CCGS Amundsen Leg-1 Cruise Report
-Bay-wide Survey of Hudson Bay-

On-ice operations from the CCGS Amundsen. A six week bay-wide survey of Hudson Bay from May 25th to July 5th, 2018. The 40 scientists on board successfully sampled and surveyed 123 stations, both planned and opportunistic, across parts of the northern, western, central, and southern parts of the Bay. These stations included open water and on-ice sampling, as well as operations conducted via Amundsen helicopter, zodiac and barge vessels.

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Leg 1 Chief Scientist Report

Dr. David G. Barber

Summary

Leg 1 of the 2018 Amundsen cruise was successful. Many of our objectives for the cruise and BaySys project were achieved, baring a few locations in the bay in which were not able to access due to ice and weather conditions. Overall, data collection and sampling went exceptionally well, including all on board and remote based (i.e., helicopter; zodiac; barge; and on-ice) operations (see Table 1). The following is a summary of the completed cruise from May 25th to July 5th, 2018.

Week 1 of the cruise was predominately dedicated to transiting from Quebec City to the Hudson Strait via the Labrador coast. The transit took roughly 6 days and included a 7-hour Search and Rescue (SAR) call on May 30th, 2018. During the first 2 days of this transit, we completed Amundsen familiarization and safety tours on board, and emergency alarm and procedures were tested. In addition, safe operations meetings for scientists and Amundsen crew were organized and held during the first week of the cruise. This included safety meetings for sea-ice work, river work, helicopter safety and operations, optical instrument operations, rosette operations, mooring operations, and general water sampling operations. Individual toolbox meetings were held prior to the start of each operation beginning on day 6, and the skippy boat – used for on-ice operations – was also briefly tested during this time. During the first week of Leg 1, general science meetings were scheduled each evening and time allowed for a research presentation from six scientists/students.

The Amundsen crew and scientists shifted to a 24 hour schedule starting on May 31th, and continued until the final week of operations. Our first stations were conducted on May 31th, 2018, along the entrance into the Hudson Strait. With the need to make up as much time as possible to enter Hudson Bay, the number of stations conducted along the strait was reduced to four. Thereafter, we began extensive station operations across the Bay entrances and used helicopter operations extensively for remote ice stations in areas of heavy ice concentration. This allowed for a much broader area coverage of operations. On June 5th, we deployed our first mooring (CMO03) just north of Coates Island, and by June 6th, we had entered into Hudson Bay for our first stations on Bay ice (Stn. 16). At station 16, three remote short-term ice instruments were deployed with the intent to be recovered later in the campaign. Prior to our June 7th community visit off the shore of Chesterfield Inlet (see below for more details), we conducted the first of three MVP transects along the west coast of Hudson Bay, providing a continuous profile of sea temperature, salinity, and depth, among other measurements.

We spent Week 3 sampling between the coast and the western-most ice edge of Hudson Bay, at that time spaced about 110 nautical miles apart. Two additional MVP transect lines were completed from the coast into the open water, and five river systems were successfully sampled for water via helicopter (i.e., Chesterfield; Wilson; Ferguson; Tha-anne; Thlewiaza). Where

possible, land fast ice was also sampled. During this time intensive drone surveys of the coast lines were conducted along with photo surveys of the sea ice edge via the helicopter. The zodiac also proved useful along this coast as two multi-station transects were conducted beginning at the edge of the land fast ice of the Wilson and Thlewiaza Rivers, respectively, and continued out into the open water toward the Amundsen's position. From each of these major river regions, we positioned stations strategically out from the coast and into the ice edge of the Hudson Bay with intermediate stations in between to provide information across the entire water continuum of from coast, to the sea-ice. Prior to the crew change in Rankin Inlet, we located and recovered the short-term ice station instruments near station 16. On June 14th, we arrived in Rankin Inlet for a partial scientist crew change, and due to unfortunate circumstances, needed to change to Captain Alain Gariépy, as Captain Claude LaFrance had to unexpectedly depart for a family emergency.

Week 4 of Leg 1 saw many changes to the overall cruise plan. Originally planning a direct route across the bay in 4 days, we instead found that the ice was still heavily concentrated in this region and that we were unlikely to cross the bay in the proposed amount of time. After 2 days transit (by June 16th) we made it to our second mooring station (Stn.29/CMO02) in the north-central region of the bay. After the successful deployment of the mooring and a few operations conducted on board, we were called to respond to a second SAR near Whale Cove, back on the west coast of the bay. This SAR call was completed in 1 day. After completing the call, the decision was made to head south on a direct route towards the Nelson Estuary, and from there to follow the southern coast of the bay to get to the eastern side. During this transit, we stopped at the mooring AN01, but determined that the ice cover remained too high to recover it at the moment. Once arriving at the Nelson Estuary by June 18th, the mooring NE02 was recovered and a short nearby station was completed and the Nelson and Hayes Rivers were sampled via helicopter. Navigating the southern coast proved to be more difficult than anticipated, as large, thick, and sediment-laden freshwater ice floes slowed progress. Along with two ice sampling stations in the ice edge, we managed to sample both the Severn, and Winisk Rivers via helicopter. While in this region, the decision to deploy 10 ice beacons was made to track the movement of the ice pack and gain insight into the double gyre current movement in this area of the bay. By the end of week 4, we had completed 34 stations, but needed to come up with a new plan to make it back to the Nelson as we were nearing the end of our allotted time for Leg 1.

As week 5 began, we made a decision to head north into the ice pack and towards deeper water in central Hudson Bay. We transited about 150 nm north and conducted stations along a direct route from the southern coast. Once the ice became too thick and concentrated, we began our transect line back south towards the Nelson Estuary. Following our arrival in the Nelson Estuary, we deployed a wave buoy along with an ADCP mooring (June 25th). Shortly after the start of our next station operation, we were called for our third SAR at the northern-most part of the bay, just outside Cape Dorset. This SAR response lasted 2.6 days. Following the completion of the call, and our new position north of Coates Island, it was decided that we resample station 15 for an extended time series with and without ice cover. During our transit back towards the Nelson, we recovered the AN01 mooring just north of Churchill, and deployed the CMO01 mooring nearby. In addition to this deployment, we were able to sample the Seal, Knife, and Churchill Rivers all via helicopter.

Once back at the Nelson Estuary, we spent three days (June 29th – July 1st) doing intensive sampling by zodiac, barge, and helicopter. The winds were high in this region making it difficult to manage all the operations on board smaller vessels, however, we sampled seven stations along the Nelson River transect, three stations along the south transect from the coast to the position of the Amundsen, and three stations along a modified western coast transect using Rosette casts and bucket sampling. In addition, onboard operations were conducted at two locations within the estuary. On June 29th, the helicopter was used to conduct a large scale gridded photo survey of the estuary with the aim to locate beluga pods and visual changes to the water in the estuary, and the following day, it was sent out onto the coastal mud flats to collect sediment samples. The wave buoy and ADCP mooring deployed a few days earlier were recovered before leaving the area on July 1st, and heading north towards Churchill to finish the campaign by July 2nd. Once back in Churchill we hosted a successful community visit on board (~ 150 people), and held the Knowledge Exchange Workshop.

Table 1 List of all station types and number of times each were completed during Leg 1

Amundsen Station Type	**Number Completed**
Nutrient	20
Basic	09
Full	14
Other*	02
Total	45
Remote Station Type**	
Helicopter	54
Zodiac & Barge	24
Total	78
Total Stations Conducted	**123**

***opportunistic ice grab and single mooring turnovers with no other operations associated with the station ID**
****all remote sea ice & landfast ice sampling, and open water and river sampling. Does NOT include ice sampling as part of Full Station Amundsen ice cage operations**

Community Visits and the Knowledge Exchange Workshop

Chesterfield Inlet Community Visit

On June 7th, the Amundsen anchored offshore, and hosted a community visit with Chesterfield Inlet. We brought 17 members of the community over to the ship via helicopter, including Mayor Simionie Sammurtok, HTO council members, and younger high school graduates interested in ocean sciences. Overall, the visit went very well. After arriving, they were brought on a tour of the ship, which included seven science stations highlighting some of the many different operations and labs on board. These stations included a visit to the Rosette deployment area and data rooms to learn about oceanography and water sampling. The sea-ice team discuss their operations along with the radiometer, and the benthos and sediment labs were used to showcase and discuss some of the many diverse organisms that have been collected throughout the Bay.

The aft labs were used to discuss oil contaminants and optical instruments, and on the foredeck, water chemistry was discussed. Lastly, the community guests were taken to the 600 deck labs to learn about food web sciences, including phytoplankton, nutrient, fish larvae, and adult fish. Following the tour, the members of Chester were invited inside for lunch in the Officer's mess, followed by a brief presentation detailing the BaySys project and what it is that we hope to accomplish in Hudson Bay going forward. This presentation was followed by a discussion with the community on what their experiences and the changes they see on the bay each year, including the reduction in the local goose and large beluga populations. Some of the fishermen also noted catching certain species of fish that are rarely seen in this part of the bay.

Churchill Community Visit and Knowledge Exchange Workshop

The Churchill community visit took place during the morning of Tuesday, July 3rd. For a 2 hour timeslot, the Amundsen hosted over 100 community members who were excited to visit the ship and given a tour of the exterior work stations and instruments, along with the wheelhouse. The community visitors we sent on a self-guided walking tour of the ship, while specific areas were designated for certain instrument and operation showcasing. Participants from our science teams answered any questions from the visitors and gave brief presentations of their research when the groups came on board.

The Knowledge Exchange Workshop event took place over two days, which included a zodiac-based beluga tour, and community-hosted wine and cheese reception on July 2nd, followed by a full day tour, workshop, and discussion panel on board the Amundsen on July 3rd. This workshop event was well attended (~40) by dignitaries and invited guests from all over Canada, and was organized as an way to bring discussions of the Arctic, and in particular Hudson Bay, from the scientists, and community leaders, to the policy-makers, stakeholders, and general public in the south. Overall, the Knowledge Exchange Workshop was a success.

Leg 2a BaySys Component

With the eastern coast of Hudson Bay inaccessible during Leg 1, we suggested having a particular set of eastern coast rivers sampled via helicopter with the support of the Leg 2a crew and scientists (i.e., Inukjuak; Puvirnituq; Akulivik). Leg 2a is scheduled to travel across the Bay from Churchill to Inukjuak, and then north along the coast towards the Hudson Strait. In addition to river sampling, we are hoping to have scientists collect ice cores opportunistically from the central and eastern side of the bay. The addition of these datasets from Leg 2a will help avoid gaps in the regional distribution of our analyses and results.

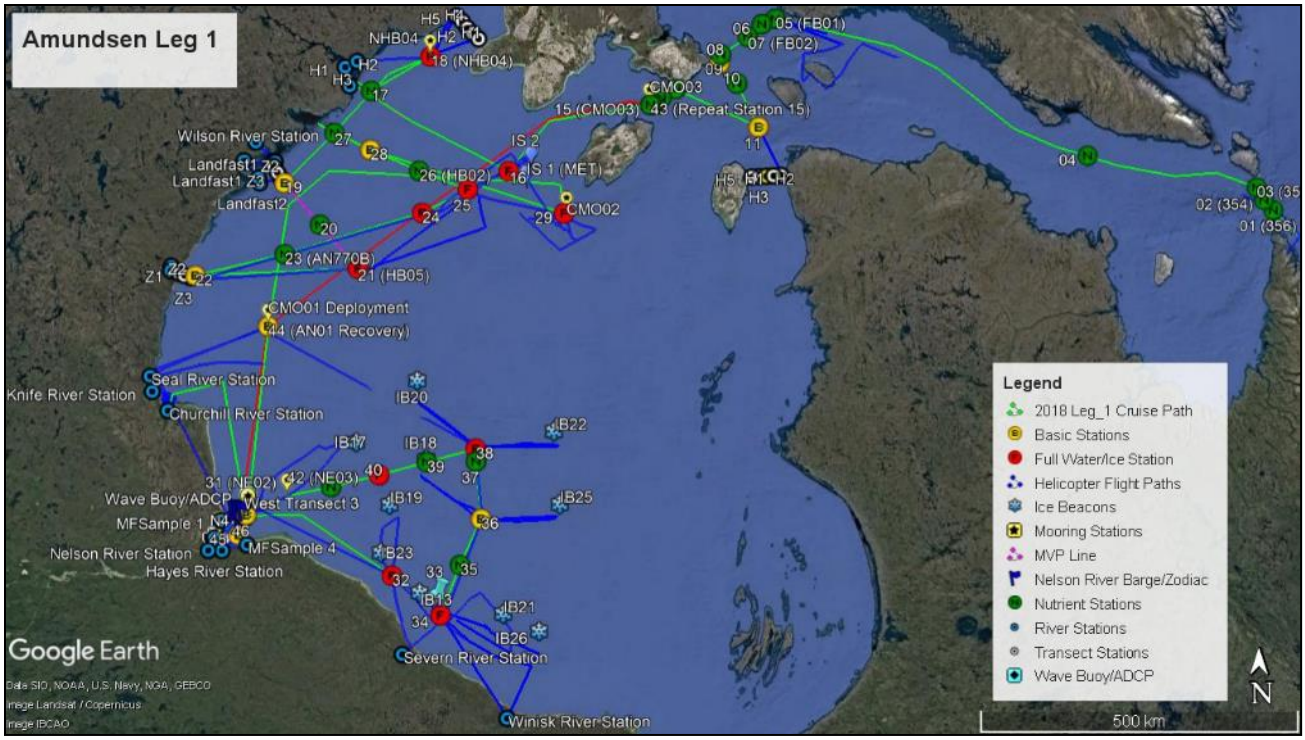

Figure 1 Complete Leg 1 cruise track with all stations and remote tracks included

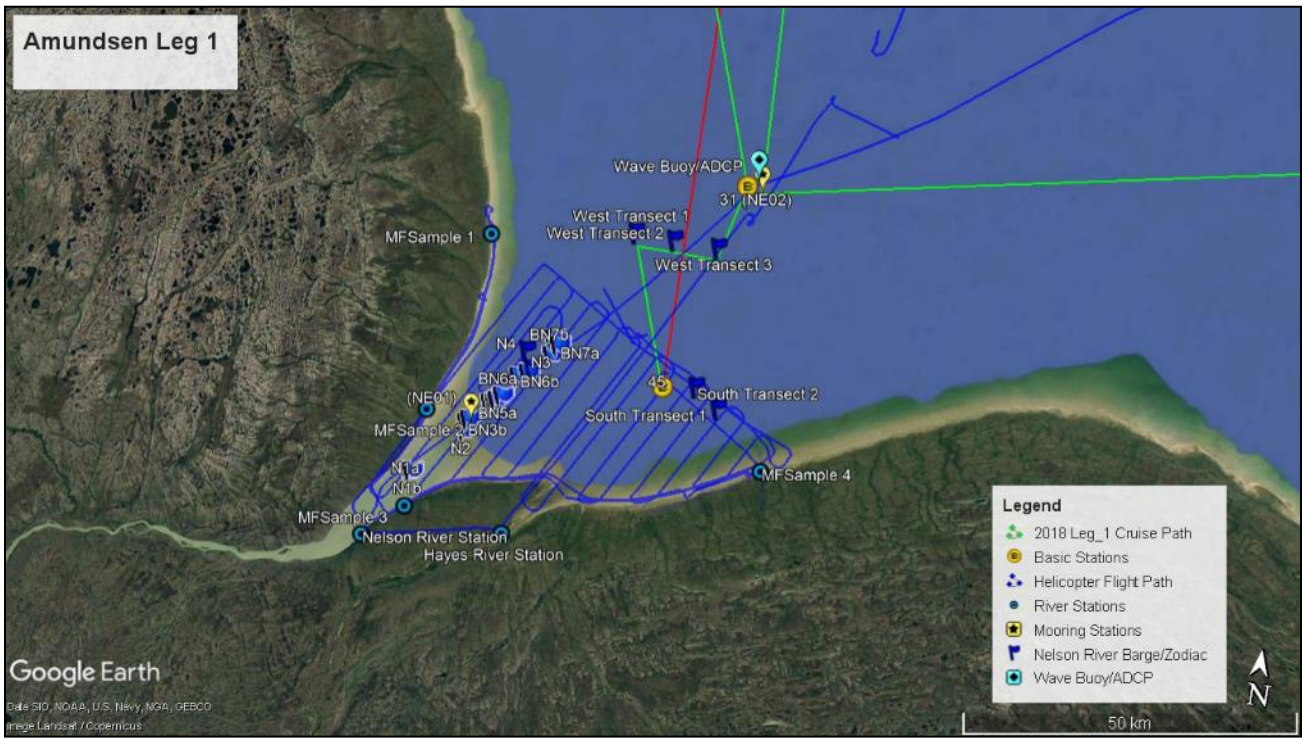

Figure 2 Nelson Estuary cruise track with all stations and remote tracks included

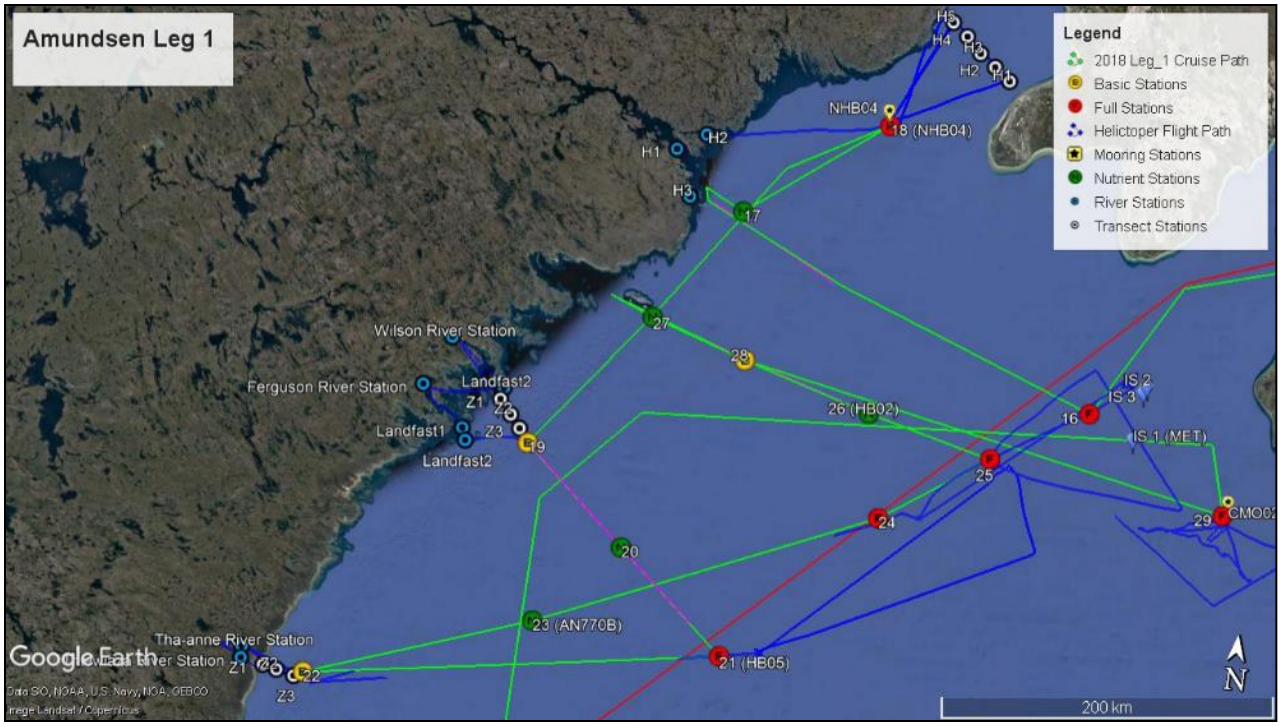

Figure 3 Western Hudson Bay cruise track with all stations and remote tracks included

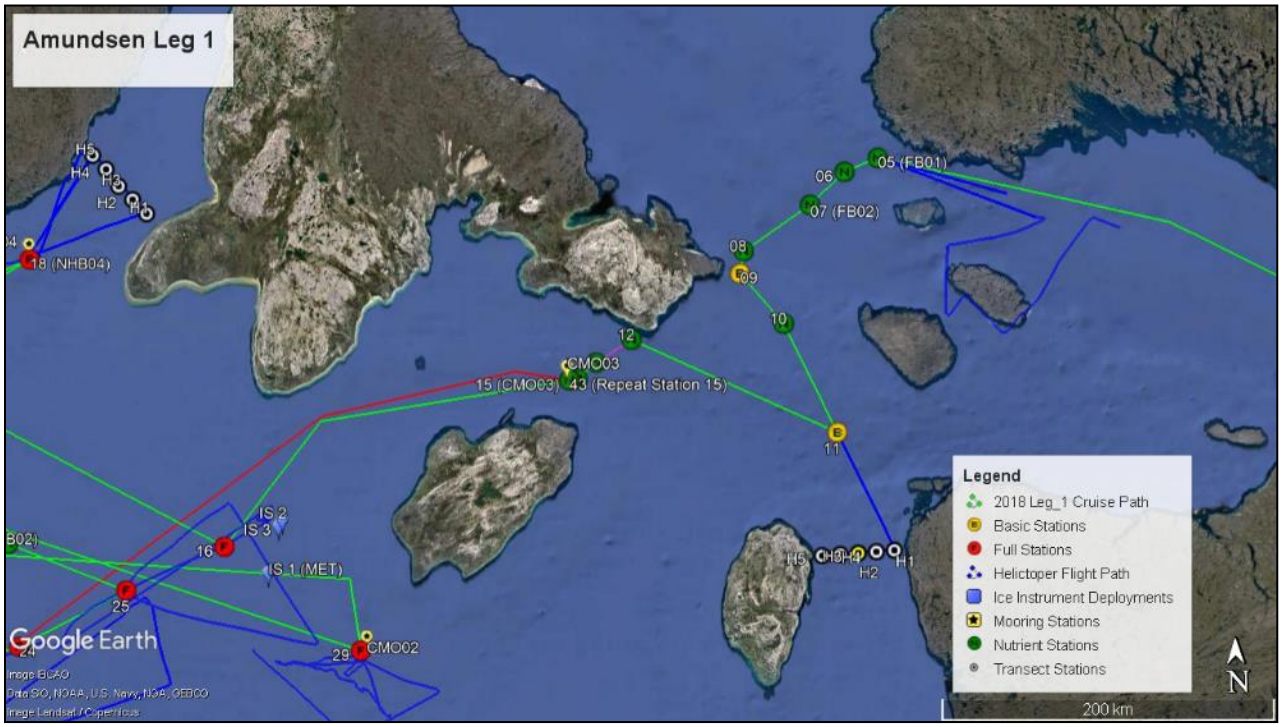

Figure 4 Northern entrance into Hudson Bay. Cruise track with all stations and remote tracks included

BaySys Team 1

Climate and Marine System - Sea Ice

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Introduction and Objectives

The BaySys 2018 cruise provided a unique opportunity to sample the seasonal ice cover in Hudson Bay during the melt season. Previously during February and March 2017, as part of the BaySys program, mobile sea ice was sampled near Churchill via helicopter, and landfast ice near the Nelson estuary via snowmobile. Combined, these three programs provided the opportunity to sample landfast and mobile sea ice during both the winter and summer months, and gain a more complete understanding of the seasonal and spatial variability in the sea ice cover of Hudson Bay.

While many other teams onboard the Amundsen were interested in collecting ice samples for carbon, mercury, contaminants, nutrients, and biology/optics our team was interested in characterising the physical properties of the ice cover. This data will go towards our own research, but also provide context on the ice conditions for the other BaySys teams. In order to describe the physical properties of an ice cover we were interested in describing the temperature and salinity profiles within the ice, measuring its thickness, assessing its roughness, quantifying its aerial concentration and the floe size distribution, monitoring its radiometric signatures to compare to satellite observations, and tracking its drift. To do this, we used a variety of field techniques from direct *in situ* physical measurements, to remote sensing and autonomous platforms that remained on the ice cover. Below is a brief description of our methods and examples of the preliminary results that we have collected.

Operations Conducted and Methodology

Ice Sampling

Ice samples were collected using a 9 cm Mark II Kovacs core barrel. Full or partial ice cores were taken to measure the temperature and salinity throughout the sea ice. Holes were drilled to the center of the core at 10 cm intervals beginning 5 cm from the ice-air interface. A Traceable Digital Thermometer was then inserted into the drilled hole and temperature was recorded. Salinity ice cores were cut with a saw into 10 cm sections, put into buckets, melted overnight, and salinity measurements were taken with a Thermo Scientific Orion 3-star salinometer from pure melt the following day. These profiles provide information on the state of the sea ice to assess whether the ice is growing or melting. An ice core for temperature and salinity was taken

at every ice station for a total of 15 stations throughout Hudson Bay. Partial ice cores were taken only in southern Hudson Bay where the ice was much thicker with ice floes >3m thick.

Figure 5 Laura Dalman measuring the ice temperature profile of an ice core

Manual measurements of ice thickness were collected at each site with a 2" kovacs ice auger and a Kovacs ice thickness tape. Both the manual auger head and a Stihl gas-powered auger were used to drill holes at specific sites or along transects. Additional ice thickness measurements were to be collected with a towed Electromagnetic Induction System, however both systems were malfunctioning and were therefore not used.

Remote Sensing

During the 2018 BaySys Leg 1 field season, passive microwave radiometric scans of ice floes were completed at 14 stations located in the north/northwest and southwest sectors of Hudson Bay. Scans were completed while situated beside the ice floe which would later be sampled for physical properties, at incidence angles ranging from 25 – 80^{o} in both horizontal and vertical polarizations at 19, 37 and 89 GHz. Physical sampling was then completed after scanning on the ice, measuring snow presence/depth, wetness, and salinity within the footprint of the radiometer. Drone surveys were also completed for 11 of the 14 full stations to capture an aerial survey of the sampled floe and surrounding area. Drone surveys were completed using a DJI Phantom 4 and DraganFly Commander, which capture RGB and multispectral imagery respectively. Aerial imagery was used to classify sea ice surface features, such as melt pond size or sediment presence. As well, digital elevation models were generated using photogrammetric techniques, providing a 3D model of the surface roughness of sea ice within the survey area. Physical and drone sampling was combined to classify the physical properties of the scanned floe, to be compared to the measured brightness temperatures from the passive microwave radiometer.

