Joint Ocean Ice Study (JOIS) 2016
Cruise Report

Report on the Oceanographic Research Conducted aboard the *CCGS Louis S. St-Laurent,* September 22 to October 18, 2016 IOS Cruise ID 2016-16

Bill Williams, Sarah Zimmermann
Fisheries and Oceans Canada
Institute of Ocean Sciences Sidney, B.C.

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1. OVERVIEW

The Joint Ocean Ice Study (JOIS) in 2016 is an important contribution from Fisheries and Oceans Canada to international Arctic climate research programs. It is a collaboration between Fisheries and Oceans Canada researchers with colleagues in the USA from Woods Hole Oceanographic Institution (WHOI). 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).

In 2016, JOIS also 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, 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.
- Naval Postgraduate School, Monterey, California.
- Applied Physics Laboratory, University of Washington, Seattle, Washington.

Canada:
- Trent University, Peterborough, Ontario.
- Université Laval, Quebec City, Quebec.
- University of British Columbia, Vancouver, British Columbia.
- University of Ottawa, Ottawa, Ontario
- Concordia University, Montreal, Quebec
- University of Victoria, Victoria, British Columbia
- Vancouver Aquarium, Vancouver, British Columbia

Research questions seek to understand the impacts of global change on the physical and geochemical environment of the Canada Basin of the Arctic Ocean and the corresponding biological response. We thus collect data to link decadal-scale perturbations in the Arctic atmosphere to inter-annual basin-scale changes in the ocean, 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.

2. CRUISE SUMMARY

The JOIS science program onboard the *CCGS Louis S. St-Laurent* began September 22th and finished October 18th, 2016. The research was conducted in the Canada Basin from the Beaufort Slope in the south to 80°N by a research team of 27 people of which 7 were students. Full depth CTD/Rosette casts with water samples were conducted. These casts measured biological, geochemical and physical properties of the seawater. Underway expendable temperature and salinity probes (XCTDs) were deployed between the CTD/Rosette casts to increase the spatial resolution of CTD measurements. Moorings and ice-buoys were serviced and deployed in the deep basin and Northwind Ridge 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. Surface drifters were deployed to track ocean currents. 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, is shown in Figure 1 below.

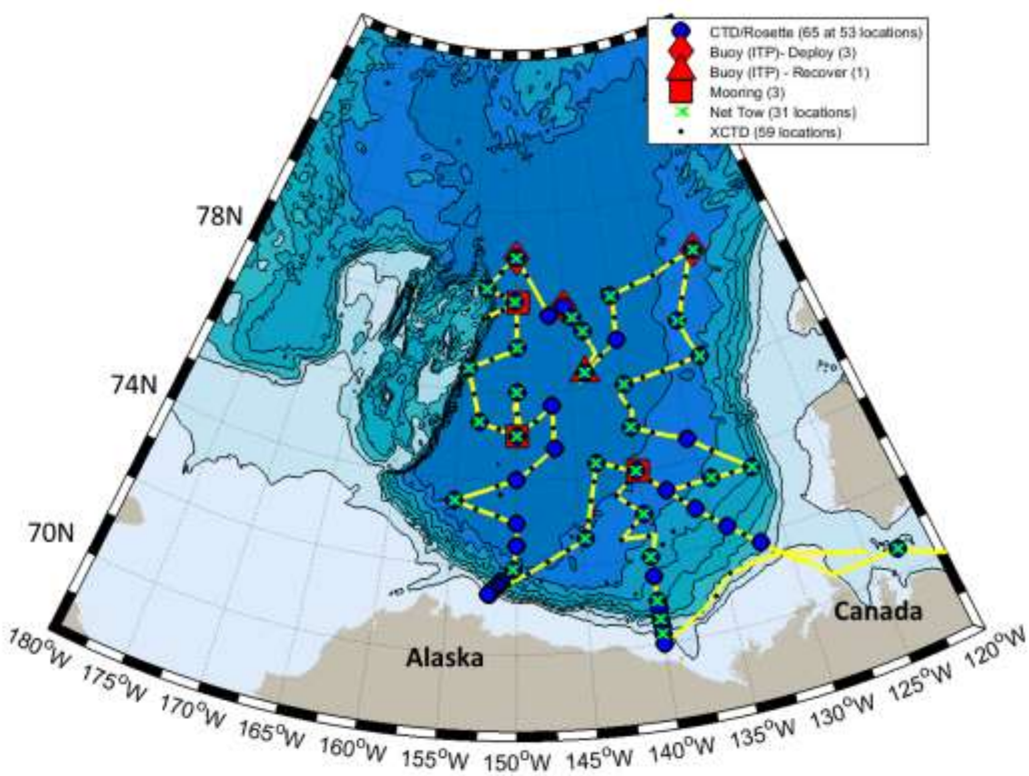

Figure 1.The JOIS-2016 cruise track showing the location of science stations.

2.1 Program Components

Measurements:

- At CTD/Rosette Stations:

- 65 CTD/Rosette Casts at 53 Stations (DFO) with 1424 Niskin bottle water samples collected for hydrography, geochemistry and pelagic biology (bacteria, microbial diversity and phytoplankton) analysis (DFO, Trent U, TUMSAT, WHOI, U Laval, Concordia, UBC, U Victoria, Vancouver Aquarium). Water samples taken:
  - At all full depth stations: Salinity, dissolved O_2 gas, Nutrients (NO_3^-, PO_4^{3-}, SiO_4^{4-}), Barium, ^{18}O isotope in H_2O, Bacteria, Alkalinity, Dissolved Inorganic Carbon (DIC), Coloured Dissolved Organic Matter (CDOM), Chlorophyll-a, dissolved ^{16}O, ^{17}O and ^{18}O in dissolved O_2 (triple oxygen isotopes),
  - At selected stations: microbial diversity, ammonium, dissolved N_2/Ar ratio, microplastics, N_2O/CH_4, $^{13}CH_4$, Dissolved Organic Material (DOM) and ^{134}Cs.
- 62 Vertical Net Casts at 29 select CTD/Rosette stations with one cast each to 100m and 500m per station, where possible. Additional tows to 1000m were conducted at 3 stations. Mesh size is 150 µm and 236 µm. (DFO)

- 59 XCTD (expendable temperature, salinity and depth profiler) Casts typically to 1100m depth (DFO, JAMSTEC, WHOI)

- Mooring and buoy operations
  - 3 Mooring Recoveries/Deployments in the deep basin (BGOS-A,B,D; WHOI)
  - 1 Ice-Based Observatories (IBO, WHOI)
    consisting of:
    1 Ice-Tethered Profiler (ITP98, WHOI)
    1 Arctic Ocean Flux Buoy (AOFB34, NPS)
    1 Seasonal Ice Mass Balance Buoy (SIMBB, CRREL)
    1 O-buoy (OBuoy13, BLOS)
  - 2 Ice Tethered Profilers deployed over the side of the ship in open water (ITP99, ITP97, WHOI)
  - 1 Buoy Recovery (ITP67, WHOI)

- Ice Observations (OSU/KIT)
  Hourly visual ice observations from bridge with periodic photographs taken from 2 cameras mounted on Monkey's Island (one forward-looking and one looking down on the EM31).
  Underway ice thickness measurements electromagnetic inductive sensor (EM31-ICE).
  Sea-ice radiation balance for solar and far-infrared using a CNR-4 net-radiometer mounted on the bow while the ship was in sea ice and underway.
  On-ice measurements at the IBO site including:
  -EM31 ice thickness transects
  -Drill-hole ice thickness transects
  -Ice-cores for temperature, salinity and structure profiles
  -Ice-cores for microdiversity and microplastics.
  -Snow pit

- Underway collection of meteorological, depth, and navigation data, surface photosynthetically active radiation (PAR), and near-surface seawater measurements of salinity, temperature, chlorophyll-a fluorescence, CDOM fluorescence as well as pCO2 (DFO, UMontana).
  A combined 216 water samples were collected from the underway seawater loop for salinity, ^{18}O, nutrients, chlorophyll-a, DIC, Alkalinity (DFO), DOM and CDOM (TrentU), and microbial diversity (ULaval).

- Daily dispatches to the web (WHOI)

- Surface Drifters
  - 24 Spot Messenger Trace surface drift trackers deployed in open water in 6 groups of 4 spaced out from near shore to basin, between Cape Bathurst and CB22 at 73.44N, 137.99W. The 6th group were deployed with the CARTHE drifters (DFO).
  - 20 CARTHE drifters were released in 2 groups (Yale)
    - 18 were deployed near CB22 with the last group of SMT drifters
    - 2 were deployed near the ice edge

3. COMMENTS ON OPERATION

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We steamed anti-clockwise around the Beaufort Gyre this year, first steaming north along our eastern stations and then heading west across the northern stations and south along the western stations. Our last mooring operations were at BGOS-D and the final CTD/Rosette stations on the southern end of 140W over the slope of the Canadian Beaufort Shelf. This was the second year we steamed anticlockwise with the goal of

- performing the northern ice-work, i.e. installing ice-buoys, as early in the cruise as possible to take advantage of the longer days as the length of daylight was decreasing through the cruise,
- giving more time for ice cover to grow in the south to minimize the amount of work performed in open seas, and
- waiting until closer to the end of the cruise to collect the shelf/slope stations as their number could be reduced if we were running out of time.

This year the arctic was tied with 2007 for the second lowest year of summer ice cover (the lowest year was 2012). In our research area this was exhibited by the majority of our repeat stations being ice-free, covered with new ice, or in the northwest region partially covered by loose ridged ice originating from farther north.

Storms over the southern Beaufort occurred as we approached the southern end of the 150W section. We delayed our transit, adding in stations of interest, and were able to complete the line arriving just as the seas were settling. The effect of the storms can be seen in the data from the southern end of the 150 and 140W sections.

See the figures below for details of the ice cover during the expedition as well as comments below in the Ice Watch Report

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.

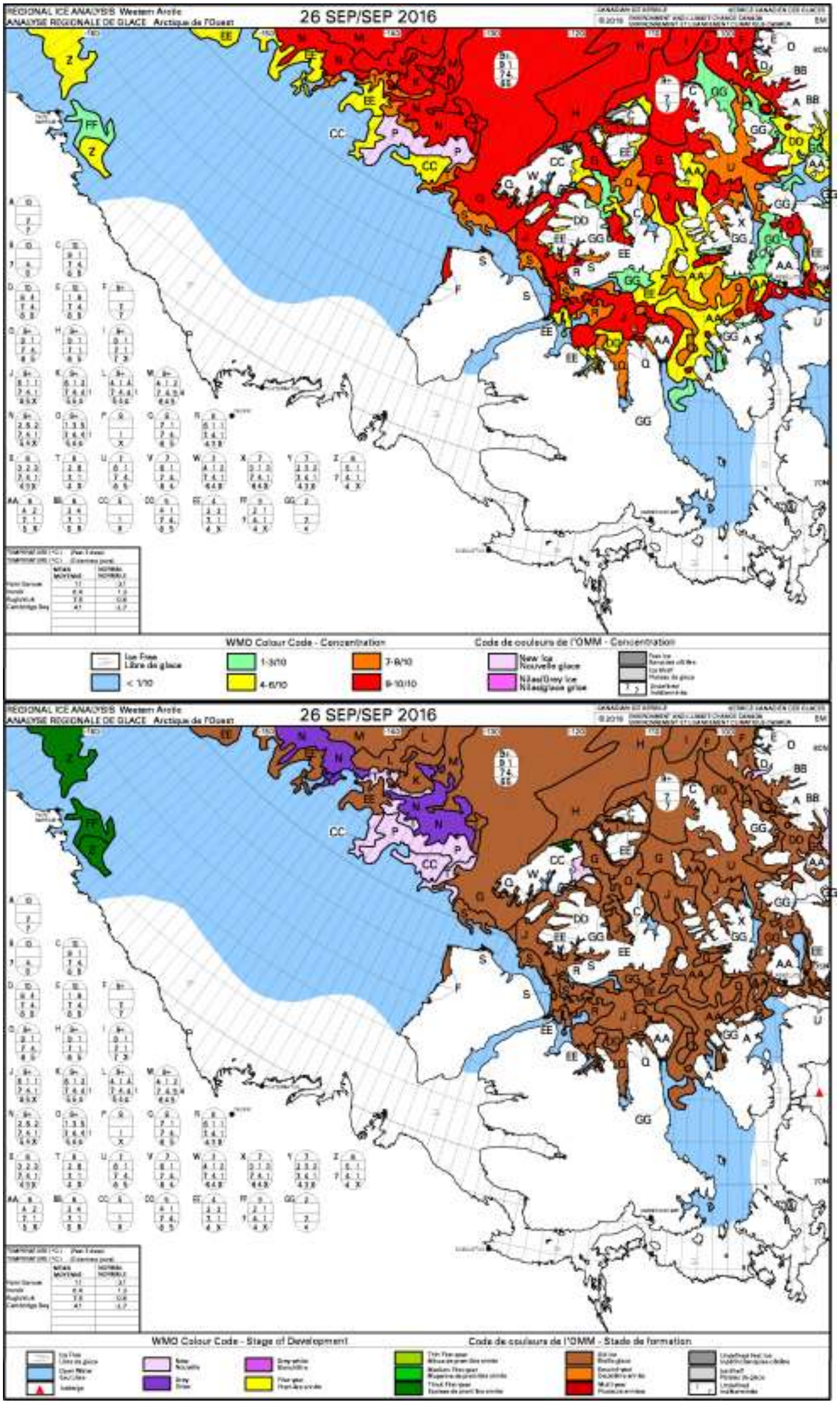

Figure 2a: Canadian Ice Service ice concentration and stage charts from the beginning of the cruise.

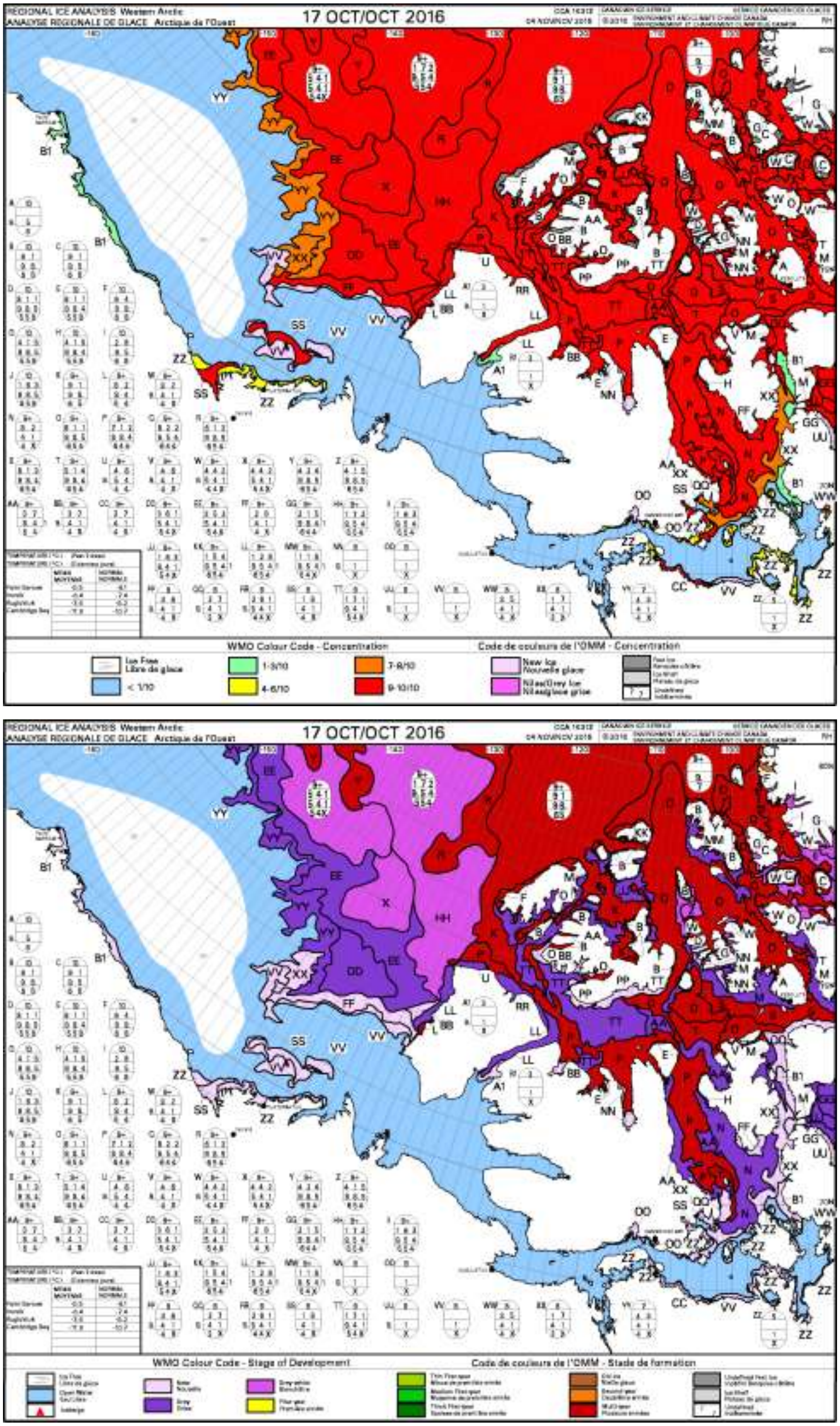

Figure 2b. Canadian Ice Service ice concentration and stage charts for the end of cruise. Note the large areas of new ice. On Oct 1st the ice 'ages' increase by a year.

Completion of planned activities:

Our primary goals were met during this successful program due to efficient multitasking and above average transit speeds in light ice, which maximized the time available for sampling and the spatial coverage. We were also fortunate to have minimal mechanical delays and no medevac or search and rescue this year. Efficient fueling just as we came on board in Kugluktuk meant the ship was able to depart as planned. No planned stations were dropped this year, rather standard stations from previous years were added back in, as time became available towards the end of the expedition.

Autumn in the Beaufort Gyre has short days, cold temperatures and high winds. Work in these conditions is difficult in comparison to summertime and we appreciate the hard work of the crew to accommodate us.

4. ACKNOWLEDGMENTS

The science team would like to thank Captains Wayne Duffet and Tony Potts 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. Of special note was the engineering department's rapid response to examine and repair problems, or even suspected problems, with equipment such as with the CTD winch brake and container labs drainage and plumbing. We would also like to thank the deck crew for their assistance. It was a pleasure to work with the helicopter pilot and mechanic and we would like to thank them for their support on the ice, and transportation. Importantly, we'd like to acknowledge Fisheries and Oceans Canada, the National Science Foundation (USA), National Institute for Polar Research (Japan) and the Japan Agency for Marine Earth Science and Technology for their continued support of this program.

This was the program's 14th annual expedition and the exciting and valuable results are a direct result of working with such experienced, well trained and professional crews.

5. 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.

5.1 Rosette/CTD Casts

PI: Bill Williams (DFO-IOS)
Mike Dempsey (DFO-IOS)

CTD/Rosette set-up

On JOIS 2016, the CTD system used was a Seabird 9/11. Seabird SBE9 s/n 756 was used for the entire cruise with s/n 1189 in reserve as a spare. The CTD is 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 data were collected real-time using the SBE 11+ deck unit and computer running Seasave V7.25.0.151 acquisition software. The CTD was set up with two temperature sensors, two conductivity sensors, dissolved oxygen sensor, chlorophyll fluorometer, transmissometer, CDOM fluorometer, cosine PAR and altimeter. In addition, an ISUS nitrate sensor was used on some casts shallower than 1000 m. A surface PAR sensor connected to the CTD deck unit was integrated into the CTD data for all casts. In addition a serial communicating surface PAR sensor providing continuous 1hz data was mounted beside the other SPAR unit. Continuous PAR data was collected for the whole cruise. These 1-minute averaged data are reported with the underway suite of sensors.

During a typical station

During JOIS 2016, CTD stations were much simplified from previous years. This year the underway ADCP was not installed and bongo stations reduced to a few standard positions, periphery sampling stations and opportunistic stations. Typically, a station would consist of one CTD cast to 5 m of the bottom. On several occasions, casts were carried out to 1000m only for specialty large volume water sampling(RNA/DNA, microplastics and Cs isotope) casts. Cast were also done at some BGOS mooring sites for calibration of the SAMI and WQM instruments In 2016 during JOIS, there were a total of 65 CTD/Rosette casts.

Figure 1. Typical rosette deployment in ice covered waters
Figure 2. Brooke Ocean Technology IMS winch display
Figure 3 Hawbolt oceanographic winch and operator

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 10 m and the pumps turned on. This soak cools the sensors to ambient sea water temperature and removes bubbles from the sensors. After 3 minutes the package was brought up to just below the surface to begin a clean cast, and lowered at 30m/min to 300m, then at 60m/min to within 10m of the bottom. Routinely, the winch was switched from low to high gear and vice versa at 900m to make operation smoother. Niskin bottles were normally closed during the upcast without a stop. During a 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, lowered 1 m, raised 2 m, lowered 1 m 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.

The configuration file contained all sensors including the ISUS (appears as "user polynomial in seasave), even it was used only on a few of the casts. The data fields were ignored in processing on casts when the sensors were not installed.
Initially, the con file was set up in the same format of other IOS Arctic SBE 9 configuration files

Ch0 = chlorophyll fluorometer
Ch1= transmisssometer
Ch2 = dissolved oxygen
Ch3 = altimeter
Ch4 = CDOM fluorometer
Ch5 = free
CH6 = Cosine Par
CH7 = ISUS (if fitted)

Prior to JOIS cruise 2016, the SBE3plus temperature, SBE4c conductivity and SBE43 oxygen sensors and Wetlabs CStar transmisometer were returned for re-calibration by the factories in November 2015. The altimeter and CDOM fluorometer were both new units this year. In addition, other sensors were checked for functionality and the plumbing tubing re-newed checked for functionality.

See appendix for CTD sensor configuration

Performance notes

Problems were encountered from the first cast. There was a confusion over ranges in the altimeter plot in SeaSave with a new to JOIS operator. The range was set outside the expected bottom depth and the altimeter signal was not seen. Approximately 10m of wire was laid on the bottom after the rosette landed on the bottom at AG05. The wire was kinked and identified as needing a re-termination soon. Also during the first cast, an old con file was used instead of the most current version. This was corrected on subsequent casts. Before ROS3, CB1 the sea cable was chopped back 15 m and re-terminated.

