982	149.9943	3725	50-100	0	665	
47	ROS33	27/09/2019	10:31	71.9483	150.2633	2970	0-50	0	470	caught fish
48			10:38	71.9483	150.2633	2970	50-100	0	838	
49			11:06	71.9483	150.2633	2970	100-200	0	1572	
50	ROS35	27/09/2019	17:31	71.6783	151.1267	2081	0-50	0	470	
51			17:38	71.6783	151.1267	2081	50-100	0	505	
52			17:51	71.6783	151.1267	2081	100-200	0	472	
53	ROS37	28/09/2019	9:17	72.5983	144.7017	3432	0-50	0	240	net was broken
54	ROS38	28/09/2019	18:37	73.6983	146.6983	3739	0-50	0	470	
55			18:44	73.6983	146.6983	3739	50-100	0	505	
56			18:57	73.6983	146.6983	3739	100-200	0	472	
57	ROS40	29/09/2019	9:40	74.2983	143.3067	3702	0-50	0	495	
59			10:08	74.2983	143.3067	3702	100-200	0	1110	
60	ROS42	29/09/2019	21:03	73.9267	140.0622	3523	0-50	0		
61			21:10	73.9267	140.0622	3523	50-100	0		
62			21:22	73.9267	140.0622	3523	100-200	0		
63	ROS43	30/09/2019	4:18	73.4483	138.0067	3132	0-50	0	182	
64			4:24	73.4483	138.0067	3132	50-100	0	165	
65	ROS44	30/09/2019	11:01	73.0033	140.0067	3226	0-50	0	256	
66			11:09	73.0033	140.0067	3226	50-100	0	203	
67			11:25	73.0033	140.0067	3226	100-200	0	646	
68	ROS46	01/10/2019	1:36	71.5850	140.0008	2500	0-50	0	?	
69			1:47	71.5850	140.0008	2500	50-100	?	828	
70			2:06	71.5850	140.0008	2500	100-200	0	211	
71	ROS47	01/10/2019	6:31	71.0005	139.9967	2000	0-50	0	140	
72			6:37	71.0005	139.9967	2000	50-100	0	262	
73			6:58	71.0005	139.9967	2000	100-200	0	120	

74	ROS48	01/10/2019	10:03	70.8083	139.9983	1511	0-50	0	342	
75			10:09	70.8083	139.9983	1511	50-100	0	462	
76	ROS50	01/10/2019	14:47	70.3983	140.9967	504	0-50	0	442	
77				70.3983	140.9967	504	50-100	0	335	
78			15:17	70.3983	140.9933	504	100-200	0	1243	

5.2.5 Microbial Diversity Casts

At each station, 8 depths were consistently sampled and were defined: surface (usually ~ 5 m), mixed layer (~25 m), subsurface chlorophyll maximum, the core of the Pacific Summer Water (32.3), core of the Pacific Winter Water (33.1), temperature maxim (T-max), the Atlantic halocline at 1500 m and the bottom depth

Station	Cast	Date and Time	Latitude (°N)	Longitude (°W)	Depth sampled	Samples	Comments
AG5[a]	1	2019-09-13 7:33:00 PM	70.5532	122.9072	5m, ML, SCM, below SCM, 32.3, 33.1, T_{max}, Bot-10	DNA/RNA, Prot, FCM-L, FISH_euk, FISH_bact, DAPI	Station FICUS, FCML (bacteria) moitié de volume de paraformaldéhyde ajoutée (100ml au lieu de 200) (Probleme pipette, Celine Gueguen)
CB31b[b]	4	2019-09-14 12:05:00 AM	72.3493	134.0015	5m, ML, SCM, 32.3, 33.1, T_{max}, Bot-10	DNA/RNA, FISH_euk, FISH_bact, DAPI	FCML (bacteria) moitié de volume de paraformaldéhyde ajoutée (100ml au lieu de 200) (Probleme pipette, Celine Gueguen)
CB50[j]	6	2019-09-15 1:09:00 PM	73.5018	134.2492	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA, FISH_euk, FISH_bact, DAPI	FCML (bacteria) moitié de volume de paraformaldéhyde ajoutée (100ml au lieu de 200) (Probleme pipette, Celine Gueguen)
CB40[a]	7	2019-09-15 9:17:00 PM	74.4993	135.4313	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA, FISH_euk, FISH_bact, DAPI	FCML (bacteria) moitié de volume de paraformaldéhyde ajoutée (100ml au lieu de 200) (Probleme pipette, Celine Gueguen)
CB17[c]	9	2019-09-16 4:04:00 PM	76.0002	139.9982	5m, ML, SCM, 32.3, 33.1, T_{max}, AW	DNA/RNA, FISH_euk, FISH_bact, DAPI	FCML (bacteria) moitié de volume de paraformaldéhyde ajoutée (100ml au lieu de 200) (Probleme pipette, Celine Gueguen)