Sampled ice at each of the stations varied in melt progression, ice composition and surface characteristics. Ice sampled during early June in the north sector of the bay showed no melt features, with all ice floes being very large with a more uniform surface elevation. Floes were covered with a layer of dry fresh snow (~10 cm) covering a deeper layer of saturated, highly saline snow (~5 cm). The radiometric signature of these floes shows uniform brightness temperatures across the range of incidence angles, with brightness temperatures residing between 170 and 270 K for each frequency/polarization.

Ice in the southwestern sector of the bay had different physical and surface properties compared to the northern ice. This ice was sampled during late June, meaning that melt features were more prominent. Ice in this area contained sediment in the surface layer, had larger ridge features, and was thicker than the northern ice. Snow on the ice was thinner (~3 cm) and was fresh. Melt ponds were often covered by a layer of ice (~1 cm thick). The radiometric signature of this ice was slightly different, showing diverging brightness temperatures at higher incidence angles. As well, brightness temperatures for the horizontal polarization varied greater than the vertical polarization over the range of incidence angles.

Autonomous Instruments

Ice Beacons

To measure sea ice drift 10 ice beacons were deployed on large ice floes in central and southern Hudson Bay. Ice Beacons are contained within sealed PVC tubes (13 cm diameter x 50 cm length) that house a small processor, GPS and Iridium antennae, and a battery pack. Once the units are activated they transmit their GPS location at user-defined intervals (typically 1 hour) to an online web portal. The ice beacons transmit their location until the ice floe breaks up and they sink.

Table 2 Ice drift beacon deployment details

Beacon #	IMEI	Deployment Date	Coordinates
17	607220	18-06-2018	58.61729 -89.57683
19	206980	19-06-2018	57.72522 -88.05737
23	503520	19-06-2018	57.12653 -88.35158
13	504190	20-06-2018	56.60985 -87.08107
21	300430	21-06-2018	54.40994 -85.89129
26	908870	21-06-2018	56.10707 -84.56303
25	907730	22-06-2018	57.87995 -84.22141
18	201080	22-06-2018	58.29801 -87.60599
20	300000	23-06-2018	59.26393 -87.99193
22	300440	23-06-2018	58.79762 -84.22619

Below is a map of the 10 beacon locations and near-real time sea ice concentration (0 - 100%) from June 24th. The 10 beacons provide good spatial coverage of the ice cover and will hopefully last well into July as the ice cover melts out and breaks up. Note that the near-real time sea ice concentration is provided by NSIDC and is based on space borne passive microwave sensors that have known limitations during the melt season due to liquid water at the ice surface. Ice charts from the Canadian Ice Service provided higher resolution data that is more reliable, but for this exercise the near-real time data is suitable.

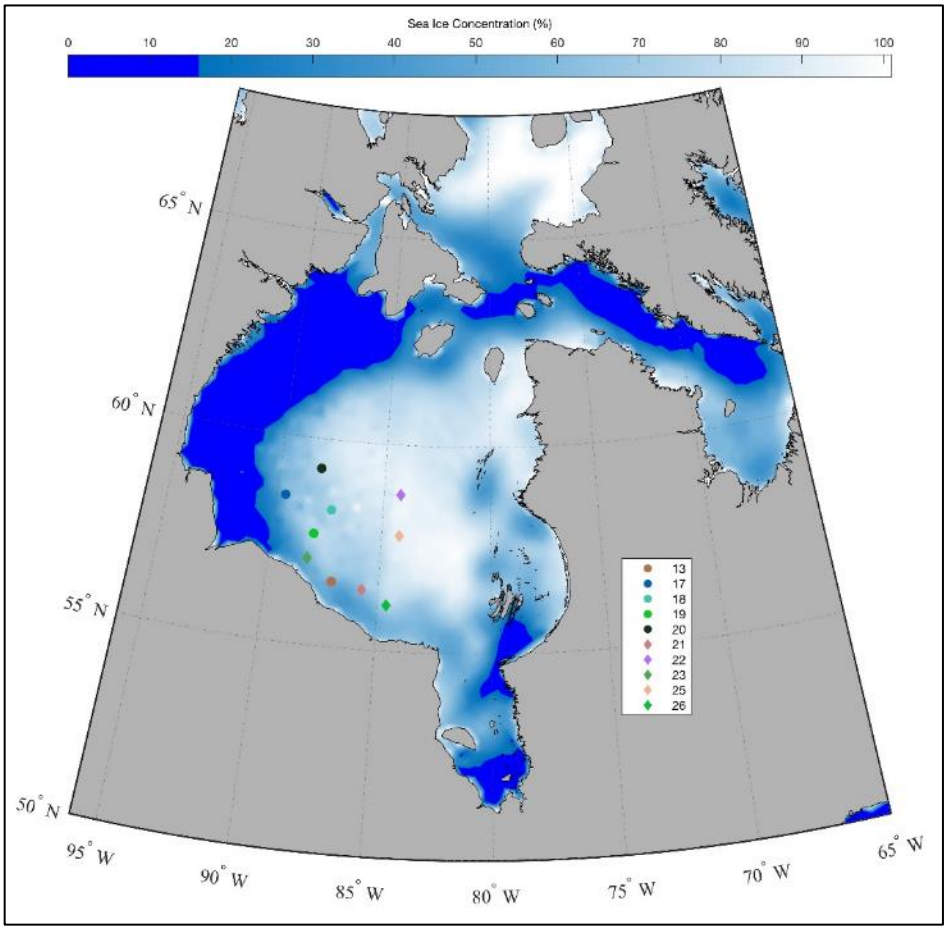

Figure 6 Ice beacon positions and sea ice concentration on June 24th, 2018

Short Deployment of on-ice Weather Station and CT Lines

Taking advantage of our multiple trips across the marginal ice zone in northwestern Hudson Bay we deployed a suite of autonomous instruments for a 6-day period to capture a high-resolution dataset on atmosphere-ice-ocean interactions. Two ice tethered moorings and a meteorological station were deployed on large pans of sea ice. The mooring lines contained CT sensors and an upward looking ADCP, while the meteorological station contained an Air temperature sensor (Campbell Scientific 107 Temperature Probe), a barometer (Campbell Scientific 61302V), turbine anemometer (RM Young 05106-10 Wind Monitor, Marine) and an under-ice acoustic

sounder (Teledyne Benthos 9602) to monitor sea ice melt. To correct the wind direction for floe rotation an electronic compass (R.M. Young 32500) was calibrated and setup on the tower, while an additional ice beacon was deployed ~50m from the co-located ice tethered mooring to provide two GPS positions to verify the compass measurement of floe rotation. The station was operated by a CR-1000 and powered by a Lithium Ion Battery, both of which were located in the white weatherproof enclosure visible in Figure 3. The systems were deployed on June 6th and recovered on June 12th, both via helicopter. A complimentary ice core was collected during deployment, however no core was collected during recovery because the floe had broken up considerably and the mooring and met station was recovered while the helicopter hovered.

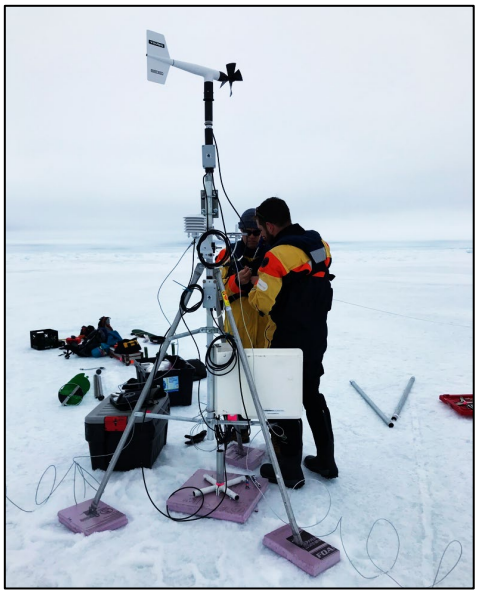

Figure 7 Photograph of the on-ice meteorological station setup

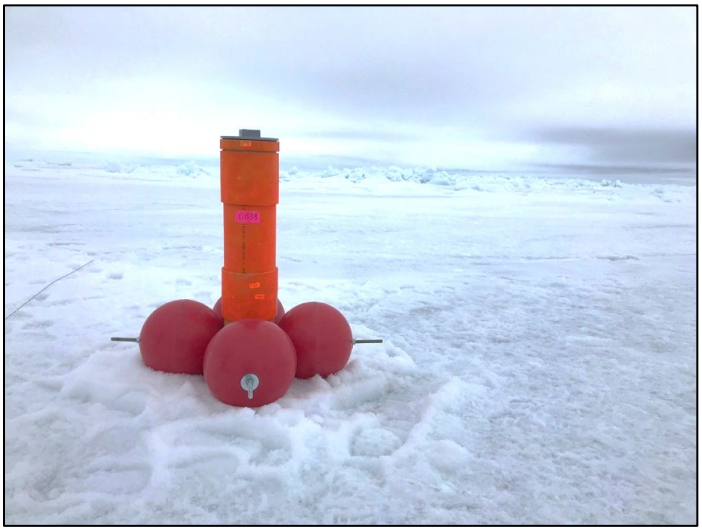

Figure 8 The surface portion of the ice-tethered mooring. There is a GPS tracker within the surface unit that allowed us to recover the unit after 6 days

Further details on the oceanographic observations and mooring operations are presented on page 17.

Preliminary Results

Physical samples

Two samples profiles of the Temperature and Salinity are provided below. Overall the sea ice was relatively warm and near isothermal at every site. The salinity varied from values typical of first year sea ice (5 – 7) to values indicative of freshwater ice (0 – 1).

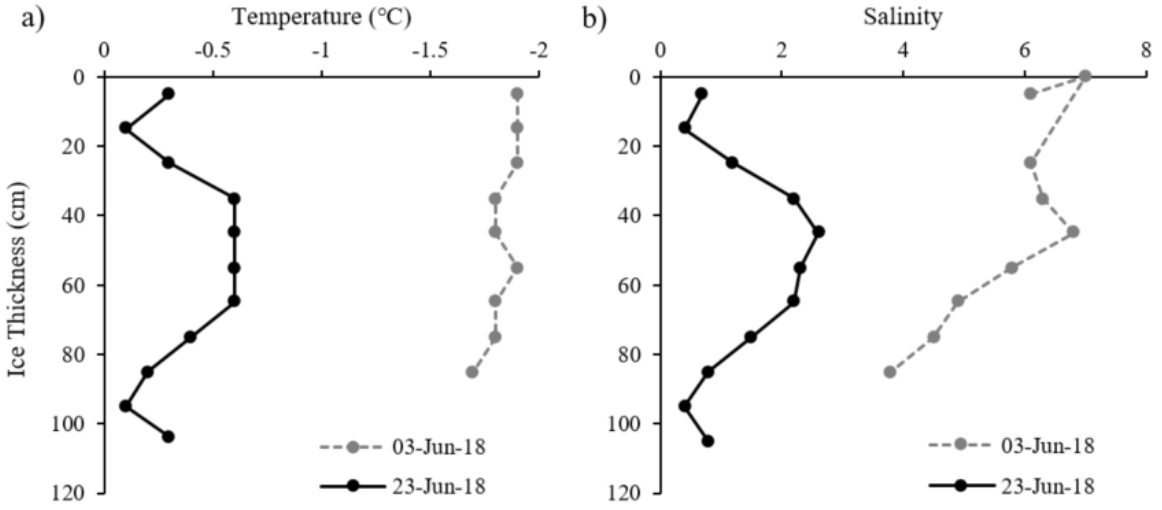

Figure 9 Temperature (a) and salinity (b) profiles for ice floes sampled in northern Hudson Bay (03-Jun-18) and southern Hudson Bay (23-Jun-18)

Remote Sensing

No preliminary results are available from this equipment at this time.

Autonomous Instruments

Ice Beacons

Below are two examples of the ice beacon data from beacons 21 and 26. A map with the points coloured by ice drift speed (km/d) and the time series of ice drift speeds are provided for each beacon. The ice clearly quite mobile and in near constant motion, with frequent reversals and loops along its trajectory. The periodic loops are to the left of the trajectory and are therefore not inertial, but instead likely tidally driven. This will be explored further following the loss of all ice beacons in late-July or early-August. Note that there is a 5 day gap in the data during early July, the Iridium servers at Solara Communications were down during that time and they are in the process of retrieving this data from the Iridium servers.

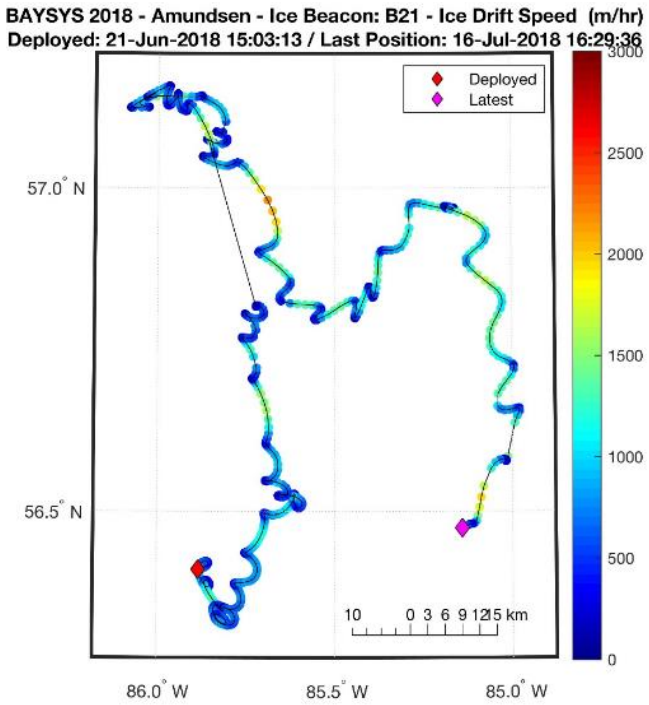

Figure *10 Ice beacon 21 position and drift speed*

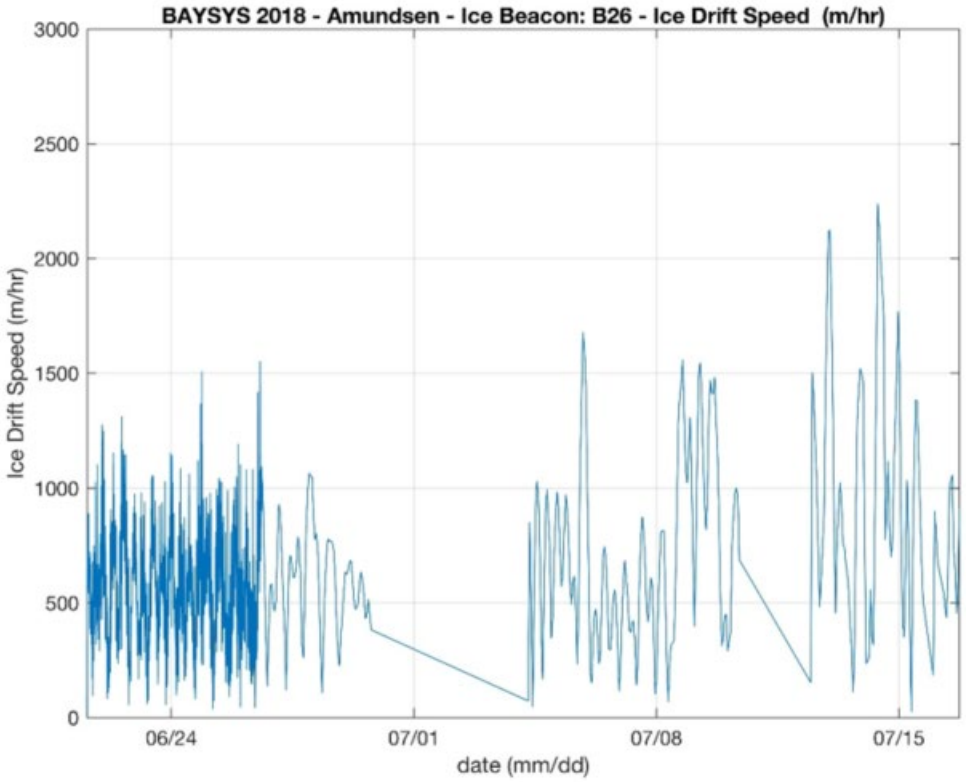

Figure 11 Ice beacon 26 drift speed

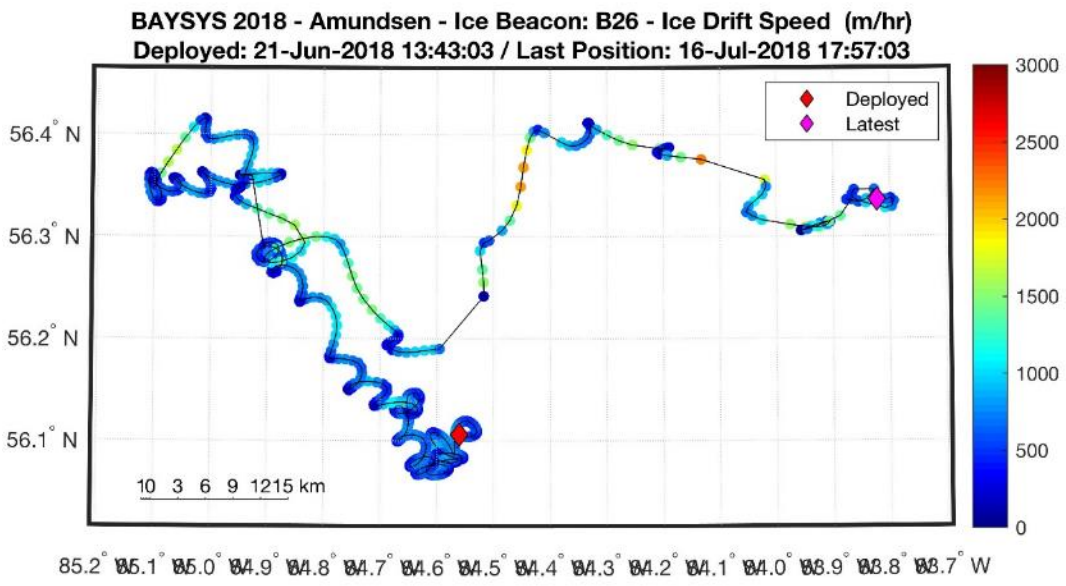

Figure 12 Ice beacon 26 position and drift speed

Short Deployment of on-ice Weather Station and CT Lines

The data from this short-term deployment is still being processed and not available to be shared at this time.

Mooring Operations in Hudson Bay

Principal Investigators: Jens Ehn[1]; CJ Mundy[1]. Cruise Participants: Sergei Kirillov[1]; Keesha Peterson[1]; Yanique Campbell[1]

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Introduction and Objectives

The initial cruise plan intended the recovery of five BaySys moorings deployed in the Hudson Bay in September 2016 (NE01 and JB02) and in October 2017 (NE02, NE03 and AN01). The change of cruise plan due to several SAR operations and heavy ice conditions in the central and southern parts of Hudson Bay did not allow us to reach the position of JB02 mooring at the mouth of James Bay. Two separate components of NE01 mooring deployed at ~30 m depth in the inner Nelson estuary zone were also not recovered. Although we were able to communicate with both acoustic releases, all our attempts to release the CT-line from the anchor and recovery pod from the bottom mount (Figure 13) failed. Later, the subsurface float from the CT-line was found nearby on the shoreline during one of the reconnaissance helicopter flight. Taking into account that float was initially located at ~20 m depth, we suggest that deep ice keels could have caused the damage of that mooring. Such deep keels could be associated with large *stamukhi* which were formed in the Nelson region due to the extremely strong tidal dynamics resulting in ice piling at the edge of landfast ice.

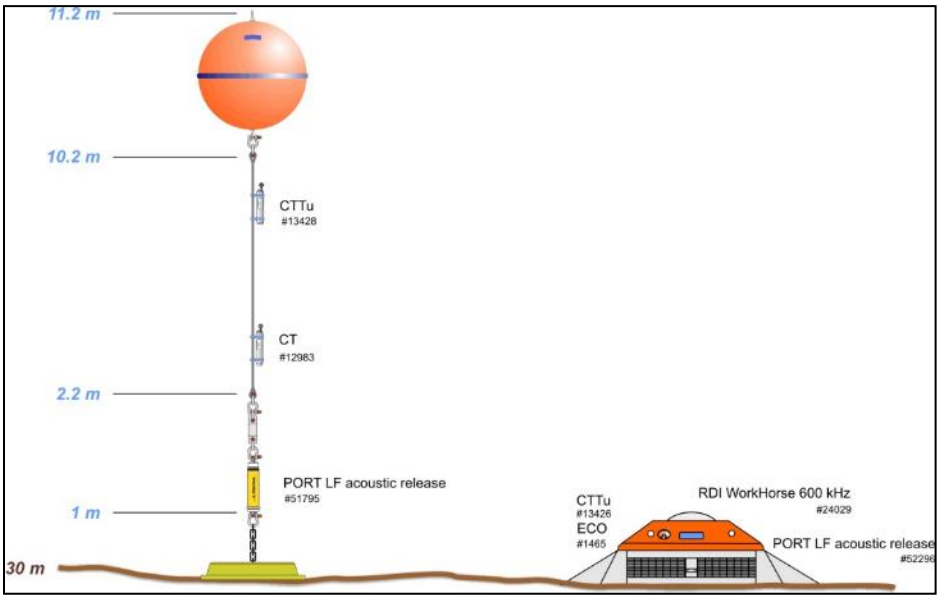

Figure 13 The configuration of the lost mooring NE01

Three other moorings deployed in October 2017 were successfully recovered in June 18, 25 and 28 (see Table 2). The zodiac was used at every recovery station to draw the mooring line to the ship (Figure 14) for further lifting with a capstan and A-frame from the foredeck.

Table 3 The positions of recovered, deployed and short-term moorings

Date	CTD cast	Mooring ID	LAT (N)	LON (W)	Operation	Time (UTC)	Water depth (m)
05-Jun	AM18-015	*CMO-C*	63º 11.001’	081º 58.873’	Mooring deployment	13:30	194
06-Jun	AM18-H06	*Ice-tethered setup*	62.2815º	85.9543º	Mooring deployment	15:15	
06-Jun	AM18-H07	*Ice-tethered setup*	62.2592º	85.8273º	Mooring deployment	22:00	
08-Jun	AM18-018	*CMO-D*	63º 42.760’	088º 25.583’	Mooring deployment	12:30	119
12-Jun	AM18-H24	*Ice-tethered setup*	62.4396º	85.3650º	Mooring recovery	15:30	
12-Jun	AM18-H25	*Ice-tethered setup*	62.4595º	85.5283º	Mooring recovery	18:45	
16-Jun	AM18-029	*CMO-B*	61º 45.613’	084º 18.172’	Mooring deployment	09:00	179
18-Jun	AM18-031	*NE02*	57º 29.907’	091º 48.250’	Mooring recovery	16:15	43
25-Jun	No cast	*NE03*	57º 49.776’	090º 52.817’	Mooring recovery	12:45	53
25-Jun	No cast	*Wave buoy*	57°30.15’	091°47.51’	Mooring deployment	18:00	43
28-Jun	AM18-044	*CMO-A*	59º 58.610’	091º 56.422’	Mooring deployment	15:00	106
28-Jun	AM18-044	*AN01*	59º 58.443’	091º 57.236’	Mooring recovery	15:30	105
01-Jul	AM18-046	*Wave buoy*	57°30.15’	57°30.15’	Mooring recovery	21:40	43

Figure 14 Mooring recovery with an assistance of zodiac

Preliminary Results

Data from all instruments was examined after recovery to determine if all equipment worked properly and recorded reliable data. We also examined the pressure records from all available sensors to adjust the depths of moored instruments and prepared the final schemes for the moorings' configurations (Figure 15). In general, all recovered instruments worked well and 8-month time series of temperature, salinity, current velocities, ice thickness/waves etc. were correctly recorded (see Table 3).