During the whole cruise, the hydraulic brake on the Hawboldt winch was not operating. Normally the hydraulic cylinder forces the brake bands open when the winch lever is operated. There was negligent movement in the cylinder and the cause was diagnosed as likely being a) blocakage in the lines or valves in the brake drum actuator circuit or b) blown seals in the cylinder itself. As there were no appropriate hydraulic spares on board, the decision to operate using the handwheel manual brake was made.

Unlike 2015, there were no major water sampler or communication issues. There were however continuous single bottle failures caused by grease balls falling off the wire into the pylon trigger. Over the winter, Hawboldt winch SRO47-3640 had the old wire removed and new 6000m of Rochester 0.322" 3 conductor CTD wire installed. It was also lubricated at IOS using Core Lube and the dedicated compressed air applicator. The lubrication normally dries and forms a thin coat. Unfortunately, possibly due to interaction between the light oil used in wire manufacture and the Core Lube, the wire was still sticky to the touch several weeks after application. The resultant stiff grease balls with the consistency of dried mud, found their way into the BOT IMS fairlead rollers (seized when frozen), the pylon trigger (causing untripped bottles) and onto the decks and walking surfaces of the ship. The IMS block fairlead rollers were swapped (better used for ruined rollers – only one size of spare new in stock) before ROS43 after they were almost sawn through while frozen in ice and grease.

Niskin 23 did not fire 3 times and 24 di dot fire 3 times. The bottle 23 error follows the 452 pylon trigger. The 24 failures follow the 498 trigger. Likely this was caused by wire lubricant falling in the trigger. It may however be something particular to the pylon itself when used with the different trigger units.

Due to the absence of ice in the south western portion of the JOIS study area, several rough deployments and recoveries were made in 2-3m swells during ROS 38-40. The wire was kinked and birdcaged approximately 7 m from the termination. 1-3 strands were observed proud of the outer armour back to approximately 200m up the wire. The likely cause was spinning and shock loads while near the surface. It is also possible that the wire was not cut back far enough either after ROS 1 or after the mudding of the rosette at the beginning of UNCLOS 2016-15. ~200m of wire was cut off and the wire reterminated before ROS49

Generally Niskins sealed well. One was swapped out due to a broken mounting block (niskin #5 after ROS4). The triggers on the pylon were removed and cleaned often. Pylon "498" was observed to be more reliable. Pylon "452' had recurring hang ups on Niskin "23, and was removed from service.

During ROS27, a new type of communication failure occurred with the SBE11 deck unit. Communications with the CTD and water sampler quickly grew worse until complete failure around 1100 m. The rosette was recovered and the source of the problem was discovered to be the cable for the Biospherical QSP-2100 SPAR plugged into the deck unit. It was removed from ROS27B onwards. PAR data was being continuous logged independently from a QSP-2150 SPAR mounted nearby. Repair of the cable was assigned a low priority.

Minor noise problems were encountered on the fluorometer and transmissometer. The cable was changed twice (once for CSTAR adaptor) due to noise. The transmissometer was also found to have large offset on ROS24. The problem was solved by aggressive cleaning of the lenses and changing the adaptor cable.

A new CDOM fluorometer was installed in 2016. Initially it was installed with factory gain settings, but these were increased to maximum sensitivity before ROS17.

On ROS 40, the altimeter did not detect the bottom and the cast was terminated early at a safe estimated height above the bottom. The altimeter (s/n 62670) was replaced by the spare unit (s/n 1161) for the remainder of the cruise. There was one cast on UNCLOS 2016-15 with similar result, but the unit worked well the rest of the cruise. 62670 should be returned and tested at the factory, possibly under warrantee. After cast 57, the electrical termination of the Seacable was observed to be wound up. It was unspun but the mechanical termination was free to turn in the clevis. Normally the helical rods in the termination bind in the internal cone of the clevis and do not turn once under tension. The mechanical termination was disassembled and inspected. The insert was confirmed to be the right size for 0.322” cable. The helical rods were discarded and another set was installed. The termination did not slip again on the cruise once it was pulled under full tension.

However on cast 58, the CTD operator was unable to fire all bottles using the Seasave GUI. Once on deck the electrical termination was checked again and although there was no obvious serious damage, it was decied to redo the electrical termination before the next cast. A new 6’ MCIL-2-FS pigtail was used on the wire. No problems were encountered during the remaining casts.

See Appendix for table of stations.

5.2 Chemisty 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 1. Water Sample Summary for Main CTD/Rosette.

Parameter	Canada Basin Casts	Depths (m)	Analyzed	Investigator
Dissolved Oxygen	All	Full depth	Onboard	Bill Williams (IOS)
ONAr	Select		Shore lab	Roberta Hamme (UVic)
Ar/O_2 and TOI	Select	5-650	Shore lab	Rachel Stanley (WHOI / Wellesley)
	Most stations	5 and 80		
		Full depth		
N_2O / CH_4	Select	Full depth	Shore lab	Philippe Tortell (UBC)
$^{13}CH4$	Select	Full depth	Shore lab	Philippe Tortell (UBC)
DIC/alkalinity	All		Onboard	Bill Williams (IOS)
CDOM	All	5-1500	Shore lab	Celine Gueguen (UTrent)
DOM	Select		Shore Lab	Celine Gueguen (UTrent)
Chl-*a*	All	Top 300 with occasional deeper	Shore lab	Bill Williams (IOS)
Bacteria	All	Full depth	Shore lab	Connie Lovejoy (Ulaval)
Nutrients	All	Full depth	Onboard and	Bill Williams (IOS)

			Shore lab	
Ammonium	Stations near shelf		Onboard	Bill Williams (IOS)
Salinity	All	Full depth	Onboard	Bill Williams (IOS)
$\delta^{18}O$	All		Shore lab	Bill Williams (IOS)
Barium	All		Shore lab	Bill Williams (IOS)
DNA/RNA	Select		Shore lab	Connie Lovejoy (Ulaval)
^{134} Cs	Select		Shore lab	John Smith (DFO-BIO)
Microplastics	Select	Full depth (special cast)	Shore lab	Peter Ross (Vancouver Aquarium)

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

5.2.1 N_2/Ar and Noble Gas Samples

Sampled by Glenn Cooper and Mike Dempsey (IOS-DFO)
PI: Roberta Hamme (UVic)

N_2/Ar is a gas tracer used to determine the state of the marine nitrogen cycle in a water mass. The tracer allows us to utilize the signal of biological nitrogen fixation and removal processes found in N_2 gas by subtracting out the effects of physical processes using Ar as a proxy. The Arctic Ocean connects the Atlantic and Pacific Oceans, which are known to have very different nitrogen cycle processes dominating. We hope to use these measurements to gain a new perspective on the transition of the nitrogen cycle from the Pacific to the Atlantic.

N_2 saturation is only altered physically by air-sea gas exchange processes and mixing. Biologically N_2 gas is removed by nitrogen fixation, and added by several biological removal processes which all convert biological nitrogen into N_2 gas when taken to completion. Many other measurements can only observe one of these biological processes, making it difficult to determine if there is a net loss or gain of nitrogen to the system. The benefit of the N_2/Ar tracer is that it observes the net state rather than the rate of individual processes. This both eliminates differentiation of processes, but also spatial differentiation both water column and sedimentary processes are important to the net state of the nitrogen cycle in the water column.

Noble gases are used as tracers of physical processes as they are only affected by a limited set of processes. Different noble gases react differently to physical processes which allows us to observe water mass properties and aids in our understanding of water mass formation.

5.2.2 Methane and Nitrous Oxide in the Arctic

Sampled by CTD Watch

PI: Lindsey Fenwick and Philippe Tortell (UBC)

Quantifying the distribution of greenhouse gases in the Arctic Ocean water column is necessary to understand potential biogeochemical climate feedbacks. As the Arctic Ocean warms, methane (CH4) may be released from destabilizing gas hydrates on the continental shelf, while the thaw of subsea permafrost may supply organic matter that fuels microbial methanogensis and denitrification, which produces nitrous oxide (N2O). While previous measurements of CH4 and N2O have been reported in Arctic waters, no study to date has measured water column distributions of these gases over a widespread area in the Arctic within a single sampling season. This synoptic coverage is important to provide a snap shot of spatial CH4 and N2O variability. Our sampling transect provided a large-scale, three-dimensional view of CH4 and N2O concentrations across contrasting hydrographic environments, from the deep oligotrophic waters of the deep Canada Basin, to the high productivity continental shelf regions. Our work contributes new insight into the cycling of two important climate-active gases in the Arctic Ocean, and provides a benchmark against which to compare future measurements in a rapidly evolving system.

5.2.3 O_2/Ar & Triple Oxygen Isotopes

Zoe Sandwith (WHOI)
P.I.: Rachel Stanley (WHOI)

O_2/Ar and Triple Oxygen Isotopes (TOI – a collective term for ^{16}O, ^{17}O, and ^{18}O), are gas tracers that can be used to directly quantify rates of Net Community Production (NCP) and Gross Primary Production (GPP). They are ultimately used to help create a better understanding of present-day carbon cycling in a system. Both tracers are measured directly from dissolved gas extracted from seawater. NCP is derived from the measurement of O_2/Ar ratios, and GPP is derived from TOI. These measurements will help us understand how rates of biological production respond to changes in environmental pressures, and can help constrain ecosystem models for the Beaufort Gyre region.

Traditionally, most estimates of biological production have been of Net Primary Production (NPP) by methods such as ^{14}C bottle incubation and satellite algorithms. In contrast, TOI and O_2/Ar generate a different picture of the story: NPP is photosynthesis minus autotrophic respiration, whereas NCP is photosynthesis minus autotrophic and heterotrophic respiration. The relationships between these and GPP, the total photosynthetic flux, are outlined in figure 1. NCP is a more important climatic variable than NPP since NCP is the net amount of carbon taken up by the biological pump. By measuring both NCP and GPP concurrently, we can separately look at the effects of photosynthesis and respiration in a system.

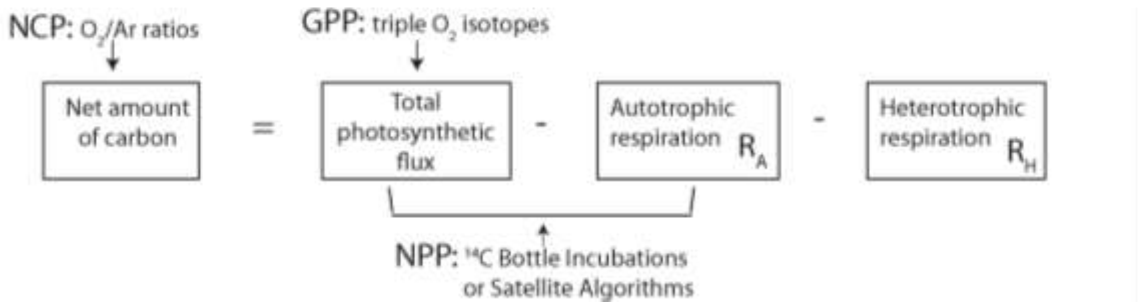

Figure 2. Schematic illustrating the different types of biological production.

Net Community Production (NCP), Gross Primary Production (GPP), and Net Primary Production (NPP).

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

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.

5.3 XCTD Profiles

Operators: Alek Petty (NASA-GSFC/UMD) and Seita Hoshino (KITAMI)
PI: Andrey Proshutinsky (WHOI), Motoyo Itoh (JAMSTEC), Bill Williams (DFO-IOS)

Overview

Profiles of temperature and salinity were measured on board the *CCGS Louis S. St. Laurent* (LSSL) from September 25th to October 16th (actual cruise dates were Sep 20th-Oct 18th), 2016 using expendable probes capable of being deployed while the ship was underway. Profiles were collected at 58 stations along the ship's track in total. A second probe was deployed at one of the stations when the first probe failed due to the wire being broken by ice. The lack of thick sea ice throughout the cruise meant that this only happened one other time, and the ship could often maintain speed, especially when XCTD-3s were being used. We had occasional issues with the GPS logger, which required a soft reset of the navigation options in the logging software.

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. Three 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
XCTD-3	1000	20

The data is communicated back to a digital data converter MK-21 (Lockheed-Martin-Sippican, Inc) and a computer onboard the ship by a fine wire which breaks when the probe reaches its maximum depth.
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)

In this cruise, 58 XCTDs were launched into the Beaufort Sea, at varying intervals depending on the geographic area. They were most often deployed between rosette casts. Only two deployments had issues, when sea ice broke the copper wire. A repeat deployment immediately after one shallow (200 m) failure (with the ship stationary) was a success. The lack of thick sea ice meant that deployment was relatively easy, and when we were in open water, the XCTD-3s could be deployed without the ship having to slow down. A list of deployments can be found in the appendix. Figure 1: XCTD probe deployment from the ship's stern (2011) and XCTD setup showing launcher, log book, and laptop sitting on top of data converter Win MK-21.

See Appendix for table of stations.

5.4 Zooplankton Vertical Net Haul.

Kelly Young, Mike Dempsey, Glenn Cooper, Chris Clark (DFO-IOS); Mathura Mahaan (Trent U); Jean Mensa (Yale)
PI: John Nelson, Bill Williams (DFO-IOS)

Zooplankton sampling and preservation for JOIS 2016-16 were overseen by Kelly Young. The sampling was conducted on board by Mike Dempsey, Mathura Mahaan and Jean Mensa (night watch; DFO-IOS, Trent University and Yale respectively), and Glenn Cooper and Chris Clark (day watch, DFO-IOS) using a standard Bongo net system. One side was fitted with a 150 µm net and 236 µm on the other net. Both sides had a calibrated TSK flowmeter installed to measure the amount of water flowing through the nets. In addition, a RBR Virtuoso pressure recorder was mounted on the gimble rod to record the actual depth of each net cast.

Figure 3. Mike Dempsey and Mathura Mahaan deploy bongo nets during JOIS 2016

A total of 62 bongo vertical net hauls were completed at 29 stations (see Appedix). The sampling strategy followed 2015 sampling given the late season sampling. Most of the adult zooplankton population was expected to have entered diaphase in deeper water than earlier in the year. Sampling was to 100m and 500m vertical tows at most stations, with an additional 1000m cast at 3 stations (at or near mooring stations that had sufficient time). Bongos were deployed on the foredeck using a Swann 310 hydraulic winch and 3/16" wire through the forward starboard A-frame. Rinsing of the nets was accomplished by using the salt water tap on the port side near the outer door near the lounge. An electrically heated hose was used to keep the hose from freezing during the cast; water was left running during the cast to prevent freezing as well.

Samples collected from the 236 µm mesh nets were preserved in 95% ethanol, while those collected from the 150 µm were preserved in 10% formalin for both 500 m and 100 m net tows. The formalin samples will be examined for species identification and the ethanol samples for DNA sequence analysis.

The bongo box was shortened and had a removable side installed for 2015 to ease launching and recovery of the 25kg pig weight. This wooden box should be replaced with an aluminum box, as the wooden one is very heavy (especially once soaked with water) and is falling apart.

A few stations were omitted during the cruise due to weather. Cold temperatures and high winds precluded samples being taken when the wind exceeded 25 knts. Low temperatures result in unacceptable amounts of ice build up when rinsing down the nets and high winds make the nets impractical to handle. Both conditions can result in a safety hazard for the samplers.

See Appendix for table of samples and stations.

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

David Colatrianod (PhD Candidate, Concordia University), Arthi Ramachandran (PhD Candidate, Concordia University), Adam Monier (Reasearch fellow,Univeristy of Exeter)
P.I.: Connie Lovejoy (ULaval)

Introduction and objectives

The Canada Basin in the Western Arctic Ocean is a complex hydrographic system and its physical oceanography is strongly coupled to meteorological drivers. This coupling influences chemical and biological dynamics at different regional scales (McLaughlin and Carmack, 2010; Nishino et al., 2011). The changing conditions in some regions of the Arctic thought to be associated with the changing global climate are expected to affect phytoplankton communities by limiting nutrient supply, changing salinities and even increasing ocean acidification (e.g. Coupel et al., 2012; Riebesell et al., 2013; Thoisen et al., 2015). Loss of ice for example has been implicated in the shift in size of the dominant autotrophs in the Arctic (Li et al., 2009), which would have implications on the feeding ecology of larger heterotrophic organisms by limiting the range and size of prey items available, and on the overall carbon transfer and cycling in the region. 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). As a consequence, a significant shift on the importance of microbial loop and microzooplankton in bridging the pico-bacterioplankton to classical food web is predicted (Sherr et al., 2012). However, despite the ecological importance, apparent abundance and wide distribution of these microorganisms, several aspects of their ecology, diversity and oceanography are still poorly understood. As change continues, knowledge on the taxonomic and functional diversity of microbial life will become critical for predicting consequences of a warmer, more stratified Arctic Ocean.
In recent years, Lovejoy and colleagues have extensively characterized the taxonomic composition of arctic microbial communities (Bacteria, Archaea, picoeukaryotes) using molecular approaches, and recently venturing into targeted high throughput sequencing (HTS) approaches (Galand et al., 2009; Kirchman et al., 2009; Monier et al., 2015). Past JOIS 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, in order to further broaden our understanding of these ecological functions, knowledge of their metabolic activities and characteristics are needed. For example, Walsh has been combining metagenomics and metaproteomics to study the metabolic diversity and activity of marine Bacteria and Archaea (Georges et al., 2014). Thus, for JOIS 2016, a collaborative effort between the two laboratories (Lovejoy and Walsh) will be employed utilizing targeted sequencing, metagenomic and metatranscriptomic approaches to gain insights on Arctic microbial communities. In collaboration, we aim to generate and analyze a set of 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. This physical stratification impacts the vertical structure of microbial communities. Therefore, at several locations in the CB we will analyze samples from different layers to maximize the microbial diversity represented in our dataset and to facilitate comparative metagenomic studies.

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, there is much less metagenomic representation from high latitude seas, particularly the open Arctic Ocean. Hence the availability of a metagenomic dataset representative of the Arctic Ocean would fill an important void in metagenomic coverage of the global oceans.

Methodology

Samples were collected at 31 (Figure 1) stations that were mostly visited in 2012-2015 but extending to deeper waters including Arctic Deep Water, Atlantic Water, and the core of the Pacific Winter Water. Samples were collected at 2-8 depths per station to include the understudied deep waters. Additional samples from ice cores were also collected for other possible investigations.

Sampled depths were selected based on water column characteristics profiled by the downcast of the CTD of the maindeck rosette. Typical depths include surface (~5 m), mixed layer (~20 m), subsurface chlorophyll maximum (SCM), 100 m depth, PWW characterized by 33.1 psu, AW at 800 m and ADW from 2500-3000 m. Nucleic acid (DNA/RNA, single-cells in Gly-TE), microscopy samples (DAPI, FISH, FCM), and pigment samples (chlorophyll a, HPLC) were collected for each station.

DNA and RNA

DNA/RNA samples from large (>3 µm) and small (0.22 -3 µm) fractions were collected by filtering 5 L 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. All filter samples were immersed in RNAlater solution (Ambio) and left for at least 15 minutes at room temperature before being stored at -80°C.

In the lab, DNA and RNA material will be simultaneously extracted from the filter as described by Dasilva et al. (2014). RNA will be first converted to cDNA before being used for targeted sequencing (Comeau et al., 2011). Metagenomic data 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 supply, and the quantity and source of organic carbon on the metabolic diversity and capabilities of microbial communities. These environmental factors are all set to change with a warming Arctic (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 the response of microbes to change.

The metagenome will also represent an essential resource for development of forthcoming projects. For example, The Walsh lab will leverage the metagenomics resource produced to perform functional metaproteomics studies of arctic microbial communities. Compared to other marine systems, there are far fewer metagenomic datasets available for the Arctic Ocean, which limits the power of metaproteomics approaches that rely on protein sequence databases for peptide identification. Over the last few years, the Walsh lab has used metaproteomics to investigate seasonal and spatial patterns in microbial metabolism in the coastal ocean. As part of the Arctic project, samples suitable for metaproteomics are also being collected. Hence, a nonredundant protein sequence database will be 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.

Fractionated Chlorophyll-a

Samples were collected for phototrophic biomass estimate using chlorophyll-*a* as the proxy. The total fraction chl-*a* samples were obtained by filtering 500 mL of seawater at each station and depth sampled through 0.7 μm GF/F filters (Millipore). The 0.7-3μm fraction chl-*a* samples were obtained by pre-filtering 500 mL of seawater through 3 μm polycarbonate filters before filtering through 0.7 μm GF/F filters. All samples were wrapped in foil, labelled and stored at -80°C until ethanol extracted for chl-*a* analysis onshore (ULaval).

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 each station and depth sampled. In summary, 100 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.

Fluorescent in situ Hybridization (FISH)

FISH is a technique that uses fluorescent-labelled nucleic acid probes to identify specific phylogenetic group under the microscope. Samples for FISH were collected in duplicate for eukaryotes and bacteria at each station and depth sampled. Seawater was fixed with 3.7 % (final concentration) formaldehyde (Sigma-Adrich) and processed within 1-6 hours after sampling. For eukaryotic organisms, 100 mL of fixed sample was filtered onto a 0.8 µm polycarbonate filters (AMDM) and for bacteria, 25 mL was filtered onto 0.2 µm polycarbonate filters (AMDM). Filters were air-dried and stored at -80ºC until analysis in the laboratory.

Single-cell genetics

For single cells genetic, 100 µL of TE-Glycerol was added to 1 mL of water samples in a 2 mL cryovial tube. Samples were incubated for at least 30 minutes with the preservative at room temperature before being stored at -80ºC. Cells preserved in this manner will be singularly picked and be used for genetics/genomic studies.

Bacterial and pico/nanoeukaryote cell count

Cell counts of both prokaryotic (<2 µm) and photosynthetic pico/nanoeukaryotes (2-10 µm) will also be estimated by flow cytometry. An aliquot from each sample were fist collected in 50 mL falcon tubes, then under the hood, 1.8 mL seawater were added to 200 µl 10% glutaraldehyde in 2 mL cryogenic vials. Samples were first incubated in room temperature for at least 30 minutes and then flash frozen in liquid nitrogen before being finally stored in -80ºC until transportation to ULaval. Before counting, bacterial nuclear material is stained with Sybr Green I (Life Sciences) while photosynthetic eukaryotic cells are detected by chlorophyll autofluorescence.

Summary

A total of 155 samples from different depths at 31 stations 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.

Issues

Like in JOIS 2015, the RNA/DNA group was provided with 2 dedicated bottles primarily for collecting in the first 100 m during full casts and 6 bottles in special casts. For the other depths, we just collected the excess from other bottles particularly in deeper waters.