PP7[i]	10	2019-09-17 1:59:00 AM	76.5393	135.4358	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA, FISH_euk, FISH_bact, DAPI	FCML (bacteria) moitié de volume de paraformaldéhyde ajoutée (100ml au lieu de 200) (Probleme pipette, Celine Gueguen)
CB15[d]	11	2019-09-17 12:58:00 PM	77.000	140.0030	5m, SCM	DNA/RNA, FISH_euk, FISH_bact	no more water on others NISKIN, FCML (bacteria) moitié de volume de paraformaldéhyde ajoutée (100ml au lieu de 200) (Probleme pipette, Celine Gueguen)
CB16[g]	13	2019-09-18 8:16:00 AM	78.0038	140.0075	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA, FISH_euk, FISH_bact, DAPI	
ITP1[k]	14	2019-09-18 11:36:00 PM	79.0070	137.0957	5m, ML, SCM, below SCM, 32.3, 33.1, T_{max}	DNA/RNA, FISH_euk, FISH_bact, DAPI	
NE1[k]	16	2019-09-20 2:49:00 AM	80.0317	140.1378	5m, ML, SCM, 32.3, 33.2, Tmax, AW, Bot-10	DNA/RNA, Prot, FCM-L, FISH_euk, FISH_bact, DAPI	FICUS station, DAPI not stained with DAPI…(forget to incubate 10min with dapi)
CB11[a]	19	2019-09-22 11:51:00 AM	79.0013	149.9905	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA, FISH_euk, FISH_bact, DAPI	
CB10[h]	20	2019-09-23 4:28:00 AM	78.3252	153.1412	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA, FISH_euk, FISH_bact, DAPI	

CB9[a]	22	2019-09-23 8:41:00 PM	77.9952	150.0362	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA, FISH_euk, FISH_bact, DAPI	
CB7[f]	25	2019-09-25 2:18:00 AM	75.9987	149.9937	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA, FISH_euk, FISH_bact, DAPI	
CB4[d]	27	2019-09-25 6:59:00 PM	74.9983	149.9970	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA,Prot, FCM-L, FISH_euk, FISH_bact, DAPI.	FICUS station.
CB3[a]	30	2019-09-26 1:48:00 PM	74.0002	149.9947	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA, FISH_euk, FISH_bact, DAPI	
CB2[a]	31	2019-09-26 10:17:00 PM	72.9992	150.0185	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA, FISH_euk, FISH_bact, DAPI	Tmax =5°C!
BL8[e]	33	2019-09-27 10:05:00 AM	71.9497	150.2668	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA, FISH_euk, FISH_bact, DAPI	
STNA[a]	37	2019-09-28 8:59:00 AM	72.6002	144.7018	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA, FISH_euk, FISH_bact, DAPI	

CB21[a]	41	2019-09-29 5:19:00 PM	73.9908	140.0430	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA, Prot, FCM-L, FISH_euk, FISH_bact, DAPI	FICUS station.
CB27[c]	44	2019-09-30 10:39:00 AM	73.0037	140.0055	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA, FISH_euk, FISH_bact, DAPI	
CB28b[c]	47	2019-10-01 6:23:00 AM	71.0010	139.9963	5m, ML, SCM, 32.3, 33.1, T_{max}, AW, Bot-10	DNA/RNA, FISH_euk, FISH_bact, DAPI	
[a] Stations sampled in 2019, 208, 2017, 2016, 2015, 2014, 2013, 2012							
[b] Stations sampled in 2019, 2018, 2017, 2016, 2015, 2014, 2013							
[c] Stations sampled in 2019, 2018, 2017, 2016, 2015, 2014							
[d] Stations sampled in 2019, 2018, 2017, 2016, 2015, 2014, 2012							
[e] Stations sampled in 2019, 20118, 2017, 2016, 2015, 2013, 2012							
[f] Stations sampled in 2019, 2018, 2017, 2016, 2014							
[g] Stations sampled in 2019, 2016, 2015, 2014, 2013, 2012							
[h] Stations sampled in 2019, 2016, 2015, 2014, 2013							
[i] Stations sampled in 2019, 2015, 2014							
[j] Stations sampled in 2019, 2013							
[k] Stations sampled in 2019 only.							