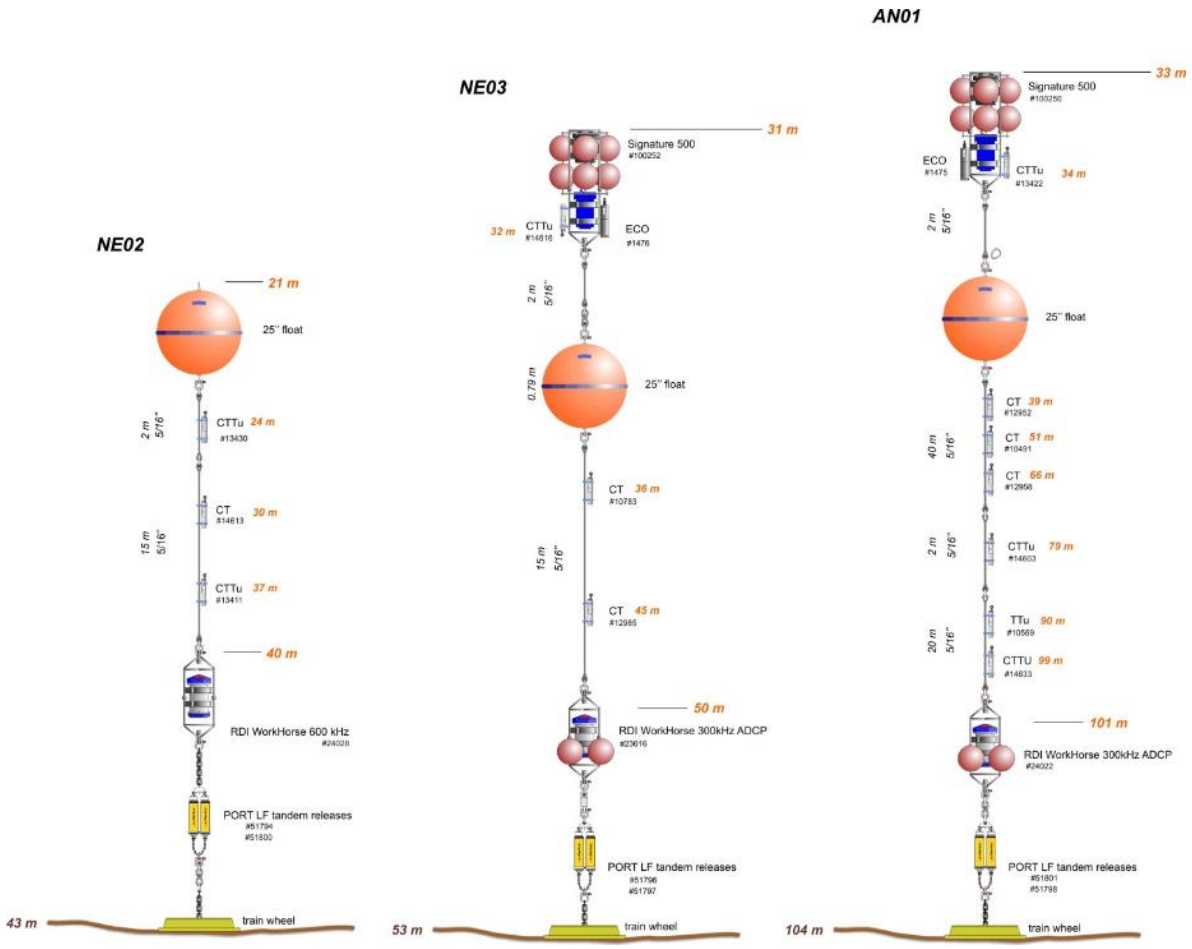

Figure 15 NE02 (Nelson Outer Estuary), NE03 (Nelson River outer shelf) and AN01 (Churchill shelf), mooring configurations as recovered

Table 4 Status of data at recovered moorings

Mooring	Instrument	Depth, m	Start time	End time	Period	Data status	Notes
NE02	WH600	40	29 Oct, 2017	18 Jun, 2018		OK	
	RBR CTTu	24	29 Oct, 2017	18 Jun, 2018	15 min	OK	
	RBR CT	30	29 Oct, 2017	18 Jun, 2018	15 min	OK	
	RBR CTTu	37	29 Oct, 2017	18 Jun, 2018	15 min	OK	
NE03	Signature 500	31	29 Oct, 2017	25 Jun, 2018		OK	
	WH300	50	29 Oct, 2017	25 Jun, 2018		OK	
	ECO	32	29 Oct, 2017	25 Jun, 2018	30 min		Not retrieved yet
	RBR CTTu	32	29 Oct, 2017	25 Jun, 2018	15 min	OK	
	RBR CT	36	29 Oct, 2017	25 Jun, 2018	15 min	OK	
	RBR CT	45	29 Oct, 2017	25 Jun, 2018	15 min	OK	
AN01	Signature 500	33	1 Nov, 2017	28 Jun, 2018		OK	
	WH300	101	1 Nov, 2017	28 Jun, 2018		OK	
	ECO	34	1 Nov, 2017	28 Jun, 2018	30 min		Not retrieved yet
	RBR CTTu	34	1 Nov, 2017	28 Jun, 2018	15 min	OK	
	RBR CT	39	1 Nov, 2017	28 Jun, 2018	15 min	OK	

	RBR CT	51	1 Nov, 2017	28 Jun, 2018	15 min	OK	
	RBR CT	66	1 Nov, 2017	28 Jun, 2018	15 min	OK	
	RBR CTTu	79	1 Nov, 2017	28 Jun, 2018	15 min	OK	
	RBR TTu	90	1 Nov, 2017	28 Jun, 2018	15 min	OK	
	RBR CTTu	99	1 Nov, 2017	28 Jun, 2018	15 min	OK	

Mooring Deployments

Four moorings were deployed along the main shipping channels across Hudson Bay as a part of Environmental Observing system related to the Churchill Marine Observatory project. The positions of all these moorings are shown in Figure 16 and also listed in Table 2. All deployed moorings were equipped with similar instruments except CMO-C site where 2 sediment traps (at 63 and 167 m) and a SeaFET pH sensor (at 30 m) were added to the line (see Figure 17). The sediment trap motors were turned on at exactly 20:00 UTC on 4 June 2018 (interval 0) and they would begin rotating the carousel in 48 hours with a 36 day interval between rotations.

Figure 16 Positions of CMO moorings deployed in the Hudson Bay in June 2018

The following set of standard instruments was used for each mooring:

- Ice Profiling Sonar (IPS5) at 30 m
- Acoustic Doppler Current Profiler (WH300 Sentinel ADCP) at 60 m
- Acoustic Zooplankton Fish Profiler (AZFP). The depth of units varied from 75 to 90 m at different moorings
- a broadband underwater acoustic recorder (TR-ORCA) deployed in between 80 and 150 m depth
- Wetlab ECO triplet logger (measuring turbidity, chlorphyll-a and CDOM fluorescences) at 30 m
- 3 SBE37 CTD (conductivity-temperature-depth) sensors at 30 m, 60 m and near the bottom.

All instruments were programmed for about 15-months deployment with the planned recovery in the fall, 2019. All moorings were deployed anchor last from the foredeck using the A-frame (Figure 19).

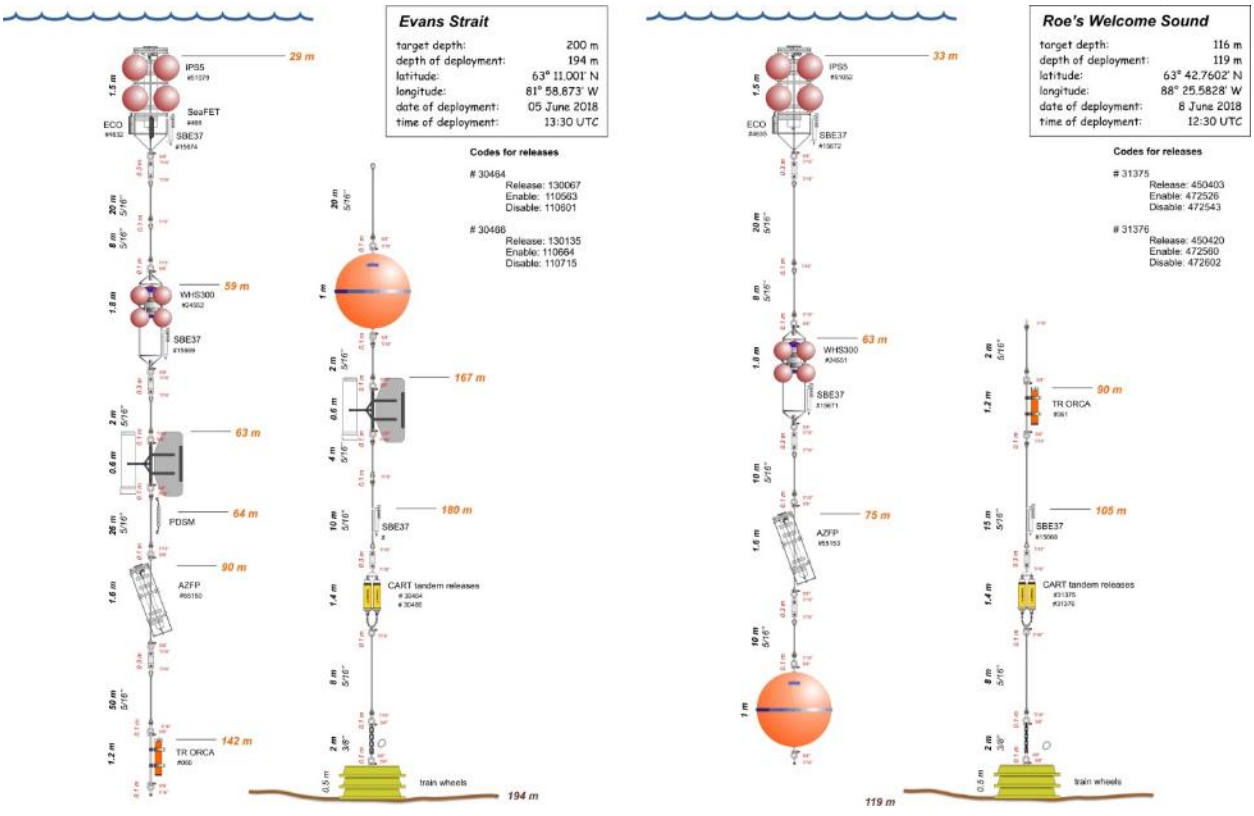

Figure 17 The configuration of CMO-C (Evans Strait) and CMO-D (Roes Welcome Sound) moorings

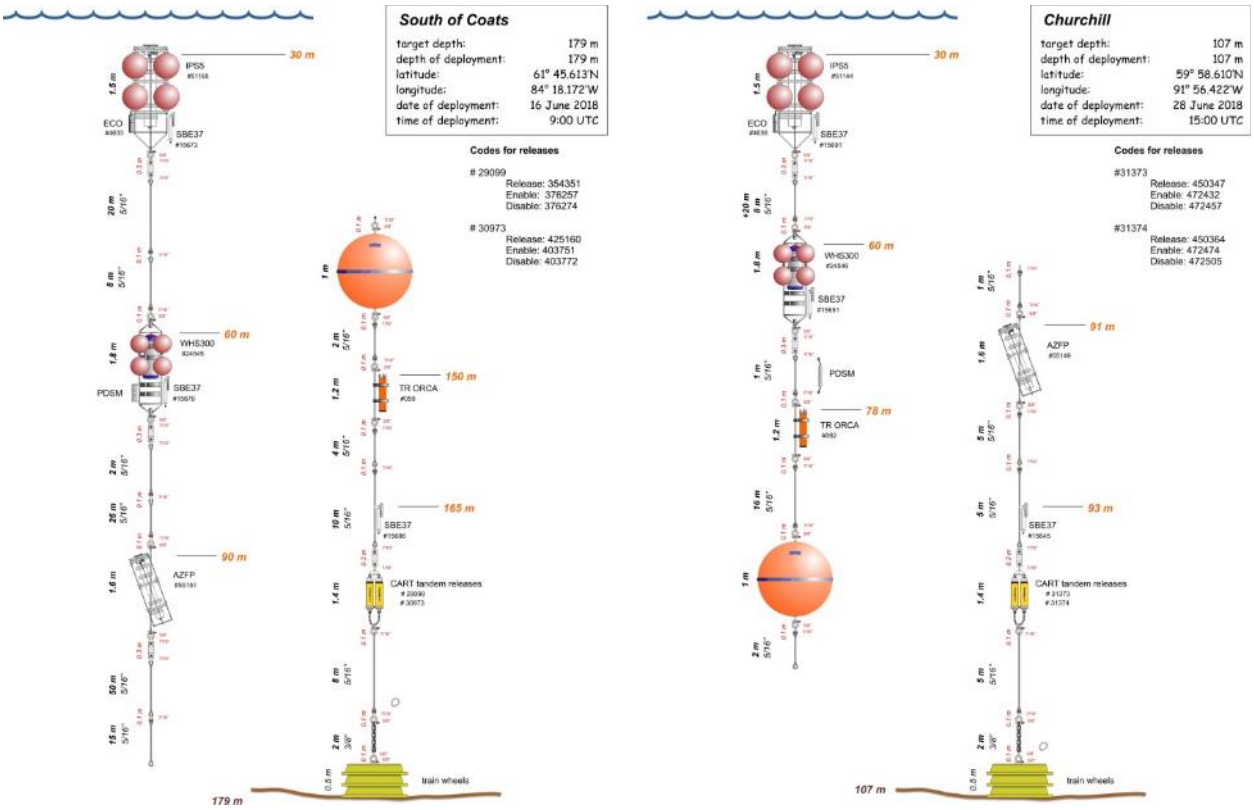

Figure 18 The configuration of CMO-B (South of Coats) and CMO-A (Churchill) moorings

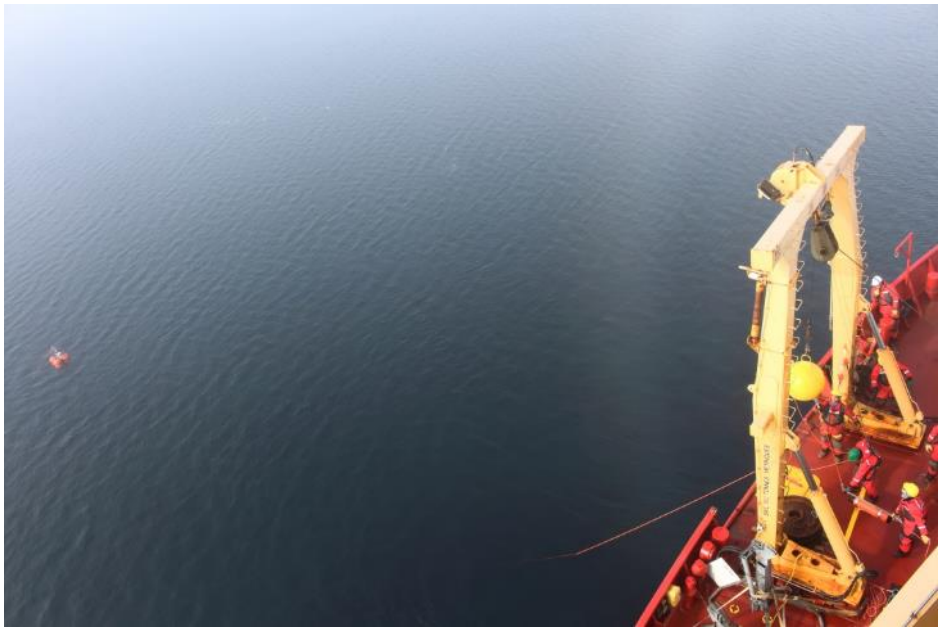

Figure 19 Anchor last mooring deployment from the foredeck

Short-term moorings

Three short-term moorings were deployed during Leg 1. Two of them were ice-tethered setups that included a line of RBR CT sensors mounted between 2 and 14 meters, an upward looking Aquadopp 600 kHz ADCP at 13 m, and a GPS beacon (Figure 20). The eastern mooring was additionally equipped with a basic meteorological tower measuring air temperature, pressure, wind speed and direction, and sea ice thickness.

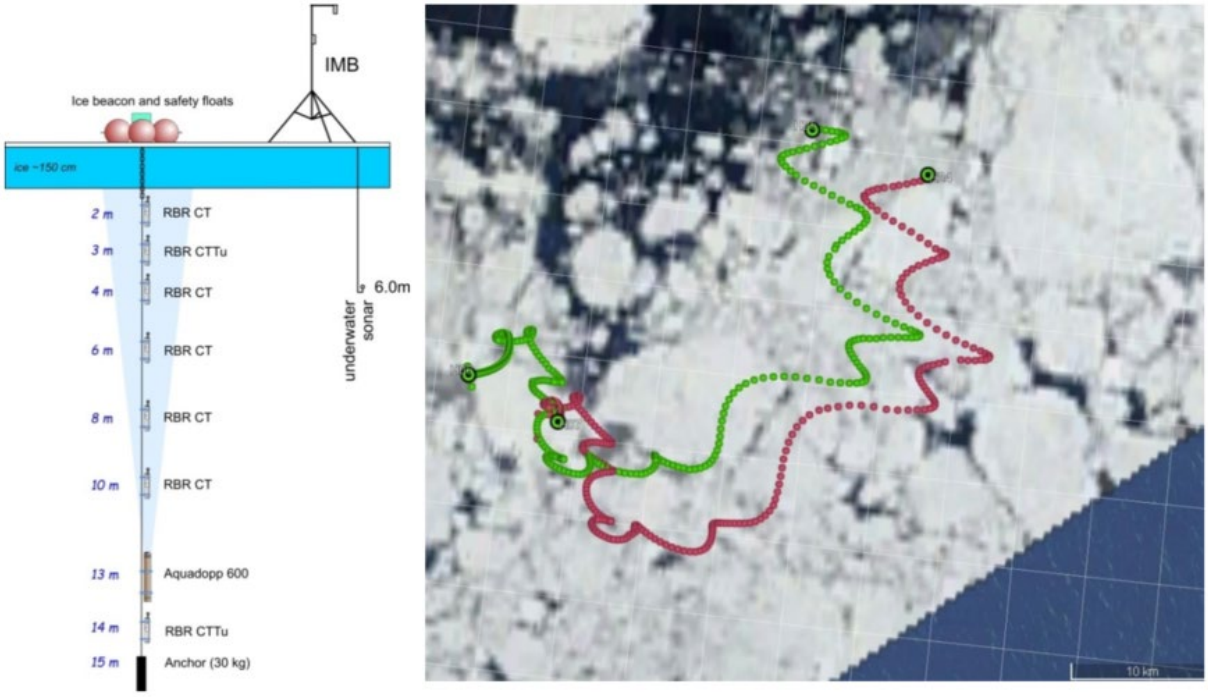

Figure 20 The configuration of the ice-tethered moorings and their trajectories between June 6 and 12

In the Nelson estuary region, a TRIAXYS wave buoy equipped with g3 sensor was deployed between June 25 and July 1 to measure the directional pattern of surface waves. The deployment took place at the beginning of a period of high winds (>10 m/s) over the region that persisted for several days. The objective of the wave buoy was to capture storm wave conditions in the region as a function of wind and the fetch distance created by the ice edge that was receding to the east. The growth and propagation of waves as a function of these parameters will be assessed. In addition, temperature and salinity data in the upper few metres will supplement the wave measurements, allowing for insight into wind-wave mixing in the mixed layer.

The synchronous measurements carried out with Nortek Signature 500 ADCP that was deployed at TRIAXYS site at 30 m depth is aimed to validate and compare TRIAXYS and ADCP records

to each other. Figure 21 shows the diagram of experimental setup and Table 2 contains the coordinates of TRIAXYS site.

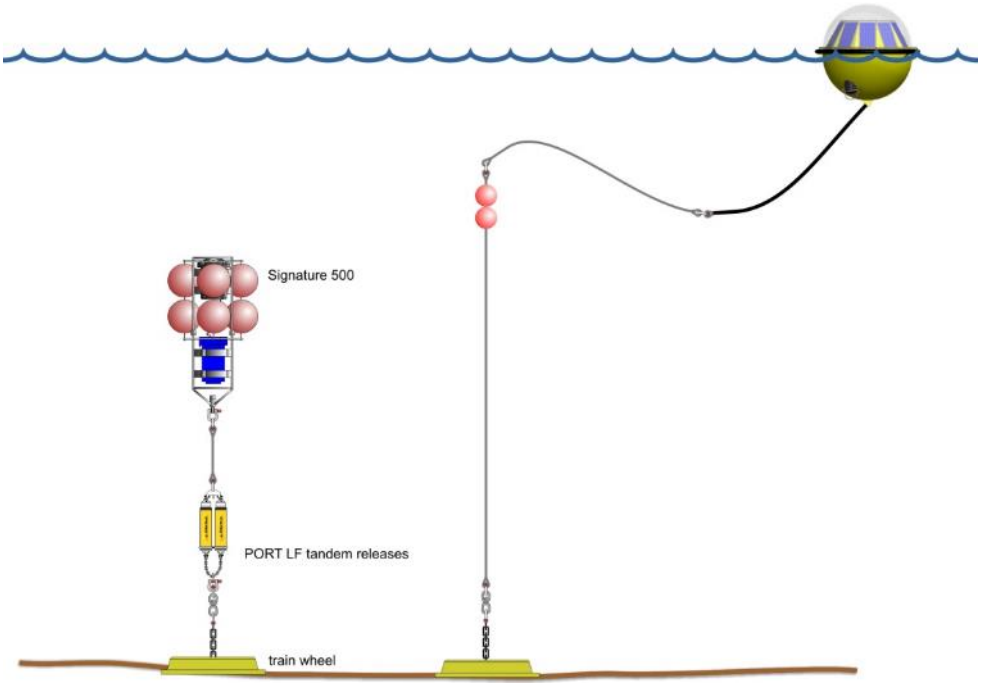

Figure 21 TRIAXYS wave buoy and Signature 500 ADCP setup for the wave measurements in the Nelson region

BaySys Team 3

Apparent and Inherent Optical Properties of Open and Ice-covered Hudson Bay in Relation to Primary Production Dynamics and Distribution of Organic and Inorganic Matter, Tracing of Freshwater and River Plumes

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Introduction and Objectives

The research goal of our team was to use optical measurements accompanied by water and ice sampling for biological and oceanographic parameters to gain information about spring primary production and the distribution and concentration freshwater, sediments and organic matter in the Hudson Bay System (HBS). The system is influenced by a large freshwater input from rivers and sea ice melt at this time of the year. Three PhD projects dealing with different aspects of the main objectives were involved in this cruise:

Atreya Basu
Being a member of the BaySys Team 1- Marine and climate system and as a PhD student it is my mandate to map the freshwater distribution in the Hudson Bay during the spring freshet season. Thus, this study will focus on the response of surface freshwater distribution during the open water season to climate variability and hydroelectric regulation. My approach is to use satellite-derived optical proxies and field-based observations, carried out in the fall and spring season, for the development of a Hudson Bay specific ocean color remote sensing algorithms which characterizes the freshwater distribution. One of the main challenges will be the partitioning of freshwater origins such as sea ice melt and riverine components. Hudson Bay is fully ice-covered over several months and has a large number of rivers draining into the bay. The coastal waters will be one of the prime geographical focus areas of my research with an emphasis on the Nelson-Hayes river estuary. To achieve the following objectives, *in situ* field data collection is a mandatory requirement and for which I am onboard the *CCGS Amundsen*. The collected dataset is going to supply crucial information to fill the following objectives:

- Studying the optical interdependency among CDOM and particulates in the Hudson Bay: A precursor to the freshwater tracing algorithm
- Studying the distribution of runoff, sea ice melt, sea ice during spring freshet in the Hudson Bay using salinity- δ^{18}O-CDOM measurements
- Tracing river plumes in the coastal Hudson Bay (Canada) using satellite remote sensing: Influence of Non-Algal Particles on Remote sensing reflectance and aCDOM retrieval

- Optical delineation the Nelson-Hayes River plume extent (Hudson Bay, Canada) using a satellite remote sensing approach (2012-2018)

Lucas Barbedos de Freitas

The dataset acquired during the BaySys 2018 Expedition will improve the satellite Net Primary Production (NPP) model developed over the last year at UQAR-Takuvik. The model is based on in situ samples of biological parameters as well as in-water and above water radiometry measurements [Babin et al., 2015; Lee et al., 2015]. Hudson Bay is characterized as a domain of optically complex waters with relatively high spatial-temporal variability in the optical properties [Xi et al., 2013, 2014, 2015], therefore, measurements have to be carried out on a high spatial resolution. The collected dataset is going to supply crucial information to fill the following objectives:

- Regionalize the remote sensing depth and wavelength resolved net phytoplankton primary production model [*Platt et al.*, 1980] through in situ radiometry, Apparent Optical Properties (AOP), satellite match-up and water column structure in HBS
- Perform a sensitivity study of the NPP algorithm to bio-optical parameters ([Chl *a*], photosynthetic parameters, diffuse attenuation coefficient for downwelling irradiance (Kd(λ)) and oceanographic processes to estimate the absolute model uncertainty
- Assess the uncertainty of the satellite NPP model when there are evidences that the bloom occurred under ice
- Evaluate the capability of the satellite NPP model to access under-ice production

Lisa Matthes

An indication for significant phytoplankton growth in late spring is the changing sea ice conditions of the Hudson Bay system during the last decades such as a significant decline of -15.1 % /decade in sea ice concentration in the western and north-western parts of the Bay [Hochheim et al. 2010]. Up to now, primary production measurements were mainly performed in open water between June and September in Hudson Bay [Legendre and Simard 1979; Grainger 1982; Ferland et al. 2011], neglecting a potential under-ice and/or ice algae spring bloom and resulting in low annual production estimates. Additionally, little is known about the photophysiological adaptation of present algae communities to these quickly changing environmental conditions in late spring. My project aims to investigate the following objects during the summer cruise:

- Investigate the role of spectral light availability on the timing and location of spring primary production with a retreating sea-ice cover in Hudson Bay
- Quantify the seasonal variability in spectral light attenuation in the upper water column associated with biological properties of primary producers, dissolved organic matter and non-algal particles
- Describe the variability in primary production in the Nelson estuary along a salinity gradient during spring melt

Operations Conducted and Methodology

Sampling was conducted in the open water of Hudson Bay, on ice and via helicopter at several rivers (Figure 22). Water samples for the analysis of oceanographic, optical and biological parameters were collected from the rosette at 6 optical depths as well as at deeper depths according to stratification patterns of the water column. Simultaneously, optical instruments were deployed from the foredeck to measure the reflection of light at the water surface, the extinction of light in the water column and the concentration and distribution of particulate and dissolved matter impacting the propagation of light through absorption and scattering processes. Table 4 provides an overview about the sampled parameters at each station.