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5.6 Microplastics sampling

Sarah Zimmermann and CTD Watch (DFO-IOS)
P.I.: Peter Ross (Vancouver Aquarium)

Summary

Plastic debris are now ubiquitous in our marine environments. They are separated in two main categories: macroplastics (> 5 mm) and microplastics (< 5 mm). Larger, macroplastic debris distribution and threat to the marine biota are fairly well documented. On the other hand, less is known on the distribution and possible detrimental effects on the marine biota.

The scope of this sampling effort during the JOIS 2016 expedition was to define the spatial distribution of microplastics at the surface (0-10 m) in the Arctic Canada Basin, and obtain a few depth profiles and ice cores, as logistics permitted.

5.7 Underway Measurements

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

Underway measurements summary

Underway sampling included:

- From the seawater loop system:
    a. Electronic measurements of salinity, temperature (inlet and lab), fluorescence, CDOM. *Please see pCO_2 section by Cory Beatty (UMontana) for underway measurements of pCO2.*

b. Water samples for
    i. Chl-a, Salinity, Nutrients, O18
    ii. CDOM, DOM (*Celine Gueguen*, *TrentU*)
    iii. Microplasitcs.(*Peter Ross*, *Vancouver Aquarium*)
c. Flow rate

- The Shipboard Computer System (SCS) was used to log the seawater loop system listed above as well as:
    a. NMEA strings (GPGGA, GPVTG, GPZDA, HEHDT and GPHDT) for position and heading
    b. AVOS weather observations of: air temperature, humidity, wind speed and direction, barometric pressure
    c. Sounder reported depth and applied soundspeed
    d. Surface Photosynthetically Active Radiation (PAR)

Seawater Loop

The ship's seawater loop system draws seawater from below the ship's hull, near the bow, at 9m depth, using a 3" Moyno Progressive Cavity pump Model #2L6SSQ3SAA, driven by a geared motor. A temperature sensor approximately 4m downstream from the pump measures the seawater temperature and puts this into the TSG data stream. 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 seaweater to instruments and sampling locations (Figure 1). This system allows measurements to be made of the sea surface water without having to stop the ship for sampling. The water is as unaltered as possible coming directly from outside of the hull through stainless steel piping without recirculation in a sea-chest. On one of the manifold arms is a Kates mechanical flow rate controller followed by a vortex debubbler, installed inline to remove bubbles in the supply to the SBE-21 thermosalinograph (TSG).

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. Discrete Water Samples were collected from the fluorometer tubing outflow in the TSG lab.

Figure 4. Seawater loop system

The seawater loop provides uncontaminated seawater from 9m depth to the science lab for underway measurements. This is the configuration during 2016-16 (JOIS). During the previous leg, 2016-15 (UNCLOS), the configuration was the same except the pCO2 system under the plastic sheet was not installed.

Figure 5. The Moyno pump installed in the engine room.

Figure 6. 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.

Figure 7. Honeywell controller for the pump. Controller is located in the TSG lab.

Autonomous measurements

A remote temperature sensor was installed in the engine room, in-line, approximately 4m from pump at intake: an SBE-38 inline thermometer, readings from which are integrated into the SBE-21 data stream. This is the closest measurement to actual sea temperature.

Figure 8. SBE38 temperature sensor in the engine room. Data are brought up to the TSG lab and added into Seasave Acquisition with the lab TSG data.

In the TSG lab, the Instruments in the TSG were:
Seabird SBE 21 Thermosalinograph s/n 3297
Seabird SBE-38 Thermometer s/n 0319
Seapoint Chlorophyll Fluorometer s/n SCF 3652
WET Labs CDOM s/n WSCD-1281

The fluorometer and CDOM sensors were plumbed off of a separate manifold output than that supplying the Temperature and Conductivity sensors. 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.

Figure 9. TSG manifold.

Figure 10. Seawater maniold and debubbler.

The data are being collected through SeaBird's Seasave Acquisition program v 7.23.2. onto a laptop. The computer also provided a means 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).

Flow rate was measured using an in-line sensor on the TSG manifold. The sensor measures spin revolutions with time and logged to a text file using an interface box to the computer. The flowrate data needs calibration to manual flow measurements and to be matched by time to the TSG data.

For 2016:
Using the Honeywell controller, pressure set points was 18 PSI with resulting 28 to 33% output
.
Measured flow rates to the sensors during 2016-16 were:

TSG	3.5s/L
Fluorometer pair	7.3 s/L
pCO2	ranged from 26 to 50 s/L

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. Data saved in this format can be easily accessed by other programs or displayed using the SCS software.

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

Note during 2016-16 SCS and network configuration issues resulted in a number of missed days of data recording. Days data were recorded for are listed below under ***Issues with the underway system and data***

Please see the appendix for the data string key.

The system collects:
:
Position - $GPGGA
Position information

Course and Speed Over Ground - $GPVTG
Track made good
Time interval is 2 seconds

Time and Date - $ZDA
Time and date information in UTC.
Time interval is 4 seconds.

Ship's Heading - $HEHDT (Ship's Gyro)
Time interval is 1 second

Ship's Heading - $GPHDT (POSMV)
Time interval is 10 seconds

Depth - $SDDPT
12 or 3.5kHz sounder. The sounders report depth under hull (ie add 9 m for full water depth) and the sounders are always using a variable soundspeed set by the user in Knudsen software. Apply the correct soundspeed to improve accuracy.
Time interval is 1 second.

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 ares mounted on the starboard side, about 12' above the bridge-top.

Seawater Loop (TSG)
Sea surface properties from sea water loop. Intake is ~9m below waterline.
Time interval is 5 seconds.

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.

Time interval is 5 seconds.

Surface PAR
Surface PAR continuously logging sensor is on starboard side above CTD operations. Time interval is 1 second.

Photosynthetically Active Radiation (PAR)

The continuous logging Biospherical Scalar PAR Reference Sensor QSR2150A (S/N 50228, calibration date 21 June 2016), was mounted above the CTD operation area, 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 aft of the sensor and the ship's 'house' about 50 feet forward.

Issues with the underway system and data

During 2016-15:
The Moyno pump was replaced with its spare on August 24. The flow to the TSG was sometimes full of bubbles despite the debubbler, although due to the light ice and the amount of time following g the Oden, less so than previous years; still, careful processing of the time series will be required to remove the affected measurements.

2016-16:
Wind data:
Oct 1 to Oct 5 – wind speed data are bad due to icing
Oct 6- visually confirmed wind direction looks good but anemometer is still running a bit roughly, mostly you can hear its not running smoothly, wind speed still likely under reporting
Oct 13 – visually confirmed anemometer appears to be running well, free of ice.

SCS and network configuration issues resulted in a number of missed days of data recording. Data were recorded for:

GGA-RAW*	Aug 9 to Oct 17
VTG-RAW*	Aug 9 to Sep 18, Sep 27 to Oct 17th
ZDA-RAW*	Aug 9 to Oct 17th
HDT-POSMV*	Aug 9 to Sep 18th
HDT-Gyro*	Sep 19 to 22, Oct 4 to 18th
DBT-RAW*	Aug 9 to Sep 19, Oct 5 to Oct 18
AVOS-serial-AVRTE*	Aug 9 to Oct 17
SBE-38-serialport*	Aug 9 to Oct 17th
TSG-serial*	Aug 9 to Sep 19th, Sep 24 to Oct 17th
ASCII-PAR-serialport*	Sep 19 to Oct 1, Oct 5 to Oct 17.

The new surface PAR data had the wrong surface incident calibration factor for the associated units. Up to 3 Oct 2016 14:14 UTC the units are uE/cm2/sec and after the correction they are uE/m2/sec. The factor was changed from 6.216 to 0.000622 and the resulting output is 10,000 larger, in agreement with the CTD's surface PAR sensor.

5.8 Moorings and Buoys

Rick Krishfield (P.I.), Will O'Strom, Jeff O'Brien, Chris Basque (WHOI), and Cory Beatty (U Montana).
P.I.s not in attendance: Andrey Proshutinsky, John Toole (both WHOI) and Mary-Louise Timmermanns (Yale U), Mike DeGrandpre (U Montana)

Summary

As part of the Beaufort Gyre Observing System (BGOS; www.whoi.edu/ beaufortgyre), three bottom-tethered moorings deployed in 2015 were recovered, data was retrieved from the instruments, refurbished, and redeployed at the same locations in October 2016 from the *CCGS Louis S. St. Laurent* during the JOIS 2016-16 Expedition. Furthermore, three Ice-Tethered Profiler (ITP; www.whoi.edu/itp) buoys were deployed: one on an ice floe with an Arctic Ocean Flux Buoy (AOFB) and Seasonal Ice Mass Balance (SIMB), and two over the side of the ship in open water. An ITP which was deployed in 2013 was also recovered. A summary of moorings and buoys recovered, deployed, and serviced are listed in Tables 1 to 3.

Table 1. Mooring recovery and deployment summary.

Mooring Name	2015 Location	2016 Recovery	2016 Deployment	2016 Location	Bottom Depth (m)
BGOS-A	75° 0.8357' N 149° 55.1832' W	6-Oct 18:01 UTC	7-Oct 18:47 UTC	75° 0.670' N 149° 54.178' W	3827
BGOS-B	77° 59.9927' N 149° 59.9275' W	3-Oct 17:13 UTC	4-Oct 18:06 UTC	78° 0.063' N 149° 59.838' W	3826
BGOS-D	7° 59.8964' N 140° 4.2644' W	12-Oct 17:10 UTC	12-Oct 20:45 UTC	74° 0.005' N 139° 59.991' W	3512

Table 2. Ice-Based Observatory buoy deployment summary.

IBO	ITP / Buoy System	Date	Location
1	ITP98 / SIMB/ AOFB34	29-Sep 01:24	78° 34.2' N 130° 3.6' W

2	ITP99	1-Oct 21:12	77° 53.0' N 145° 7.9' W
3	ITP97	2-Oct 21:30	79° 0.9' N 150° 7.9' W

Table 3. Buoy recovery summary.

Recovery	Buoy	Date	Location
1	ITP67	30-Sep 23:59	76° 45.2' N 142° 22.7' W

Moorings

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

Thirteen years of data have been acquired by the mooring systems, which document the state of the ocean and ice cover in the Beaufort Gyre. The seasonal and interannual variability of the ice draft, ocean temperature, salinity, velocity, and sea surface height in the deep Canada Basin are being documented and analyzed to discern the changes in the heat and freshwater budgets. One of the most striking observations in the past decade has been a reduction in both sea-ice extent and thickness, particularly in the BG region. Ocean changes have been as prominent as the reduction of ice volume: between 2003-2013 the BG accumulated more than 5000 km^3 of liquid freshwater, an increase of approximately 25% relative to the climatology of the 1970s. The magnitude of the liquid freshwater increased remarkably from 2003 to 2008 (from 17,000 to 22,000 km^3), after which it appears to have largely stabilized through 2012. In fact, combining both solid (ice) and liquid (seawater) fresh water components, indicated that a modest net export of 320 km^3 of fresh water from the region occurred between 2010 and 2012, suggesting that the ocean anticyclonic circulation regime may have weakened. In 2013, the liquid fresh water component was at it lowest value since 2007, however, in 2014, freshwater in the BG rebounded back to its 2008-2012 mean, and in 2015 attained an all time high. In 2016, we freshwater determined from the CTD stations indicate an even larger magnitude of freshwater, suggesting that the historic cyclical nature of freshwater accumulation and release in the BG may no longer pertain.

Buoys

The moorings only extend up to about 30 m from the ice surface in order to prevent collision with ice keels, so automated ice-tethered buoys are used to sample the upper ocean. On this cruise, we deployed 3 Ice-Tethered Profiler buoys (or ITPs), and assisted with the deployments of one US Army CRREL Seasonal IMBB, and one Naval Postgraduate School Arctic Ocean Flux Buoy (AOFB). The combination of multiple platforms at one location is called an Ice Based Observatory (IBO).

The centerpiece ITPs obtain profiles of seawater temperature and salinity from 7 to 760 m twice each day and broadcast that information back by satellite telephone. The 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 4).

Table 3. Project websites

Project	**Website Address**
Beaufort Gyre Observing System	www.whoi.edu/beaufortgyre
Beaufort Gyre Observing System dispatches	www.whoi.edu/page.do?pid=147117
Ice-Tethered Profiler buoys	www.whoi.edu/itp
Ice Mass Balance buoys	imb.erdc.dren.mil
Arctic Ocean Flux Buoy	www.oc.nps.navy.mil/~stanton/fluxbuoy

Initiated in fall 2004, the international ITP program over the last 12 years has seen the deployment of 95 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.

Operations

The mooring deployment and recovery operations were conducted from the foredeck using a dual capstan winch as described in WHOI Technical Report 2005-05 (Kemp et al., 2005). Before each recovery, an hour long precision acoustic survey was performed using an Edgetech 8011A release deck unit connected to the ship's transducer and MCal software in order to fix the anchor location to within ~10 m. The mooring top transponder (located beneath the sphere at about 30 m) was also triangulated and located by located by the ship's 400 khz fish finder to pinpoint the top of the mooring at mooring B which was within the ice pack, but not at moorings A and D, as no ice was present.

In coordination with the Captain acoustic release commands were sent to the release instruments just above anchor, which let go of the anchor, so that the floatation on the mooring could bring the systems to the surface. Then the floatation, wire rope, and instruments were hauled back on board. Data was dumped from the scientific instruments, batteries, sensors, and other hardware are replaced as necessary, and then the systems were subsequently redeployed for another year. The moorings were redeployed anchor first, which required the use of a dual capstan winch system to safely handle the heavy loads. At the two moorings where ice was not present (A and D), we were fortunate to have calm weather conditions as anchor first deployments cannot be conducted in a significant wave field. Typically it took between 4-6 hours to recover or deploy the 3800 m long systems.

Complete year-long data sets with good data were recovered from all ULSs (upward looking sonar), all ADCPs, one of the AWACS (acoustic wave and current profiler), every BPR (bottom pressure recorder), and all three sediment traps collected samples for the duration of the deployment. All MMPs were recovered with full year-long profiler CTD data records (although two of these systems either did not obtain velocity measurements, or obtained sporadic velocity measurements). One AWACS failed due to a flooded battery pack.

ITP deployment operations on the ice were conducted with the aid of helicopter transport to and from one site according to procedures described in a WHOI Technical Report 2007-05 (Newhall et al., 2007). Due to the thin ice conditions, reconnaissance operations took 2 days for finding adequate ice to deploy the IBO, as suitable ice could not be located on the first day, and weather limited daylight conditions constrained the operations. Not including the time to reconnaissance, drill and select the ice floes (which was only 0.75 m thick), this deployment operation took between nearly 7 hours, including transportation of gear and personnel each way to the site. Ice analyses were also performed by others in the science party while the IBO deployment operations took place. While a second IBO deployment on an ice station was desired, no other floes of adequate thickness (>0.5 m) and size (>100 m wide) we found that could be safely accessed with the helicopter. Consequently, the 2 remaining ITPs were deployed over the side of the ship in open water using the ship's bow A-frame, and an SIMB and Ice-Tethered Micro-mooring (ITM) could not be deployed during the cruise.

IBO 1 deployed on September 29, 2016 consisting of AOFB 34 (left), ITP 98 (center) and SIMB (right) shortly after deployment, with the *CCGS Louis S. St. Laurent* in the background.

One ITP surface package and tether deployed in the Makarov Basin in 2013 was also recovered during this cruise. The recovery was conducted using the ship's A-frame to haul out the instrumentation in thin ice conditions. While it was hoped that profiler data that was not transmitted could be recovered, unfortunately, the profiler apparently dragged on the bottom and was torn from the tether.

Other

Dispatches documenting all aspects of the expedition were composed by Peter Lourie and posted in near real time on the WHOI website at: http://www.whoi.edu/page.do?pid=154796.

5.9 RAS (Remote Access sampler) recovery and deployment

P.I.: Michiyo Yamamoto-Kawai (TUMSAT, michiyo@kaiyodai.ac.jp)
Mika Hasegawa, Yuanxin Zhang (TUMSAT)

Recovery

A Remote Access Sampler (RAS), WQM and SUNA sensors were recovered at mooring station BGOS-A. Please see cruise report 2014 for equipment details and report 2015 for settings.

The RAS was installed with 48 sample bags (Kynar) and was set to collect 450 mL of seawater in each bag. Of 48, one bag was broken and 4 were low in sample volume. Samples were analyzed for DIC and alkalinity onboard. Samples were also subsampled for analysis of $\delta^{18}O$, nutrients, and salinity (Table 1). Fourteen samples were selected for DNA sequencing in order to determine the species composition of the microbial communities, before, during and after the putative algal bloom observed with in situ Chl a. Seawater samples, with volumes ranging from 100 to 200 mL, were filtered through 0.22 micron filters, which were then preserved with RNA Later. Next, DNA will be extracted from the cells collected on the filters for rDNA gene amplification and sequencing at the Sequencing Centre of the University of Exeter (UK); rDNA gene sequences will be used for taxonomic classification of microbial assemblages across the 14 samples.

Table 1. List of RAS samples

#	DIC	TA	Sal	18O	nuts	#	DIC	TA	Sal	18O	nuts
1	○	○	○	○	○	25	○	○	○	○	○
2	○	○	○	○	○	26	○	○	○	○	○
3	○	○	○	○	○	27	○	○	○	○	○
4	○	○	○	○	○	28	○	○	○	○	○
5	○	○	○	○	○	29	○	○	○	○	○
6	○	○	×	○	○	30	○	○	×	×	○
7	○	○	○	○	○	31	○	○	○	○	○
8	×	×	×	×	×	32	○	○	○	○	○
9	○	○	○	○	○	33	○	○	○	○	○
10	○	○	○	○	○	34	○	○	○	○	○
11	○	○	○	○	○	35	○	○	○	○	○
12	○	○	○	○	○	36	○	○	○	○	○
13	○	○	○	○	○	37	○	○	○	○	○
14	○	○	×	○	○	38	○	○	○	○	○
15	○	○	○	○	○	39	○	○	○	○	○
16	○	○	○	○	○	40	○	○	○	○	○
17	○	○	○	○	○	41	○	○	○	○	○
18	○	○	○	○	○	42	○	○	○	○	○
19	○	○	○	○	○	43	○	○	○	○	○
20	○	○	○	○	○	44	○	○	○	○	○
21	○	○	○	○	○	45	○	○	○	○	○
22	×	○	×	○	○	46	○	○	○	○	○

23	○	○	○	○	○	47	○	○	○	○	○
24	○	○	○	○	○	48	○	○	○	○	○

1.1.1.2. Deployment

The RAS-A, SUNA and WQM were redeployed at BGOS-A. The settings are summarized in Tables 2 and 3. RAS was set to collect 48 of 500 mL seawater samples. 400 µL of saturated $HgCl_2$ was added to each sample bag before the deployment.

Sampling tubes between the multi-port valve and sample bags are filled with salty water made of DMQ with NaCl and Na_2CO_3 to have salinity of ~38 and alkalinity of ~1000 µmol/L. This water was sampled for $\delta^{18}O$, salinity and alkalinity analysis for the correction to make after the recovery of the RAS.

Table 2. BGOS-A RAS/SUNA/WQM settings.

	RAS	SUNA	WQM
sirial No.	12905-01	SUNA-06	WQM-406
sampling start date	2016/10/8 2:00:00 (UTC)	2016/10/8 1:46:30 (UTC)	2016/10/8 1:50:00 (UTC)
sampling schedule	see table 3	every 6 hours	every 6 hours
other information	No filter, Kynar bags (bag#6 Tedlar)	light frame 120 sec, wiper ON	sampling time 5 minutes

Table 3. RAS sampling schedule (UTC)

#	Date and Time	#	Date and Time	#	Date and Time
1	2016/10/08 2:00:00	17	2017/02/04 2:00:00	33	2017/06/04 2:00:00
2	2016/10/15 2:00:00	18	2017/02/12 2:00:00	34	2017/06/12 2:00:00
3	2016/10/23 2:00:00	19	2017/02/20 2:00:00	35	2017/06/20 2:00:00
4	2016/10/31 2:00:00	20	2017/02/28 2:00:00	36	2017/06/28 2:00:00
5	2016/11/08 2:00:00	21	2017/03/08 2:00:00	37	2017/07/06 2:00:00
6	2016/11/16 2:00:00	22	2017/03/16 2:00:00	38	2017/07/14 2:00:00
7	2016/11/24 2:00:00	23	2017/03/24 2:00:00	39	2017/07/22 2:00:00
8	2016/12/02 2:00:00	24	2017/04/01 2:00:00	40	2017/07/30 2:00:00

9	2016/12/10 2:00:00	25	2017/04/09 2:00:00	41	2017/07/30 2:00:00
10	2016/12/18 2:00:00	26	2017/04/09 2:00:00	42	2017/08/07 2:00:00
11	2016/12/26 2:00:00	27	2017/04/17 2:00:00	43	2017/08/15 2:00:00
12	2017/01/03 2:00:00	28	2017/04/25 2:00:00	44	2017/08/23 2:00:00
13	2017/01/11 2:00:00	29	2017/05/03 2:00:00	45	2017/08/31 2:00:00
14	2017/01/11 2:00:00	30	2017/05/11 2:00:00	46	2017/09/08 2:00:00
15	2017/01/19 2:00:00	31	2017/05/19 2:00:00	47	2017/09/16 2:00:00
16	2017/01/27 2:00:00	32	2017/05/27 2:00:00	48	2017/09/23 2:00:00

5.10Underway and Moored pCO2 and PH Measurements

Cory Beatty (UMontana, Cory.Beatty@umontana.edu)
P.I.: Mike DeGrandpre (UMontana, michael.degrandpre@umontana.edu)

Overview: U.S. National Science Foundation Project: Collaborative Research: An Arctic Ocean Sea Surface pCO_2 and pH Observing Network

This project is a collaboration between the University of Montana and Woods Hole Oceanographic Institution (Rick Krishfield and John Toole). The primary objective is to provide the Arctic research community with high temporal resolution time-series of sea surface partial pressure of CO_2 ($p$$CO_2$), Temperature and dissolved oxygen (DO). The $p$$CO_2$ and DO sensors will be deployed on a WHOI ice-tethered profiler (ITP). Placed on the ITP cable just under the ice, the sensors will send their data via satellite using the WHOI ITP interface. On each of the 3 BGOS moorings, a SAMI-CO2/SAMI-pH pair equipped with DO, photosynthetically active radiation (PAR), Fluorescence and temperature sensors will be deployed at a depth of approximately 35 meters.