5.2.6 Ice Based Observatory (Buoy) Operations

Table 15. 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	ITP119 (open water)	18-Sep 19:00	79° 00.3' N 137° 04.3' W
2	ITP117 w/ SAMI-CO2, TOP01, SIMB	19-Sep 20:00	80° 55.01' N 135° 31.91' W
3	ITP118 w/ SAMI-CO2	20-Sep 23:30	80° 02.46' N 140° 10.20' W
4	ITP112	22-Sep 20:00	78° 59.69' N 150° 08.43' W
5	ITP107 w/ SAMI-CO2+Mcat (recovery)	23-Sep 17:30	78° 11.09' N 151° 45.28' W

Table 16. pCO2 and pH sensors summary (UMontana)

Measurement system	Instrument IDs	Location	Duration
Underway infrared-equilibrator pCO_2	SUPER (Sunburst Sensors)	Entire cruise track (see IOS report in this document)	9/10/2019 - 10/2/2019
ITP SAMI-CO_2 w/ DO and PAR sensors	WHOI ITP 117, SAMI-CO2 (C9u)	First ITP ice deployment, CO2 ~ 4.5 m depth (see WHOI cruise report in this document)	9/19/2019 - present
ITP SAMI-CO_2 w/ DO and PAR sensors	WHOI ITP 118, SAMI-CO2 (C207)	Second ITP ice deployment, CO2 ~ 4.5 m depth (see WHOI cruise report in this document)	9/20/2019 - present

5.3 CTD/Rosette Sensor Configuration

CTD

CTD#	Make	Model	Serial#	Used with Rosette?	Casts Used
Primary	SeaBird	911+	756	Yes	All Casts
Secondary	SeaBird	911+	724		Damaged at start of cruise, but available for spares

Calibration and Accuracy Information CTD #756 PRIMARY							
Sensor		**Accuracy**	**Pre-Cruise**		**Post Cruise**		**Comment**
Name	**S/N**		**Date**	**Location**	**Date**	**Location**	
Pressure Sensor	91164	Nominal 1.2 m	26 Feb 2010	SeaBird Lab			
Temperature, SBE3plus	4322	Nominal ± 0.001 °C	8 Nov 2018	SeaBird Lab			
Conductivity, SBE4C	2809	Nominal 0.003 mS/cm	6 Nov 2018	SeaBird Lab			
Pump, SBE5T	5-3869						
Secondary Temp., SBE3plus	4239	Nominal ± 0.001 °C	9 Nov 2018	SeaBird Lab			
Secondary Cond., SBE4C	2810	Nominal 0.003 mS/cm	6 Nov 2018	SeaBird Lab			
Secondary Pump, SBE5T	5-3871						

Calibration and Accuracy Information, External Sensors							
Sensor		**Accuracy**	**Pre-Cruise**		**Post Cruise**		**Comment**
Name	**S/N**		**Date**	**Location**	**Date**	**Location**	

SBE 43 Dissolved Oxygen sensor	1489		13 Aug 2019	SeaBird Lab			CTD Voltage Channel 2 On Primary pump;
Datasonics Altimeter, Benthos	PSA-916D, 72144		12 May 2017	Benthos			CTD Voltage Channel 3
Seapoint Fluorometer (Chl-a)	SCF 2841		2006 w/ in-house check XX	Seapoint			CTD Voltage Channel 0 On Secondary Pump;
Wetlabs Transmissometer	C-Star CST-1052DR		18 Jun 2019	IOS (In-house bench test)			CTD Voltage Channel 1
WETLabs ECO CDOM	1076		11 Jun 2006	WETLabs			CTD Voltage Channel 4
Satlantic Cosine Log PAR	517		25 Jun 2014	Satlantic			CTD Voltage Channel 6
Biospherical Surface PAR QSR2200	20498		4 Apr 2016	Biospherical			
Biospherical PAR QSR2150 (Continuous)	50228		21 Jun 2016	Biospherical			