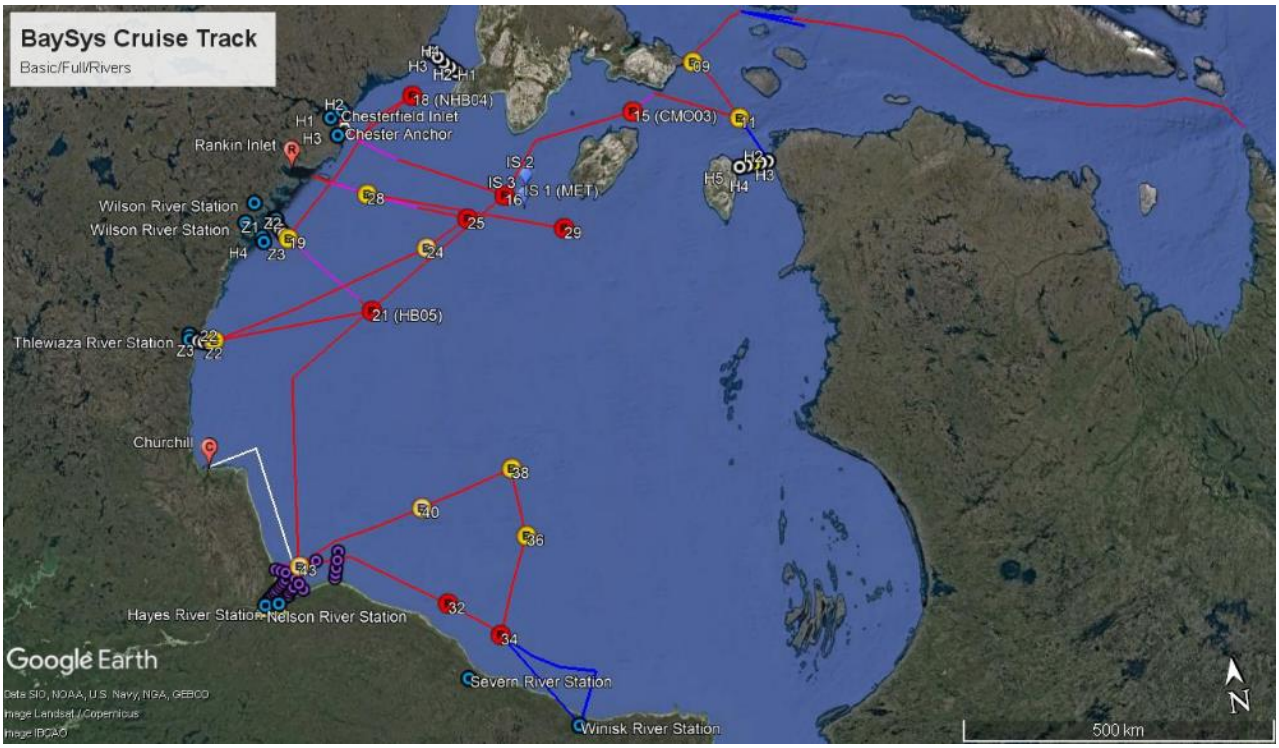

Figure 22 Water sampling and the deployment of optical instruments were performed at full and basic stations (B, F). Ice work including under-ice light measurements and the sampling of ice cores was carried out at several stations

Optical Operations

From the foredeck, measurements of surface reflection were conducted with the Hyperspectral Surface Acquisition System (HyperSAS, Satlantic, USA) following the methodology of *Mobley* [1999]. In-water radiometric profiles of light extinction were recorded by the submersible spectroradiometer Compact Optic Profile System (C-OPS, Biospherical Instruments Inc., USA) using similar methodology of *Hooker et al.*, (2013). To complete dataset interpretation, Secchi disk depth was measured before the deployment of the C-OPS. Additionally, a photographic report was performed continually during each station and ship transects to monitor the sea-ice, atmospheric and sea state.

Total atmospheric ozone, water vapor and aerosol measurements are conducted using the handheld ozone monitor and Sun photometer Microtops II [*Morys et al.*, 2001]. This dataset will help to improve the atmospheric correction related to ocean color satellite observations.

Measurements of the inherent optical properties such as absorption and scattering by particles (phytoplankton, sediment, detritus) and colored dissolved organic matter (CDOM) were conducted via instruments (AC-S, BB9, BB3, CTD-probe, fluorometer) attached to a metal frame. The frame was lowered with the help of the A-frame at the foredeck to the water surface and several profiles from the water surface to the bottom were recorded. The deployment of the Laser in-situ Scattero-/Transmissometer (LISST 100x, Sequoia Scientific Inc., USA) followed to measure particle size distribution and concentration along the same profile.

To determine the optical depths for water sampling via the rosette, a Profiling Natural Fluorometer (PNF-300, Biospherical Instruments Inc., USA) was deployed from the foredeck. The ship was positioned towards the sun, so that the recorded light profile was not contaminated by the ship shade. Afterwards, the diffuse attenuation coefficient of downwelling irradiance was calculated to determine 6 optical depths: 100 %, 30 %, 15 %, 5 %, 1 %, and 0.2 %.

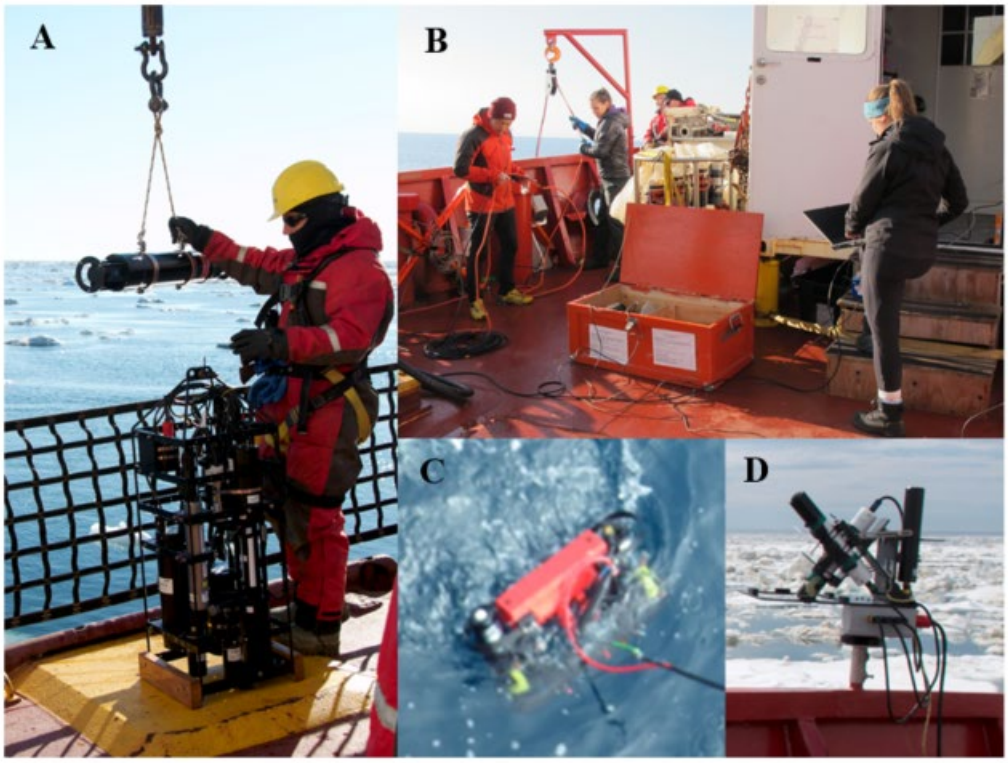

Figure 23 Optical instruments A) LISST, IOP-frame, B) PNF, C) C-OPS, D) HyperSAS (Photo Credit: Lucette Barber, Lisa Matthes, Lucas Barbedos de Freitas)

Water Sampling

^{14}C incubations

Measurements to determine primary production in function of a light gradient were performed at 22 different locations during the cruise (see Table 4). Production vs. Irradiance (PE) curves were measured by incubating sea water, melt pond water and melted scrapes of the bottom ice cores inoculated with ^{14}C. The incubations were conducted according to the radioactive safety guidelines in the Radvan after the protocol of Takuvik (Marcel Babin, Université Laval). The incubator is a custom-made instrument adapted after the one presented in Babin et al. 1994 (Figure 24).

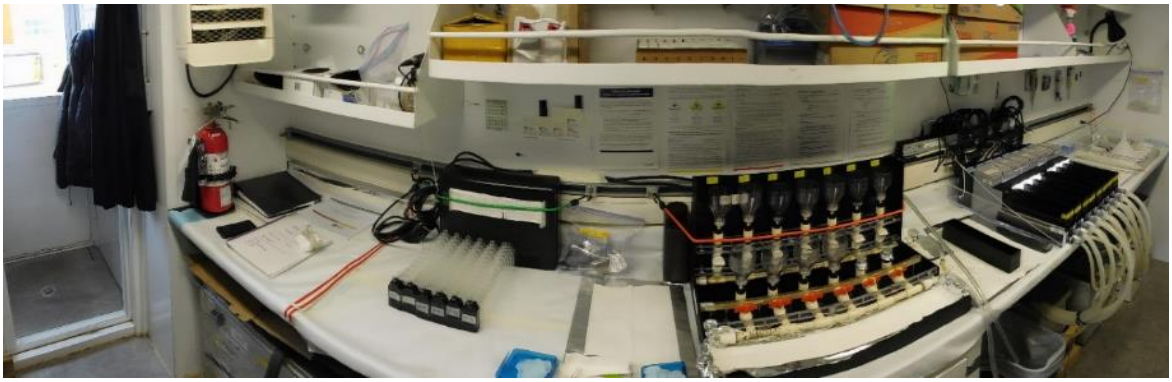

Figure 24 General set-up for the PE incubations in the Radvan. From right to left: inoculation space, incubator, filtration ramp, clean work space (Photo Credit: Rachel Hussherr)

Six or seven incubations were carried out at each station: either 6 optical depths (determined by PAR measurements from PNF 300) in the water column if the station was in open water, or 4 optical depths + ice bottom scrapes + melt pond/ interface water if the station was a mix of open water and sea ice floes. The seawater from each sampled depth was incubated in an individual incubation chamber for 3 to 4 hours depending of the *in situ* production in the water column. After filtration, samples were placed in a Beckman Coulter LS 6500 scintillation counter to count the 14C uptake of algae cells. Afterwards, PE curves (Counts per minute in function of irradiance) were made for every water sample at each station.

Filtrations

Water samples, taken with the rosette from several water depths, were filtered for various parameters (Table 5). Thereby, sampling depths (optical depths, discrete depth levels based on stratification) were in line with the water sampling of other teams to gain a full picture of the biological, chemical and physical processes in the water column. Filtrations took place in the aft filtration lab under green light to minimize photo damage of the studied organic matter.

Table 5 Water sampling parameters collected during Leg 1

Sampling depth	Parameter	Description
Optical depths, Ice samples	Chl *a*	Chlorophyll *a*
Optical depths, Ice samples	HPLC	High-performance liquid chromatography for pigment analysis
Optical depths, Ice samples, Discrete depths	POC/N	Particulate organic carbon and nitrogen
Optical depths, Ice samples, Discrete depths	a_p	Particulate absorption
Ice samples	Taxonomy	Species identification
Discrete depths	TSS	Total suspended sediment
Discrete depths	CDOM/FDOM	Colored dissolved organic matter
Discrete depths	Salinity	Salinity
Discrete depths	$\delta^{18}O$	Oxygen isotopes

Chorophyll *a* was analysed on board with a Fluorometer (Turner 10AU, Turner Designs, USA) following the method described in *Parsons et al. [1984*]. The filters for the analysis of the remaining parameters were stored in the fridge (4°C) or freezer (-80°C) to be transported back to the lab with the crew change. Additionally, water samples were collected for $\delta^{18}O$ and salinity measurements at discrete depth levels. Salinity samples were analysed using the onboard salinometer.

Ice Sampling

To complete data collection for the investigation of spring primary production in Hudson Bay, samples of algae inhabiting the ice bottom were taken at each ice station. The last 5 cm of three ice cores as well as scrapes from the bottom of another three cores were collected to be filtered onboard for the biological parameters listed in table 2 as well as ^{14}C incubations (Figure 25B). Additionally, water from the ice interface and melt ponds were collected via pump for the same objective. However, before ice cores for ice algae biomass were sampled, optical measurements were carried out in the undisturbed area to determine light availability for primary production at the ice bottom. Spectral albedo $\alpha(\lambda)$ of different sea ice surface properties was measured prior to the under-ice light sampling with one hyperspectral radiometer (1 planar RAMSES-ACC, TriOS GmbH, Germany, Figure 25A). Transmitted irradiance beneath the sea ice cover was recorded via a custom-built double-hinged aluminum pole (L-arm) and 3 hyperspectral radiometers (1 planar RAMSES-ACC, 2 scalar RAMSES-ASC, TriOS GmbH, Germany). Finally, ice thickness, freeboard, melt pond depth and snow height were measured at the ice core sampling site.

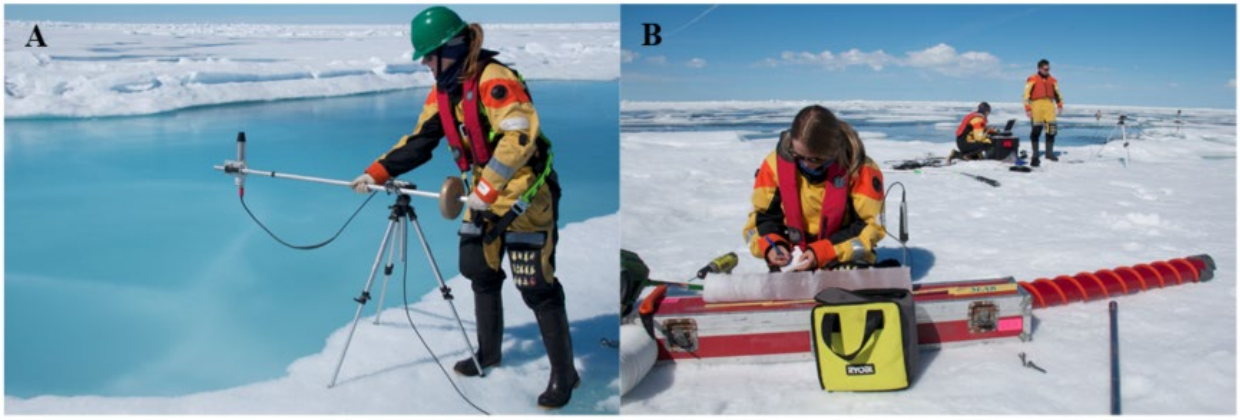

Figure 25 Measurement of surface albedo (A) and ice core sampling (B)

Table 6 Sampled parameters at each station type (Nutrient, Basic, Ice, Transect, Helicopter, River, Estuary)

Date	Station	Station type	Bottom depth [m]	Optical deployment	^{14}C	Chl a	HPLC	POC/ N	a_p	Taxonomy	TSS	CDOM/ FDOM	Sal	^{18}O	Sediment core
31-May	N01	Nutrient	386									x			
31-May	N02	Nutrient	566			x	x	x	x			x			
31-May	Brash	Random				x		x	x						
31-May	N03	Nutrient	419			x						x			
01-Jun	B04	Nutrient	283			x	x	x	x			x			
02-Jun	FB05	Nutrient	245			x	x	x	x		x	x			
02-Jun	FB07	Nutrient	274			x		x	x		x	x	x	x	
02-Jun	FB05-H	Helicopter										x	x	x	x
03-Jun	FB09	Basic	104	x	x	x	x	x	x		x	x			
03-Jun	B10	Nutrient	199			x			x			x	x	x	
04-Jun	B11	Basic	321	x	x	x	x	x	x		x	x			
04-Jun	B11-Ice	Full/Ice										x	x	x	x
04-Jun	H3	Helicopter										x	x	x	
05-Jun	B12	Nutrient	83			x			x			x	x	x	
05-Jun	B13	Nutrient	144			x			x			x	x	x	
05-Jun	B15	Basic	189	x	x	x	x	x	x		x	x			
06-Jun	B16	Full/Ice	132	x	x	x	x	x	x	x	x	x			x
07-Jun	B17	Basic	90			x	x	x	x		x				
08-Jun	B18	Full/Ice	114	x	x	x	x	x	x	x	x				x
09-Jun	B19	Full/Water	86		x	x	x	x	x		x	x			
09-Jun	B19-Wilson	River				x		x				x	x	x	
		Estuary													
09-Jun	B19-Ferguson	River				x		x				x	x	x	
		Estuary													
09-Jun	B19-Zodiak	Transect										x	x	x	
09-Jun	B20	Nutrient	109			x	x	x	x			x	x	x	
10-Jun	B21	Full/Ice	147	x	x	x	x	x	x	x	x	x	x	x	
11-Jun	B22	Full/Water	65	x	x	x	x	x	x		x	x	x	x	
11-Jun	B22-Thanne	River				x		x	x			x			
11-Jun	B22-Thlewiaza	River				x		x	x			x			
11-Jun	B19-Zodiak	Transect										x	x	x	

Date	Station	Station type	Bottom depth [m]	Optical deployment	^{14}C	Chl a	HPLC	POC/ N	a_p	Taxonomy	TSS	CDOM/ FDOM	Sal	^{18}O	Sediment core
11-Jun	B23	Nutrient	110			x	x	x	x			x	x	x	
12-Jun	B24	Full/Ice	185	x	x	x	x	x	x	x	x	x	x	x	
13-Jun	B25	Full/Ice	149	x	x	x	x	x	x	x	x	x	x	x	
14-Jun	B26	Nutrient	129									x	x	x	
15-Jun	B28	Basic	160			x	x	x	x			x			
16-Jun	B29	Full/Water	175	x		x		x	x		x	x			
18-Jun	B31 (AN02)	Nutrient	46			x		x	x		x	x	x	x	
18-Jun	Nelson	River				x		x	x		x	x			
18-Jun	Hayes	River				x		x	x		x	x			
19-Jun	B32	Full/Ice	31	x	x	x	x	x	x		x	x			x
19-Jun	Severn	River				x		x	x		x	x			
19-Jun	B32	Full/Ice										x	x	x	
20-Jun	B33	Nutrient/Ice (Bucket)				x		x	x	x	x	x	x	x	
20-Jun	Winisk	River				x		x	x		x	x	x	x	
20-Jun	B33-H(1-3)	Full/Ice							x			x	x	x	
20-Jun	B34	Full/Ice	45	x	x	x	x	x	x		x	x	x	x	
21-Jun	B34b	Full/Ice		x		x	x	x	x	x		x	x	x	x
21-Jun	B34b-Z	Full/Water				x		x	x		x	x	x	x	
21-Jun	B35	Nutrient	60			x		x	x		x	x			
22-Jun	B36	Full/Ice	126	x	x	x	x	x	x	x	x	x	x	x	x
22-Jun	B36-HA	Helicopter				x						x			
22-Jun	B36-HB	Helicopter				x						x			
22-Jun	B36-HC	Helicopter				x						x			
22-Jun	B36-HD	Helicopter				x						x			
23-Jun	B38	Full/Ice	179	x	x	x	x	x	x		x	x			x
24-Jun	B39	Nutrients	180									x	x	x	
24-Jun	B40	Basic/Ice	90	x	x	x	x	x	x		x	x			
27-Jun	B15-2	Nutrient	190			x	x	x	x			x	x	x	
27-Jun	L1	TSG				x	x	x	x						
27-Jun	L2	TSG				x	x	x	x						
27-Jun	L3	TSG				x	x	x	x						
28-Jun	B44	Basic	104	x	x	x	x	x	x		x	x	x	x	
29-Jun	Nelson-A	River	~5	x	x	x	x	x	x		x		x	x	
29-Jun	N-B	River	~5	x	x	x	x	x	x		x		x	x	
29-Jun	South-Transect	Estuary				x	x	x	x		x				
30-Jun	B45-R	Water			x	x	x	x	x		x		x	x	
30-Jun	N-C	River		x	x	x	x	x	x		x		x	x	
30-Jun	N-D	River		x	x	x	x	x	x		x		x	x	
01-Jul	B46-R	Water		x	x	x	x	x	x		x		x	x	
01-Jul	West-Transect	Estuary	15										x	x	

Preliminary results

Location of the Highest Chlorophyll *a* Concentration

The surface chlorophyll maximum (SCM) is shallower in low productive areas (close to the coast, ice edge and eastern entrance to Hudson Bay) compared to the very productive area in the center of the open water in the north-west of the bay (Figure 26). In this area, nutrients must have been completely depleted in the surface water column, so that a high phytoplankton abundance is only visible on top of the pycnocline through which nutrients diffuse from the richer bottom water layer. The southern part also showed a shallow SCM and a low phytoplankton concentration which could be related to the high ice coverage and an existing light limitation.

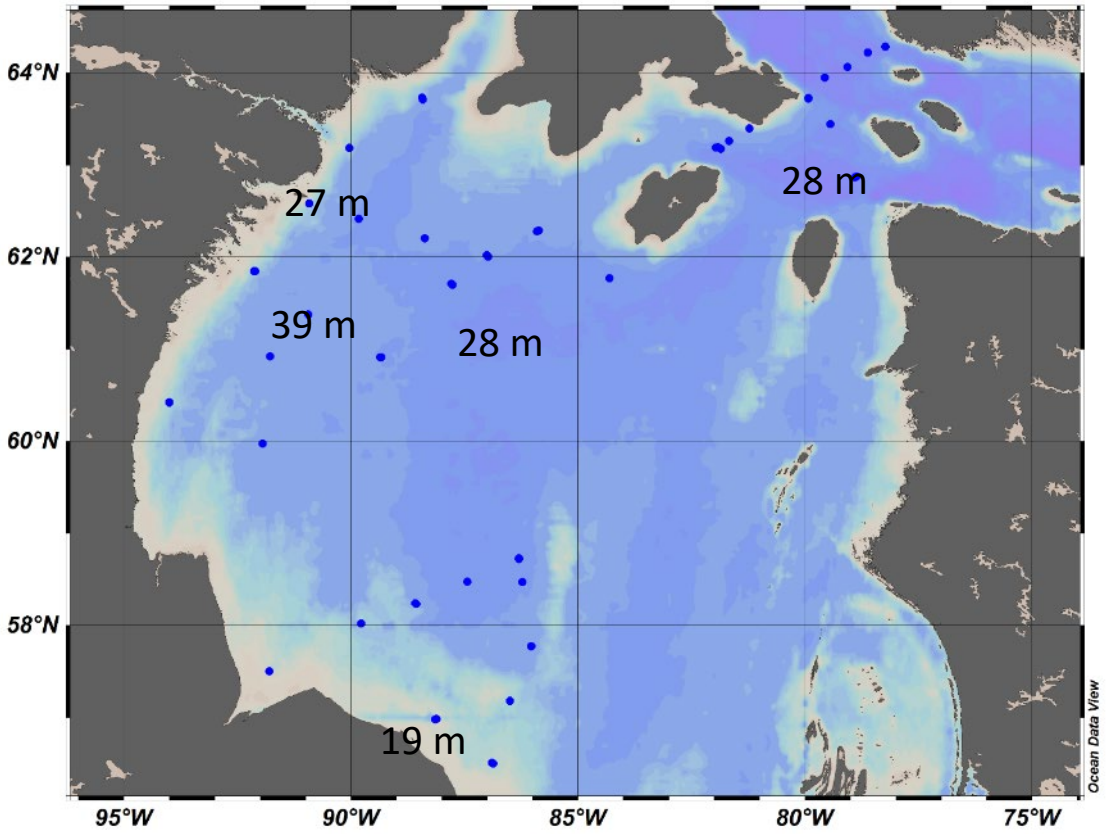

Figure 26 Depth of the surface chlorophyll maximum

Chlorophyll Concentration in the Water Column and Ice Bottom

The concentration of chlorophyll *a* as a proxy for phytoplankton and ice algae abundance was measured at 6 optical depths in open and ice-covered water column, at the ice bottom and upstream of several rivers (Figure 27). Chlorophyll *a* concentration was higher at the SCM compared to the surface water layer. At the ice bottom, chlorophyll *a* concentration was much higher than expected. This is probably related to the large observed abundance of filamentous algae (genus *Melosira*) hanging down from the ice bottom in northern Hudson Bay. In southern Hudson Bay, a lower ice algae abundance was observed which could be related to the late sampling time (bloom terminated) and/or a higher freshwater concentration in the surface water layer. Chlorophyll *a* concentration of sampled rivers was lower at the north-west coast compared to the south coast. The highest concentration was measured in the Hayes River.

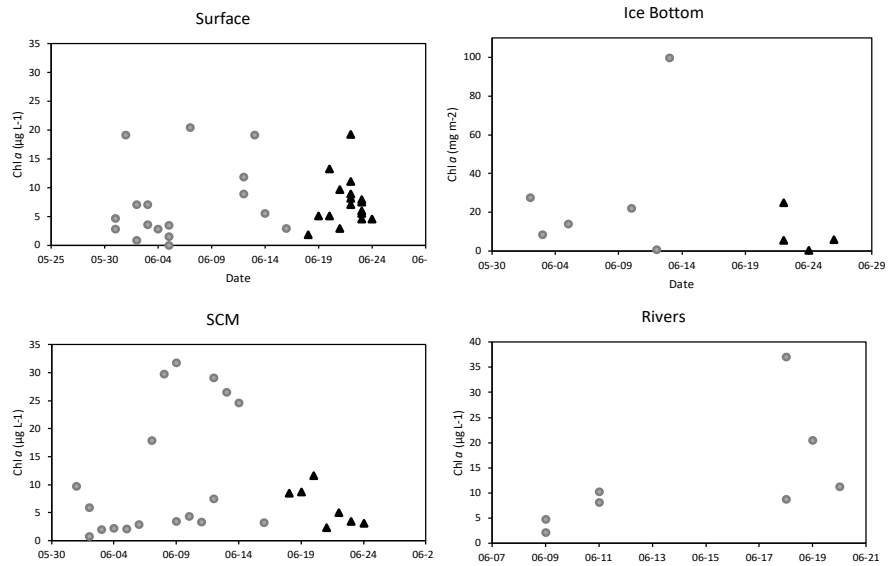

Figure 27 Chlorophyll a concentration sampled at the water surface in north-west Hudson Bay (grey) and south Hudson Bay (black), at the depth of the surface chlorophyll maximum (SCM), the ice bottom and upstream of rivers at the west and south coast of Hudson Bay

Additional Observations in the Nelson-Hayes Estuary

Ship- and ice-based observations described above were supplemented using the ship's barge and Zodiac to sample across salinity gradients in the Nelson-Hayes estuary (Figure 28). Stations NA, NB (barge) and S1–S3 (Zodiac) were visited on 29 June; NC, NC (Zodiac) and BN3–BN7 (barge) and were visited on 30 June. W1–W3 were sampled on 1 July by rosette from the Amundsen. Stations NA and BN3 were in fresh water. At stations S1-S3, water was collected for Team Optics/Biology by the carbon and mercury teams.

Surface water samples collected at each station were filtered for TSS, a_p, chlorophyll a and CDOM. The frame with attached inherent optical properties instruments (Wetlabs AC-S, BB9, BB3, CTD-probe, fluorometer) and the LISST instrument were deployed at stations NA and NB only (Atreya Basu). The Compact Optic Profile System was used to record radiometric profiles of light extinction at stations NA, NB and BN3–BN7 (Lucas Barbedos De Freitas). An Idronaut CTD was deployed at all Zodiac stations to record profiles of conductivity, temperature and optical backscatter. A Seabird 19+ CTD was deployed at barge stations to record conductivity, temperature, oxygen, chlorophyll fluorescence, CDOM fluorescence, beam transmission, and photosynthetically-active radiation through the water column. (The Seabird 19+ was also deployed from the Zodiac and/or from the ice at stations 32, 33, 34, 36, 38 and 40 in southern and south-central Hudson Bay to record profiles away from upper water column disturbance by the ship's thrusters.)