Figure 11. SAMI-CO_2 and Seabird Microcat w/ dissolved Oxygen deployed on ITP 99 during the second ITP deployment.

Cruise Objectives

1. Deploy 1 SAMI-CO_2 on WHOI ITP 99.
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. Deploy Seabird Microcat equipped with a dissolved Oxygen sensor on WHOI ITP 99.
4. Deploy 1 SAMI-CO2/SAMI pH pair on each of the three BGOS moorings (BGOS-,BGOS-B and BGOS-D).
5. Assist with other shipboard research activities and to interact with ocean scientists from other institutions.

Cruise Accomplishments

We deployed a SAMI-CO_2 as well as a Seabird Microcat equipped with a dissolved Oxygen sensor on ITP 99 during the 2nd ITP deployment (deployed in open water due to lack of sufficient ice floes). 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. We also deployed a SAMI-CO2/SAMI-pH pair on the BGOS-A, BGOS-B and BGOS-D moorings.The sensor data collection is summarized in Table 1 below.

Table 4. pCO$_2$ and pH sensor data collection summary

Measurement system	Instrument IDs	Location	Duration
underway infrared-equilibrator pCO$_2$	SUPER (Sunburst Sensors)	Entire cruise track (see IOS report in this document)	9/23/16-10/17/16
ITP SAMI-CO$_2$ and Seabird Microcat w/ DO sensor	WHOI ITP 99, SAMI-CO2 S11u	Second ITP deployment, CO2 ~ 8 m depth, Microcat ~ 7 m depth (see WHOI cruise report in this document)	10/1/16 - present
SAMI-CO2 / SAMI-pH	CO2 : S48u, pH : S47u	BGOS-A mooring	10/7/16 – present
SAMI-CO2 / SAMI-pH	CO2 : C38 pH : P5	BGOS-B mooring	10/4/16 - present
SAMI-CO2 / SAMI-pH	CO2 : C37 pH : S68u	BGOS-D mooring	10/13/16 - present

5.11 Ice Watch Report

P.I. Jenny Hutchings (OSU), Kazu Tateyama (KITAMI)
Ice observers participating in this year's program where:

- Alek Petty (NASA Goddard Space Flight Center/University of Maryland)
- Seita Hoshino (KITAMI)

As in previous years, the ice observations recorded during the Louis S. St. Laurent 2016 cruise will provide detailed information for the interpretation of satellite imagery of the ice pack. Cores and transects were taken during the one ice station, to further characterize the perennial ice.

Observations from the Bridge: Methodology

We split the ice watch into 12 hour shifts throughout the cruise. We aimed to make an observation every hour, on the hour. However, as we were only two in number, and the period of ice presence was shorter than normal (~10 days), we were occasionally preoccupied with side-EM and Radiometer installation/packing. We did maintain our shifts for the 8/9 days before and after travelling through the ice pack (mainly due to XCTD duties) but did not include these long periods of open water in the ASSIST software. The observations thus start and end around the time period of our traverse through the ice pack. Similar to 2012, the record low summer sea ice minimum, the number of ice observations was severely reduced, especially in comparison to 2015.

Ice conditions were noted within 1nm about the ship, when visibility allowed, along the ships track during the observation period. During night we relied upon the ships search lights to observe the ice, and decreased the frequency of ice watch (to zero when the light was too low to make a valid observation).

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. As this cruise was after September 15 and freeze up had commenced, any ice recorded as second year (SY) would have been formed in the previous winter, having survived one summer. *Similar to 2015, it was tough to discriminate between second year ice (SYI) and multiyear ice (MYI) as the ice floes were thin and small (~100 m diameter), meaning we didn't observe much overturning. We noted some of the blue colours suggesting some of this ice was older (as noted in 2015). On our first ice station we noted 50cm level MY ice with very low salinities (less than 3 PPT throughout the core).*

For more information on visual observations collected please see the document 'ASSISTv3_CheatSheets.xls'. Data is archived at icewatch.gina.alaska.edu and more information about the Ice Watch program and ASSIST can be found at www.iarc.uaf.edu/icewatch.

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.
Please note, that in 2015 the port camera was turned 90º, so it is not longer looking at ice over turning but monitoring the ice moving under Kitami's crane mounted EM-31 and passive microwave radiometers. This was done for two reasons:

1. *a zodiac was moved a new location blocking the view of the overturning ice*
2. *we wished to monitor if ice was not being overturned under the em-31.*

For the 2016 images, the quality of the bow looking Netcam was pretty low (images looked washed out and low resolution). Both also suffered from occasional fogging/condensation issues during the cruise which we tried to fix as we went.
The imagery was saved in real-time onto the ScienceNet server.

Ice Stations

We followed the standard JOIS protocol of

1. Collecting snow depth, ice thickness and freeboard data along transects and
2. Collecting ice cores

at each ice station. In addition Seita Hoshino recorded snow pit information. Alek Petty used a sled mounted EM-31 to extend ice thickness measurements across the transect and around the ice station.

See documents 'TransectInstructions.docx' and 'CoreInstructions.docx' describing the methodology.

Ice Station 1

Ice was accessed by helicopter.
Two 50 m transects were laid at right angles to each other, crossing in the middle. Note that the transects were shortened (normally 100 m) due to the thin/unsafe ice conditions.

Ice cores were collected at three sites along the first/primary ice transect line (0m, 25 m, 50 m). The cores were collected at a maximum of 3 meters from the transect line.

Further Ice Stations were cancelled due to the poor ice conditions (not thick/big enough). This was unfortunate, as we were especially hoping to collect more ice cores, including cores to assess the internal ice structure (as in 2015).

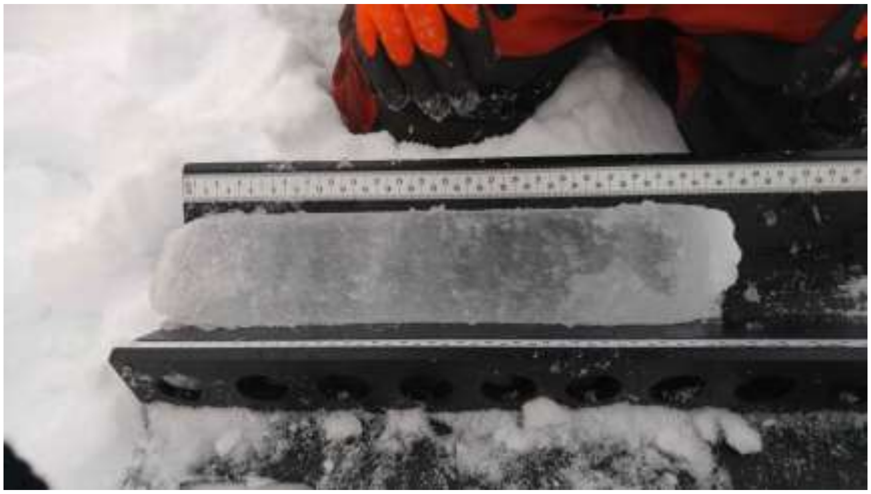
Ice Cores

Ice Station	Site	Core	Purpose	PI
1	1	A	Temp/Salinity	Hutchings
1	1	AD	DNA/RNA	Monier
1	1	AM	Microplastics	Zimmermann
1	2	B	Temp/Salinity	Hutchings
1	2	BD	DNA/RNA	Monier
1	2	BM	Microplastics	Zimmermann
1	3	C	Temp/Salinity	Hutchings
1	3	CD	DNA/RNA	Monier
1	3	C?	?	?

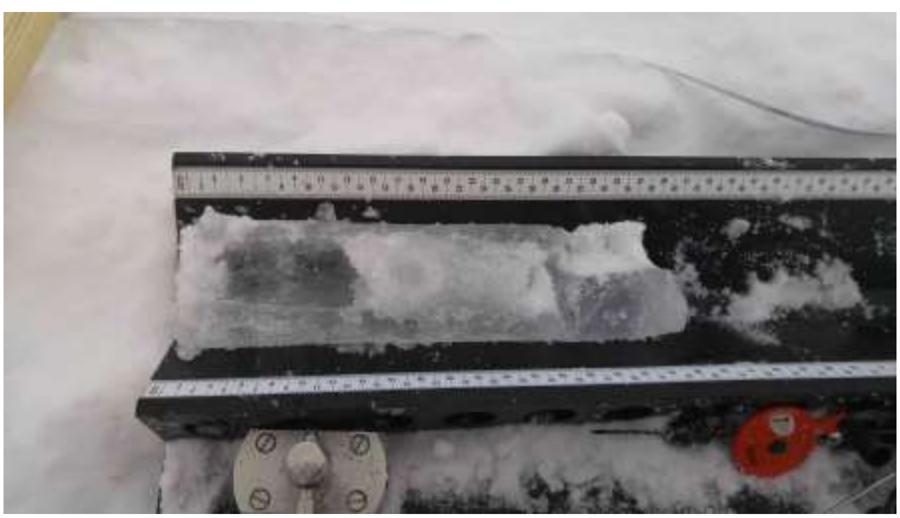
Note that images of each ice core section can be found in the data repository.

The microplastic and DNA/RNA cores were not measured for temperature or divided into sections. They were instead broken up as required and placed into plastic bags for post-processing.

Mention issue with microplastic core.


Ice Station 1, Site 1 Core A, Temperature/Salinity Core
Top was very rough, bottom was a bit chipped.


Ice Station 1, Site 2 Core B, Temperature/Salinity Core
Crack at 5 cm, last section only 7 cm long


Ice Station 1, Site 3 Core C, Temperature/Salinity Core
Big chip from 0-14 cm, mushy from 14-29 cm, chip from 29-37 cm

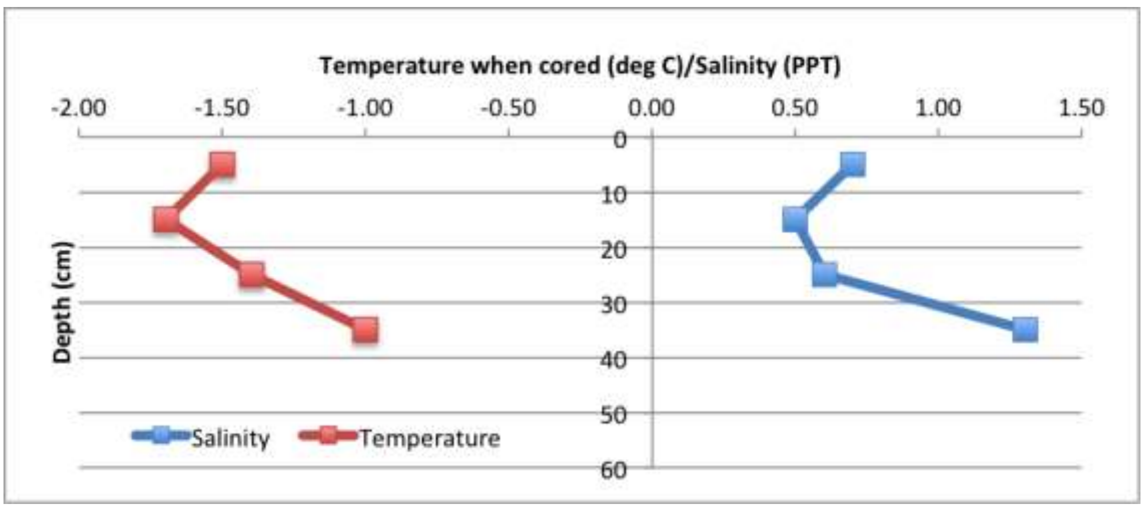
__Temperature, Salinity and Density Profiles__

Temperature, salinity and density profiles were measured at each core site following the methodology described in the 'how-to' document in the appendix.

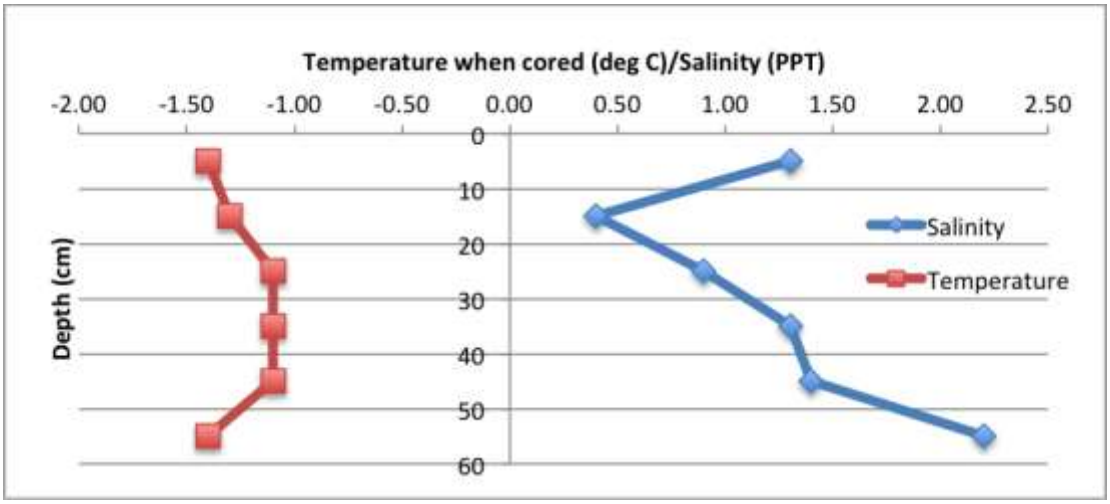
Density will be calculated at a later date, and it should be noted there are large errors associated with these density measurements (Hutchings et al. 2015), and the data is best used averaged across many cores. Our aim is to characterize bulk density of MY ice in the Beaufort region. *One issue with the 2016 cores was the irregular morphology of the core sections. Measuring the width of the cores (10 cm sections) avoids the fact that many of the core sections had large holes around the surface where the ice had broken off, potentially as it was drilled. This could introduce further errors in the estimation of ice density.*

Calibration of salinometer
The OSU salinometer was having issues, so we borrowed a salinometer from IOS. We calibrated salinometer with a 34ppt standard and deionized water. The standard was cut in half, volume wise, with deionized water several times and measurements recorded for salinities in the range 0f 1-34ppt. Note that the accuracy of the salinity estimates is thought to be ~0.5 ppt.

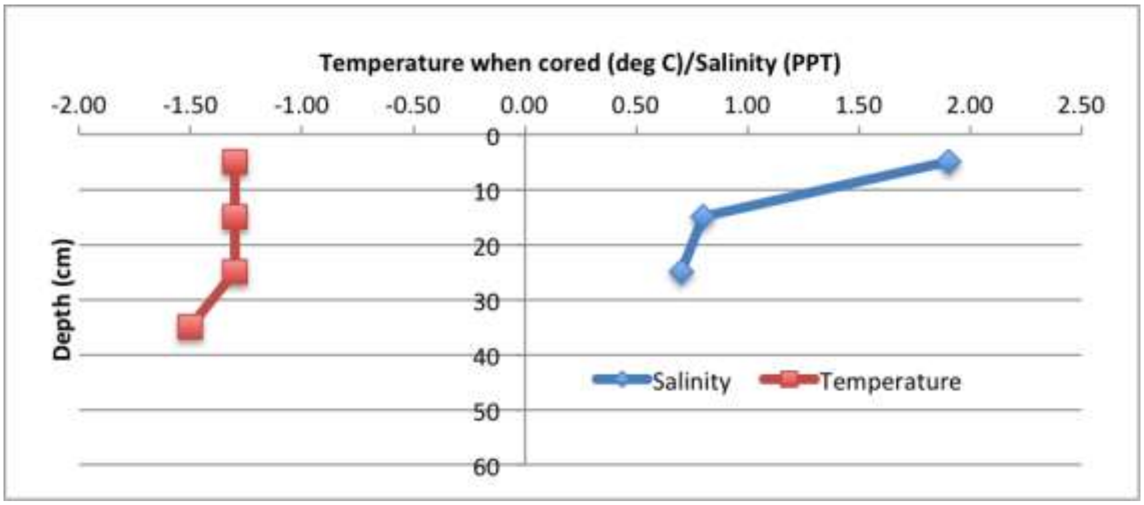
Ice core profiles from Ice Station 1.



Core A



Core B



Core C

Ice Thickness Transects

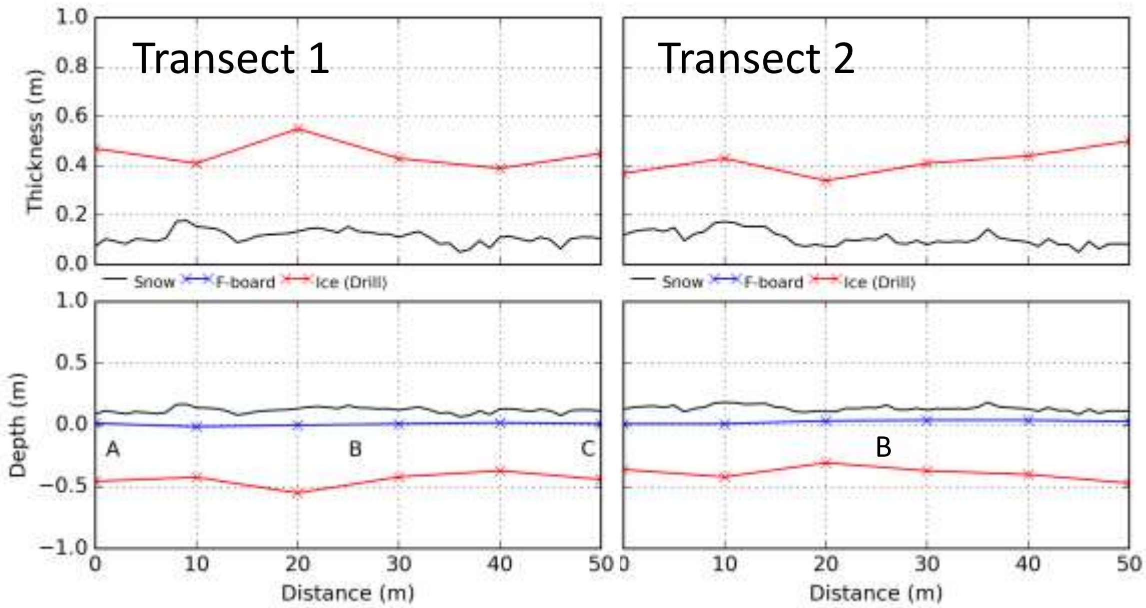
Due to the poor/unsafe ice conditions (very thin ice, significant cracks in the ice floe), we were unable to follow the standard JOIS procedure of making 2 100m transects at right angles to each other. We instead settled for 2 50 m transects with thickness and freeboard measurements every 10m ad snow depth every meter.

Snow Pits

Seita Hoshino measured snow properties with a snow pit at the 0 m mark of transect 1. The data (e.g. snow density) is on the ScienceNet server (detailed below).

Ground truth ice thickness, freeboard (drilled) and snow depth measurements

Ice thickness was measured directly with the use of a drill. This was done every 10m along the transect. Snow depth and freeboard was also measured at these locations. Snow depth was also measured at 1-m intervals along the 50 m transects.

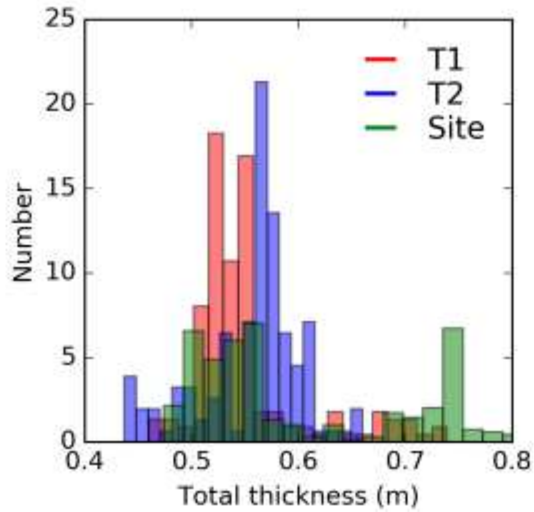


Ice thickness (black line), freeboard (blue line) and snow depth (red line) for the two transects. The bottom plots the results relative to sea level. Note that the snow depth data are every meter.

The modal ice thickness at both locations is similar (~0.5-0.6m), but there is much higher variability at ice station 1, with significant areas of thicker ice. This is reflected in the mean ice thickness at both ice stations (1.2m mean at IS1, 0.7m mean at IS2).

Ice Thickness from EM-31

At both ice stations, ice thickness was measured with an EM-31 antenna mounted on a sled. The EM-31 data logger has an in-built GPS that recorded location. However, due to floe drift, the absolute position does not reflect the relative position on the floe of the EM-31 track, which was designed along 2 transcts and an extra transect around the buoy site. The ship's GPS can be used to correct for floe drift if the ship is locked in to the ice floe – this was not the case at ice station 1. Ideally, a second GPS should be setup on the floe to correct for this, but time constraints limited this. It is still clear where the EM was logging data over the transects. In this case one must assume a constant EM velocity to interpolate onto the drilled groundtruth thickness sites (located every 10 m) if the exact GPS coordinates of both are not known.



Histogram of ice thickness (ice plus snow thickness) collected from the EM sensor over transect 1 (red), transect 2 (blue) and the buoy site (green). The distance from the EM to the snow surface (0.35 m) was subtracted before plotting.

We can see (qualitatively) that the ice plus snow thickness is similar (mean and mode) for data collected with the drill and by the EM. Mean/mode of around 0.5 to 0.6 m. We found some thicker ice when taking the EM further from the transect lines, around the buoy deployment site (0.75 m), but never observed a thickness over 1 meter.

Summary of Ice Along the Cruise Track


A typical scene taken of young grey/grey-white ice. Image with a GoPro camera taken from inside the bridge.