Deck Units

Type	*make*	*model*	*serial*	*comment*
Deck Unit	Seabird	11plus	680	
Deck Unit	Seabird	11plus	649	

Rosette Pylons

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

Water Sampler Carousel	Seabird	32	591	
Water Sampler Carousel	Seabird	32	498	

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	SCF365 1		Jun 2014 2pt check 15 Feb 2018	Seapoint 2pt check at IOS			30x gain cable (0 to 5V = 0 to 5mg/mL)
Wetlabs ECO CDOM Fluorometer	WSCD-1281		9 Jun 2011	Wetlabs			Thorough cleaning pre-cruise

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

SBE4c conductivity sensor
Measurement Range 0.0 to 7.0 Siemens/meter (S/m)

Settling Time 0.7 seconds to within 0.0001 S/m
Initial Accuracy 0.0003 S/m
Stability 0.0003 S/m/month
Time Response 0.060 seconds (pumped)

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

5.4 Underway Measurement

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

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.
For 2018, the manifold leaks were repaired and the permanent tubing from manifold to TSG replaced. No in-line flowmeter was used with the TSG this year.

Figure 23. Seawater loop system. Photo by Fred Marin.

The seawater loop provides uncontaminated seawater from 9m depth to the science lab for underway measurements. This is the configuration during 2017-11 (JOIS).

Figure 24. TSG manifold. (similar for 2019)

Figure 25. The Moyno pump installed in the engine room. This picture is from 2016 but same layout for 2019 – with exception of the pressure sensor moved farther to the right.

Figure 26. 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 2019.

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 27. 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 15 Feb 2018. 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 s/n 3274?

Computer
Laptop "WNBCIOS9011688"?

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

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

The data were collected through SeaBird's Seasave acquisition program v Seasave V 7.26.7.107 onto a laptop using a serial to usb adapter cable. GPS was provided to the

SBE-21 data stream using the NMEA from PC option rather than the interface box. A 5 second sample rate was recorded.

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

On a third arm of the manifold, an automated system for measurements of pCO2 from the seawater and atmosphere was used. This year's measurements were made with a an infrared equilibrator-based system (SUPER-CO2, Sunburst Sensors) owned by Mike DeGrandpre (UMontana) and operated onboard by Cory Beatty. Data were recorded through the cruise with discreet DIC, Alkalinity water samples drawn for comparison. For more information please see the report: DeGrandpre-Beatty 2019 Cruise Report.docx.

Flow rate was measured manually

For 2019:
Using the Honeywell controller, pressure set point was 18 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	27.7 s/L (2.2 L/min)

Water samples

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

5.4.2 SCS Data Collection System

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.

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.

The list of *.RAW files and order of variables within the data string:

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

Furano GPS only
File: GPRMC_*.Raw
Time interval 1 second

Description of *.RAW file string
GPRMC_20191001-000000.Raw
10/01/2019,00:00:01.252,$GPRMC,000012.00,A,7143.6620,N,14000.2776,W,8.6,177.0,011019,20.6,E*78
10/01/2019,00:00:02.268,$GPRMC,000013.00,A,7143.6596,N,14000.2775,W,8.6,177.4,011019,20.6,E*70

Comma delimited column after string name
a. Time HHMMSS.S
b. Status A= Active, V=Void
c. Latitude
d. Latitude N or S
e. Longitude
f. Longitude E or W
g. Speed over ground in knots
h. Course over ground in degrees (True)
i. Date DDMMYY
j. Magnetic variation in degrees
k. Checksum data, always begins with *

Position - $GPGGA
Position information

Marine Star GPS File: GGA-RAW_*.Raw
Time interval of GPS is 1 second.
Description of *.RAW file string
GGA-RAW_20191001-000000.Raw