Figure 22 also shows locations of sediment samples MF1–MF4, collected from the tidal mud flats on 30 June. Samples were collected at 0–5 and 10–15 cm depth at each location.

Figure 28 Stations sampled by barge or Zodiac in the Nelson-Hayes estuary. The map on the right shows station locations in the area bounded by the box in the map on the left. Waypoints were recorded at the beginning and end of the period of observations and sampling at stations BN3-BN7. Similar drift at other stations in the estuary was not recorded.

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Zooplankton and Fish Ecology/Acoustics

Principal Investigator: Louis Fortier[1]. Cruise participants: Cyril Aubry[1], Sarah Schembri[1] and Tommy Pontbriand[1]

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Introduction and Objectives

The main objective of our team during Leg 1 was the monitoring of key parameters (abundance, diversity, biomass and distribution) for zooplankton and fish using various sampling devices and the EK60 echosounder. The specific objectives were to:

- Compare zooplankton and fish species assemblages in different areas of the Hudson Bay system: comparison of coastal species assemblages with off-shore ones; comparison between the West, South and East coasts of the Hudson Bay.
- Find out which fish species develop in estuaries and along the ice-edge during the spring-melt season.
- Capture adult fish in Hudson Bay for the first time.

Operations Conducted and Methodology

The following is a list of the operations that were conducted during the Leg 1 campaign.

Double Square Net (DSN) (1 × 750µm, 1 × 500µm, 1 × 50µm)
The Ichtyoplankton net is a rectangular frame carrying two 4.5 m long, 1 m² mouth aperture, square-conical nets and an external 10 cm diameter, 50 µm mesh net (to collect microzooplanktonic prey of the fish larvae). The DSN was equipped with three KC® flowmeters; one for the 750 µm net, one for the 500 µm net and a control flowmeter between the two nets. The sampler was towed obliquely from the side of the ship at a speed of ca. 2-3 knots to a maximum depth of 90m (depth estimated during deployment from cable length and angle; real depth obtained afterward from a Star-Oddi® mini-CTD attached to the frame). For on board analysis, all fish larvae collected with the DSN were identified, measured and preserved individually in 95% ethanol + 1% glycerol. Zooplankton samples from the 500 µm mesh and the 50 µm mesh nets were preserved in 10% formalin solution for further taxonomic identification. The zooplankton from the 750 µm mesh net was given to the contaminant team (Ainsleigh Loria, PI: Gary Stern) for mercury and pollutant analysis.

5 Net Vertical Sampler (5NVS) (3 × 200µm, 1 × 500µm, 1 × 50µm)
The zooplankton sampler is made up of four 1 m² metal frames attached together and rigged with four 4.5 m long, conical-square plankton nets, an external 10 cm diameter, 50 µm mesh net. The 5NVS was equipped with five KC Denmark ® flowmeters – each of the nets with a

mesh size larger than 50 µm was equipped with a flowmeter and a control flowmeter was attached on the centre of the frame. The sampler was deployed vertically from 10 meters off the bottom to the surface. After removal of any fish larvae/juveniles (identified, measured and preserved separately in 95% ethanol + 1% glycerol), zooplankton samples from the 500 µm, 50 µm and one of the 200 µm mesh nets were preserved in 10% formaldehyde solution for abundance measurements. The zooplankton from the second 200 µm mesh net were split into fractions (depending on the size of the sample); one fraction was preserved in alcohol for genetic analysis and a second fraction was divided into zooplankton smaller and larger than 1000 µm, dried and frozen for biomass analysis. The third 200 µm mesh net was given to Ainsleigh Loria (PI: Gary Stern) for contaminant analysis.

Hydrobios (9 × 200 µm)
The hydrobios is a multi-net plankton sampler. The hydrobios is equipped with nine 200 µm mesh nets (opening 0.5 m^2). This allows for depth specific sampling of the water column. The Hydrobios is also equipped with a CTD to record water column properties while collecting biological samples. The deployment is vertical from 15 m off the bottom to the surface. The nets open and close one by one as the pressure decreases while the net is going up in the water column. The depth at which the different nets open and close is programmed prior to deployment. The zooplankton samples were preserved in 10% formalin solution for further taxonomic identification.

Benthic Beam Trawl

This trawl includes a Demersal fish sampler. It is a rectangular net with a 3 m^2 mouth aperture, 32 mm mesh size in the first section, 16mm in the last section, and a 10 mm mesh liner. The net was lowered on the seafloor and towed for 5 to 20 minutes at a speed of 3 knots. Adult fish collected with this sampler were identified, measured and stored at -20^{0}C while larvae were preserved in 95% ethanol + 1% glycerol.

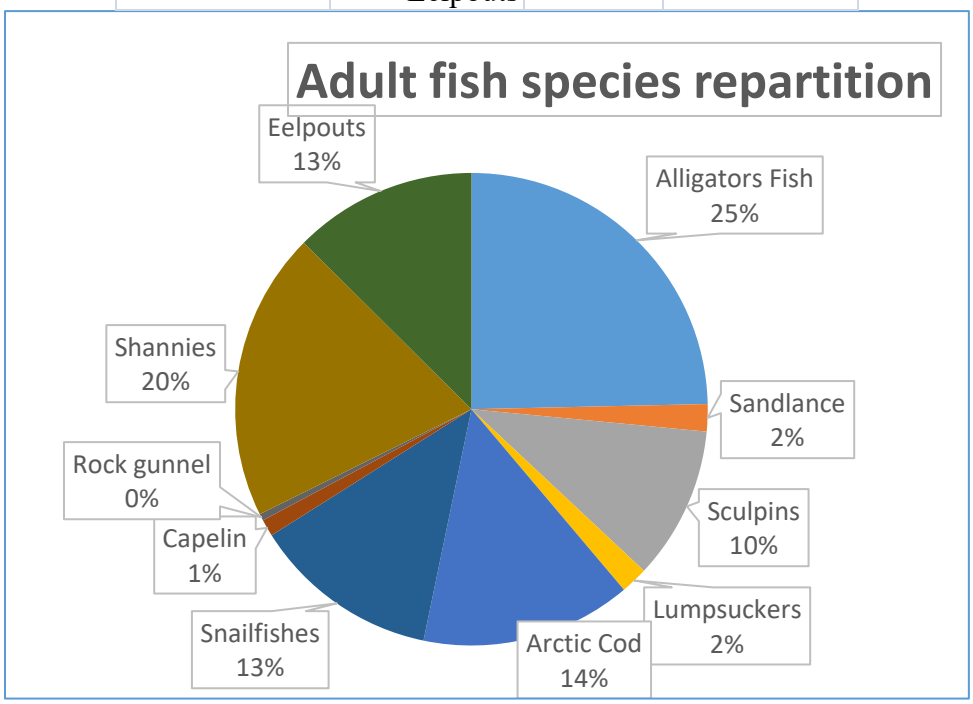
Ring Net
Small ichtyoplankton net, 3.25 m long conical net with a circular 65 cm diameter opening and 500 µm mesh size. A TSK flowmeter is attached to the opening. The ring net was deployed from the zodiac or barge in river estuaries or when heavy ice cover prevented the use of the DSN. The net is towed from the back of the zodiac at about 2 to 3 kts, about 30 m of rope is deployed. All fish larvae collected were identified, measured and preserved individually in 95% ethanol + 1% glycerol.

Acoustic Monitoring. The Simrad® EK60 echosounder of the *CCGS Amundsen* allows our group to continuously monitor the spatial and vertical distribution and biomass of zooplankton and pelagic fish that have a swim bladder such as cod (*Boreogadus saida*) and capelin (*Mallotus villosus*). The hull-mounted transducers are in operation 24h a day thus providing an extensive mapping of where the fishes are along the ship track.

Preliminary Results

Table 7 Summary of fish catches

Fish Family	Common Name	Adult	Larvae
Agonidae	Alligators Fish	106	62
Ammodytidae	Sandlance	8	274
Cottidae	Sculpins	45	742
Cyclopteridae	Lumpsuckers	8	3
Gadidae	Arctic Cod	62	43
Gasterosteidae			1
Liparidae	Snailfishes	55	149
Osmeridae	Capelin	5	13
Pholidae	Rock gunnel	2	3
Stichaeidae	Shannies	85	1066
Unidentified			73
Zoarcidae	Eelpouts	54	5



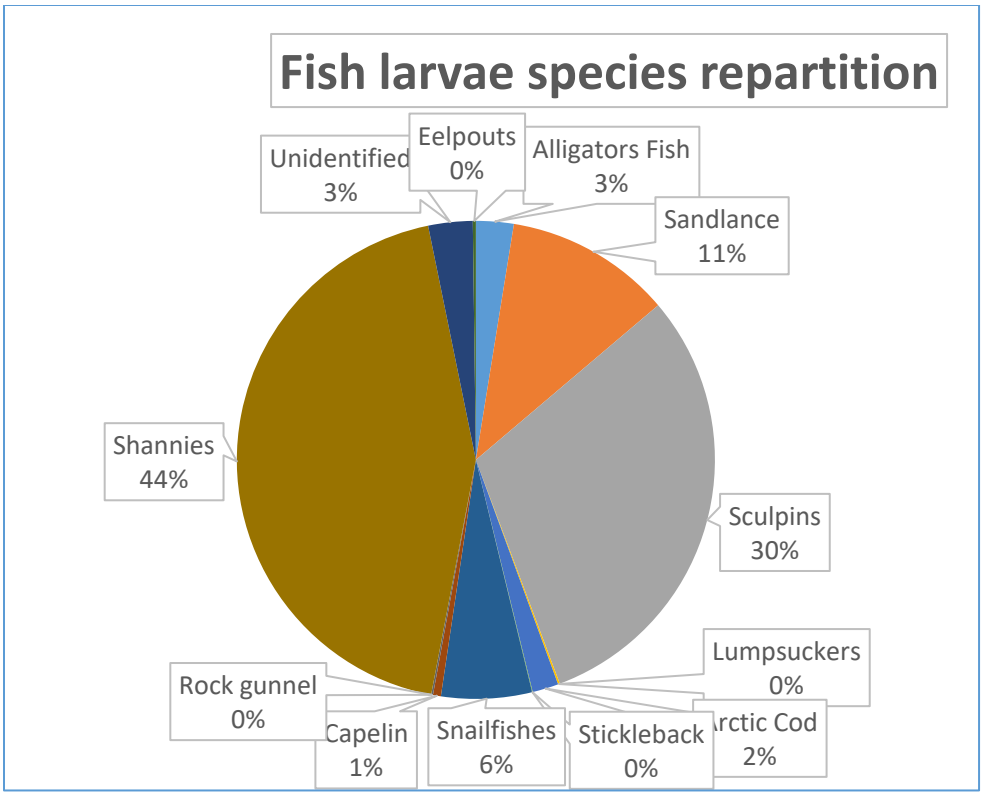


Table 8 Summary of net operations

Station	Sampling_date	4x1m2 (vertical)	2x1m2 (oblique)	Beamtrawl	Hydrobios	Ringnet 0.60m	Ringnet 1m
04	01 Jun 2018	X					
05	02 Jun 2018	X					
09	03 Jun 2018	X	X	X			
10	04 Jun 2018	X	X	X			
11	04 Jun 2018	X					
15	05 Jun 2018	X	X	X			
16	06 Jun 2018	X	X	X			
17	07 Jun 2018	X					
17a	07 Jun 2018					X	
17b	07 Jun 2018					X	
18	08 Jun 2018	X	X	X	X		
19	09 Jun 2018	X	X	X			
19c	09 Jun 2018					X	
21	10 Jun 2018	X	X	X	X		
22	11 Jun 2018	X	X	X			
22a	11 Jun 2018					X	
24	12 Jun 2018	X			X		
25	13 Jun 2018		X		X		

28	15 Jun 2018	X	X	X			
29	16 Jun 2018	X	X	X			
32	19 Jun 2018	X					
32a	19 Jun 2018					X	
34	21 Jun 2018		X				
36	22 Jun 2018	X			X		
38	23 Jun 2018		X				
40	24 Jun 2018	X					
43	27 Jun 2018		X	X			
44	28 Jun 2018		X	X	X		
45	30 Jun 2018			X			
46	01 Jul 2018	X	X	X			
BN3	30 Jun 2018						X
BN5	30 Jun 2018						X
BN7	30 Jun 2018						X

Marine productivity: Carbon and nutrients fluxes

Principal Investigator: Jean-Éric Tremblay[1]. Cruise Participants: Jonathan Gagnon[1], Janghan Lee[1], Kasey Cameron-Bergeron[1]

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Introduction and Objectives

The Arctic climate displays high inter-annual variability and decadal oscillations that modulate growth conditions for marine primary producers. Much deeper perturbations recently became evident in conjunction with globally rising CO_2 levels and temperatures (IPCC 2007). Environmental changes already observed include a decline in the volume and extent of the sea-ice cover (Johannessen et al. 1999, Comiso et al. 2008), an advance in the melt period (Overpeck et al. 1997, Comiso 2006), and an increase in river discharge to the Arctic Ocean (Peterson et al. 2002, McClelland et al. 2006) due to increasing precipitation and terrestrial ice melt (Peterson et al. 2006). Consequently a longer ice-free season was observed in both Arctic (Laxon et al. 2003) and subarctic (Stabeno & Overland 2001) environments. These changes entail a longer growth season associated with a greater penetration of light into surface waters, which is expected to favoring phytoplankton production (Rysgaard et al. 1999), food web productivity and CO_2 drawdown by the ocean. However, phytoplankton productivity is likely to be limited by light but also by allochtonous nitrogen availability. The supply of allochtonous nitrogen is influenced by climate-driven processes, mainly the large-scale circulation, river discharge, upwelling and regional mixing processes. In the global change context, it appears crucial to improve the knowledge of the environmental processes (i.e. mainly light and nutrient availability) interacting to control phytoplankton productivity in the Canadian Arctic. Also, changes in fatty acid proportions and concentrations will reflect shifts in phytoplankton dynamics including species composition and size structure, and will reveal changes in marine energy pathways and ecosystem stability[123].

The main goals of our team were to establish the horizontal and vertical distributions of phytoplankton nutrients and to measure the primary production located at the surface of the water column using O2/Ar ratios and tracers incubations. Auxiliary objective was to calibrate the *ISUS* nitrate probe attached to the Rosette.

Operations Conducted and Methodology

Samples for inorganic nutrients (ammonium, nitrite, nitrate, orthophosphate and orthosilicic acid) were taken at all NUTRIENTS/BASIC/FULL stations (Table 8) to establish detailed vertical profiles. Samples were stored at 4°C in the dark and analyzed for nitrate, nitrite, orthophosphate and orthosilicic acid within a few hours on a Bran+Luebbe AutoAnalyzer 3 using standard colorimetric methods adapted for the analyzer (Grasshoff et al. 1999). Additional samples for ammonium determination were taken at stations where incubations were performed and processed immediately after collection using the fluorometric method of Holmes et al.

(1999). A quadrupole mass spectrometer (PrismaPlus, Pfeiffer Vacuum) was used to measure the dissolved gases (N2, O2, CO2, Ar) coming for the underway seawater line located in the 610 laboratory. O2 to Ar ratios will later be analyzed to measure primary production that occurred up to 10 days prior of the ship's passage in all the areas visited.

To examine the potential effects of environmental conditions (e.g. acidity, alkalinity, free C02) on energy transfer through food chain, we realized at Full and Basic stations, 3L filtration in duplicate from water surface and SCM with pre-combusted GF/C, to analyse the lipids composition, which is the densest form of energy, in particulate organic matter. Samples of 100 to 1000 mg of earlier and adult stage of copepods were also realized and stored on GF/F filters by -80°C to aims our objectives. Moreover, the pH of SCM and surface water has been measured by spectrophotometer by using red phenol and cresol purple colorants. Then we stored 500 ml of water from each depth to determine the alkalinity in laboratory as soon as possible after the end of the mission. Finally, we continue the long-term analysis conducted during previous year such as filtration of POC/PN, POP, BSi and incubation of phytoplankton with 15N. To determine nitrate, ammonium and urea uptake rates and primary production, water samples from the surface were incubated with 15N and 13C tracers. The bottles were then incubated for 24 h using on deck incubator and light controlled incubators to establish the relation between photosynthesis and irradiance. After 24 h, the water samples were filtered through a pre-combusted GF/F filters and the filters dried for 24 h at 60°C for further analyses. Nutrients at T_0 were measured with the Auto-Analyzer. Incubations were then terminated by filtration through a pre-combusted GF/F filters and stored for further analyses. Isotopic ratios of nitrogen and carbon from all GF/F filters will further be analyzed using mass spectrometry.

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Table 9 List of sampling stations and measurements during Leg 1

						Filtrations								Incubations			
Station	Cast	Nutrients	NH4	15N-NO3	Urea	Ab. Nat. POM	Total Sele.	POP	Bsi	PIC	POC PN	Lipids POM	Taxo	Upt. NH4	Upt. NO3	Upt. Urea	N2 Fix
1	1	x		x													
2	2	x		x													
3	3	x		x													
4	4	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
5	5	x		x													
6	6	x		x													
7	7	x		x													
8	8	x		x													
9	9	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
9	10	x		x													
10	11	x		x													
11	12	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
11	13	x		x													
12	14	x		x													
13	15	x		x													
15	17	x		x													
15	18	x		x													
16	19	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
16	20	x		x													
17	21	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
18	22	x		x													
18	23	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
19	24	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
19	25	x		x													
20	26	x		x													
21	27	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
21	28	x		x													
22	29	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
22	30	x															
23	31	x	x		x	x		x	x	x	x		x				
24	32	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
24	33	x		x													
25	34	x		x													
25	35	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
26	36	x		x													
27	37	x		x													
28	38	x	x		x	x		x	x	x	x		x				
29	39	x		x													
31	40	x		x													
32	41	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
32	42	x															
34	43	x	x		x	x		x	x	x	x		x	x	x	x	x
34	44	x		x													
35	45	x		x													
36	46	x		x													
36	47	x	x		x	x		x	x	x	x		x	x	x	x	x
37	48	x		x													
38	49	x	x		x	x		x	x	x	x		x	x	x	x	x
38	50	x		x													
39	51	x		x													
40	52	x	x		x	x		x	x	x	x		x	x	x	x	x
40	53	x		x													
41	54	x		x													
15B	55	x															
44	56	x	x		x	x		x	x	x	x		x	x	x	x	x
44	57	x		x													
45	58	x	x		x	x		x	x	x	x		x	x	x	x	x
45	59	x	x		x	x		x	x	x	x		x	x	x	x	x
W-T 01	60	x		x													
W-T 02	61	x		x													
W-T 03	62	x		x													
46	63	x	x		x	x		x	x	x	x		x	x	x	x	x
46	64	x		x													
9	ice	x	x			x	x	x	x	x	x	x	x				
H3	ice	x	x			x	x	x	x	x	x	x	x				
16	ice	x	x			x	x	x	x	x	x	x	x				
NE01	from the barge	x	x	x	x	x		x	x	x	x		x	x	x	x	x
NE02	from the barge	x	x	x	x (?)	x		x	x	x	x		x				
NE03	from the zodiac	x	x	x	x	x		x	x	x	x		x	x	x	x	x
NE04	from the zodiac	x	x	x	x	x		x	x	x	x		x	x	x	x	x
Wilson	from the helicopter	x	x	x	x	x		x	x	x	x		x	x	x	x	x
Ferguson	from the helicopter	x	x	x	x	x		x	x	x	x		x	x	x	x	x
Tha-Anne	from the helicopter	x	x	x	x	x		x	x	x	x		x	x	x	x	x
Thlewiaza	from the helicopter	x	x	x	x	x		x	x	x	x		x	x	x	x	x
Nelson	from the helicopter	x	x	x	x	x		x	x	x	x		x	x	x	x	x
Hayes	from the helicopter	x	x	x	x	x		x	x	x	x		x	x	x	x	x
Severn	from the helicopter	x	x	x	x	x		x	x	x	x		x	x	x	x	x
Winisk	from the helicopter	x	x	x	x	x		x	x	x	x		x	x	x	x	x
Seal	from the helicopter	x	x	x	x	x		x	x	x	x		x	x	x	x	x
Knife	from the helicopter	x	x	x	x	x		x	x	x	x		x	x	x	x	x
Churchill	from the helicopter	x	x	x	x	x		x	x	x	x		x	x	x	x	x
Churchill	Zodiac	x	x	x	x			x	x	x	x		x	x	x	x	

Macrofauna Diversity across Hudson Bay Complex

Principal Investigator: Philippe Archambault[1]; Cruise Participant: Marie Pierrejean[1]; Catherine Van Doorn[1]

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Introduction and Objectives

Most epibenthic (*i.e.* benthic organisms living at the surface of sediments) and endobenthic (*i.e.* living inside the sediments) are either sessile or have low mobility. They are therefore directly affected by changes in their environment. For instance, global change affects physical parameters such as sea ice extent and thickness, but also impacts ecosystem functioning and the structure of food webs including those of benthic communities (Darnis et al. 2012, Kedra et al. 2015). Benthic invertebrates of the Hudson Bay Complex are exposed to two major stresses in space and time: climate change and freshwater discharge from several rivers (Grant Ingram and Prinsenberg 1998). These stressors will also likely cause an increase in shipping transport (Arctic-Council 2009) through the expansion of fisheries in the Hudson Bay Complex or shipping activities (e.g. Churchill and Deception Bay ports) and the establishment of aquatic invasive species because of ballast water (Goldsmit et al. 2017). The RCP8.5 emission scenario predicts a salinity anomaly greater than or equal to -0.5 PSU along coastlines (NOAA-ESRL). In addition to climate-induced changes, freshwater discharge along the coastlines will show notable increase in the southeastern portion of the Nelson basin (Clair et al. 1998, McCullough et al. 2012). This could have great consequences on ecological communities, as salinity gradients control species richness (Witman et al. 2008) and can influence the distribution of species.

Many studies have shown a temporal shift in Arctic benthic communities (Cusson et al. 2007; Renaud et al. 2007; Taylor et al. 2017), but data for the Hudson Bay Complex are scarce and few recent data are available. However, knowledge on benthic biodiversity in the Hudson Bay Complex has increased during the past decade thanks to scientific programs like MERICA (2003), ArcticNet (2010), CHONe (Snelgrove et al. 2012), BaySys (2016), and BriGhT (Bridging Global Change, Inuit Health and the Transforming Arctic Ocean) (2017). The main objective is to describe benthic communities in the Hudson Bay Complex and to determine the relationship between the distribution of organisms and environmental parameters. In the second time, to link the presence of a given community with environmental parameters, a community distribution model will be developed.

Operations Conducted and Methodology

At 22 stations, the Agassiz trawl (Figure 29) was deployed to collect macrofauna (Table 10). Catches were passed through a 2 mm mesh sieve. When possible, specimens were identified to the lowest taxonomic level, then count and weight. The unidentified specimens were preserved

in a 4% seawater-formalin solution. Fishes collected and some benthic organisms were kept for Fortier's laboratory and contaminants. Corals and sponges were preserved.
At 21 stations, the box core was deployed to quantitatively sample diversity, abundance and biomass of infauna and to sample sediment. Unfortunately, the bottom of XX sites was sandy or rocky and the sampling was not possible. Sediments of a surface area of 0.125 m^2 and 10-15 cm in depth were collected and sieved through a 0.5 mm mesh and preserved in a 4% formaldehyde solution for further identification in the laboratory (Table 9). Sub-cores of sediments were collected for sediment pigment content, organic matter and sediment grain size; for sediment pigments, the top 1 cm was collected, although for sediment grain size, the top 5 cm was collected. Sediment pigment samples were frozen at -80°C, and organic matter and sediment grain size samples were frozen at -20°C.

Figure 29 Sampling with the agassiz trawl

The small benthic trawl was deployed at 4 stations and one time from the barge. It was deployed at a depth of 15 m at station 17 but did not seem to reach the bottom according to the species

found. At station 22, the trawl stayed stuck and got ripped: we were not able to sample. It was fixed for the next station. It was deployed in the Nelson River but we were not able to sample due to the weather. In total, 3 samples were taken at station 17, 19 and 34.

Freshwater Influence on Microbial Communities of the Hudson Bay System

Principal Investigators: Connie Lovejoy[1]; Cruise Participant: Loïc Jacquemot[1]

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Introduction and Objectives

Freshwater is a major component of Hudson Bay System and influence physical, biogeochemical and biological processes within the bay. As part as the BaySys team 3, my project aims to understand the influence of freshwater marine coupling on the microbial communities (protists, bacteria and archaea). My objectives are to identify key environmental factors (salinity, nutrients, temperature, pH) influencing the diversity, distribution and interactions within microbial assemblages at different scales, from the entire Hudson Bay System to local coastal regions of the bay. We will particularly focus on salinity gradient observed in surface at the ice edge and between river and coastal ocean in estuarine systems. In estuaries, combining effects of upstream and downstream processes are known to structure microbial plankton communities and to induce a clear taxonomic transition from river to ocean (Harvey et al., 1997), as they regulate the balance between advection of organisms from adjacent ecosystems (here river and coastal ocean) and selection by local-environmental conditions, predation or competition (Crump et al., 2004; Niño-García et al., 2016; Ruiz-González et al., 2015). Recent molecular techniques such as 16S/18S amplicons sequencing and shotgun metagenomic will allow us to gain further into the structure of plankton communities and the potential genetic adaptations to salinity gradients. We hypothesize that microbial communities' distribution in the Hudson Bay will be drive by freshwater circulation in surface. Some species will present genetic adaptations to these freshwater gradients.