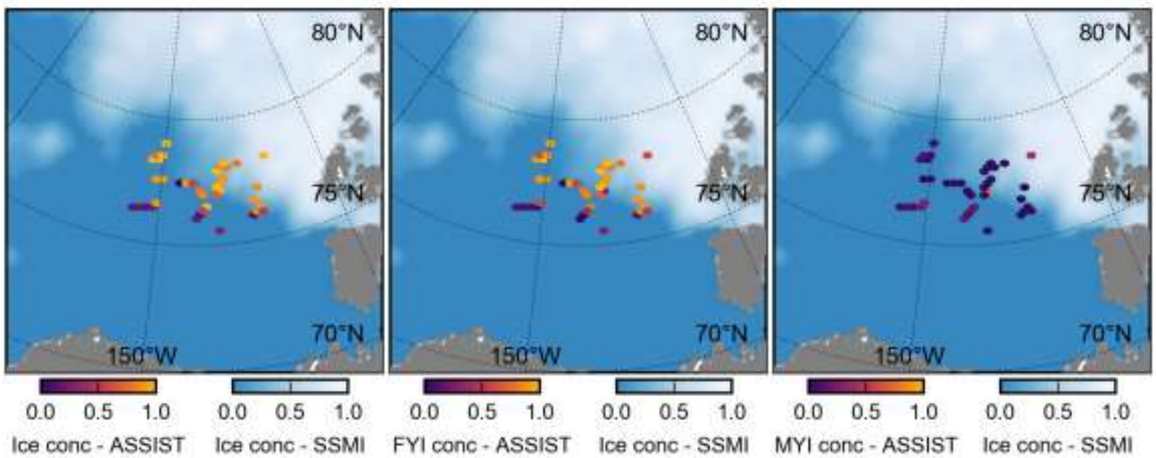
This year we travelled 'backwards' around the JOIS loop (similar to 2015), hitting the 145W line first, finding ice thick enough for an ice station in the north (towards 79N) and then returning south down the 150W line before heading east. There were some large deviations along the way, especially in the search for ice thick enough to support another ice station

In general the ice edge was very far north (bordering the original cruise track) and we thus had to navigate further north to find ice concentrated/thick enough for an Ice Station. We only spent around 9 days within the ice pack. This appeared similar to the records of the 2012 cruise (the year of the record Arctic sea ice minimum). We arrived in the Beaufort around the onset of freeze-up, but the freeze-up didn't appear to be occurring rapidly (confirmed by a lack of ice extent increase over our cruise time period) and the lack of much southern ice drift. Note that as we had over a week of open water at the start and end of the cruise we started and ended the Ice Watch when we hit the ice pack. We thus didn't include many observations of the open water before and after.

Images taken during Ice Watch of (left) small pancakes within older white ice (right) Small floes of thick multiyear ice.

Young ice types were encountered throughout the cruise, and young grey/grey-white ice dominated the ice landscape. Every stage of new ice development from grease ice to young-white ice was observed. We noted nilas, grease ice, and pancakes. The pancakes varied in size throughout the cruise, mainly based on how far into the ice pack we were (large areas of small pancakes were observed as we entered the ice pack). The younger ice was interspersed with older, multiyear ice floes of varying concentration on occasion.

Similar to the reports from 2015, the older multiyear ice floes were pretty level, with less evidence of hummocking and ridges than you would expect from MY ice. This is thought to be the older ice that may have re-circulated in the center of the Beaufort Gyre, or was transported in from the Central Arctic due to the strong summer (August) cyclone. The older ice was in small floes (50-500 m diameter) and at concentrations from 1/10 to 8/10.



ASSIST IceWatch estimates of total ice concentration (left), first-year ice concentration (middle) and multiyear ice (right). Note that the multiyear ice estimates include second year ice and older. SSMI ice concentration is from the 17th September, 2 days before the start of the cruise.

The ship rarely had to navigate towards leads to avoid thick ice. The only noticeable maneuvers involved s small deviations to avoid the small, thick multiyear ice floes as they entered the ship's line of sight. RADARSAT imagery wasn't used as much as on previous cruises. It was rare to see thick ice (greater than 2 m) being overturned by the ship.

Data

lsloaa::sciencenet/2016-16-JOIS/Data/Ice

- /IceStations/

IceStation1SnowPit.xlsx
IceStation1Transect1.xlsx
IceStation1Transect2.xlsx
IceStation1CoreData.xls
JOIS2016_IS1_EM.xls – EM data on Ice Station
/IceCorePhotos

- /IceWatch/

JOIS2016_IceWatch.xls
ASSISTv3_CheatSheets.xlsx - Description of data file, with header codes
/IceWatchPhotos/

- NetRad

/2012 /2013 /2014 /2015 /2016 /Calibration

- EM-Underway -KITAMI EM-31 'sushi' underway cruise data

Many Thanks to the following volunteers who helped at Ice Station 1:
Arthi Ramachandran, Adam Monier, Mathura Mahaan, Mike Dempsey, Chris Clarke, Jean Mensa, plus the crew who helped us maintain safe operations.

5.12 EM ice obsersvations Cruise Report

P.I. Kazutaka Tataeyama, Associate Professor, Kitami Institute of Technology, Japan

EM/Net radiometer observations were carried out by following members

- Seita Hoshino, Doctoral student, Kitami Institute of Technology, Japan
- Alek Petty ,NASA Goddard Space Flight Center, Maryland, USA

Measurements:
Following ship underway ice observations were conducted starting from CB16 to (EM) and PP06 (Radiometer) as shown in Fig.1.

1. Ice thickness measured by an electromagnetic induction device (EM)
2. Short wave and Long wave measured by CNR 4 (Net Radiometer)

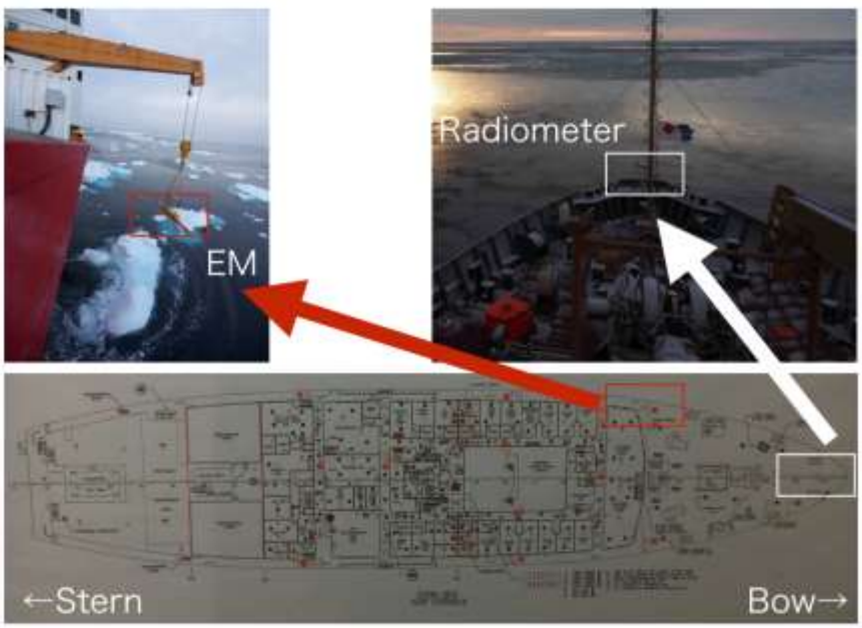


Figure 1 Positions of EM sensors and Radiometer.

Purpose and methods:
An Electro-Magnetic induction device EM31/ICE (EM) and a laser altimeter LD90-3100HS were used for indirect sea-ice thickness measurement continuously. 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) by using inversion method. LD90-3100HS provides a distance between the instruments and snow/sea-ice surface (Z_L). The total thickness of snow and sea-ice (Z_{S+I}) can be derived by subtracting Z_L from Z_E. Ice concentration also can be measured by EM system.

Sea-ice thickness in the Canada Basin was recorded by EM system in order to research inter annual thickness change. The EM sensor covered by a yellow-orange color waterproof case was deployed from the foredeck's crane on the port side, collecting data while underway.

CNR-4 recorded the radiation balance of solar and far infrared (IR). This data will be used for assuming ice albedo feedback and help interpret satellite image of sea ice. CNR-4 provides output voltage (mV) in which can be converted to short wave and long wave irradiance .

EM data are collected every 0.1 second and Radiometer date are collected every 10 second.

Results:

1. EM ice thickness profiles

EM observations were carried out during 27 September and 6 October (Fig.2). 6 profiles of EM survey were derived as summarized in table 1. The total distance of 6 profiles were 1,315 km. EM was calibrated over open water twice on 1 and 6 October as shown in Fig.3. Individual ice thickness profiles are indicated in Fig. 4.

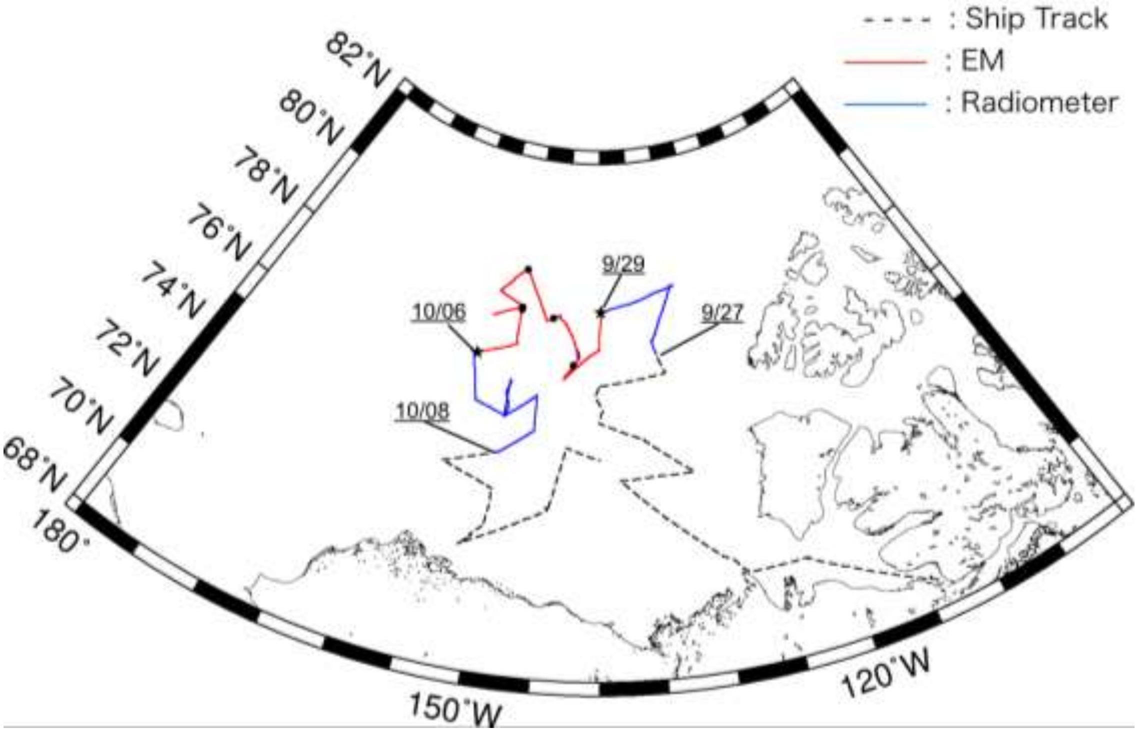


Figure 2 Ship track (Black dashed line) during 23 September - 12 October, and survey track of EM (red line) and Radiometer (blue line) during 27 September - 8 October.

Table. 1 EM observation log.

Profile Number	Start Time(UTC)	Start Position	End Time(UTC)	End Position	Length of Profile [km]
1	2016/9/29 21:31:00	77.993133 N 139.765771 W	2016/9/30 16:30:00	76.357381 N 143.538186 W	288.65
2	2016/9/30 20:35:00	76.552563 N 143.032762 W	2016/10/1 22:14:00	77.883747 N 145.042292 W	188.95
3	2016/10/2 0:01:00	77.786616 N 145.799748 W	2016/10/2 18:04:00	79.000467 N 150.089055 W	191.98
4	2016/10/2 18:06:00	79.000568 N 150.090866 W	2016/10/3 16:53:00	77.996586 N 150.008229 W	216.81
5	2016/10/4 0:04:00	77.982937 N 149.958681 W	2016/10/4 16:51:00	77.989111 N 149.937993 W	190.17
6	2016/10/5 2:29:00	77.912187 N 150.016758 W	2016/10/6 0:15:00	76.357381 N 143.538186 W	242.16

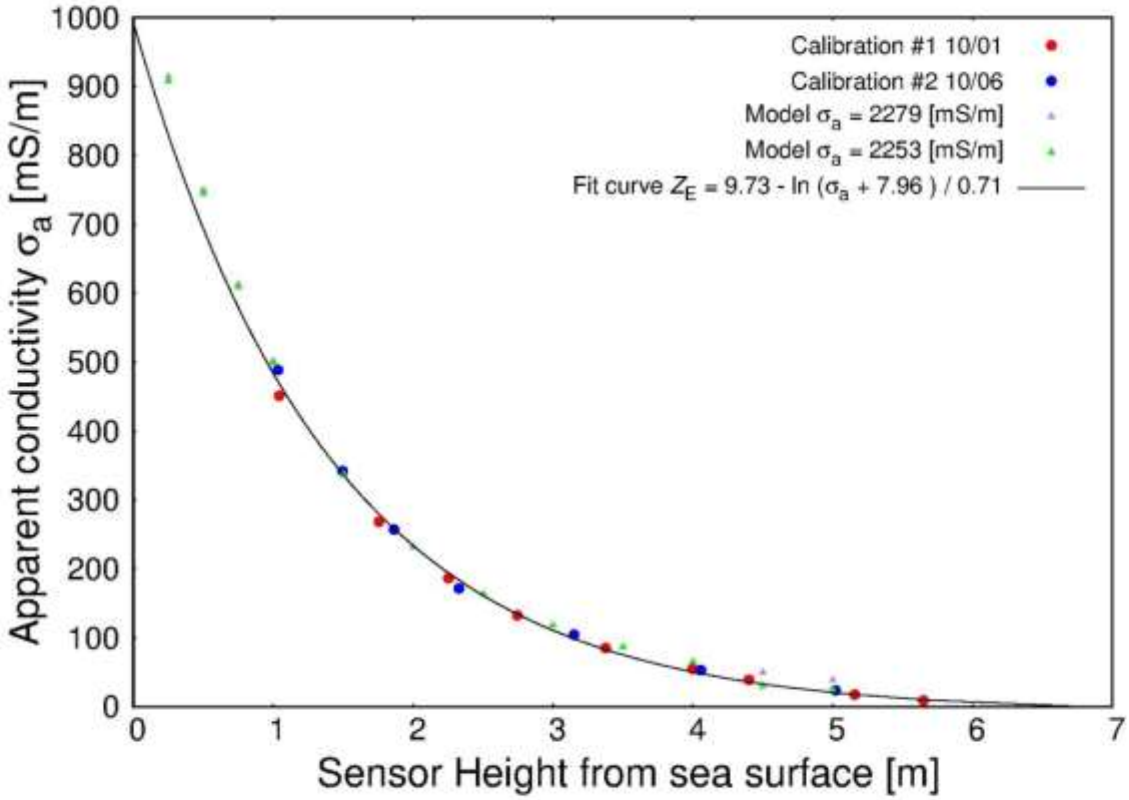


Fig. 3 Result of EM calibrations open water

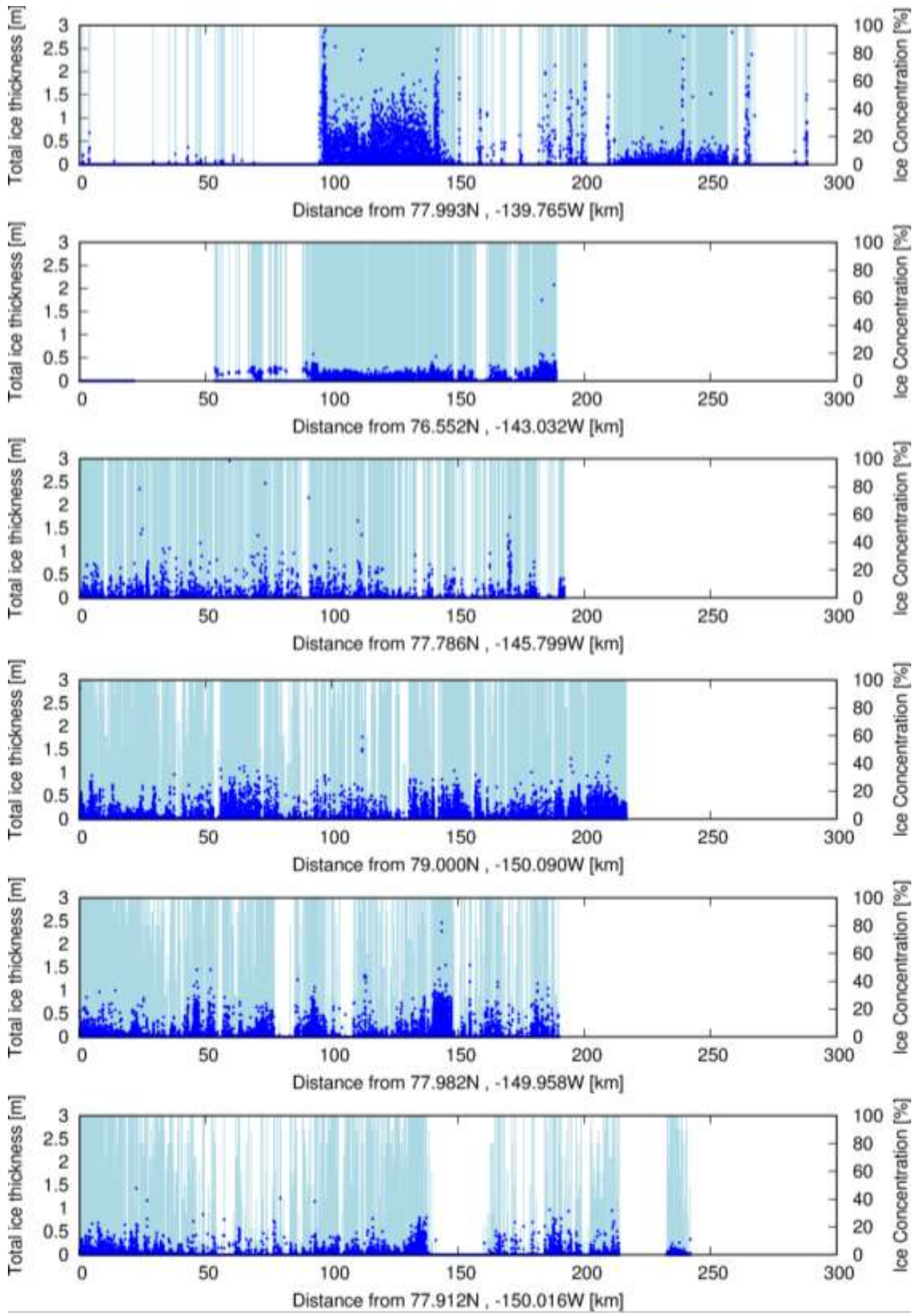


Figure 4 Profiles of EM observations.

2. Net Radiometer Profiles

Unfortunately, there was an error in the configuration of the output voltage of the radiometer (followed on from 2015), which drastically reduced the precision of the data obtained, and limited the range in radiation values measured. We thus only obtained useable data of IR temperature and the general trend in radiation. The diurnal cycle, for example, is missing from the radiation data. We hope to rectify this issue for next year as this can be easily fixed.

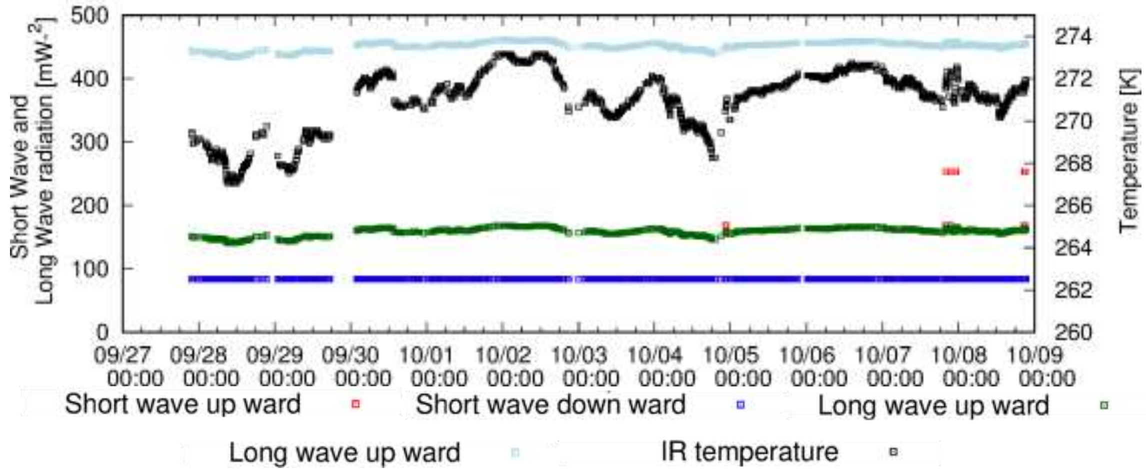


Fig.5 Profiles of Radiometer observation.

5.13 CARTHE Surface Drifter Deployment Report

Jean Mensa (Yale U)
P.I.Mary-Louise Timmermans (Yale U)

Surface drifters were employed during JOIS 2016 with the goal of studying Lagrangian dispersion in the ice free Artic Ocean.

Methods

20 CARTHE drifters were deployed in two phases: a main release of 18 drifters, coordinated with the deployment of drifters from IOS, and the release of 2 drifters near the ice edge.

CARTHE drifters are small (40cm x 40cm x 50cm) biodegradable drifters composed of a floating torus and a drifting wing connected by a flexible neck (Figure 1). The design was developed in collaboration with the SUSTAIN wave tank facility of the University of Miami with the goal of developing a drifter that would be advected by surface true Lagrangian+Eulerian forces minimizing fictitious velocities (i.e., the drifter “surfing” on waves).

Drifters report position every 5 minutes and use a SPOT GPS. Position accuracy depends on the number of satellites seen by the GPS unit and it is expected to vary between 10m and 1m. Batteries last few months in temperate oceans. It is unclear how long they will last in the Arctic. The current experiment will help determining these variables.

Figure 12 CARTHE drifters with floating element and wings connected by a flexible neck.

Open water release
18 drifters were released September 25th after station CB23a (cast 5). Drifters have a unique ID which was recorded together with their release time (UTC). Coordinates of the initial position were not logged because of a problem with the portable GPS used during the experiment but can be retrieved from the release time.

4:20am – 1056, 1051, 1054
4:21am – 1074, 22, 1059
4:22am – 25, 24, 1058
4:23am – 1070, 1052, 1055
4:24am – 26, 1078, 1053
4:25am – 23, 1057, 27

Drifter 1058 lost the drogue during release and will be analyzed separately.