10/01/2019,00:00:01.002,$GPGGA,000013.0,7143.66062,N,14000.29010,W,2,12,0.8,29.1,M,-2.6,M,6.0,0133*44
10/01/2019,00:00:02.002,$GPGGA,000014.0,7143.65812,N,14000.28939,W,2,12,0.8,28.8,M,-2.6,M,7.0,0133*45

Comma delimited column after string name
1) Time HHMMSS.S
2) Latitude
3) Latitude N or S
4) Longitude
5) Longitude E or W
8) Horizontal dilution

Furuno GPS File: GPGGA_*.Raw
Time interval of GPS is 1 second or less.
Description of *.RAW file string
GPGGA_20191001-000000.Raw
10/01/2019,00:00:00.236,$GPGGA,000011.00,7143.6643,N,14000.2776,W,2,12,0.5,26.9,M,-4.2,M,,*5A
10/01/2019,00:00:01.049,$GPGGA,,7143.664,N,14000.277,W,2,,,,,,,*4F
10/01/2019,00:00:01.455,$GPGGA,000012.00,7143.6620,N,14000.2776,W,2,12,0.5,26.4,M,-4.2,M,,*51
10/01/2019,00:00:02.065,$GPGGA,,7143.662,N,14000.277,W,2,,,,,,,*49
Comma delimited column after string name
1) Time HHMMSS.SS
2) Latitude
3) Latitude N or S
4) Longitude
5) Longitude E or W
8) Horizontal dilution

Course and Speed Over Ground - $GPVTG

Marine Star GPS File: VTG-RAW_*.Raw,
Track made good
Time interval varies, 1 to 2 seconds
Description of *.RAW file string
VTG-RAW_20191001-000000.Raw
10/01/2019,00:00:01.049,$GPVTG,175.40,T,-824.50,M,9.25,N,17.12,K,D*3C
10/01/2019,00:00:02.049,$GPVTG,174.99,T,-824.91,M,8.92,N,16.52,K,D*3C

Furuno GPS File: GPVTG_*.Raw
Track made good
Time interval varies, about 1 second
Description of *.RAW file string

GPVTG_20191001-000000.Raw
10/01/2019,00:00:00.440,$GPVTG,,,,,008.6,N,015.9,K,A*39
10/01/2019,00:00:00.846,$GPVTG,177.0,T,156.4,M,8.602,N,15.931,K*7A
10/01/2019,00:00:01.455,$GPVTG,,,,,008.6,N,015.9,K,A*39
10/01/2019,00:00:01.861,$GPVTG,177.4,T,156.8,M,8.593,N,15.914,K*7E

Comma delimited column after string name
1) Course made good, true north
2) T for true north
3) Course made good, magnetic north
4) M for magnetic north
5) Speed made good, Knots
6) N for knots
7) Speed made good, Km?
8) K for kilometer?

Time and Date - $GPZDA
Time and date information in UTC.

Marine Star GPS File: ZDA-RAW_*.Raw
Time interval varies from 1 to 11 seconds.

Description of *.RAW file strings
ZDA-RAW_20191001-000000.Raw
10/01/2019,00:00:00.580,$GPZDA,000012.032,01,10,2019,00,00*5E
10/01/2019,00:00:01.174,$GPZDA,000013.031,01,10,2019,00,00*5C

Furuno GPS File: GPZDA_*.Raw
Time and date information in UTC.
Time interval varies from 1 to 11 seconds.

Description of *.RAW file strings
GPZDA_20191001-000000.Raw
10/01/2019,00:00:00.440,$GPZDA,000012.00,01,10,2019,00,00*6F
10/01/2019,00:00:01.252,$GPZDA,000013.00,01,10,2019,00,00*6E

Comma delimited column after string name
1) Time UTC, hhmmss.sss
2) Day UTC, dd
3) Month, mm
4) Year, yyyy

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

File: HDT-Gyro_*.Raw
Time interval varies from less than 1 second to 10 seconds

Description of *.RAW file string
HDT-Gyro_20191001-000000.Raw
10/01/2019,00:00:00.236,$HEHDT,175.63,T*19
10/01/2019,00:00:00.440,$HEHDT,175.63,T*19
10/01/2019,00:00:00.440,$HEHDT,175.62,T*18