Operations Conducted and Methodology

156 water samples were collected during the mission onboard the CCGS Amundsen (Figure 30). We collected oceanic vertical profiles at 4 depths (surface, SCM, 70m and bottom) with the rosette and surface river water using the zodiac and the helicopter. We also use the zodiac to collect water at the ice edge or under the ice using a pump. Water for environmental DNA was collected into clean acid rinsed carboys of 10L. We immediately filtered 6 litres of water through a 50 um nylon mesh, a 47-mm diameter 3-um polycarbonacte filter and finally through a 0.2 um Sterivex unit (Millipore Canada Ltd, Mississauga, ON, Canada). 3-um filter were folded and placed in 15 ml tubes with RNA-later buffer (ref). RNA-later buffer was added to the Sterivex units and the samples were stored at -80°C until nucleic acid extraction as in Potvin and Lovejoy (2009). Additional water was used to fix cells for flow cytometry, DAPI visualization on inverted microscope and fish analysis. All samples were stored at -80°C.

Figure 30 Locations of samples obtained during the BaySys mission (Leg 1). Blue dot was collected with the rosette and green dot were collected in river by helicopter

Preliminary Results

Laboratory work is necessary (DNA extraction and sequencing) to provide any preliminary results.

BaySys Team 4

Carbon Exchange Dynamics, Air-Surface Fluxes and Surface Climate

Principal Investigator: Tim Papakyriakou[1]; Cruise Participants: Tim Papakyriakou[1] (Leg 1a); Dave Capelle[1] Mohamed Ahmed[2], Rachel Mandryk[1] Yekaterina (Kate) Yezhova[1]

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Introduction and Objectives

The biogeochemical cycling of carbon is continually changing within the Arctic Ocean as a consequence of climate change. In particular, Arctic Seas appear to be fresher, and freshwater in the system strongly impacts seawater carbonate chemistry, including air-sea exchange and rates and patterns of acidification. Of all the Arctic Seas, Hudson Bay receives disproportionately large amounts of river input, and many of largest rivers are regulated for hydroelectric production. The impact of river water on the carbon system depends on water properties, which are closely tied to watershed characteristics and season. Our cruise objectives were to measure principal components of the carbon system across Hudson Bay, including those variables deemed most influential at moderating the transformation, transport and distribution of carbon. Central to the cruise objectives were to include in freshwater from the Bay's major rivers. Measurements were made within the water column, at the air-sea (or air-ice) interface, and in the atmosphere.

Operations Conducted and Methodology

Multiple observation platforms have been utilized throughout the cruise to collect data pertaining to the atmosphere and the surface ocean, such as a meteorological tower on the ship's foredeck, an underway pCO_2 system in the engine room, an underway FDOM system in the engine room, an underway optode / GTD (PIGI) system in the forward lab, and radiation sensors above the wheelhouse of the ship (Figure 31), the ship's rosette, and distributed sampling by helicopter, small boat and on sea ice.

Automated Systems
Table 9 lists the variables that are monitored, the location where the sensor is installed and height, along with the sampling and averaging frequency (if applicable).

Table 10 Summary of variable inventory and instrumentation. Deck height above sea surface was measured on 27-May at 6.4 m

Variable	Instrumentation	Location	Ht above Main Deck (m)	Ht above sea srfc	Sample/Ave Frequency (s)
Air temperature (Ta)	HMP155A	foredeck tower	8.74	15.14	1 / 60
relative humidity (RH)	HMP155A	foredeck tower	8.74	15.14	1 / 60
wind speed (ws-2D)	RM Young 05106-10	foredeck tower	10.45	16.85	1 / 60
barometric pressure (Patm)	RM Young 61302V	foredeck tower			
incident solar radiation	Eppley Pyranometer (model PSP)	wheel-house platform	On top of wheelhouse		2 / 60
incident long-wave radiation	Eppley Pyrgeometer (model PIR)	wheel-house platform	On top of wheelhouse		2 / 60
photosynthetically active radiation (PAR)	Kipp & Zonen PARLite	wheel-house platform	On top of wheelhouse		2 / 60
$UV_{A\&B}$	Kipp & Zonen UVS-AB-T	wheel-house platform	On top of wheelhouse		2 / 60
wind speed 3D (u, v, w)	CSAT3 Sonic	foredeck tower	9.29	15.69	0.1 (10 Hz)/60
wind speed 3D (u, v, w, Ts)	Gill Wind Master Pro	foredeck tower	7.68	14.08	0.1 (10 Hz)/60
Atm CO_2 and H_2O	LICOR LI7500A	foredeck tower	9.06	15.46	0.1 (10 Hz)/60
Atm CO_2 and H_2O	LICOR LI7200	foredeck tower	9.06	15.46	0.1 (10 Hz)/60
Atm CO_2, CH_4 and H_2O	LGR	foredeck tower	9.06	15.46	0.1 (10 Hz)/60
rotational motion (accx, accy, accz, r x, r_y, r_z)	Systron Donner MotionPak	foredeck tower	9.15	15.55	0.1 (10 Hz)/60
Underway seawater pCO_2, O_2, temperature (Tsw) and salinity	General Oceanics 8050 pCO_2	under-way system, foreward engine room	~-5 m		3 / 60
Weather conditions	Campbell digital camera (CC5MPX)	wheel-house platform	meteorological parameter		2 min

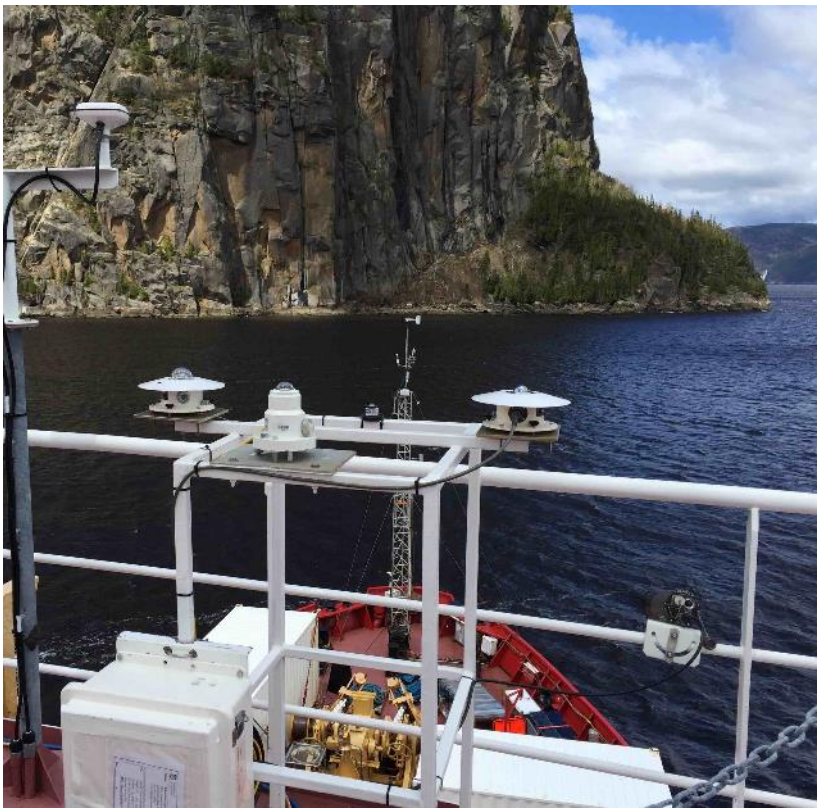

Figure 31 The radiation sensors and digital camera located above the wheelhouse of the Amundsen. Shown are the pyrgeometer (right), pyranometer (left) and PAR sensor (centre back) and UV sensor (centre front). The automated digital camera is mounted on the rail below and to the right of the prygeometer.

The micrometeorological tower located on the front deck of the Amundsen provides continuous monitoring of meteorological variables and eddy covariance parameters (Figure 32). The tower consists of slow response sensors that record bulk meteorological conditions (air temperature, humidity, wind speed/direction) and fast response sensors that record the eddy covariance parameters (CO_2/H_2O/CH_4 concentration, 3D wind velocity, 3D ship motion, air temperature). All data was logged to Campbell Scientific data loggers; a model CR3000 logger was used for the eddy covariance data, a CR1000 logger for the slow response met data. Eddy covariance data were sampled at 10 Hz while slow response sensors were scanned every 2 s and saved as 1-minute averages. All loggers were synchronized to UTC time using the ship's GPS system as a reference. The set-up includes two closed path eddy covariance systems: i) LI-7200 based system (CO_2 and H_2O) and ii) LGR (model) based system (CO_2, H_2O and CH_4). In both systems air was drawn through ½" Synflex® tubing at 10 L/m and ~ 25 L/m, respectively for the LI7200 and LGR systems. Some connections in both systems were ¼". Pressure in the LI7200 was kept within 8%-9% of barometric pressure using a by-pass system that allowed higher flow rates upstream of the gas analyzer, thus allowing for turbulent flow. The LI7200 closed-path system was situated at the base of starboard rail inside a weatherproof enclosure, approximately 3 m from the tower base and approximately 13 m from the intake. Air was partially dried upstream of

the gas analyzer using a nafian drier (Perma Pure PD-100T-48SS) and zero gas generator (Aadco model 747-30). Counter flow through the nafian drier was maintained between 13 and 14 l pm. Periodically, zero and span gas were introduced to the LI7200.

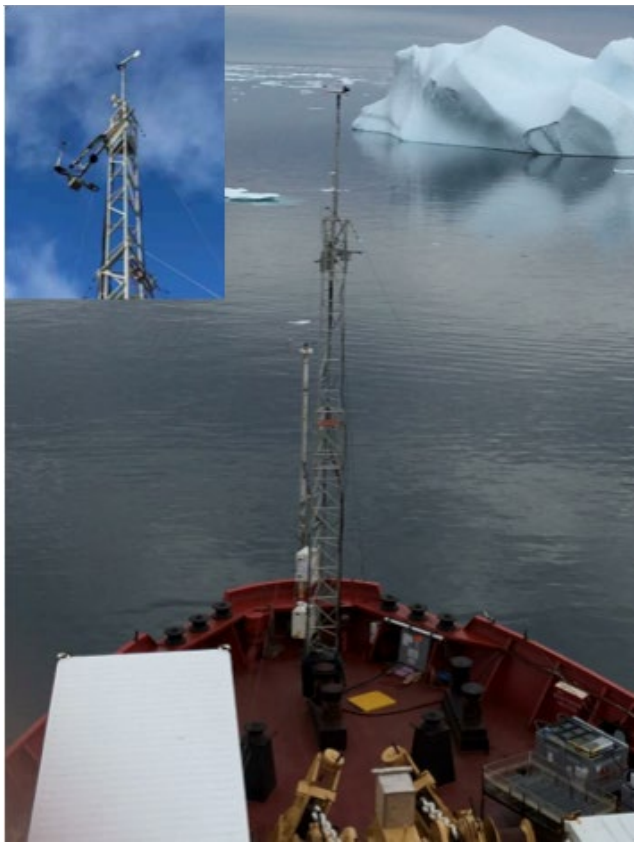

Figure 32 The metrological tower located on the foredeck of the Amundsen with EC flux system (inset)

A digital camera (Campbell CC5MPX) was mounted on the forward rail above the bridge and pointed forward to record the ice cover and sea-state in front of the ship at 2 minute intervals. The camera has a resolution of 5 megapixels, and is housed in an enclosure to protect it from the elements. An internal heater keeps the temperature of the enclosure above 15degC, which helps prevent ice and moisture buildup on the lens. The camera was connected by a 100' long inverted Ethernet cable to the ship's network via a switch in the Met-Ocean container beside the wheelhouse, allowing pictures to be automatically backed up to a data server in the acquisition room.

A General Oceanics 8050 pCO_2 system has been installed on the ship to measure dissolved CO_2 within the upper 5-7 m of the sea surface in near real time (Figure 33). The system is located in the engine room of the *CCGS Amundsen*, and draws sample water from the ship's clean water intake. The water is passed into a sealed container through a shower head, maintaining a constant headspace. This set up allows the air in the headspace to come into equilibrium with the CO_2 concentration of the seawater, and the air is then cycled from the container into an LI-7000

gas analyzer in a closed loop. The system also passes subsample of the water stream through an Idronaut Ocean Seven CTD, which measured this cruise temperature, conductivity, pressure, and dissolved oxygen. All data was sent directly to a computer using software customized to the instrument. Zero and span were set on the LI-7000 every 8 h using ultra-high purity N_2 as a zero gas, and a gas with known CO_2 concentration as a span gas (474.98 ppm). Additionally, air at two different CO_2 concentrations (315.58 ppm, and 585.20 ppm) were run through the system and are traceable to World Meteorological Organization (WMO) standards. Discrete water samples were collected from the water inlet line periodically (~weekly) to calibrate pCO_2, salinity, and Oxygen.

Figure 33 The underway system located in the engine room of the Amundsen

An underway FDOM sensor has been installed on the ship to measure fluorescence within the upper 7m in response of dissolved organic matter in the water (Figure 34). This system located in the engine room on the same intake line that the ship's thermal-salinograph system (TSG) system are using for the purpose of data matching later. The FDOM sensor recording the measurements every 30 sec with an FDOM water samples were collecting every 12h for calibrations. The TSG system recording continuous measurements every second for the sea water temperature, salinity, fluorescence, and sound velocity.

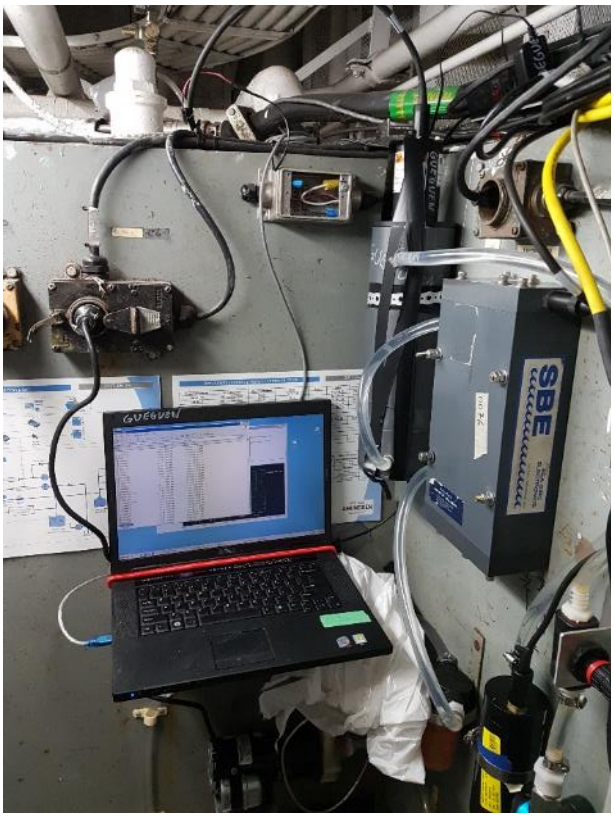

Figure 34 The FDOM underway system located in the engine room beside the ship TSG system

The PIGI (Pressure of In-situ Gases Instrument) has been installed in the forward lab and consist of a 2-stage chamber setup (Figure 35). The first chamber (primary camber) consists of debubbler that allows bubbles to exist from the top and bubble-free water to exist via the bottom. The bubble free water goes to the second chamber, via a downstream pump, that contains two instruments: an Optode and Gas Tension Device (GTD). The optode measures O_2 concentration, and the GTD measures total dissolved gas pressure (which can be used to drive N_2 concentrations.

Figure 35 The underway optode / GTD (PIGI) system installed in the forward lab

Discrete Water Sampling

i) Ship Rosette

Additionally, water samples were collected from the rosette for the analysis of dissolved inorganic carbon (DIC), total alkalinity (TA), stable oxygen and carbon isotopes ($\delta^{18}O$, C^{13}-DIC; C^{13}-CH_4), Ba^+ and other ions, methane (CH_4), dissolved organic carbon (DOC), total dissolved nitrogen (TDN), and salinity. These measurements will allow us to study the carbon chemistry of various water mixtures across the cruise track. The salinity samples were analyzed onboard in the salinometer room by using the AUTOSAL machine to compare it with the salinity log obtained from the CTD rosette and ensure accurate salinity measurements are available for deriving solubility constants for our discrete samples. Other analyses will occur at various labs after the cruise. A complete list of discrete water samples is shown in Spreadsheet 2 (attached Excel file: Baysys_cruise_report_Amundsen_2018_leg01_Team4_Tables.xlsx).

ii) Surface Water Sampling (ship bow, zodiac, skippy boat)

Additional discrete surface samples were collected using a submersible pump and/or horizontal Niskin bottle in order to measure unmixed surface water which is not possible with the ship's rosette. Ideally, samples were collected from the zodiac or skippy boat more than 100m from the ship, but less than 500m. When this wasn't possible, samples were collected from the foredeck immediately upon arrival on station, to maximize the chance of collecting undisturbed water. Three depths were sampled, 0m, 1m, and 7m, and a CTD (Idronaut or Cast-Away) was performed immediately after water sampling. A list of stations with high-resolution surface samples is shown in Spreadsheet 3 (attached Excel file: Baysys_cruise_report_Amundsen_2018_leg01_Team4_Tables.xlsx).

iii) Helicopter Sampling

The helicopter was used to sample from ice floes, rivers, and landfast ice. At each site, ice-water interface water samples were collected, and occasionally a second, deeper sample (7 m), using a submersible pump (Waterra Cyclone pump) powered by a 12V battery. Water was pumped through 3/8" ID vinyl tubing into 250 mL BOD glass bottles with sintered glass stoppers, and 4 L glass jars with narrow mouth plastic screw caps. Samples were stored in the dark and processed/preserved upon return to the ship within 4 hours of sampling, for DIC, TA, 18O, Ba, CH_4, 13C-DIC, 13C-CH_4, salinity, DOC, TDN. Subsampling from the 4L glass bottle was done using a 50 mL glass syringe with a 15 cm long 1/8" ID vinyl tube attached to the end. The syringe was rinsed 3x with sample water and filled without bubbles before rinsing and filling sample bottles, also without bubbles.

CTDs were always performed when water samples were collected by helicopter, up to 50 m depth using an Idronaut.

iv) Ice and Under-ice Water

Ice cores were collected at select ice stations accessed either by the ship's cage or helicopter. Up to 5 x 10cm sections were vacuum sealed from each core and melted at room temperature before subsampling for 18O, Ba, Salinity, DIC, and TA. In many cases only the upper 1m of ice was sampled due to the very thick ice cover and time constraints. Where possible, under ice water was collected by submersible pump and subsampled in the same was as under-ice water collected by helicopter (see above). Ice samples are included in Spreadsheet 2 (attached Excel file: Baysys_cruise_report_Amundsen_2018_leg01_Team4_Tables.xlsx.

Preliminary Results

The data at this time are very preliminary and require additional processing before making reliable inferences, but it appears that the bay is overall under-saturated in pCO_2, suggesting the bay is net autotrophic and a net sink for atmospheric CO_2 during the spring. Unfortunately, no preliminary results from discrete water samples are available at this time.

BaySys Team 5

Contributions of Climate Change and Hydroelectric Regulation to the Variability and Change of Freshwater-Marine Coupling in the Hudson Bay System

Team Leads: Fei Wang[1], Allison Zacharias[2], Sarah Wakelin[2]; Team Members: Zou Zou Kuzyk[1], David Lobb[1], Philip Owens[3] Ellen Petticrew[3], Robie Macdonald[1], Gary Stern[1]; Cruise Participants: Kathleen Munson[1], James Singer[1], Zhiyuan (Jeff) Gao[1], Samantha Huyghe[1], Ainsleigh Loria[1] Punarbasu Chaudhuri[4]

[1]University of Manitoba, [2]Manitoba Hydro, [3]University of Northern British Columbia

Part I: Water and Ice

Principal Investigator: Feiyue Wang[1]; Cruise Participants: Kathleen Munson[1], James Singer[1], Zhiyuan Gao[1]

[1]Center for Earth Observation Science, Department of Environment and Geography, University of Manitoba, Winnipeg, MB, R3T 2N2, Canada

Introduction and Objectives

Mercury is a containment of global concern. Away from industrialized area, mercury is observed to accumulate through food webs in the Arctic marine ecosystem, which provokes concern from northern communities whose daily diet is heavily dependent on Arctic marine biota. The speciation of mercury determines its toxicity, the methylated species are known as a neurotoxin and can cause adverse effect on living organisms. On the other hand, dissolved organic matter (DOM) in the water column plays an important role in regulating mercury redox chemistry and mediating methylation/demethylation capability (Luo et al. 2017; Soerensen et al. 2017). However, the mechanism behind in the seawater is not well understood due to lack of structural and molecular information of marine DOM.

The Canadian Arctic is experiencing a period with extensive influence caused by climate change, which may greatly affect the fate of mercury (Stern et al. 2012). These changes include increased freshwater inputs and changing sea ice conditions.

The objective of this cruise is to build a mercury (total mercury and methylmercury) budget in Hudson Bay by seawater samples collected from the rosette, ice sampling, zodiac, barge and helicopter sampling for rivers and sediment core sampling. Selected water and ice samples will be analyzed for DOM characterization, which may assist in interpreting the fate of mercury in the Arctic. Incubation experiments were conducted using seawater samples from subsurface chlorophyll maximum, oxygen minimum and bottom, as well as in sediment cores to determine the net methylation capability in different Hudson Bay reservoirs to determine their impact on the mass budget of mercury.

Operations Conducted and Methodology

In order to assess the ability to collect contamination-free water samples during Leg 1, we cleaned the Amundsen rosette Niskin bottles in the rosette shack by soaking 0.1% citronax overnight in the bottle. We then rinsed then bottles several times. Random Niskin bottles were tested for contamination by adding reagent grade water (Milli Q) to the bottles and collecting blank tests after the allowing the MQ to sit in the bottle for an hour. Total mercury (THg) was analyzed from each bottle in the Portable In-Situ Laboratory for Mercury Speciation (PILMS). Every bottle tested was found to be clean (below detection limit defined as three times the standard deviation of reagent blank values) for THg analysis.

During the rosette sampling, the door to the rosette shack was closed all the time, both unfiltered and filtered seawater samples were collected from targeted depths, including 10 m, 20 m, 30 m, subsurface chlorophyll maximum, 50 m, 60 m, 80 m, 100 m, 140 m, 160 m, 200 m and bottom. Filtered samples were collected by directly attaching a capsule filter (0.45 μm, Acropak) to the Niskin spigot. Samples were collected in both 250mL amber glass bottles and 50 mL Falcon tubes. Amber glass bottles were preserved with 0.5% HCl and will be transported back to University of Manitoba for methylmercury and total mercury analysis. Samples collected in Falcon tubes were brominated (0.5 % BrCl) for 8 hours and analyzed onboard in PILMS for total mercury analysis on a Tekran 2600 using manufacturer-based adaptations of standard protocols (EPA 1631). A full list of stations collected for mercury analysis is noted in Table 10.

Table 11 Amundsen 2018 Leg 1 rosette water sample collection (HgT: total mercury; MeHg: methylmercury)

Time	Station ID	Latitude	Longitude	Cast type	Depth (m)	deep bottle (m)	Samples collected
18:00:01 31/05/2018	N01 (356)	60.81326	-64.53336	Nutrients	328.75	378	HgT, MeHg
21:56:38 31/05/2018	N02 (354)	60.97350	-64.77335	Nutrients	571.13	555	HgT, MeHg
00:55:43 01/06/2018	N03 (352)	61.15020	-64.80869	Nutrients	430.12	408	HgT, MeHg
21:32:25 02/06/2018	05 (FB01)	64.28652	-78.23075	Nutrients	233.03	228	HgT, MeHg
03:27:11 03/06/2018	07 (FB02)	64.06526	-79.06239	Nutrients	270	259	HgT, MeHg
20:22:26 03/06/2018	09 (FB03)	63.72014	-79.92091	Chem	94.15	91	HgT, MeHg
18:57:02 04/06/2018	11	62.87649	-78.86373	Chem	315.56	300	HgT, MeHg
07:47:48 05/06/2018	12	63.39575	-81.22443	Nutrients	85.78	74	HgT, MeHg
17:40:55 05/06/2018	15	63.17518	-81.84978	Chem	189.97	179	HgT, MeHg
21:28:57 06/06/2018	16	62.28897	-85.85817	Chem	134.24	122	HgT, MeHg, DOM characterization
21:52:02 07/06/2018	17	63.18464	-90.03573	Bio-Chem	88.43	80	HgT, MeHg
08:34:38 08/06/2018	18	63.71367	-88.41683	Chem	115.61	104	HgT, MeHg
15:26:46 09/06/2018	19	61.84652	-92.13222	Chem	78.33	69	HgT, MeHg
17:40:14 10/06/2018	21	60.91036	-89.32936	Chem	149.3	135	HgT, MeHg
14:35:02 11/06/2018	22	60.42076	1000.65000	Chem	63.56	53	HgT, MeHg

22:43:44 12/06/2018	24	61.71082	-87.78786	Chem	188.81	177	HgT, MeHg, DOM characterization
01:19:37 15/06/2018	28	62.41552	-89.83392	Nuts-Chem	163.63	150	HgT, MeHg
13:05:13 16/06/2018	29	61.76978	-84.30910	Chem	176.99	164	HgT, MeHg
18:19:26 18/06/2018	31	57.50009	-91.79532	Nutrients	47.4	37	HgT, MeHg
19:26:14 19/06/2018	32	56.98203	-88.14683	Chem	35.03	24	HgT, MeHg, DOM characterization
01:09:36 21/06/2018	34	56.49983	-86.86875	Chem	43.78	33	HgT, MeHg, DOM characterization
02:42:34 22/06/2018	35	57.17978	-86.49995	Nutrients	61.46	51	HgT, MeHg, DOM characterization
15:19:45 22/06/2018	36	57.77413	-86.03131	Chem	128.34	116	HgT, MeHg, DOM characterization
03:07:08 23/06/2018	37	58.46892	-86.22553	Nutrients	169.68	157	HgT, MeHg, DOM characterization
19:17:04 23/06/2018	38	58.73043	-86.30196	Chem	180.99	168	HgT, MeHg, DOM characterization
18:47:11 24/06/2018	40	58.23979	-88.58159	Chem	87.07	75	HgT, MeHg, Methylation incubation
	43 (15 rep)			Chem	189.97	100	HgT, MeHg
	44			Chem		91	HgT, MeHg, DOM characterization
	45			Bio-Chem	18	10	HgT, MeHg, Methylation incubation

In order to determine the magnitude of the sea ice mercury reservoir in Hudson Bay, ice cores were collected at selected ice stations and sectioned *in situ* on the ice floes. Cores were collected using a core barrel (9 cm ID, Kovac Mark II). In order to keep samples free of contamination, ice sections were trimmed using ceramic knife to remove the outer ice layer that came into contact with the core barrel. Trimmed sections were transported in double Ziploc bags and melted at room temperature in PILMS. Unfiltered ice melts were poured off for methylmercury and total mercury analysis and filtration (0.45 μm Pall filtere, Nalgene filter cups) under low pressure (~10 psi) using a vacuum pump in PILMS. Both filtered and unfiltered ice melts were preserved according to the same method as seawater samples. Ice interface waters and melt pond waters were collected in some stations. The details of ice samples are noted in Table 11.