Drifters were released in groups of 4: a triplet of CARTHE drifters plus one ISO drifter 6 triplets (Figure 2). In each group, two drifters were released from starboard and two from port side. Starboard and port pairs were separated by approximately 30m (more 10-20m?). The first pair was followed 10 seconds later by a second pair with one CARTHE drifter and one ISO drifter. Given a speed of 5kts, the separation from the first pair was of about 50m. This sequence completed a triplet of CARTHE drifter and one ISO drifter. Triplets were released ~100m apart (20 seconds). IOS drifters were included in the first 4 triplets only, while CARTHE drifters were released over a total of 6 triplets. The separation in scales will allow to compute metrics such as the scale dependent FSLE and will define the pairs for the scale dependent relative dispersion.

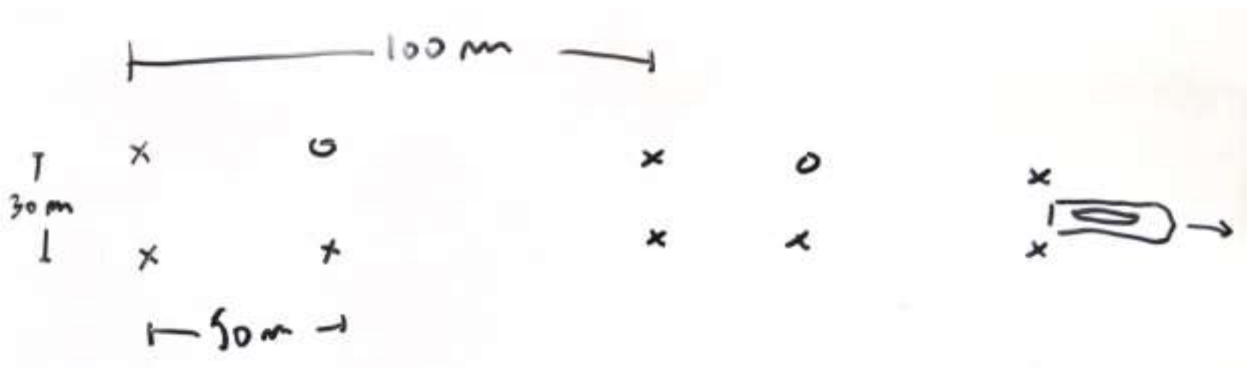


Figure 13 Release patter for the main deployment. Crosses represent CARTHE drifters while circles IOS drifters. LSSL is represented moving eastward.

The goal of this first release is to sample waters along the shelf in ice free areas. The release of CARTHE drifters followed 4 releases of IOS drifters between CB1 and CB23 (more information in Chris Clark's report). IOS drifters previously released showed eastward advection potentially driven by a coastal current induced by southerly winds. The release of CARTHE drifters followed two days of 20-30 knots winds but was done in calm waters with weak winds. The first few hours of trajectories (Figure 3), showed intense inertial oscillations and the anomalous movement of the un-drogued drifter with ID 1058.

Figure 14 Trajectories of the 18 CARTHE drifters released at CB23. BG_1058 is the un-drogued drifter.

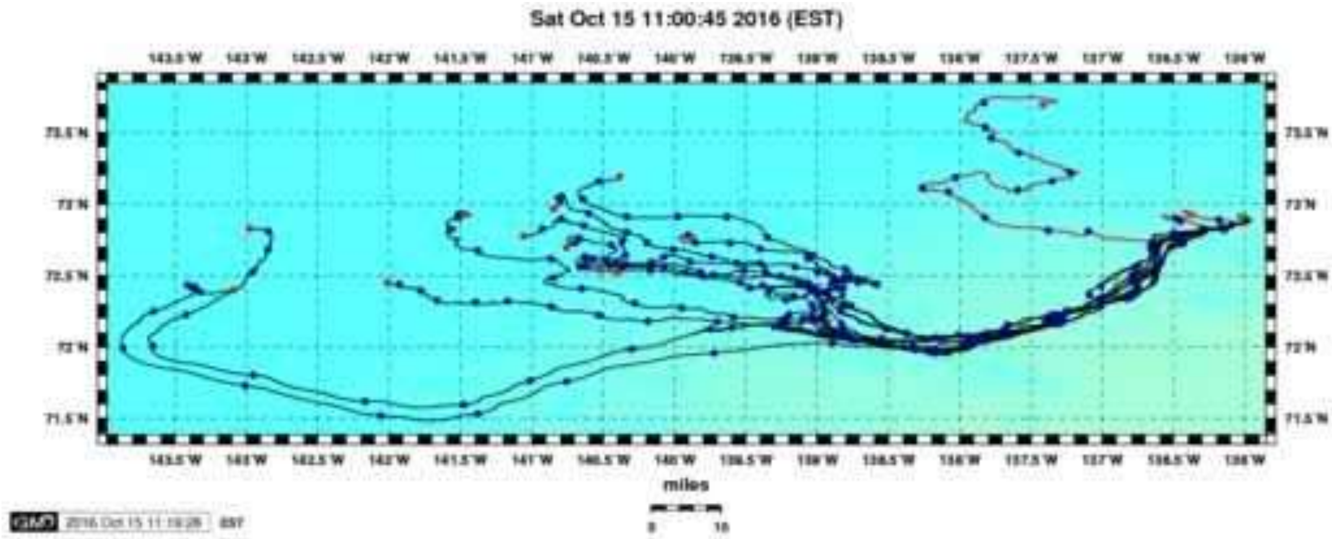


Figure 4 Trajectories of the 18 drifters released in proximity of CB23 as of Saturday October 15th.

Drifters remains at this time considerably coherent as they are advected west (Figure 4). Trajectories show some inertial oscillations but mostly are affected by a rather strong westward current along the shelf. Trajectories present some artifacts (straight segments and kinks) due to drops in the communications. Also 6 drifters stopped transmitting after few days for unknown reasons. This kind of problems in the positioning are relatively common with SPOT but seem more severe in the current experiment.

Ice edge release

2 drifters (ID 484 and ID 1050) were activated and kept on deck in order to check the quality of the transmission of the SPOT GPS as the ship moved north. Transmission rates from these two units were good all the way to 78N. The highest latitude reached by the LSSL before starting moving south. The two drifters were released once the LSSL reached the ice edge in open waters,

L0484
UTC Oct 6, 2016 6:05:15
76 deg 2.32 min
154 deg 5.486 min

L1050
UTC Oct 6, 2016 6:05:32
76 deg 2.295 min
154 deg 5.460 min

Main goals of this release are firstly to test the performance of CARTHE drifters in regions with partial ice cover and secondarily to gain some insight on the type of dynamics that can be observed in these regions. A detailed analysis of the Lagrangian transport at the ice edge will require a larger number of drifters. A region in open waters few miles from the ice edge was chosen for the release. Satellite imager from RadarSat-2 (Figure 5) showed a clear transition from FYI to open waters. The release was done between station NWR2 (cast 28) and CB5 (cast 29) with the first station on thin ice and the second in open waters. The region is interesting because the growing ice edged is potentially source of density gradients and submesoscale dynamics. Ice growth induces brine rejection and potentially denser mixed layer waters than in ice free regions. In this specific istance, salinity profiles of the two stations show larger salinity under sea ice but with shallow mixed layer which could be an indication of restartification post frontal relaxation (Figure 6).

Drifter trajectories show inertial oscillations on top of eastward advection. At the time of this report, trajectories are about 8 days old (Figure 7) and do not show significant separation yet. Some lag in the trajectories is observed. This is attributed to a problem with GlobalStar, the company managing the GPS data for SPOT. This problem resulted in few hours of missing data during day 4 after release but seems to be resolved now.

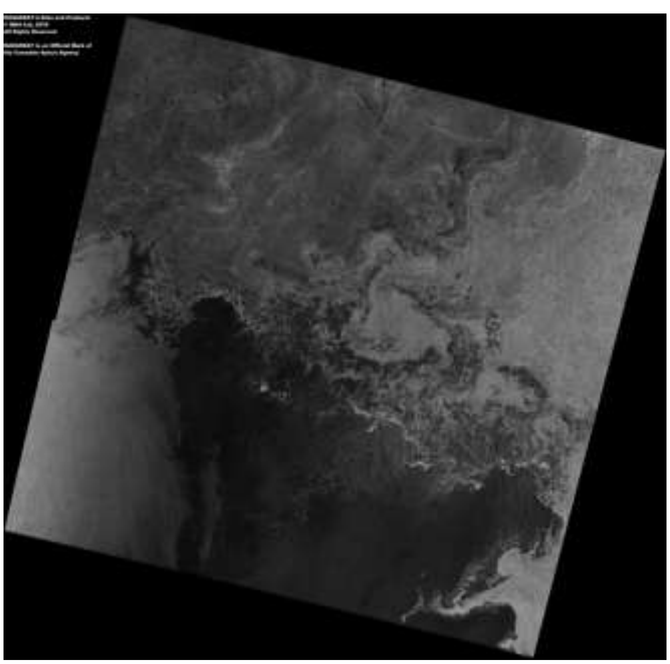


Figure 5 Ice cover from RadarSat in proximity of the release of two CARTHE drifters.

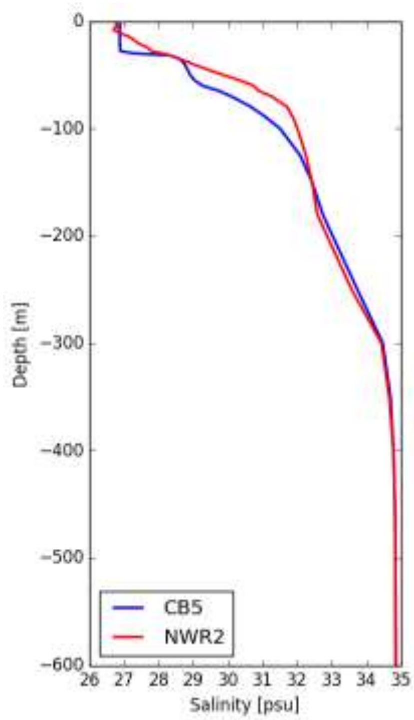


Figure 6 Salinity profiles from CB5 and NWR2.

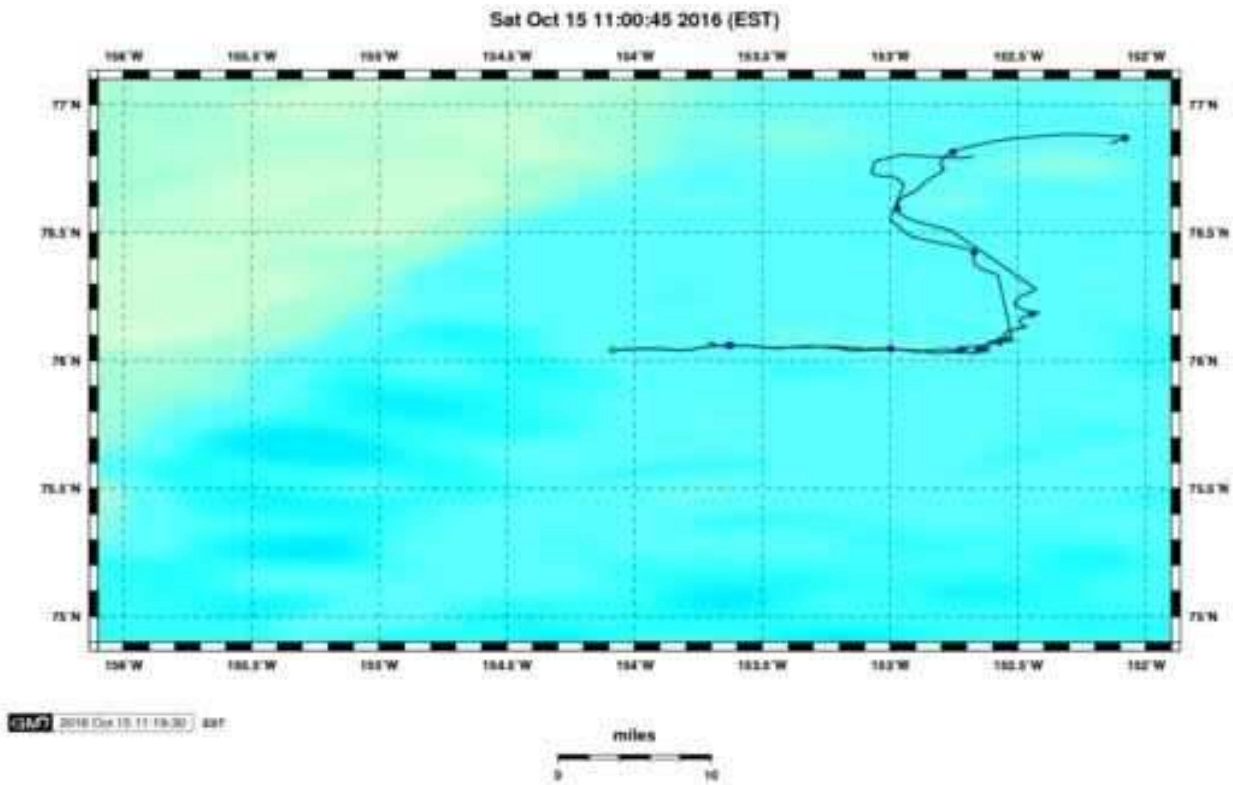


Figure 15 Trajectories of the two drifters released at the ice edge as of Saturday October 15th.

Technical considerations

While GPS coverage seems to be good all the way to 78 north, the drifters are showing significant noise in the trajectories. This will be further investigated in order to assess the origin of this problem. In general, a sturdier drifter might be needed for future experiments in the Arctic. An ice edge release would be of great interest in the future and the current test will help determining its feasibility.

Batteries autonomy will be evaluated in the next few weeks but we expect shorter battery life than in the mid latitudes. For this kind of experiments 2 m

5.14 "Sponge Bobber" Surface Drifter deployments

Chris Clarke (DFO-IOS)
PI Bill Williams (DFO-IOS)

‘Sponge Bobber’ surface drifters, that are designed and constructed at the Institute of Ocean Sciences and comprise of a SPOT Messenger Trace, surface float and drogue (see photo above by Mengnan Zhao) were deployed in the Beaufort Sea this year to assess surface currents in the Beaufort, as well as continue to assess their high-latitude transmission of location and cold weather durability. 24 of 25 Sponge Bobbers were deployed in six locations, in batches of four, close to the beginning of the expedition in late September. As the 25th Sponge Bobber was a spare, it was turned on during our final deployment and left of the aft deck to test high latitude transmission. The first batch of four Sponge Bobbers were deployed at the Cape Bathurst Upwelling Site (approximately 70N 127.5W), and then the next five batches were deployed at intervals between existing stations (CB1 to CB21). The last two batches of four were deployed in conjunction with Jean Mensa’s CARTHE drifters.
All Sponge Bobbers were set to report position every 30 minutes in order to conserve battery life and extend the period in which the SPOT’s transmitted its position. It is a worthy consideration to modify the SPOT’s batteries in a similar fashion to the CARTHE drifter’s, in order to extend the transmission time of the Sponge Bobbers.
Sponge Bobbers were deployed by dropping over the side of the aft deck of the ship. One Sponge Bobber deployed on the last station, IOS ID #544, was visibly damaged upon impact with the water upon deployment – the drogue snapped where it is joined with the surface float but remained intact. It continued to transmit its location for several days afterwards. This damage likely could have been avoided if the Sponge Bobber was deployed in a gentler manner, such as being lowered the surface with a rope, or by making the drogue’s wooden dowel arm more robust by increasing its diameter.

IOS_ID	***First Reported Position***	***Lat***	***Long***	***SPOT Trace ID***
478	9/23/2016 22:01	70.55968	-127.675	2519362
479	9/23/2016 22:02	70.55972	-127.679	2521275
480	9/23/2016 22:01	70.55972	-127.673	2519780
481	9/23/2016 22:01	70.55972	-127.671	2518740
482	9/24/2016 2:34	71.10084	-129.548	2519091
483	9/24/2016 2:26	71.10037	-129.551	2521909
484	9/24/2016 2:34	71.10183	-129.551	2519194
485	9/24/2016 2:34	71.10214	-129.552	2521906
486	9/24/2016 4:50	71.39632	-130.563	2521913
487	9/24/2016 4:50	71.39718	-130.564	2518360
532	9/24/2016 4:59	71.39906	-130.565	2518995
533	9/24/2016 4:53	71.39846	-130.569	2521853
534	9/24/2016 9:19	71.77654	-131.861	2519440
535	9/24/2016 9:17	71.7762	-131.863	2519025
536	9/24/2016 9:17	71.77633	-131.862	2519970
537	9/24/2016 9:38	71.77695	-131.864	2518560
538	9/24/2016 16:51	72.61198	-134.919	2511545
539	9/24/2016 16:52	72.61402	-134.928	2519655
540	9/24/2016 16:50	72.61181	-134.919	2519342
541	9/24/2016 16:59	72.62025	-134.954	2519826
542	9/24/2016 21:15	72.90111	-135.993	2519113

543	9/24/2016 21:13	72.89988	-135.982	2519956
544	9/24/2016 21:18	72.90302	-136.007	2519118
545	9/24/2016 21:13	72.90018	-135.983	2520744
546	9/24/2016 18:36	72.84433	-135.796	2519297

Table xx.xx: Deployment time and location for the 24 'Sponge Bobber' surface drifters.

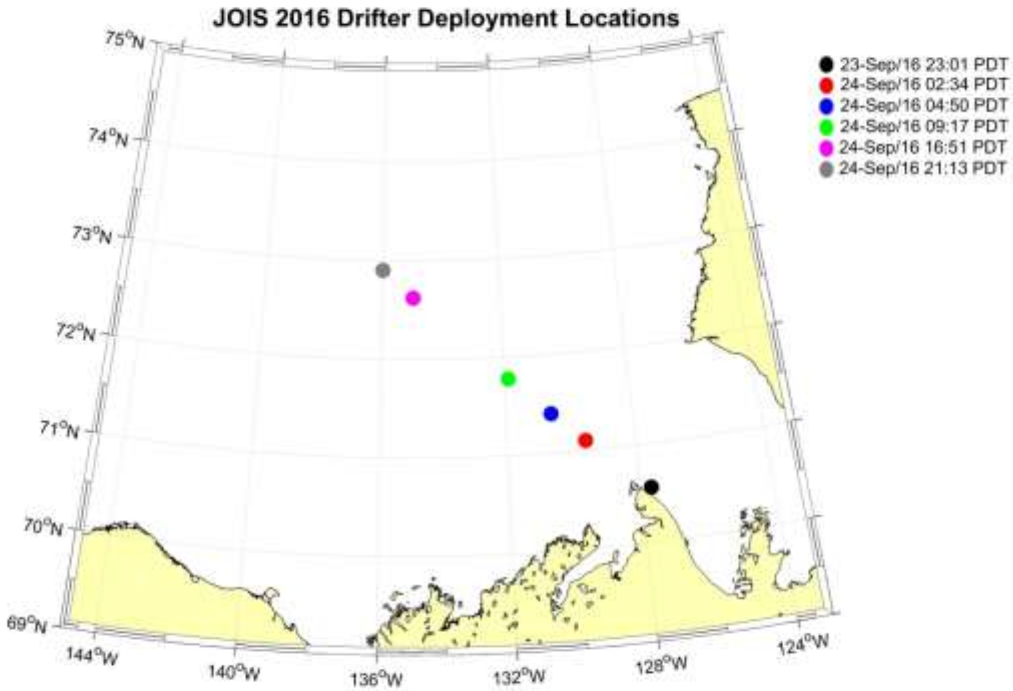


Figure xx.xx: Deployment locations of the six batches of 4 Sponge Bobber surface drifters.

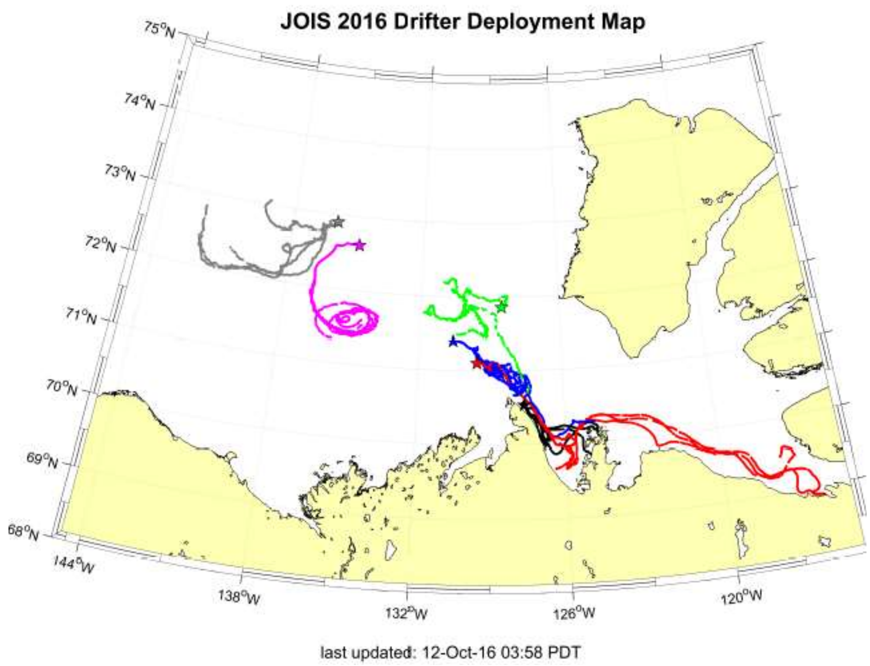


Figure xx.xx: Drift track of all 24 Sponge Bobber surface drifters.

***

6. APPENDIX

6.1 SCIENCE PARTICIPANTS 2016-16

Table 5. Onboard Science Team for 2016-16.