Comma delimited column after string name
1) Ship's heading – True North

Ship's Heading - $GPHDT (POSMV) – NOT Available in 2019
Time interval is 10 seconds

Description of *.RAW file string
HDT-POSMV_20160818-000100.Raw
08/19/2016,00:01:34.336,$GPHDT,47.861,T*09
08/19/2016,00:01:45.334,$GPHDT,47.985,T*02

Comma delimited column after string name
1) Ship's heading – True North

Depth – "Sounder"
Sounder and String Changed in 2018
Depth is measured using the 3.5, 12 or 30kHz transducers using a new for 2018 Knudsen CHIRP 3260 Echosounder, labeled "Science". The CHS-purchased CHIRP 3260 is still there but 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 soundspeed variables are set by the user in the Knudsen software. 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 is less than a second but values updates every 5 to 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. We did not use the 3.5 kHz unless necessary due to the loud pinging noise that could be heard in the occupied 600 staterooms.

File: Knudsen-Sounder_*.Raw

Description of *.RAW file string

Knudsen-Sounder_20191001-000000.Raw
10/01/2019,00:00:01.096,Sounder,01102019,000010,,,,12.0kHz,2594.52,9.00,30
.0kHz,0.00,9.00,1464
10/01/2019,00:00:01.096,Sounder,01102019,000010,,,,12.0kHz,2594.52,9.00,30
.0kHz,0.00,9.00,1464

Comma delimited column after string name

1) Date UTC: DDMMYYYY
2) Time UTC: hhmmss
3) Sounder frequency (3.5kHz)
4) Depth (3.5kHz)
5) Applied draft (3.5kHz)
6) Sounder frequency (12kHz)
7) Depth (12kHz)
8) Applied draft (12kHz)
9) Sounder frequency (30kHz)
10) Depth (30kHz)
11) Applied draft (30kHz)
12) Soundspeed m/s

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.
Barometer – not sure where this is mounted.
Time interval is 1 sec

File: AVOS-serial-AVRTE_*.RAW
Description of *.RAW file string
AVOS-serial-AVRTE_20191001-000000.Raw
10/01/2019,00:00:05.457,$AVRTE,191001,000016,00840,CGBN,19.6,101,281,,,,
998.59,,-0.7,100,,,,3.9,,,180.1,13.4*41
10/01/2019,00:00:07.049,$AVRTE,191001,000017,00840,CGBN,10.3,143,323,,,,
998.52,,-0.6,100,,,,8.5,,,179.5,13.4*4C

Comma delimited column after string name

1) Date UTC: YYMMDD
2) Time UTC: hhmmss
3) Region?

4) Ship's Call Sign
5) Relative wind speed, knots
6) Apparent wind direction, degrees true north
7) Relative wind direction, degrees where ship's bow is "North"
8) Space for 2nd wind sensor, not installed
9) Space for 2nd wind sensor, not installed
10) Space for 2nd wind sensor, not installed
11) Barometric pressure, Mbar (same as mmhg)
12) Space for 2nd barometer, not installed
13) Air temperature, degrees C
14) Relative Humidity, %
15) Space for 2nd temperature sensor
16) Space for 2nd humidity sensor
18) Space for Sea Surface Temperature, degrees C (this is NOT the same as the sea water loop TSG intake reading – different source)
19) Wind gusts, knots
20) Blank space for 2nd wind sensor gust
21) Heading ($HEHDT) direction, "Compass 1", degrees
22) AVOS fluxgate compass direction, "Compass 2", degrees
23) AVOS battery voltage

Seawater Loop (TSG)

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

File: TSG-serial-*.Raw

Description of *.RAW file string
TSG-serial-_20191001-000000.Raw

```
10/01/2019,00:00:03.437,    0.67    0.19    26.492    22.986    0.098
0.09768    0.06593    274.000023
10/01/2019,00:00:08.440,    0.67    0.19    26.491    22.988    0.101
0.10134    0.06593    274.000081
```

Comma delimited column after SCS date and time stamp
1) Sea Surface Temperature in lab, Deg C
2) Sea Surface Temperature at intake, Deg C
3) Sea Surface Salinity, PSU
4) Sea Surface Conductivity in lab, mS/cm
5) Sea Surface Fluorescence (Chlorophyll-a), ug/L
6) Sea Surface Fluorescence (Chlorophyll-a) voltage, V
7) Sea Surface Wetlabs ECO CDOM Fluorometer voltage, V

8) Julian Day

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 earlier section for description of TSG sensors.