Table 12 Stations sampled for ice

Time	Station ID	Latitude	Longitude	Sampled by
	5			Helicopter
	9_H3			helicopter
18:44:48 06/06/2018	16	62.27823	-85.89189	Ice cage
20:10:02 08/06/2018	18	63.72603	-88.32335	Ice cage
14:36:36 13/06/2018	25	61.99977	-86.97196	Ice cage
18:27:09 23/06/2018	38	58.72937	-86.30572	Ice cage

Additional samples were collected from surface waters during helicopter and zodiac deployments to ice and open water stations. Because the upper water is both subject to mixing and mercury contamination from the ship, surface (< 10 m) samples cannot be collected from the rosette. Instead, surface water, including interface water under ice floes, was collected using a battery powered submersible cyclone pump (Proactiv, 12V). The pump and tubing were tested for total mercury contamination prior to sample collection and compared to values obtained using a Go-Flo bottle. For each station, blanks were collected on site to test sampling environment.

Table 13 River estuary sampling by Barge and Zodiac

Date	Time (UTC)	Name	Latitude	Longitude
2018-06-7?	After visit hydr	River 1 ice edge (chesterfield inlet) St17	63.3738	-90.630833
2018-06-7	After visit hydr	River 1 intermediate St17	63.285	-90.353333
2018-06-7	After visit hydr	River 1 rosette St17	61.191666	-90.541666
2018-06-8	19:29	St18 skippy	63.7313862	-88.3224324
2018-06-10	19:39	St19	61.9570016	-92.2719114
2018-06-11	17:17	St22 estuary	60.479666	-94.563833
2018-06-11	18:15	St22 intermediate	60.475833	-94.527683
2018-06-11	18:53	St22 rosette	60.446666	-94.005
2018-06-19	17:10	St32 Rosette open water near dirty ice	56.9866728	-88.1352983
2018-06-19	16:40	St 32 Under dirty ice	56.9839734	-88.120189
2018-06-20	18:20	St34 5m from ice	56.506166	-90.883166
2018-06-20	19:12	St34 open water area	56.496266	-86.878433
2018-06-29	Afternoon	Nelson southern transect st1	57.1842333	-91.81105
2018-06-29	Afternoon	Nelson southern transect st2	57.2081	-91.8711
2018-06-29	14:20	Nelson 1(barge)	57.0533682	-92.5321723
2018-06-29	18:50	Nelson 2 (barge)	Greg, gps not on cw	
2018-06-30	14:21	Nelson water 3	57.2059296	-92.2824796
2018-06-30	19:48	Nelson water 4	57.22215	-92.29395

In order to determine the magnitude of the riverine mercury and methylmercury inputs into Hudson Bay, surface water samples were collected from rivers reached by helicopter at stations targeting freshwater (salinity = 0). River water was collected using a submersible pump (Proactiv, 12 V) attached to an extendable painter pole the end of which was kept afloat with an

empty 4 L plastic acid bottle to keep the pump near the water surface. Filtered and unfiltered water samples were collected from the pump.

Table 14 River sampling by helicopter

Date	Time (UTC)	Name	Latitude	Longitude
2018-06-10	14:08	Thlewiaza River	60.4851	-94.8167
2018-06-10	13:15	Tha-anne River	60.5461	-94.8292
2018-06-18	18:55	Nelson River	56.9659	-92.6305
2018-06-18	20:50	Hayes River	56.9955	-92.2924
2018-06-19	18:42	Severn River	55.9603	-87.7081
2018-06-20	17:15	Winisk River	55.2275	-85.2114
2018-06-28	19:08	Seal River	59.0739	-94.8425
2018-06-28	20:06	Knife River	58.8831	-94.7031
2018-06-28	20:42	Churchill River	58.6781	-94.2033

In selected stations, water and ice samples were collected for the purpose of DOM characterization. For the rosette sampling, targeted depth included 10 m, subsurface chlorophyll maximum and bottom. Ice cores were sectioned into a size of 10 to 15 cm from top, middle and bottom part. Only filtered water samples were used for DOM, it can be either capsule filter directly from the Niskin bottle or filtration using vacuum pump. For both seawater samples and ice melts collected for DOM, 200 mL was stored in an amber glass bottle in the chest freezer, and up to 500 mL was loaded through a solid phase extraction (SPE) setup using Bond Elut PPL cartridges from Agilent. The volume of ice melts loaded on the cartridges varied depending on the size of the ice section. The loaded cartridges were stored in Ziploc bags separately and in the freezer until further treatment.

Preliminary Results

Not applicable at the moment.

References

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Part II: Sediment

Principal Investigators: Zou Zou Kuzyk[1], David Lobb[1]; Cruise Participants: Samantha Huyghe[1]; Punarbasu Chaudhuri

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Introduction and Objectives

The objectives of the sediment collection were, 1) To revise and update the estimate of the total sediment sink for Hudson Bay in consideration of both oceanographic and geologic domains using a combination of geophysical and geochemical data, and 2) To investigate the processes contributing to sedimentation patterns and rates using approximately monthly sediment trap samples spanning a year to document seasonal distribution of fluxes. The samples collected on this cruise will go towards objective 1 and filling the gaps in the data from archived and previous published data. The cores are also being supplemented by subbottom data, collected on Leg 1, to compare the geophysical data from each coring location with the geochemical data that will be obtained from the cores.

Operations Conducted and Methodology

Sediment Sampling

A box corer was used to collect sediment cores at basic and full stations where there were not too many rocks (the Agassiz trawl was used to assess the presence of large rocks that could damage the box corer). The box corer was deployed using the a-frame and winch on the port side of the ship. If the bottom of the box corer was sealed and the sediment inside was not slumped, a core tube was then pressed into the sediment. The sediment core was then taken to the lab on board the ship, measured, and sectioned into whirlpacks in intervals of 1 cm until 10 cm, 2 cm until 20 cm, and 5 cm after 20 cm. There were a couple of exceptions to these intervals in the cases of cores (Stations 17, 18, and 19) where there were still visible colour or textural changes past 20 cm. In these cases, the cores were sectioned 1 cm until 10 cm and 2 cm after 20 cm for higher resolution during analysis. The whirlpacks were then placed into a refrigerator and sent to the University of Manitoba for radioisotope, contaminants, and organic matter analyses.

Table 15 Locations and dates of the cores taken on Leg 1 of the 2018 Amundsen cruise

Station Number	Date	UTC	Latitude	Longitude	Depth (m)
10	04-Jun-18	5:32:39	63.45071	-79.4452	202.73
17	08-Jun-18	0:08:20	63.18458	-90.0337	91.62
18	08-Jun-18	6:10:20	63.71968	-88.4021	122.15
19	09-Jun-18	17:21:36	61.84316	-92.1328	86.18

21	10-Jun-18	21:08:18	60.91407	-89.3385	148.93
24	13-Jun-18	0:04:24	61.70548	-87.7845	N/A
28	15-Jun-18	4:10:07	62.41676	-89.8175	161.79
29	16-Jun-18	9:58:48	61.74867	-84.2958	177.46
32	19-Jun-18	21:01:05	56.97127	-88.1301	33.6
36	22-Jun-18	20:16:31	57.77581	-86.0279	127.07
38	23-Jun-18	23:21:16	58.72343	-86.2957	179.9
40	24-Jun-18	19:52:17	58.24775	-88.5965	90.08

Water Filtration

At stations near and in the Nelson River estuary, a water filtration system was run to collect suspended sediment. The filtration system was run using a pump on the ship allowing the system to draw seawater from the ship's plumbing for the duration of the station. At the end of the station the filters were removed, refrigerated, and then sent back to the University of Manitoba for further analysis.

Table 16 The location and duration of each filtration for suspended sediment

Station Number	Date	Latitude	Longitude	Duration of Filtering
40	24-Jun-18	58.24337	-88.589	8 hrs, 50 min
45	29-Jun-18	57.25124	-91.9629	7 hrs, 55 min
45	30-Jun-18	57.22999	-91.9536	11 hrs, 5 min
46	01-Jul-18	57.39829	-92.0727	7 hrs, 40 min

Part III: Mercury and Organic Contaminants Sampling and Deployments

Principal Investigator: Gary A. Stern[1]; Liisa Jantunen[2]; Cruise Participants: Ainsleigh Loria[1]

[1] *Centre for Earth Observation Science, Department of Environment and Geography, Clayton H. Riddell Faculty of Environment, Earth and Resources, University of Manitoba, Winnipeg, MB*
[2] *Environment and Climate Change Canada, Burlington, ON,*

Introduction and Objectives

As the average global temperature increases, the sea ice cover in the Arctic is declining. With a reduced ice cover throughout the year, the amount of cargo traffic and oil exploration and exploitation throughout the Arctic is expected to increase, putting this pristine environment at a higher risk of cargo-related pollution.

As a part of Arctic Net and BaySys, our group aims to collect baseline contaminant data in a variety of media in the Arctic. More specifically, we collect biological samples (zooplankton and invertebrates) to determine mercury concentrations within the food web. This year, I also collected water samples and surface sediment (sediment collected by Diana Saltymakova and Teresinha Wolfe) for organic contaminants for Liisa Jantunen. Moreover, the deployment of organic contaminant passive samplers on moorings along the primary shipping route to Churchill will help us generate an idea of the existing organic contaminant concentrations within the Bay.

Operations Conducted and Methodology

On board the *CCGS Amundsen,* we collected zooplankton alongside the Fortier group with the Tucker (1 m^2 750 µm mesh) and the Monster (1 m^2 200 µm mesh) nets. Benthic invertebrate samples were also collected using the Beam Trawl and the Agassiz trawl. The samples from the Agassiz trawl were collected and identified by Marie Pierrejean. Water samples for organic contaminants were collected from the rosette. 4 liters of surface water was collected for OPEs on the west/mid Hudson Bay, while 1 liter water samples were collected at the surface, above the thermocline and below the thermocline at passive sampler mooring sites for PFC analysis.

Organic contaminant passive samplers were deployed on moorings at 3 sites along the primary shipping route in Hudson Bay.

The following tables summarize the samples collected and the deployments that occurred related to contaminants during Leg 1 of the 2018 Amundsen cruise.

Table 17 Zooplankton samples collected during the BaySys 2018 cruise

Station	Tow	Bottom Depth (m)	Sampler Depth (m)	Species
04	Vertical	287	276	Calanus sp., Chaetognata, Climone limacina (2 cm), Hydromedusae, Bulk
05	Vertical	220	212	Calanus hyperboreus CV adult female, Ctenophora, Hydromedusae, Chaetognata, Bulk
09	Vertical	104	94	Chaetognata, Ctenophora, Bulk
09	Oblique	106	80	Chaetognata, Clione limacina (3.0-3.5 cm), Ctenophora, Bulk
10	Oblique	196	92	Calanus hyperboreus CV adult female, Clione limacina (5 cm), Ctenophora, Hydromedusae, Thysanoessa sp., Bulk
10	Vertical	199	189	Chaetognata, Themisto libellula (2.5-3.0 cm), Thysanoessa sp., Bulk
11	Vertical	320	310	Calanus hyperboreus CV adult female, Chaetognata, Ctenophora, Hydromedusae, Themisto libellula (2.5-3.0 cm, 3.5-4.0 cm), Thysanoessa sp., Bulk
15	Oblique	190	90	Ctenophora, Hyperoche medusarum, Themisto libellula (1.5-2.0 cm), Bulk
15	Vertical	191	181	Chaetognata, Ctenophora, Thysanoessa sp., Bulk
16	Oblique	135	95	Calanus hyperboreus CV adult female, Chaetognata, Ctenophora, Themisto libellula (2.0-2.5 cm), Bulk
16	Vertical	135	125	Calanus hyperboreus CV adult female, Chaetognata, Clione limacina, Bulk
17	Vertical	94	84	Chaetognata, Themisto libellula (2.0 cm), Bulk
18	Oblique	112	88	Chaetognata, Clione limacina (4.0-4.5 cm), Ctenophora, Themisto libellula (2.0-2.5 cm, 2.5-3.0 cm, 3.0-3.5 cm), Thysanoessa sp., Bulk
18	Vertical	115	105	Chaetognata, Clione limacina (4.0-4.5 cm), Ctenophora, Bulk
19	Vertical	76	66	Chaetognata, Bulk
19	Oblique	77	60	Chaetognata, Clione limacina (3.0 cm), Ctenophora, Themisto libellula (0.5-1.0 cm), Thysanoessa sp., Bulk
21	Vertical	163	133	Bulk

21	Oblique	147	92	Chaetognata, Ctenophora, Themisto libellula (0.5-1.0 cm, 2.5-3.0 cm, 3.0-3.5 cm), Bulk
22	Oblique	61	45	Clione limacina (2 cm), Ctenophora, Limacina helicina, Themisto libellula (0.0-0.5 cm, 0.5-1.0 cm, 1.0-1.5 cm, 1.5-2.0 cm), Bulk
22	Vertical	58	48	Bulk
24	Vertical	187	177	Calanus hyperboreus CV adult female, Chaetognata, Themisto libellula (2.5-3.0 cm), Thysanoessa sp., Bulk
25	Oblique	148	95	Calanus hyperboreus CV adult female, Chaetognata, Ctenophora, Clione limacina (2.0 cm, 4.0 cm), Bulk
25	Vertical	148	138	Calanus hyperboreus CV adult female, Chaetognata, Themisto libellula (2.5-3.0 cm), Thysanoessa sp., Bulk
28	Oblique	161	89	Chaetognata, Ctenophora, Themisto libellula (2.0-2.5 cm, 2.5-3.0 cm, 3.0-3.5 cm, 3.5-4.0 cm), Bulk
28	Vertical	161	89	Chaetognata, Thysanoessa sp., Bulk
29	Vertical	178	168	Calanus hyperboreus CV adult female, Chaetognata, Themisto libellula (1.5-2.0 cm, 2.0-2.5 cm, 2.5-3.0 cm), Bulk
29	Oblique	177	98	Calanus hyperboreus CV adult female, Chaetognata, Ctenophora, Themisto libellula (1.5-2.0 cm, 2.0-2.5 cm, 2.5-3.0 cm), Bulk
32	Vertical	32	22	Bulk
34	Oblique	44	34	Chaetognata, Hyperia galba, Bulk
34	Vertical	44	34	Bulk
36	Vertical	127	117	Chaetognata, Limacina helicina, Bulk
38	Oblique	178	75	Chaetognata, Ctenophora, Themisto libellula (2.5-3.0 cm, 3.5-4.0 cm), Bulk
38	Vertical	178	168	Chaetognata, Hydromedusae, Limacina helicina, Bulk
40	Vertical	86	76	Chaetognata, Bulk
43	Vertical	190	180	Chaetognata, Limacina helicina, Themisto libellula (0.5-1.0 cm, 2.0-2.5 cm, 2.5-3.0 cm), Thysanoessa sp., Bulk
43	Oblique	191	92	Chaetognata, Ctenophora, Limacina helicina, Themisto libellula (0.5-1.0 cm, 1.0-1.5 cm, 1.5-2.0 cm, 2.0-2.5 cm, 2.5-3.0 cm), Bulk

44	Oblique	106	90	Chaetognata, Hyperia galba, Limacina helicina, Themisto libellula (0.5-1.0 cm, 1.0-1.5 cm, 3.0-3.5 cm), Bulk
BN5	Reverse	14	10	Mysis sp.
45	Oblique	44	31	Bulk
45	Vertical	44	34	Bulk

Vertical tow = 1 m^2, 200 µm mesh net, oblique tow = 1 m^2, 750 µm mesh net and reverse tow = 1 m^2, 500 µm mesh net.

Table 18 Benthic invertebrate samples collected during the BaySys 2018 cruise

Station	Trawl	Depth	Species
04	Agassiz	274	Eualus gaimardii gaimardii, Gorgonocephalus sp.
09	Agassiz	237	Crossaster papposus, Rossia sp.
09	Beam Trawl	218	Anonyx sp., Argis dentata, Eualus gaimardii gaimardii, Henricia sp., Pandalus borealis, Rossia sp., Sclerocrangon boreas, Strongylocentrotus droebachiensis
15	Agassiz	189	Strongylocentrotus droebachiensis
15	Beam Trawl	200	Sclerocrangon boreas
16	Beam Trawl	135	Heliometra glacialis, Ophiacantha bidentata, Sclerocrangon boreas
17	Agassiz	94	Gorgonocephalus arcticus, Pandalus borealis
18	Beam Trawl	114	Argis dentata, Eualus gaimardii gaimardii, Heliometra glacialis, Ophiacantha bidentata
19	Agassiz	83	Argis dentata, Hyas coarctatus, Poraniomorpha sp., Strongylocentrotus droebachiensis
21	Agassiz	152	Ctenodiscus crispatus
21	Beam Trawl	152	Argis dentata
22	Agassiz	63	Chlamys islandica, Hyas coarctatus, Strongylocentrotus droebachiensis
25	Agassiz	145	Ophiura sp., Strongylocentrotus droebachiensis
28	Agassiz	162	Argis dentata, Sabinea septemcarinata, Spirotocaris intermedia
29	Agassiz	180	Ophiura sarsii
32	Agassiz	32	Strongylocentrotus droebachiensis
38	Agassiz	180	Ophiura sarsii, Pontaster tenuispinus
43	Beam Trawl	193	Argis dentata, Eualus gaimardii belcheri, Spirotocaris sp.
44	Agassiz	104	Argis dentata, Crossaster sp., Sabinea septemcarinata, Strongylocentrotus droebachiensis

Table 19 Water samples collected during the BaySys 2018 cruise

Sampling Variable	Station	Station Depth (m)	Sampling Depth	Water T (°C)	Salinity
PFCs	15	189	Surface	-0.9931	32.2388
			30 m	-1.1237	32.3298
			140 m	-1.6181	32.6255
PFCs	29	175	Surface	-1.5223	30.7520
			20 m	-1.5437	30.7590
			50 m	-1.4613	31.6827
PFCs	44	98	Surface	1.4835	29.9287
			10 m	1.6668	30.6000
			40 m	-1.6588	32.6680
OPEs	22	63	Surface	0.9763	32.2266
OPEs	26	129	Surface	1.2516	31.7071
OPEs	31	46	Surface	1.4007	28.5423
OPEs	38	177	Surface	-1.3730	31.7004

Table 20 Sediment samples collected during the BaySys 2018 cruise

Station	Date	Depth	End Latitude (N)	End Longitude (W)	Section
10	04-Jun-18	203	63.45098	79.44622	Surface
11	04-Jun-18	319	62.87041	78.85538	Surface
15	05-Jun-18	190	63.18558	81.86553	Surface
17	08-Jun-18	92	63.18437	90.03285	Surface
18	08-Jun-18	122	63.7196	88.40239	Surface
19	09-Jun-18	88	61.84331	92.13279	Surface
21	10-Jun-18	150	60.91368	89.33957	Surface
24	13-Jun-18	189	61.70507	87.78463	Surface
29	16-Jun-18	179	61.74696	84.29496	Surface
36	22-Jun-18	127	57.77598	86.02764	Surface
38	23-Jun-18	180	58.72420	86.29730	Surface

Table 21 Organic contaminant passive samplers deployed during the BaySys 2018 cruise

Name	Cage Style	Station	Date	Station depth (m)	Cage depth (m)
Hudson Bay 1	Large stainless steel	15 Mooring 1	05-Jun-18	195	60

Hudson Bay 2	Small plastic/aluminum	29	16-Jun-18	179	40
Hudson Bay 3	Large stainless steel	44 CMO01	28-Jun-18	105	62

Preliminary Results

N/A – No contaminant analyses were conducted on board.

GENICE

Isolation and characterization of hydrocarbon bacteria and their biodegradation potential

Principal investigator: Gary Stern[1]; Cruise participants: Pardis Karimi[1]

[1]University of Manitoba, Centre for Earth Observation Science, Winnipeg MB, Canada R3T 2N2; [2]University of Calgary

Part I
Introduction and Objectives

The most common environmental pollutants are Petroleum hydrocarbons, including n-alkane, cycloalkane and aromatic hydrocarbons that have been considered as serious ecological and public health concerns. Ecosystem contamination by crude oil hydrocarbons is a fundamental worldwide topic accompanying with crude oil drilling, transportation, refining and related activities which demands immediate attention for restoration. Bioremediation has been showed to be a promising, environmental friendly and economical method for mineralization of hydrocarbons to carbon dioxide and water. Due to great catabolic diversity of microorganisms, they are the best candidates among all living organisms to mineralize xenobiotic compounds into natural biogeochemical cycles. As such, the aim of Leg 1 was to collect environmental samples and to isolate oil degraders through different screening procedures in the home laboratory.

As only DNA characterization cannot be a good representative of the bacterial population in a habitat, (e.g. some of the bacteria has smaller size than the filter pore size so, they filter through), onboard enrichment methodology was used to isolate cultivable and then compare the results with molecular characterization. The rest of experiments based on the main objectives of the project will be done at the University of Manitoba.

Operations Conducted and Methodology

Sample Collection
Samples were collected from the ships route in Hudson strait and Hudson Bay to find active oil degraders and see the differences in bacterial species present in surface and bottom water, surface and bottom sediments, ice cores, and sea-ice water interface at each location. Samples included:

- surface seawater,
- bottom seawater,
- ice cores,
- melt ponds, if any,
- sea ice interface water,

- surface sediments, and
- bottom surface sediments.

Sample Processing

Seawater

15 liters of surface and bottom water were collected in clean buckets from each station and filtered through 0.2 μm filters by vacuum filtering system immediately after collection. Water samples were processed separately for:

- RNA analysis,
- DNA analysis, and
- Enrichment.

Samples after proper processing preserved at -80 ^{0}C for further analysis in the home laboratory at the University of Manitoba.

A separate set of water samples from surface and bottom of each station also was taken for salinity, nitrate, nitrite, DOC, and pH analysis, to be done at the University of Manitoba.

Enrichment done onboard and the rest of analysis and bacteria isolation/molecular characterization will be done at the University of Manitoba. Great care was taken to keep the aseptic condition throughout culturing, filtering, and preservation.

Ice

Collected samples included:

- Ice core,
- Sea-ice water, and
- Melt pond, if any.

15 liters of ice samples were collected from each station and filtered through 0.2 μm filters by vacuum filtering system immediately after collection.

Ice samples processed separately for:

- RNA analysis,
- DNA analysis, and
- Enrichment.

Samples after proper processing preserved at -80 ^{0}C for further analysis in the home laboratory at the University of Manitoba.

A separate set of water samples from surface and bottom of each station also was taken for salinity, nitrate, nitrite, DOC, and pH analysis, to be done at the University of Manitoba.

Enrichment done onboard and the rest of analysis and bacteria isolation/molecular characterization will be done at the University of Manitoba. Great care was taken to keep the aseptic condition throughout culturing, filtering, and preservation.

Surface and Bottom Surface Sediment Samples
Sediment samples collected by push core. Oxic and anoxic part of marine sediment samples collected separately to be used for:

- Enrichment,
- Hydrocarbon extraction,
- TOC,
- TN,
- pH
- Texture and structure

Enrichment done onboard and the rest of analysis and bacteria isolation/molecular characterization will be done at the University of Manitoba. Great care was taken to keep the aseptic condition throughout culturing, and preservation.

Preliminary Results

All the DNA and RNA analysis will be done at the University of Manitoba. Preserved bacteria samples after onboard enrichment will be further analysed at the University of Manitoba to isolate each bacteria based on morphological, biochemical, and molecular characteristics. Biodegradation assays also will be done at the University of Manitoba based on the outline of project.

Throughout the filtering process, it was observed that the biomass obtained from some of the stations and samples was considerably low by visual observation. Further investigation is required to understand the reason/explanation.

Baseline hydrocarbon concentration in Hudson Bay

Principal Investigator: Gary Stern[1]; Cruise participants: Diana Saltymakova[1]; Nolan Snyder[1]; Teresinha Wolfe[1]

University of Manitoba, Centre for Earth Observation Science, Winnipeg MB, Canada R3T 2N2

Introduction and Objectives

Within the Northern Arctic, global warming has led to a persistent decrease in sea-ice extent and type. Consequently, shipping and oil exploration in the Hudson Bay is becoming more feasible, allowing for a potential of petroleum derived contamination in marine environment. This impending possibility has led to a need for understanding of:

Key question: How the surface sediment, surface and bottom water hydrocarbon concentrations differ throughout the Hudson Bay? At what scale crude oil spill may affect hydrocarbons concentration in Hudson Bay waters and what are the possible consequences of the spill.

Key questions: How do the hydrocarbon-degrading microbial communities of first year ice responds to HC amendment? How does crude oil chemical composition change in response to incubation during the time? How does nutrient availability/addition (N and P as NH4+ and PO43- respectively) affect the rate of petroleum hydrocarbon degradation?

Operations Conducted and Methodology

Surface and Bottom Water was Sampled Throughout Hudson Bay
20 L filtered through 0.2 µm filter and SPE cartridge for analysis of particle and dissolved organic matter;

Ice was Sampled throughout Hudson Bay
4 m of ice was melted, filtered through 0.2 µm filter and SPE cartridge for analysis of particle and dissolved organic matter;

Sediment Sampling
Push cores were collected through the Hudson Bay and sliced every 1 cm first 10 cm, every 2 cm the second 10 cm and every 5 cm after that;

Ice was Sampled for Incubation at Station # 11 Located at Transportation Corridor
One full ice core was melted and was used as inoculum for microbial hydrocarbon degradation incubations with light crude oil. For each of the experimental conditions, three 1L bottles was set up to allow for larger volume sampling. Incubations will be sampled every 3 weeks for change in crude oil composition, microbial community succession, and cell counting.