Name	Affiliation	Role
Sarah Zimmermann	DFO-IOS	Chief Scientist
Kelly Young	DFO-IOS	CTD and Chemistry support, Zooplankton, Ammonium
Mark Belton	DFO-IOS	Dissolved Oxygen analyst
Marty Davelaar	DFO-IOS	DIC analyst
Tamara Fraser	DFO-IOS	Nutrients analyst /Lab supervisor
Glenn Cooper	DFO-IOS	Day watchleader / salinity analyst
Celine Gueguen	Trent U	Day watchstander / CDOM lead
Mathura Mahaan	Trent U	Night watchstander/ CDOM
Edmand Fok	DFO-IOS	Day watchstander / IT
Michiyo Yamamoto-Kawai	TUMSAT	Alkalinity analyst lead / RAS P.I.
Mika Hasegawa	TUMSAT	Alkalinity analyst / RAS
Zhang Yuanxin	TUMSAT	Alkalinity analyst / RAS
Mike Dempsey	DFO-IOS	Night watchleader / CTD technician
Stephen Page	DFO-IOS	Night watchstander
Chris Clarke	DFO-IOS	Night watchstander / Surface drifters
Jean Mensa	Yale U	Night watchstander / Surface drifters
David Colatriano	Concordia U	DNA/RNA sampling
Arthi Ramachandran	Concordia U	DNA/RNA sampling
Adam Monier	ULaval	DNA/RNA sampling
Alek Petty	NASA	Ice observation + XCTD watch
Seita Hoshino	KIT	Ice observation + XCTD watch
Peter Lourie	freelance	Web dispatches
Cory Beatty	UMontana	pCO2, SAMI
Rick Krishfield	WHOI	Moorings & ITPs & buoys / lead
Will Ostrom	WHOI	Moorings & ITPs & buoys
Jeff O'Brien	WHOI	Moorings & ITPs & buoys
Chris Basque	WHOI	Moorings & ITPs & buoys

Table 6. Principal Investigators Onshore for 2016-16

Name	Affiliation	Program
Bill Williams	DFO-IOS	Program lead
John Nelson	DFO-IOS/UVIC	Zooplankton net tows
John Smith	DFO-BIO	CTD/Rosette / ^{129}I / ^{134}Cs
Peter Ross	VAquarium	CTD/Rosette / Microplastics
Connie Lovejoy	ULaval	CTD/Rosette / Microbial diversity / Bacteria
Rachel Stanley	WHOI/Wellesley College	CTD/Rosette / TOI and O_2/Ar
Roberta Hamme	Uvic	N_2/Ar ratio
Philippe Tortell	UBC	CH4/N2O
Andrey Proshutinsky	WHOI	CTD/Rosette / Moorings / ITP Buoys / XCTD
John Toole	WHOI	ITP Buoys
Mary-Louise Timmermans	Yale U.	ITP Buoys / Moorings
Motoyo Itoh	JAMSTEC	CTD/Rosette / XCTD
Mike Degrandpre	UMontana	pCO2/SAMI
Don Perovich	CRREL	Ice Mass-Balance Buoy
Tim Stanton	NPS	Arctic Ocean Flux Buoy
Shigeto Nishino	JAMSTEC	CTD/Rosette
Jennifer Hutchings	OSU	Ice Observations
Kazu Tateyama	KIT	Ice Observations

Table 7. Affiliation Abbreviations.

Abbreviation	Definition
BIO	Bedford Institute of Oceanography, DFO, Dartmouth, NS, Canada
BLOS	Bigelow Laboratory for Ocean Sciences, Maine, USA
Concordia U	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, Yokosuka, Kanagawa, Japan
KIT	Kitami Institute of Technology, Kitami, Hokkaidō, Japan
NPS	Naval Postgraduate School, Monterey, California, USA
OSU	Oregon State University, Corvallis, Oregan, USA
PMEL/NOAA	Pacific Marine Environmental Laboratory / National Oceanic and Atmospheric Administration, Seattle, Washington, USA
PMST	Pacific Marine Sciences and Technology LLC, California, Oakland, USA
Trent U.	Trent University, Peterborough, Ontario, Canada
TUMSAT	Tokyo University of Marine Science and Technology, Tokyo, Japan

ULaval	University of Laval, Quebec City, Quebec, Canada
UOttawa	University of Ottawa, Ottawa, Ontario, Canada
Uvic	University of Victoria, Victoria, British Columbia, Canada
Vaquarium	Vancouver Aquarium, Vancouver, British-Columbia, Canada
WHOI	Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA
YaleU	Yale University, New Haven, Connecticut, USA

Table 8. Project websites

Project	Website Address
Beaufort Gyre Observing System	www.whoi.edu/beaufortgyre
Beaufort Gyre Observing System dispatches	http://www.whoi.edu/page.do?pid=154796
Ice-Tethered Profiler buoys	www.whoi.edu/itp
Ice Mass Balance buoys	imb.erdc.dren.mil
O-buoy Project	www.o-buoy.org
Arctic Ocean Flux Buoy	www.oc.nps.navy.mil/~stanton/fluxbuoy
JOIS website from DFO	http://dfo-mpo.gc.ca/science/collaboration/jois-eng.html
Ice observer's dispatches (NASA)	http://earthobservatory.nasa.gov/blogs/fromthefield/category/beaufort-gyre-exploration http://earthobservatory.nasa.gov/blogs/fromthefield/2016/10/25/back-on-dry-land/

6.2 LOCATION OF SCIENCE STATIONS for JOIS 2016-16

The scientific crew boarded the *CCGS Louis S. St-Laurent* icebreaker in Kugluktuk, NU, on 21 September, 2016 and returned to Kugluktuk, NU on 18 October, 2016. 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.

6.2.1 CTD/Rosette and TSG Sensor Configuration

CTD Specifications

List of sensors used on 2016-15 and 2016-16 LSSL UNCLOS and JOIS programs
The post-cruise lab Temperature and Conductivity calibrations are listed below as they were applied to process the data.

2016-15 UNCLOS Program (Casts 1 to 13)
2016-16 JOIS Program (Cast 1 to 65)

Follow below with changes:
UNCLOS

Cast 1 – No SPAR sensor in the data stream. SPAR added for Cast 2.
JOIS
Cast 17 CDOM sensitivity setting changed. This applies to rest of cruise.
Cast 27 SPAR sensor disconnected although channel left in data. This applies to rest of cruise.
Cast 41 Altimeter changed from sn 62670 to sn1161. This applies to rest of cruise.

SN 756 Seabird 9plus CTD

Temperature

	model	*serial*	*last cal.*	*Pump*	*serial*
Primary	SBE3plus	4322	02 Nov 2016	SBE5T	5-3869
Secondary	SBE3plus	4239	02 Nov 2016	SBE5T	5-3871

Conductivity

	model	*serial*	*last cal.*
Primary	SBE4C	2809	01 Nov 2016
Secondary	SBE4C	2810	01 Nov 2016

Pressure	*model*	*serial*	*last cal.*
	SBE9	91164	24 Feb 2010

External sensors

Type	*make*	*model*	*serial*	*last cal*	*channel*	*connector*	*comment*
Fluorometer	Seapoint	SCF	3654	25 May 2015	V0	JT2	On secondary pump
Transmissometer	Wetlabs	CSTAR	1052DR	21 Apr 2016	V1	JT2	
Oxygen	SBE	43	2599	02 Nov 2016	V2	JT3	On primary pump
Altimeter	Benthos Benthos	PSA-916D PSA-916D	62670 1161	28 May 2014 31 mar 2005	V3	JT3	
CDOM	Wetlabs	ECO CDOM	4305	14 Mar 2016	V4	JT5	
Free					V5	JT5	
PAR	Satlantic	Cosine LOG	517	25 Jun 2014	V6	JT6	Box D38
Nitrate	Satlantic	ISUS v2	121		V7	JT6	Max depth rating 1000m, only installed on select stations
SPAR	Biospherical	QSR2200	20498	4 Apr 2016			Logged w/ CTD cast. Part of CTD file.
SPAR	Biospherical	QSR2150A	50228	21 Jun 2016			Continuously logged to computer
Spares						Box	

Deck Units

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

Rosette Pylons

Type	*make*	*model*	*serial*	*comment*
Water Sampler Carousel	Seabird	32	**498**	
Water Sampler Carousel	Seabird	32	**452**	

Seabird SBE19+ CTD

For internally recording use
Not used on either program

TSG Seabird SBE21 sn 3297

	make	*model*	*serial*	*last cal.*	Comment
TSG	Seabird	SBE21	3297	31Dec 2015	
Intake temperature	Seabird	SBE31	0319	28 Dec 2013	
Fluorometer	Seapoint	SCF	SCF3652	Jun 2014	
CDOM	Wetlabs	ECO CDOM	WSCD-1281	24 Aug 2009	

UCTD - Ocean Science 10-400 UCTD System

Brought out but not used during 2016

6.2.2 CTD/Rosette Station List

Table 9. CTD/Rosette cast

Cast #	Station	CAST START DATE and Time (UTC)	Latitude (N)	Longitude (W)	Water Depth (m)	Cast Depth (m)	Comments
1	AG5-2	2016-09-23 17:55	70.5502	122.9073	641	632	RNA/DNA cast, assigned #'s 1-23. Bottle 7 did not close. Bottle 22-23 practice for DIC/Alk
2	AG5	2016-09-23 20:16	70.5462	122.8958	621	621	ISUS on frame, no bottle 24. bottle 7 did not close; bottle 15-16 mud on spigot; bottle 18 first reading -0.1degC, 2nd reading +0.4 degC. Extra NUTS set added (1 set fresh, 2 frozen) until nutrient analyzer up and running (continues for all casts, stop TBD)
3	CB1	2016-09-24 14:56	71.7803	131.8768	1116	1108	Bottles 7, 14 and 23 didn't fire. Bottle 8 leaky vent. Bottles 17-18 depths swapped due to 32.6 sal order
4	CB-31b	2016-09-24 20:27	72.3497	133.9930	2061	2053	
5	CB-23a	2016-09-25 02:08	72.9008	136.0043	2749	2741	Bottle 8 leak from bottom cap
6	CB22	2016-09-25 08:33	73.4483	137.9900	3116	3108	
7	CB50	2016-09-25 15:42	73.4998	134.2597	2884	2876	
8	CB51	2016-09-25 22:18	73.4995	130.8918	2486	2479	
9	CB40	2016-09-26 07:23	74.5013	135.4353	3253	3241	B-100 a typo? Went to B-10
10	CB18	2016-09-26 16:40	75.0000	139.9988	3624	3612	Bottle 1+2: Please collect deepwater for SAL from Niskin 1, include Niskin 2 if its in the very uniform bottom water (look at potential temperature). Bottle 21: take 2 chl-a after DOM
11	CB17	2016-09-27 01:40	75.9993	139.9873	3695	3685	Bottles 1-3: CDOM+bacteria sampled before DIC
12	PP6	2016-09-27 16:52	76.2617	132.4910	3046	3036	Bottle 8: top cap not seated. Slushy water
13	PP7a	2016-09-28 01:35	77.1530	133.6297	3471	3462	Slushy
14	CB78E	2016-09-28 23:11	78.5720	130.0158	3278	3269	Bottle 8: NH4 blank water test
15	CB16	2016-09-29 18:25	77.9992	139.9538	3750	3740	Bottle 1: redraw. Switched sampling for bottle 18 + 20 due to target property depth. Thin ice 10cm

16	CB15	2016-09-30 02:55	77.0072	140.0088	3728	3728	Bottle 6: oxy redraw
17	CBC-2016	2016-09-30 16:34	76.3620	143.5248	3771	3762	Switched sampling for bottle 18 + 20 due to chla peak at 106m. Bottle 8 Tmax =0.785. Removed chla rep to save water for DOM and DNA/RNA
18	CB13	2016-10-01 04:29	77.3005	143.2925	3783	3775	Bottle 7: Oxy redraw dup1. Bottle 10: NH4 blank test. Bottle 22: CDOM added during cast because SCM shows at 40 and 50
19	CB12.5	2016-10-01 09:59	77.6313	144.2497	3798	1004	bottle 23 did not trip. Hung up OR is ISUS hooped? ISUS? No ISUS sensor deployed. Ice coverage: new grey ice with snow
20	ITP-2	2016-10-01 21:42	77.8860	145.0838	3804	101	for Cory Beatty pCO2 check on ITP deployed
21	CB12	2016-10-02 02:07	77.7002	146.6910	3811	3800	bottle 2: bottom cap leaking; bottle 12: leaky valve
22	CB11	2016-10-02 17:02	79.0005	150.0375	3818	3808	Bottle 4: ONAR bottle broken; Bottle 8: Tmax = 0.83; SCM: very weak chla max
23	CB10	2016-10-03 04:13	78.2978	153.2078	2410	2399	Botles 18 and 20 samples switched due to depth SCM
24	CB9	2016-10-03 12:11	78.0208	150.1952	3823	3816	Bottle 6: NAR v185 broke, new id v240. Oxygen drawn by 7:20 local on all niskins, TOI finished by 7:40 except #16
25	CB9-DNA	2016-10-03 22:39	78.0092	149.8928	3823	1003	Bottles 1-2: distracted, triggered on way up. Bottle 6-8: microplastics, lost about 1L of water. Adjusted depths of bottles 12, 16 and 20 to capture depth in sequence
26	CB9-short	2016-10-04 14:22	78.0022	149.9993	3823	1201	Bottle 2: not enough bottles for Noble or ONAR; Bottle 6: Only single on 34.78 for Noble
27	CB8	2016-10-05 12:25	76.9950	149.9973	3826	3817	First cast only to 1200m, problem with deck unit. Restarted and labelled cast 27b. Bottle 1+2 water saved for Sal DWR. Bottle 21 top vent not tightened
28	NWR2	2016-10-06 01:09	76.5120	154.6537	2367	2355	Bottle 2: tripped too early at 1579. Bottle 7: oxy rep2 redrawn. Bottle 24: bottle did not trip
29	CB5	2016-10-06 10:06	75.3012	153.2958	3843	3833	sample number 643 reused from cast 28. DWR for nuts taken from Bottle 1-2. Bottle 3: missed target depth. Bottle 8: little dribble from o-ring
30	CB4-R1	2016-10-06 17:30	75.0075	149.9483	3826	101	RAS recovery calibration cast. 100m cast then trip bottles on way up. Bottle 4: yo-yo stop. Bottle 2: oxy redrawn. Bottle 3: leaky vent. Sounder off
31	CB7	2016-10-07 03:32	75.9987	149.9932	3830	3821	changed thermometer on oxy draw tube. Bottle 12: open vent. Bottle 21-22: yo-yo stop. Conserve water. Bottle 23-24: bubbler was on, sit at 5m for 3 minutes before trigger

32	CB4-DNA	2016-10-07 12:07	75.0027	149.9902	3826	1001	all bottles US except 4 +16 =UN. Bottle 19: 1.2L taken for DNA. Bottle 21: sal = 26.647. Bottle 23: 1.2L taken for DNA/RNA
33	CB4	2016-10-07 14:13	74.9997	149.9900	3826	3817	Bottle 8: mistakenly fired at 800m, not 600m.Bottle 14: did not fire. New oxy noodle and Mark does not like it, not one bit!
34	CB4-R2	2016-10-08 00:26	74.9893	150.0230	3826	602	yo-yo stops for bottles 1, 9-12, 15, 17, 21. Bottle 10 did not trigger, grease was on that location but removed. Bottle 1: oxy redraw rep2. Bottle 18: lost ~ 100mls for microplastics
35	CBCw	2016-10-08 05:51	75.6690	146.8375	3803	3794	Bottle 1-3: 1/2L spilled over 3 bottles. CTD operator shift EF->SP on upcast
36	CB6	2016-10-08 12:32	74.6940	146.7060	3781	3773	
37	CB3	2016-10-08 20:26	73.9978	150.0050	3824	3814	Bottle 3 misfire. Bottle 7 oxy redraw. No O18+Ba collected bottles 17-24 (forgot to fill?)
38	CBSS	2016-10-09 05:21	73.5000	155.0135	3847	3839	
39	CB2	2016-10-09 21:01	73.0007	150.0043	3749	3739	Bottle 1: oxy redraw on B. Bottle 3: fired but did not trip
40	CB2a	2016-10-10 02:48	72.5037	150.0103	3730	3725	Bottle 24: not fired
41	BL8	2016-10-10 09:09	71.9487	150.2763	2946	2935	Bottles 18-20: one N2O has 2*100ul HgCl. Bottle 22: Fired at 26, not 20m
42	BL6	2016-10-10 14:15	71.6850	151.1342	2152	2079	Bottle 23: did not fire
43	BL5	2016-10-10 17:08	71.5937	151.3603	1505	1494	CTD only
44	BL4-Cs	2016-10-10 20:06	71.5528	151.4962	1436	202	yo-yo stops for Cs bottles
45	BL4	2016-10-10 21:24	71.5497	151.4898	1436	1426	Bottle 10: tripped at 283 instead of 293
46	BL3	2016-10-11 00:08	71.4605	151.8165	526	442	lots of changes to rosette log. Bottles 4-5 fired but no samples taken (redunant)
47	BL2	2016-10-11 02:44	71.3802	151.9722	118	115	4m off bottom. Bottles 3 + 15 redundant
48	BL1	2016-10-11 04:07	71.3685	152.0653	85	81	Bottles 18-20: fired but not needed
49	STnA-Cs	2016-10-11 17:35	72.5983	144.6988	3428	231	Down to 200m then back up to 33.1. Yo-yo stop then fire all 6 bottles
50	STnA-DNA (Originaly called STnA-Cs)	2016-10-11 18:22	72.5975	144.7043	3428	1003	Bottle 4: fired~839m by mistake (should've been 800). Yo-yo for the SCM bottles. Bottle 23: extra 1/2L taken by DNA. Parts of the grey Niskin were collected in the microplastics sieve! Kept bits in sample as possibly good to know type of plastic?
51	STN-A	2016-10-11 21:10	72.6005	144.7140	3428	3418	Bottle 22: yo-yo stop at 33m. Bottle 23: triggered too early

52	CB19	2016-10-12 06:48	74.3023	143.3055	3699	3689	Bottle 9: fired at 550m, tmax @ 500m. Line thru samples on rosette sheet - not sampled? Bottle 24: did not fire
53	CB21-Plastic (Originally called CB21-DNA)	2016-10-12 14:58	74.0023	139.9428	3521	1000	No DNA taken on this cast, Microplastics only. Spill of 100-500ml per bottle.1L samples, then bottles fired at same depth filtered together for microplastics. Bottle 24 closed at surface, not a full bottle so just took a 1L sample.
54	CB21	2016-10-12 22:33	73.9973	140.0785	3521	3510	Bottle 1: oxy redraw on A. Bottle 13: oxy redraw. Bottle 24: fired but did not trip
55	CB22-2	2016-10-13 04:24	73.4498	138.0027	3123	3116	Bottle 1, 4, 24: oxy redraw. Bottle 16: open vent
56	CB21-cal	2016-10-13 12:04	74.0005	140.0103	3521	3425	Trip test and yo-yo bottles. Bottle 20: calibration for SAMI on mooring
57	CB27	2016-10-14 06:26	73.0023	140.0007	3218	3210	Bottle 23 did not fire.
58	CB29	2016-10-14 21:23	72.0007	140.0040	2691	2680	Bottles 7,13, 23, 24 closed in air. Problems with acquisition software, see cruise log. Bottle 1 oxy redraw
59	MK6	2016-10-15 02:28	71.5670	140.0218	2468	2459	Bottle 24: fired, did not trip
60	CB28b	2016-10-15 07:11	70.9998	140.0022	2080	2070	missing original page, copy cut off right side of page
61	MK4	2016-10-15 10:11	70.8092	140.0000	1542	1530	missing original page, copy cut off right side of page
62	MK3	2016-10-15 12:47	70.5672	139.9917	766	757	Bottle 3 did not fire. Added TOI's
63	MK2	2016-10-15 15:12	70.4000	139.9992	498	488	Bottle 3 did not fire. Bottles 15-20 properties shifted to match depth during CTD. Added TOI's
64	MK1	2016-10-15 17:18	70.2298	140.0020	239	228	Bottle 1-4 all at same depth, only sampled 1
65	CB28aa	2016-10-15 19:19	69.9972	139.9998	58	48	Don't use bottle 3-4, shift everything down. Green seas, snowy blustery!