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

Description of *.RAW file string
SBE-38-serialport-_20191001-000000.Raw
10/01/2019,00:00:00.455, 0.1876
10/01/2019,00:00:01.330, 0.1881

Comma delimited column after SCS date and time stamp
1) Sea Surface Temperature at intake, Deg C

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 (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).

This system was only installed at the end of the program, however the data can be used for comparison with overlapping CTD surface reference PAR measurements.

File: ASCII-PAR-serialport-*.Raw, 30 Sep to 3 Oct 2019
Time interval is 10 second.

Description of *.RAW file string
ASCII-PAR-serialport-_20191001-000000.Raw
10/01/2019,00:00:06.301,D|72.16
10/01/2019,00:00:16.627,D|71.524

Comma delimited column after SCS date and time stamp
2. D| - not sure what this is, ignore.
3. Surface PAR, uE/m2/sec (same as in CTD data)

5.4.3 Issues with the underway system and data

SCS in general –
Number and size of files: Every time SCS is restarted, the daily file logging option must be re-selected. If this is missed, the data are written to a single file (per sensor). This selection was missed a few times.

GPS –
There are two GPS feeds used. This is legacy from 2018 when there were unexpected issues with the Marine Star system. This may have been due to a switch between CHS and ship's GPS antennae.

Marine Star GPS
GNVTG, GNZDA, GPGGA: The ship's Marine Star GPS is a paid for service and the electronics officer onboard says this is the more reliable of the two GPS feeds. This was a stable feed in 2019. In 2018, this feed gave us trouble although in 2018 it was explained we were connected to CHS's Marine Star feed (?).

The NOAA server was set up to take the Marine Star feed and redistribute to other applications (CTD, XCTD, TSG, Ozi, ie any networked computer needing access to GPS).

Furano GPS
GPRMC, GPVTG, GPZDA, GPGGA: The ship maintains two Furano GPS systems. They have two side by side displays on the center island (map/logbook station) on the bridge and 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. Due to problems in 2018, SCS was set up to record this feed as well although in 2019 it appears to be redundant.

AVOS –
Previous years have had icing problems with the anemometer resulting in inaccurate wind speed. This year there was hoar frost accumulation in the -15C 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. These data should be recalculated using the ship's gyro for accurate data.

Sounder –

The transducer was initially hooked up to the wrong sounder for the first few casts. After this was fixed, the sounder worked well until the southern end of the 150W and 140W line even though the depths were comparable.

Gyro –
Fast recording speed is very useful for calibrating the LADCP for each rosette cast.

PAR -
Independent files (ie not through SCS) have data collected every 1 second.

TSG Flow Rate
Seawater flow would stop for various reasons such as sea-ice clogging the strainer at the sea-waer inlet, or pump malfunction. In order to remove TSG data during these times there needs to be a way to identify no-flow conditions. There was no flow sensor installed in the TSG system this year, but the pCO2 system did have a meter that reports flow in volts. The voltage, proportional to flow rate, can be used to indicate when flow was stopped so data can be flagged and removed.

SBE38 Intake Temperature
2019 had similar issues at start of program as with 2018. Believe this is cable/connector issue between computer and TSG "can", not the sensor.

2018: The intake temperature value was stuck on the same value for a number of hours so the SBE 38 was changed out Sep 22 from sn870 to sn319. The stuck value may actually been a problem with the computer communication program GPSgate, however after re-establishing communication there were no further SBE38 problems.

Sea Water Pump and TSG data
Notes are recorded primarily in the TSG Log Book and some information is also given in the Loop Sample Log. Highlights below:

Sep 11th — Pump turned on to flush system. TSG initially not communicating with computer. Baud rate from TSG to interface box changed from 4800 to 9600.
Intake T (SBE38) not working.

Sep 13th — 0111UTC Pump was flushed ~18hrs and is now running through TSG. Increased pump speed, changing the controller from manual to automatic with a Set Point of 18.05. Pump came up to 18.05 PV and is at 27.2 %output.

Manifold is configured with four outlet arms:

- One going to TSG
- One with no flow, just tubing to drain, to be used as needed

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

Seasave did not start up right away. Checked con file and setting and then Seasave did start – not sure why the delay.

Intake temperature (SBE38) value is stuck at a value, can change but gets stuck again. However, the reading direct to the computer through the virtual com port looks fine, so it is somehow in the routing to the TSG canister that is freezing the data. Wiggling the physical connection between computer to the black cable going to the canister will change the Seabird value so believe the problem is in this connection. After a few wiggles/ powering off/on and restarting seasave the intake temperature reading through Seasave looks fine.

Sep 15th 1230UTC ship lost power. TSG restarted. Note that file name does not reflect date/time (2019-09-13-0250.hex). *Pump speed is low 1230 to 1434 UTC*

Sep 15th 1434 UTC. Pump put back on automatic so speed increased to reach the 18.05PV set point.

Sep 19th 0507 UTC See that loop has been running dry. Engineer called and flow returns by 0515.

Sep 21st 2305 UTC No water, engine room called. Flow is back by 2317 but flow rate is slow. Celine adjusted flow to get 26s/L on fluorometer pair at 2323.

Sep 23rd 0040 UTC No flow on TSG and pCO2. Flow fixed by 0042.

Sep 23rd 0650 UTC not flow. Electrical issue in the engine room. Seasave acquisition is stopped for file TSG-2019-09-21-0434.hex

Sep 24th 0147 UTC pump is fixed. New file started (TSG-2019-09-24-0146) however SBE38 needed GPSgate feed to be opened and closed before good data started to come in. Data are good by 0211UTC. Pump speed controller failed due to seawater leak from pressure sensor frying the unit. Electrical engineers were able to bring the spare online with appropriate settings transferred from partially burnt system.
0242UTC changed speed to Auto to bring flowrate from 10psi up to 18.3 PSI set point.
No or low flow from Sep 23 0650 to Sep 24 0242.

Sep 25th 0235 Measured flow rate with 18.3 PSI and 27.1%output

Sep 29th 0130 Ship lost power
0830 Pump restarted however it is in Manual mode with low flow (~7PSI).
2045 Pump speed increased to Automated setting of 18.3 PSI. Need to confirm flow increase time with with pCO2 flow rate data, but expect to see no or low flow rate from 0130 to 2045UTC.

Oct 3rd 2346UTC End last TSG file as we are anchored at Kugluktuk. Pump turned off.

TSG Data Files:

TSG-2019-09-13-0227 Only 5min of data
TSG-2019-09-13-0249 Keep. Intake T reads -9 for first hour but then is good.
TSG-2019-09-13-0250 Keep. Misnamed, but does have data. New file after ship lost power and everything needed to be restarted.
TSG-2019-09-15-1431 New file just to set filename to actual date/time.
TSG-2019-09-18-2245
TSG-2019-09-21-0434 File closed when failed pump was noticed.
TSG-2019-09-24-0146 New file after pump repair. Good intake T starting at 0211UTC.
TSG-2019-09-27-1826
TSG-2019-09-30-0205
TSG-2019-10-02-1503

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 18.05 PV
Original Con file was from 2018 and updated before processing.

Flow rate:

TSG	4.2 sec/L	Sep 16
	3.1 sec/L	Sep 25 0235
	3.0 sec/L	Oct 2 0010
Flr pair	28sec/L	Sep 16
	24 sec/L	Sep 24 0248
	25 sec/L	Sep 25 0235

	29 Sec/L	Oct 2 0010
pCO2	36.5 sec/L	Sep 16
	36 sec/L	Sep 25 0235
	32 sec/L	Oct 2 0010

For 2020:

- Bulkhead connector on Chl sn 36512 and CDOM 1076 have chewed up rubber around some of the pins.
- For SCS adjust timestamp to all show 1 second, PAR keep at 10 seconds. (May currently be "-1" in SCS sensor configuration >message definition > Logging Rate.)
- Scott was going to let Environ Can about gyro string not going into avos
- Trial in-line non-recording flow meters to give instantaneous flow readouts? This worked well for the microplastics though constant use might overwhelm sensor?