6.2.3 XCTD

Table 10. XCTD cast deployment locations

Event Number	Filename	Date	Time (UTC)	Probe type	Serial Number	Latitude (N)	Longitude (W)	max depth	Comments
XCTD-01	C3_00118	2016-09-24	18:19	XCTD-1	15031498	72.0608	132.9107	1000	10knts open water
XCTD-02	C3_00119	2016-09-25	0:01	XCTD-1	1601-7068	72.6225	134.9645	1000	
XCTD-03	C3_00120	2016-09-25	6:20	XCTD1	16017065	73.1758	136.9925	1100	
XCTD-04	C3_00121	2016-09-25	13:18	XCTD-1	16017064	73.4705	136.1447	1000	
XCTD-05	C3_00122	2016-09-25	20:16	XCTD-1	16017067	73.4970	132.5299	1000	Open water 5 knts
XCTD-06	C3_00123	2016-09-26	4:04	XCTD-1	16017066	74.1103	133.6132	1100	
XCTD-07	C3_00124	2016-09-26	14:00	XCTD-1	16017069	74.8080	138.2006	1000	
XCTD-08	C3_00125	2016-09-26	21:47	XCTD-1	16017062	75.4786	139.9019	1000	
XCTD-09	C3_00126	2016-09-27	7:35	XCTD-1	15021376	76.0665	138.1433	1000	
XCTD-10	C3_00127	2016-09-27	11:00	XCTD-1	15031451	76.1185	136.2250	1000	
XCTD-11	C3_00128	2016-09-27	14:27	XCTD-1	15021375	76.1969	134.2862	1000	
XCTD-12	C3_00129	2016-09-28	0:17	XCTD-1	15021374	77.0983	133.5843	1100	
XCTD-13	C3_00130	2016-09-28	7:58	XCTD-1	15021377	77.5998	132.6118	1000	
XCTD-14	C3_00131	2016-09-28	12:14	XCTD-1	15021371	78.0377	131.6176	500	broke of early because of ice. Didn't repeat.
XCTD-	C3_00132	2016-09-29	8:16	XCTD-1	16917061	78.4412	132.6061	1100	ship stopped in ice

15									
XCTD-16	C3_00123	2016-09-29	2:09	XCTD-3	14036063	78.2621	135.0198	1100	
XCTD-17	C3_00134	2016-09-29	15:41	XCTD-3	14036064	78.1455	137.4180	1000	
XCTD-18	C3_00135	2016-09-29	23:56	XCTD-3	14036061	77.5086	139.9311	1000	
XCTD-19	C5_00136	2016-09-30	9:21	XCTD-3	14036060	76.6951	141.7492	1100	
XCTD-20	C5_00137	2016-09-30	13:09	XCTD-3	14036062	76.3419	143.3147	1000	
XCTD-21	C5_00138	2016-10-02	8:27	XCTD-3	14036059	78.1386	140.6641	1000	
XCTD-22	C5_00139	2016-10-02	13:40	XCTD-3	14036056	78.6048	148.9176	1000	
XCTD-23	C5_00140	2016-10-03	0:31	XCTD-3	15115603	78.6830	151.7149	200	Broke off early so repeated (See XCTD-24)
XCTD-23	C5_00141	2016-10-03	0:41	XCTD-3	14036058	78.6696	151.7236	1000	
XCTD-24	C5_00142	2016-10-03	9:04	XCTD-3	15052399	78.1632	151.6560	1000	
XCTD-25	C5_00143	2016-10-04	6:11	XCTD-3	15052398	77.6299	153.4932	1000	
XCTD-26	C5_00144	2016-10-04	7:28	XCTD-3	15052395	77.6747	153.0336	1000	
XCTD-27	C5_00145	2016-10-04	10:54	XCTD-3	15052396	77.8404	151.4934	1000	
XCTD-28	C5_00147	2016-10-05	5:44	XCTD-3	15052392	77.4981	150.0079	1000	
XCTD-29	C5_00148	2016-10-05	20:36	XCTD-3	15052397	76.7297	152.4649	1000	
XCDD-30	C5_00149	2016-10-06	6:43	XCTD-3	15052394	75.9343	153.9731	1000	
XCDD-31	C5_00150	2016-10-06	14:50	XCTD-3	15052393	75.1529	151.6116	1000	
XCTD-	C5_00151	2016-10-07	1:11	XCTD-3	15052391	75.5015	149.9926	1000	

32									
XCTD-33	C5_00152	2016-10-08	3:39	XCTD-3	15052390	75.3321	148.3451	1000	
XCTD-34	C5_00153	2016-10-08	10:27	XCTD-3	15052389	75.1635	146.7735	1000	
XCTD-35	C5_00154	2016-10-08	18:10	XCTD-3	15052400	74.2681	148.7681	1000	
XCTD-36	C5_00155	2016-10-09	1:02	XCTD-3	15052381	73.8510	151.6180	1000	
XCTD-37	C5_00156	2016-10-09	3:03	XCTD-3	15052380	73.6727	151.3267	1000	
XCTD-38	C5_00157	2016-10-09	13:01	XCTD-3	15052378	73.3194	153.2462	1000	
XCTD-39	C5_00158	2016-10-09	16:56	XCTD-3	15052377	73.1724	151.5641	1000	
XCTD-40	C5_00160	2016-10-11	7:02	XCTD-3	15053382	71.6189	150.6510	1000	
XCTD-41	C5_00161	2016-10-11	9:47	XCTD-3	15052383	71.8670	149.1679	1000	
XCTD-42	C5_00162	2016-10-11	12:27	XCTD-3	15052384	72.1191	147.6665	1000	
XCTD-42	C5_00163	2016-10-11	15:16	XCTD-3	15052385	72.3674	146.1485	1000	
XCTD-43	C5_00164	2016-10-12	1:22	XCTD-3	15052386	73.0078	144.3575	1000	
XCTD-44	C5_00165	2016-10-12	3:10	XCTD-3	15052387	73.4448	144.0357	1000	
XCTD-45	C5_00166	2016-10-12	4:58	XCTD-3	15052388	73.8780	143.6531	1000	
XCTD-46	C5_00167	2016-10-12	12:03	XCTD-1	15031453	74.1557	141.6659	1000	
XCTD-47	C5_00168	2016-10-13	2:37	XCTD-1	15031454	73.7195	139.0315	1000	
XCTD-48	C5_00169	2016-10-14	1:26	XCTD-1	15031452	73.7542	141.0143	1000	
XCTD-	C5_00170	2016-10-14	3:01	XCTD-1	16017063	73.5015	141.9986	1000	

49									
XCTD-50	C5_00171	2016-10-14	4:28	XCTD-1	16017073	73.2786	141.1146	1000	
XCTD-51	C5_00172	2016-10-14	10:51	XCTD-1	16017072	72.7449	141.0621	1000	
XCTD-52	C5_00173	2016-10-14	12:47	XCTD-1	16017071	72.4927	142.0110	1000	
XCTD-53	C5_00174	2016-10-14	15:40:00 PM	XCTD-3	16016706	72.4951	139.9529	1000	
XCTD-54	C5_00175	2016-10-14	18:04	XCTD-3	16016703	72.4997	138.0071	1000	
XCTD-55	C5_00176	2016-10-14	19:39	XCTD-3	16016709	72.2481	139.0014	1000	
XCTD-56	C5_00177	2016-10-16	0:43	XCTD-3	16016712	72.2497	138.9952	865	
XCTD-57	C5_00178	2016-10-16	14:49:00 AM	XCTD-3	16066702	70.8400	135.9100	765	
XCTD-58	C5_00179	2016-10-16	0:43	XCTD-3	16016705	71.2802	134.6024	970	

6.2.4 Zooplankton – Vertical Bongo Net Hauls

Table 11. Zooplankton vertical bongo net hauls.

Unique Key	Event #	CTD cast #	Year	Month	Day	Local Time	UTC Offset	Latitude (N)	Longitude (W)	Net Mesh (um)	Bottom Depth (m)	RBR depth	PresMethod_no
IOS1616000101A	1	2	2016	9	23	21:32	0	70.5502	122.8675	150	616	100	1
IOS1616000201A	2	2	2016	9	23	22:00	0	70.5525	122.8663	150	631	495	1
IOS1616000301A	3	7	2016	9	25	16:11	0	73.4999	134.2377	150	2882	99	1
IOS1616000401A	4	7	2016	9	25	16:45	0	73.5025	134.2312	150	2882	507	1
IOS1616000501A	5	8	2016	9	25	22:36	0	73.4985	130.9176	150	2500	115	1
IOS1616000601A	6	8	2016	9	25	23:05	0	73.4963	130.8795	150	2500	515	1
IOS1616000701A	7	10	2016	9	26	17:05	0	74.9986	139.9857	150	3615	117	1
IOS1616000801A	8	10	2016	9	26	17:33	0	74.9986	139.9825	150	3615	520	1
IOS1616000901A	9	11	2016	9	27	2:00	0	75.9984	139.9784	150	3695	98	1
IOS1616001001A	10	11	2016	9	27	2:27	0	75.9978	139.9741	150	3695	501	1
IOS1616001101A	11	12	2016	9	27	17:15	0	76.2620	132.4857	150	3054	96	1
IOS1616001201A	12	12	2016	9	27	17:41	0	76.2620	132.4854	150	3055	505	1
IOS1616001301A	13	13	2016	9	28	1:58	0	77.1510	133.6248	150	3478	101	1
IOS1616001401A	14	13	2016	9	28	2:26	0	77.1486	133.6187	150	3478	499	1
IOS1616001501A	15	14	2016	9	29	1:51	0	78.5607	130.0400	150	3279	100	1
IOS1616001601A	16	14	2016	9	29	2:18	0	78.5600	130.0488	150	3279	501	1
IOS1616001701A	17	15	2016	9	29	19:20	0	78.0080	139.9259	150	3749	95	1
IOS1616001801A	18	15	2016	9	29	19:49	0	78.0113	139.9039	150	3749	461	1
IOS1616001901A	19	17	2016	9	30	17:05	0	76.3597	143.5068	150	3772	101	1
IOS1616002001A	20	17	2016	9	30	17:32	0	76.3595	143.5082	150	3773	502	1
IOS1616002101A	21	18	2016	9	31	5:06	0	77.3012	143.2846	150	3799	100	1
IOS1616002201A	22	18	2016	9	31	5:39	0	77.3025	143.2753	150	3799	501	1
IOS1616002301A	23	19	2016	10	1	11:25	0	77.6349	144.1994	150	3799	96	1

IOS1616002401A	24	19	2016	10	1	11:53	0	77.6368	144.1801	150	3799	497	1
IOS1616002501A	25	19	2016	10	1	12:28	0	77.6374	144.1584	150	3822	493	1
IOS1616002601A	26	19	2016	10	1	13:15	0	77.6408	144.1318	150	3822	995	1
IOS1616002701A	27	22	2016	10	2	17:30	0	79.0002	150.0612	150	3822	95	1
IOS1616002801A	28	22	2016	10	2	17:51	0	79.0004	150.0800	150	3828	457	1
IOS1616002901A	29	23	2016	10	2	4:37	0	78.3007	153.2167	150	2380	99	1
IOS1616003001A	30	23	2016	10	2	5:06	0	78.3013	153.2260	150	2380	488	1
IOS1616003101A	31	24	2016	10	3	12:37	0	78.0224	150.1997	150	3827	100	1
IOS1616003201A	32	24	2016	10	3	12:05	0	78.0247	150.2042	150	3827	496	1
IOS1616003301A	33	27	2016	10	5	13:32	0	76.9914	149.9767	150	3828	91	1
IOS1616003401A	34	27	2016	10	5	13:58	0	76.9894	149.9674	150	3828	480	1
IOS1616003501A	35	28	2016	10	6	1:27	0	76.5081	154.6473	150	2330	99	1
IOS1616003601A	36	28	2016	10	6	1:55	0	76.5038	154.6338	150	2330	481	1
IOS1616003701A	37	29	2016	10	6	10:54	0	75.3011	153.3004	150	3848	95	1
IOS1616003801A	38	29	2016	10	6	11:20	0	75.2996	153.3062	150	3848	498	1
IOS1616003901A	39	31	2016	10	7	3:53	0	75.9971	149.9943	150	3837	101	1
IOS1616004001A	40	31	2016	10	7	4:20	0	75.9945	149.9944	150	3835	497	1
IOS1616004101A	41	33	2016	10	7	13:01	0	74.9998	149.9967	150	3829	1006	1
IOS1616004201A	42	33	2016	10	7	14:25	0	74.9997	149.9915	150	3828	98	1
IOS1616004301A	43	33	2016	10	7	15:00	0	74.9998	149.9897	150	3828	502	1
IOS1616004401A	44	41	2016	10	10	10:18	0	71.9489	150.3052	150	2933	107	1
IOS1616004501A	45	41	2016	10	10	10:52	0	71.9488	150.3146	150	2933	489	1
IOS1616004601A	46	51	2016	10	11	21:30	0	72.6017	144.7115	150	3434	96	1
IOS1616004701A	47	51	2016	10	11	21:56	0	72.6007	144.7106	150	3434	503	1
IOS1616004801A	48	52	2016	10	12	7:18	0	74.3054	143.3046	150	3702	100	1
IOS1616004901A	49	52	2016	10	12	7:46	0	74.3062	143.3076	150	3703	502	1
IOS1616005001A	50	53	2016	10	12	15:08	0	74.0032	139.9378	150	3513	494	1
IOS1616005101A	51	53	2016	10	12	15:40	0	74.0053	139.9359	150	3513	499	1

IOS1616005301A	53	56	2016	10	13	17:17	0	74.0030	140.0093	150	3520	905	1
IOS1616005401A	54	57	2016	10	13	6:58	0	73.0048	140.0051	150	3217	103	1
IOS1616005501A	55	57	2016	10	13	7:27	0	73.0066	140.0037	150	3218	501	1
IOS1616005601A	56	58	2016	10	14	21:46	0	72.0008	140.0116	150	2700	99	1
IOS1616005701A	57	58	2016	10	14	22:14	0	72.0018	140.0205	150	2703	498	1
IOS1616005801A	58	60	2016	10	14	7:27	0	70.9995	139.9997	150	2082	99	1
IOS1616005901A	59	60	2016	10	14	7:54	0	70.9993	139.9987	150	2081	498	1
IOS1616006001A	60	62	2016	10	15	13:09	0	70.5625	139.9968	150	800	96	1
IOS1616006101A	61	62	2016	10	15	13:35	0	70.5607	139.9945	150	800	492	1
IOS1616006201A	62	64	2016	10	15	17:36	0	70.2302	140.0010	150	242	97	1
IOS1616000101B	1	2	2016	9	23	21:32	0	70.5502	122.8675	236	616	100	2
IOS1616000201B	2	2	2016	9	23	22:00	0	70.5525	122.8663	236	631	495	2
IOS1616000301B	3	7	2016	9	25	16:11	0	73.4999	134.2377	236	2882	99	2
IOS1616000401B	4	7	2016	9	25	16:45	0	73.5025	134.2312	236	2882	507	2
IOS1616000501B	5	8	2016	9	25	22:36	0	73.4985	130.9176	236	2500	115	2
IOS1616000601B	6	8	2016	9	25	23:05	0	73.4963	130.8795	236	2500	515	2
IOS1616000701B	7	10	2016	9	26	17:05	0	74.9986	139.9857	236	3615	117	2
IOS1616000801B	8	10	2016	9	26	17:33	0	74.9986	139.9825	236	3615	520	2
IOS1616000901B	9	11	2016	9	27	2:00	0	75.9984	139.9784	236	3695	98	2
IOS1616001001B	10	11	2016	9	27	2:27	0	75.9978	139.9741	236	3695	501	2
IOS1616001101B	11	12	2016	9	27	17:15	0	76.2620	132.4857	236	3054	96	2
IOS1616001201B	12	12	2016	9	27	17:41	0	76.2620	132.4854	236	3055	505	2
IOS1616001301B	13	13	2016	9	28	1:58	0	77.1510	133.6248	236	3478	101	2
IOS1616001401B	14	13	2016	9	28	2:26	0	77.1486	133.6187	236	3478	499	2
IOS1616001501B	15	14	2016	9	29	1:51	0	78.5607	130.0400	236	3279	100	2
IOS1616001601B	16	14	2016	9	29	2:18	0	78.5600	130.0488	236	3279	501	2
IOS1616001701B	17	15	2016	9	29	19:20	0	78.0080	139.9259	236	3749	95	2
IOS1616001801B	18	15	2016	9	29	19:49	0	78.0113	139.9039	236	3749	461	2

IOS1616001901B	19	17	2016	9	30	17:05	0	76.3597	143.5068	236	3772	101	2
IOS1616002001B	20	17	2016	9	30	17:32	0	76.3595	143.5082	236	3773	502	2
IOS1616002101B	21	18	2016	9	31	5:06	0	77.3012	143.2846	236	3799	100	2
IOS1616002201B	22	18	2016	9	31	5:39	0	77.3025	143.2753	236	3799	501	2
IOS1616002301B	23	19	2016	10	1	11:25	0	77.6349	144.1994	236	3799	96	2
IOS1616002401B	24	19	2016	10	1	11:53	0	77.6368	144.1801	236	3799	497	2
IOS1616002501B	25	19	2016	10	1	12:28	0	77.6374	144.1584	236	3822	493	2
IOS1616002601B	26	19	2016	10	1	13:15	0	77.6408	144.1318	236	3822	995	2
IOS1616002701B	27	22	2016	10	2	17:30	0	79.0002	150.0612	236	3822	95	2
IOS1616002801B	28	22	2016	10	2	17:51	0	79.0004	150.0800	236	3828	457	2
IOS1616002901B	29	23	2016	10	2	4:37	0	78.3007	153.2167	236	2380	99	2
IOS1616003001B	30	23	2016	10	2	5:06	0	78.3013	153.2260	236	2380	488	2
IOS1616003101B	31	24	2016	10	3	12:37	0	78.0224	150.1997	236	3827	100	2
IOS1616003201B	32	24	2016	10	3	12:05	0	78.0247	150.2042	236	3827	496	2
IOS1616003301B	33	27	2016	10	5	13:32	0	76.9914	149.9767	236	3828	91	2
IOS1616003401B	34	27	2016	10	5	13:58	0	76.9894	149.9674	236	3828	480	2
IOS1616003501B	35	28	2016	10	6	1:27	0	76.5081	154.6473	236	2330	99	2
IOS1616003601B	36	28	2016	10	6	1:55	0	76.5038	154.6338	236	2330	481	2
IOS1616003701B	37	29	2016	10	6	10:54	0	75.3011	153.3004	236	3848	95	2
IOS1616003801B	38	29	2016	10	6	11:20	0	75.2996	153.3062	236	3848	498	2
IOS1616003901B	39	31	2016	10	7	3:53	0	75.9971	149.9943	236	3837	101	2
IOS1616004001B	40	31	2016	10	7	4:20	0	75.9945	149.9944	236	3835	497	2
IOS1616004101B	41	33	2016	10	7	13:01	0	74.9998	149.9967	236	3829	1006	2
IOS1616004201B	42	33	2016	10	7	14:25	0	74.9997	149.9915	236	3828	98	2
IOS1616004301B	43	33	2016	10	7	15:00	0	74.9998	149.9897	236	3828	502	2
IOS1616004401B	44	41	2016	10	10	10:18	0	71.9489	150.3052	236	2933	107	2
IOS1616004501B	45	41	2016	10	10	10:52	0	71.9488	150.3146	236	2933	489	2
IOS1616004601B	46	51	2016	10	11	21:30	0	72.6017	144.7115	236	3434	96	2

IOS1616004701B	47	51	2016	10	11	21:56	0	72.6007	144.7106	236	3434	503	2
IOS1616004801B	48	52	2016	10	12	7:18	0	74.3054	143.3046	236	3702	100	2
IOS1616004901B	49	52	2016	10	12	7:46	0	74.3062	143.3076	236	3703	502	2
IOS1616005001B	50	53	2016	10	12	15:08	0	74.0032	139.9378	236	3513	57	2
IOS1616005101B	51	53	2016	10	12	15:40	0	74.0053	139.9359	236	3513	494	2
IOS1616005201A	52	54	2016	10	13	23:08	0	73.9970	140.0832	150	3520	499	2
IOS1616005201B	52	54	2016	10	13	23:08	0	73.9970	140.0832	236	3520		2
IOS1616005301B	53	56	2016	10	13	17:17	0	74.0030	140.0093	236	3520	905	2
IOS1616005401B	54	57	2016	10	13	6:58	0	73.0048	140.0051	236	3217	103	2
IOS1616005501B	55	57	2016	10	13	7:27	0	73.0066	140.0037	236	3218	501	2
IOS1616005601B	56	58	2016	10	14	21:46	0	72.0008	140.0116	236	2700	99	2
IOS1616005701B	57	58	2016	10	14	22:14	0	72.0018	140.0205	236	2703	498	2
IOS1616005801B	58	60	2016	10	14	7:27	0	70.9995	139.9997	236	2082	99	2
IOS1616005901B	59	60	2016	10	14	7:54	0	70.9993	139.9987	236	2081	498	2
IOS1616006001B	60	62	2016	10	15	13:09	0	70.5625	139.9968	236	800	96	2
IOS1616006101B	61	62	2016	10	15	13:35	0	70.5607	139.9945	236	800	492	2
IOS1616006201B	62	64	2016	10	15	17:36	0	70.2302	140.0010	236	242	97	2

6.2.5 SCS Data Collection System

The list and key for what the system collects:

Position - $GPGGA
Position information
Time interval is 1 second

Description of *.RAW file string
GGA-RAW_20160809-141509.Raw
07/17/2016,00:02:01.087,$GPGGA,000204,6805.6463,N,16737.5853,W,2,10,00.8,28.1,M,03.5,M,07.0,0135*4C
07/17/2016,00:02:02.103,$GPGGA,000205,6805.6445,N,16737.5914,W,2,10,00.8,28.1,M,03.5,M,07.0,0135*4B

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

Course and Speed Over Ground - $GPVTG
Track made good
Time interval is 2 seconds

Description of *.RAW file string
VTG-RAW_20160918-000100.Raw
07/17/2016,00:02:00.478,$GPVTG,232,T,216,M,10.4,N,19.3,K,D*2E
07/17/2016,00:02:02.712,$GPVTG,232,T,217,M,10.4,N,19.3,K,D*2F

Comma delimited column after string name
1) Course made good, true north
3) Course made good, magnetic north
5) Speed made good, Knots
7) Speed made good, Km?

Time and Date - $ZDA
Time and date information in UTC.
Time interval is 4 seconds.

Description of *.RAW file string
TCOM12-ZDA-RAW_20160717-000200.Raw

07/17/2016,00:02:00.681,$GPZDA,000203,17,07,2016,07,00*4A
07/17/2016,00:02:04.744,$GPZDA,000207,17,07,2016,07,00*4E

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

Ship's Heading - $HEHDT (Ship's Gyro)
Time interval is 1 second

Description of *.RAW file string
ZDA-RAW_20160811-000100.Raw
07/17/2016,00:02:01.071,$HEHDT,228.35,T*11
07/17/2016,00:02:02.087,$HEHDT,228.35,T*11

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

Ship's Heading - $GPHDT (POSMV)
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 - $SDDPT
12 or 3.5kHz sounder. The sounders report depth under hull (ie add 9 m for full water depth) and the sounders are always using a variable soundspeed set by the user in Knudsen software. Apply the correct soundspeed to improve accuracy.
Time interval is 1 second.

Description of *.RAW file string
DBT-RAW_20160916-000100.Raw
09/16/2016,00:01:16.929,$SDDBT,16092016,000113,Metres,3.5kHz,3676.53,0.00,,,,1500
09/16/2016,00:01:17.925,$SDDBT,16092016,000113,Metres,3.5kHz,3676.53,0.00,,,,1500

Comma delimited column after string name

1) Date UTC: YYMMDD
2) Time UTC: hhmmss
3) Units
4) Sounder frequency
5) Depth
6) To 10) ?
7) 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 ares mounted on the starboard side, about 12' above the bridge-top.
Barometer – not sure where this is mounted.

Description of *.RAW file string
AVOS-serial-AVRTE_20160809-142433.RAW

08/09/2016,14:24:40.778,$AVRTE,160809,142440,00840,CGBN,32.2,338,30,,,,992.44,,7.5,92,,,,39.1,,,307.7,13.2*5A
08/09/2016,14:24:41.778,$AVRTE,160809,142441,00840,CGBN,33.3,335,27,,,,992.43,,7.5,92,,,,39.1,,,308.3,13.2*5C
Time interval is 1 sec
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, slightly warmer)
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.
Time interval is 5 seconds.

Description of *.RAW file string
TSG-serial-_20160918-000100.Raw
09/17/2016,00:03:45.941,	1.42	1.24	27.839	24.590	0.117
0.11722	0.04029	261.003310
09/17/2016,00:03:50.944,	1.43	1.25	27.844	24.595	0.122
0.12210	0.04029	261.003368

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, S/m
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.
Time interval is 5 seconds.

Description of *.RAW file string
SBE-38-serialport-_20160927-000100.Raw
09/27/2016,00:01:20.904,-0.9591
09/27/2016,00:01:21.779,-0.9597

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

Surface PAR

Surface PAR continuously logging sensor is on starboard side above CTD operations.
Time interval is 1 second.

Description of *.RAW file string
ASCII-PAR-serialport-_20161016-000100.Raw
10/16/2016,00:01:17.913,D|58.889
10/16/2016,00:01:18.944,D|59.04

Comma delimited column after SCS date and time stamp
1. D| - not sure what this is, ignore.
2. Surface PAR, uE/cm2/sec OR uE/m2/sec (see problem notes below)