Microbial Genomics for Oil Spill Preparedness in Canada's Arctic Marine Environment

Principal Investigator: Dr Casey Hubert; Cruise participants: Michael Stone; Oye Adebayo

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Introduction and Objectives

Increasing earth and sea temperatures due to global climate change has led to reduced sea-ice cover and longer ice-free summers in the Arctic. The conditions could lead to opening northern Canada to increased shipping activities and exposing the Canadian Arctic ecosystem to fuel and oil spills. One such region in the Canadian Arctic is the Hudson Bay, host to Canada's only deep-water shipping port. The Hudson Bay region has seen an increase in ship traffic shipping near Northern communities. Hence, it is an ideal region to study and predict the probable future conditions for the rest of the Canadian Arctic. The 2010 Gulf of Mexico blowout and oil spill highlighted the ability of native hydrocarbon degrading microbial communities to act as first responders and their use in bioremediation (Hazen et al., 2010; Kostka et al., 2014).

The GENICE project aims to use microbial genomics to generate credible, science-based knowledge on the role and potential of biodegradation of oil by naturally occurring microorganisms. The first goal of the project is to establish microbial baselines of ecosystems using microbial genomics. These baselines provide us with a diversity and composition of the microbial community that can be used to assess the status of the ecosystem and remediation in a post-oil spill scenario. During leg 1 of the 2018 expedition of CCGS Amundsen, the GENICE scientists onboard collected representative samples from seawater, sediments, and sea-ice to identify and map the microbial community of the Hudson Bay region.

Operations Conducted and Methodology

The coordinates of stations sampled are shown in Table 22.
From each station, one or more of the following environmental materials were collected as samples.

- Surface sea water (SSW): collected from the deck;
- Bottom sea water (BSW): collected from the rosette at 10 m above sea bed
- Sea-ice (SI): collected using an auger at ice stations
- Sediment (SED): collected from the surface (0-5cm) of box cores

For each environmental material, the samples were preserved for DNA extraction, microcosm incubations and Cell Counts. Surface sea water and sea ice sub samples were preserved for viromics analysis.

SSW:

- Surface Sea Water was obtained from the deck via bucket sampling
- Cells were fixed using 4% Formaldehyde for cell counts
- Water was filtered through 47mm 0.2µm PES membrane filter to collect microbial organisms for baseline
- A sub sample was used as an inoculum for an enrichment which will be used to isolate crude oil degrading micro-organisms from the environment
- Extra water was taken at stations in key locations to establish a baseline viromic profile of the surface sea water.

BSW:

- Bottom Sea Water (10m above sea bed) was obtained via rosette sampling (chemical/CTD cast)
- Cells were fixed using 4% Formaldehyde for cell counts
- Water was filtered through 47mm 0.2µm PES membrane filter to collect microbial organisms for baseline

SI:

- Full sea ice cores were obtained from ice floes via core barreling
- The ice was then crushed and melted with a sub sample being saved for purpose of enrichment
- Cells were fixed using 4% Formaldehyde for cell counts
- Melted water was filtered through 47mm 0.2µm PES membrane filter to collect microbial organisms for baseline
- The sub sample was used as an inoculum for an enrichment which will be used to isolate micro-organisms from the environment

SED:

- Sediment was obtained via box coring from the foredeck
- Top sediment was sampled in triplicates from the first core, with an occasional quadruplicate coming from a second core
- Cells were fixed using 4% Formaldehyde for cell counts

Table 22 List and coordinates of stations sampled

Station ID	Samples Taken	Type of Station	Latitude (surface water)	Longitude (surface water)	Latitude (bottom water)	Longitude (bottom water)	Latitude (Box Core)	Longitude (Box Core	Date	Depth (m)
4	SSW, BSW	Nutrient	(N) 62, 2.425	(W) 069, 37.105	(N) 62;2.443	(W) 069;36.892	NA	NA	01-Jun	283

9	SSW, BSW, Ice	Basic	(N) 63; 43.734	(W) 079;55.686	(N) 63;43.248	(W) 079;55.362	NA	NA	03-Jun	91
10	Box cores (single Core)	Nutrient	NA	NA	NA	NA	(N) 63.451	(W) 079.445	04-Jun	100
11	Box cores, Ice, SSW, BSW	Full/Ice	(N) 62;52.647	(W) 078;52.239	(N) 62;52.602	(W) 078;51.862	(N)62.870	(W) 078.856	04-Jun	309
15	Box Cores, SSW, BSW, SSW Virus	Basic	(N) 63;10.512	(W) 081;50.983	(N) 63;10.512	(W) 81;50.983	(N) 63.184	(W) 081.860	05-Jun	
16	Box Cores, SSW, BSW, Ice	Full/Ice	(N) 62;17.263	(W) 085;52.049	(N) 62;17.394	(W) 085;51.450	NA	NA	06-Jun	135
17	SSW, Box Cores, BSW	Basic	(N) 63;11.070	(W) 090;2.060	(N) 63;11.070	(W) 090;2.023	(N) 63.183	(W) 090.033	07-Jun	90
18	SSW, SSW virus, BSW, Ice, Box Cores	Full/Ice	(N) 63;43.811	(W) 088;25.566	(N) 63;42.830	(W) 088;25.020	(N) 63.720	(W) 088.399	08-Jun	120
19	SSW, BSW, Sediment	Full/Water	(N) 61;50.834	(W) 092;7.962	(N) 61;50.834	(W) 092;7.962	(N) 61.843	(W) 092.131	09-Jun	70
21	SSW,BSW, Sediment, Ice	Full/Ice	(N) 60;54.645	(W) 089;19.801	(N) 60;54.688	(W) 089;19.801	(N) 60.910	(W) 089.339	10-Jun	144
22	SSW, BSW,	Full/Water	(N) 60;25.290	(W) 094;0.194	(N) 60;25.272	(W) 094;0.194	NA	NA	11-Jun	63
28	Sediment, SSW, BSW	Basic	(N) 62;24.874	(W) 089; 49.945	(N) 62;27.838	(W) 089;49.883	(N) 62.416	(W) 089.820	14-Jun	160
29	Sediment, SSW, BSW	Full/Water	(N) 61;46.812	(W) 084;18.490	(N) 61;46.182	(W) 084;18.490	(N) 61.747	(W) 84.29308	16-Jun	175
32	SSW, BSW, Ice, Sediment	Full/Ice	(N) 56;58.854	(W) 088;8.749	(N) 56;58.843	(W) 088;8.743	NA	NA	19-Jun	34
34	SSW, BSW,	Full/Ice	(N) 56;30.008	(W) 086;52.052	(N) 56;30.006	(W) 086;51.971	NA	NA	20-Jun	43
36	SSW, Sediment, BSW	Full/Ice	(N) 57;46.442	(W) 086 1.865	(N) 57;46.442	(W) 086;1.847	(N) 57.776	(W) 086.027	22-Jun	126
38	SSW, BSW, Ice, Sediment	Full/Ice	(N) 58;43.825	(W) 086;18.065	(N) 58;43.847	(W) 86;18.065	(N) 58.724	(W) 086.298	23-Jun	177
40	SSW,BSW, Sediment	Basic	(N) 58;14.407	(W) 088;34.996	(N) 58;14.423	(W) 088;34.996	(N) 58.244	(W) 088.591	24-Jun	85
44	SSW, BSW	Basic	(N) 59;58.514	(W) 091;57.016	(N) 59;58.583	(W) 091 56.938	NA	NA	28-Jun	98
45	SSW, BSW, Sediment	Basic	(N) 57;13.247	(W) 091;57.213	(N) 57;13.164	(W) 091;57.427	(N)57.252	(W)91.963	30-Jun	16
46	SSW, BSW, Sediment	Basic	(N) 57;29.635	(W) 091;49.030	(N) 57;29.630	(W) 091;49.078	(N) 57.503	(W) 091.805	01-Jul	45

Preliminary Results

All samples collected will be processed upon their arrival at the University of Calgary after demobilization.

Seabed Mapping, MVP & Sub-Bottom Profiling

Principal Investigator: Amundsen Science; Cruise Participants: Matt Downton[1]; Collaborators: Catherine Van Doorn[2], Samantha Huyghe[3], Sergei Kirillov[4]

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Introduction and Objectives

The *BaySys* 2018 Amundsen Leg 1 cruise took place from May 25th to July 5th, 2018. The *Marine Geosciences Lab.* (MGL – Université Laval) was onboard and responsible for multibeam and sub-bottom data acquisition. The *MGL* has been mainly involved in mapping the seabed morphology and in acquiring sub-bottom stratigraphy during transits, choosing appropriate coring sites, assisting mooring deployment and recovery as well as deploying the *Moving Vessel Profiler* (MVP). This cruise report presents the instruments, methods and preliminary results for Leg 1.

Operations Conducted and Methodology

Kongsberg EM302 Multibeam Sonar

The Amundsen is equipped with an EM302 multibeam sonar operated with the *Seafloor Information System* (SIS). Attitude is given by an *Applanix POS-MV* receiving RTCM corrections from a *CNAV 3050* GPS receiver. Position accuracies were approximatively < 0.8 m in planimetry and < 1 m in altimetry. Beam forming at the transducer head was done by using an *AML* probe. CTD-Rosette casts, when available, were used for sound speed corrections. During long periods without CTD casts, the WOA09 model was used.

Knudsen 3260 CHIRP Sub-Bottom Profiler

Since May 2016, a new Knudsen 3260 deck unit has been installed onboard the Amundsen. It was acquired to replace the old 320-BR system that shown signs of high degradation at the end of the 2015 field season. The new system now operates using a USB connector instead of a SCSII communication port. We also installed a new operating computer (HP EliteDesk). Sub-bottom profiles were acquired all along transits at a frequency of 3.5 kHz to image sub-bottom stratigraphy of the seafloor.

Moving Vessel Profiler (MVP) 300

During Leg 1, four MVP transects were performed using a Moving Vessel Profiler (MVP 300) towed behind the ship at 8-10 kts. The MVP measures temperature, salinity, transmissivity, dissolved O_2, fluorescence and sound velocity. Mainly, our team used MVP data to correct for sound velocity during transit mapping, but these transects were also used to visualize water column properties for physical and biological purposes.

Preliminary Results

All the data acquired during the cruise was post-processed in real-time using the *CARIS HIPS&SIPS 10.4* software. This post-processing phase is essential to rapidly detect any anomaly in the data collection. The final addition of the 2018 data will be done upon the return of the ship in Quebec City.

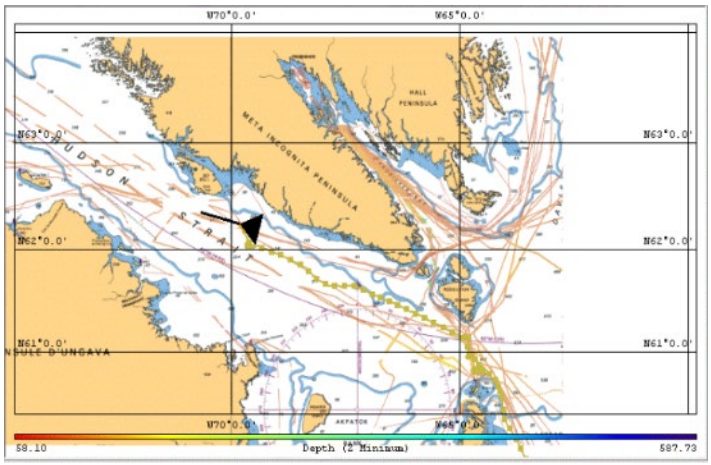

Figure 36 Example of opportunistic mapping in Hudson Strait

Transit Mapping

The mapping of the Arctic seabed is an important objective of the BaySys program. Transits routes were surveyed systematically to increase the multibeam dataset. These data will be shared with the Canadian Hydrographic Service (CHS) to update marine charts and might be useful for future work with Amundsen Science (Figure 36). Overall, the multibeam worked well and generated new data in previously poorly charted areas.

Since 2016, our team has been developing a bathymetry database to easily access all the bathymetry data acquired since the beginning of the ArcticNet program. This ArcMap based database is a raster catalog of more than 3500 data grids (15'x30' spatial extent) that can be rapidly added to navigation charts in order to improve the multibeam coverage of the Arctic (Figure 37). In 2017, the sub-bottom profiles acquired since 2003 were added to this database, making it easier to choose alternative coring sites during the cruise depending on ice conditions.

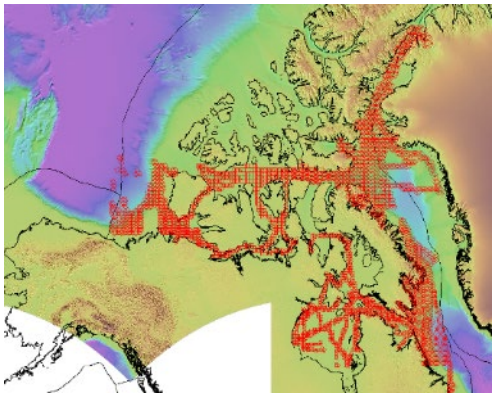

Figure 37 Image of the Amundsen Bathy-CHIRP Database for bathymetric and sub-bottom data collection

MVP transects

During Leg 1, six MVP transects were performed. Due to ice and sheave issues, only four MVP transects provided useful data (1801003 – 1801006). The casts (Table 21) were performed as part of the BaySys program. Figures 38 – 41 shows the preliminary data.

Table 23 Description of the relevant MVP transects performed during Leg 1

MVP transect	Location	Speed (kts)	Nb. of casts
1801003	62.86859°N 88.92363°W – 63.29666°N 90.38346°W	8-10	124
1801004	61.84291°N 92.13785°W – 61.37693°N 90.9538°W	8-10	113
1801005	61.38983°N 90.95297°W – 61.00155°N 90.07916°W	8-10	93
1801006	62.20248°N 88.39438°W – 62.5818°N 90.91398°W	8-10	247

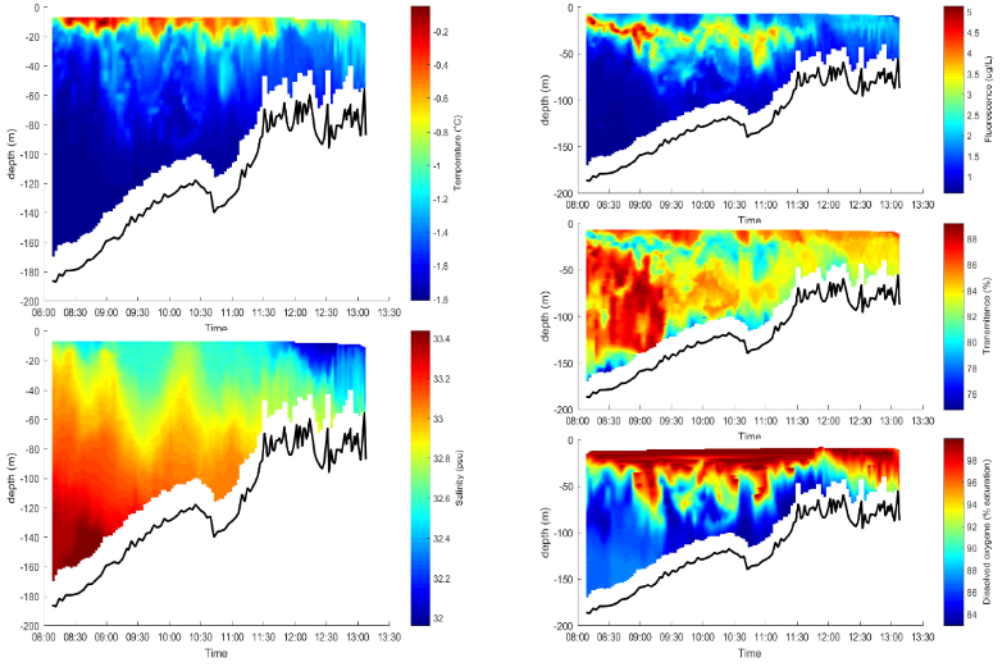

Figure 38 Preliminary results of the MVP transect 1801003 performed during Leg 1 displaying Temperature, Salinity, Fluorescence, Transmittance, and Dissolved Oxygen

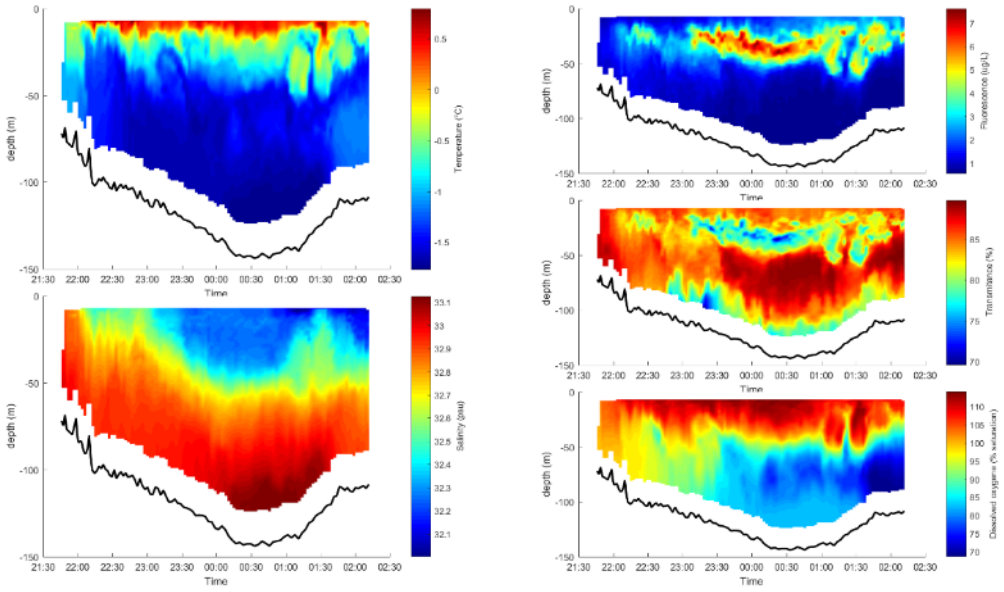

Figure 39 Preliminary results of the MVP transect 1801004 performed during Leg 1 displaying Temperature, Salinity, Fluorescence, Transmittance, and Dissolved Oxygen

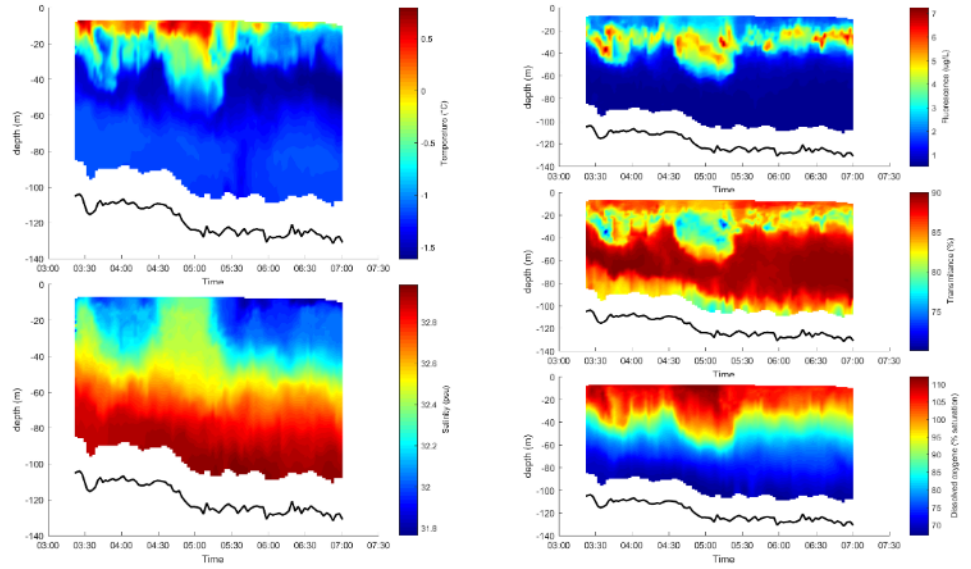

Figure 40 Preliminary results of the MVP transect 1801005 performed during Leg 1 displaying Temperature, Salinity, Fluorescence, Transmittance, and Dissolved Oxygen

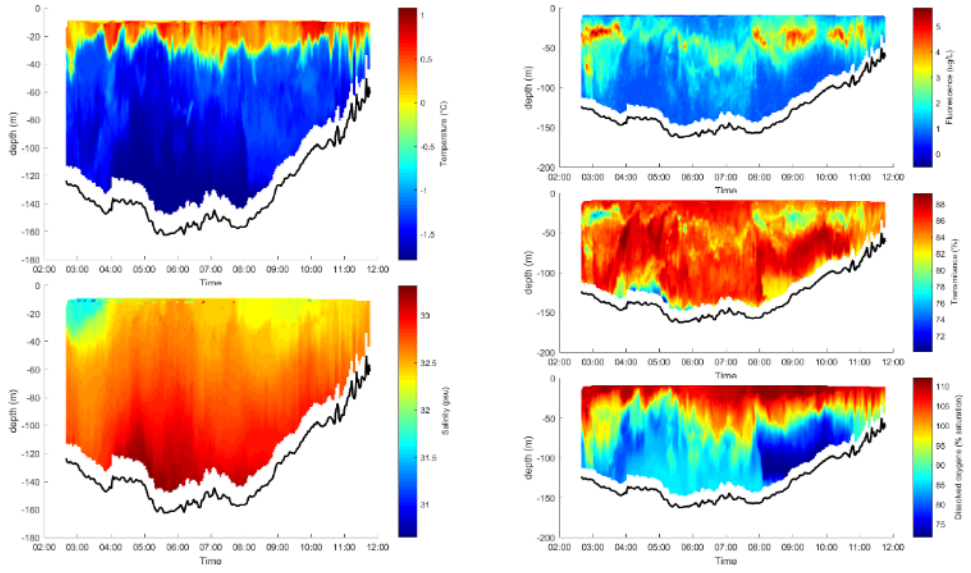

Figure 41 Preliminary results of the MVP transect 1801006 performed during Leg 1 displaying Temperature, Salinity, Fluorescence, Transmittance, and Dissolved Oxygen

Mooring Deployment and Recovery

The role of the mapping team during mooring deployment and recovery was to 1) ensure the mooring was still in its position (identify the buoys and the exact position), 2) validate the depths of the deployment sites, 3) map the surface morphology of the sites and 4) determine the verticality of the moorings after deployment.

The survey lines from the mooring were processed in CARIS HIPS&SIPS after the survey to find the exact position of the mooring. The procedure started with the visualization of the water column data to find the buoys (Figure 42). The buoys scattering was added to bathymetry to find the final position of the deployment.

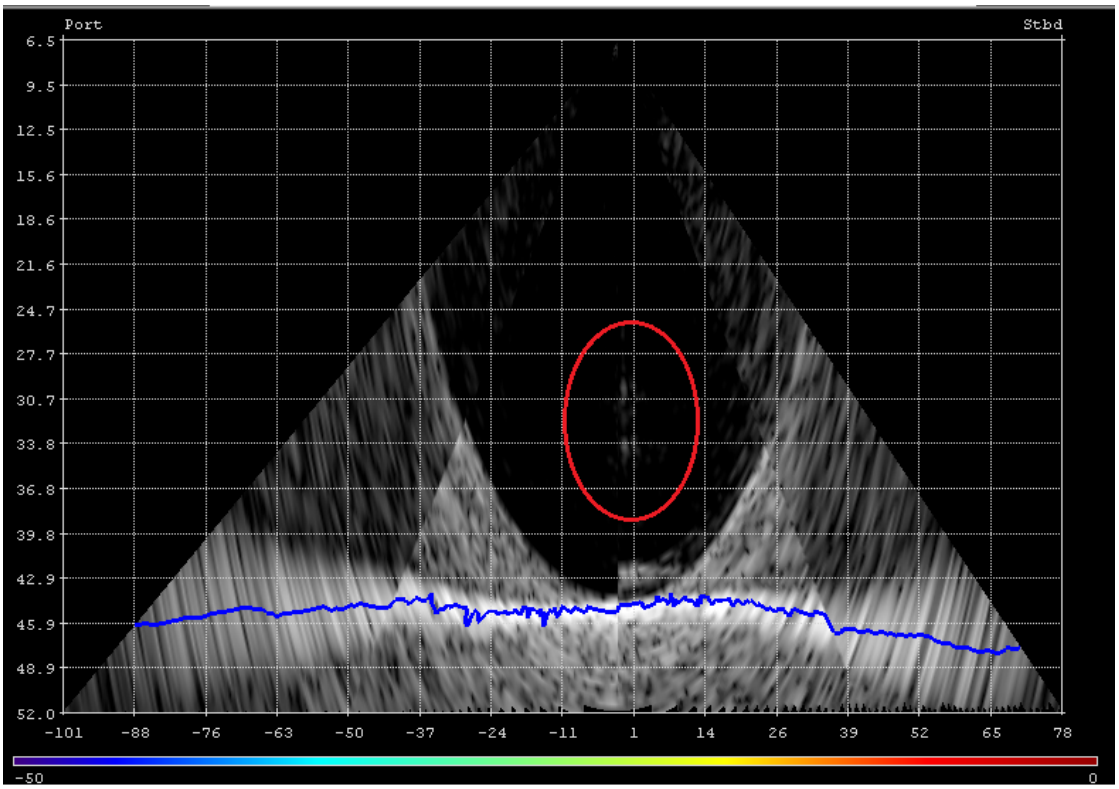

Figure 42 SIS water Column display of Mooring on July 25th before recovery. The red circle shows the buoys

Sediment Cores

During Leg 1, many box cores were sampled. Coring sites were chosen in real time while doing a seismic survey, or by analysing sub-bottom profiles of previous years. Details of the cores, their location and length of recovery, as well as the targeted type of sediment/feature are presented in the coring team report.

Figures were produce by the mapping team for every coring sites to indicate the target on the acoustic sub-bottom profile (Figure 43).

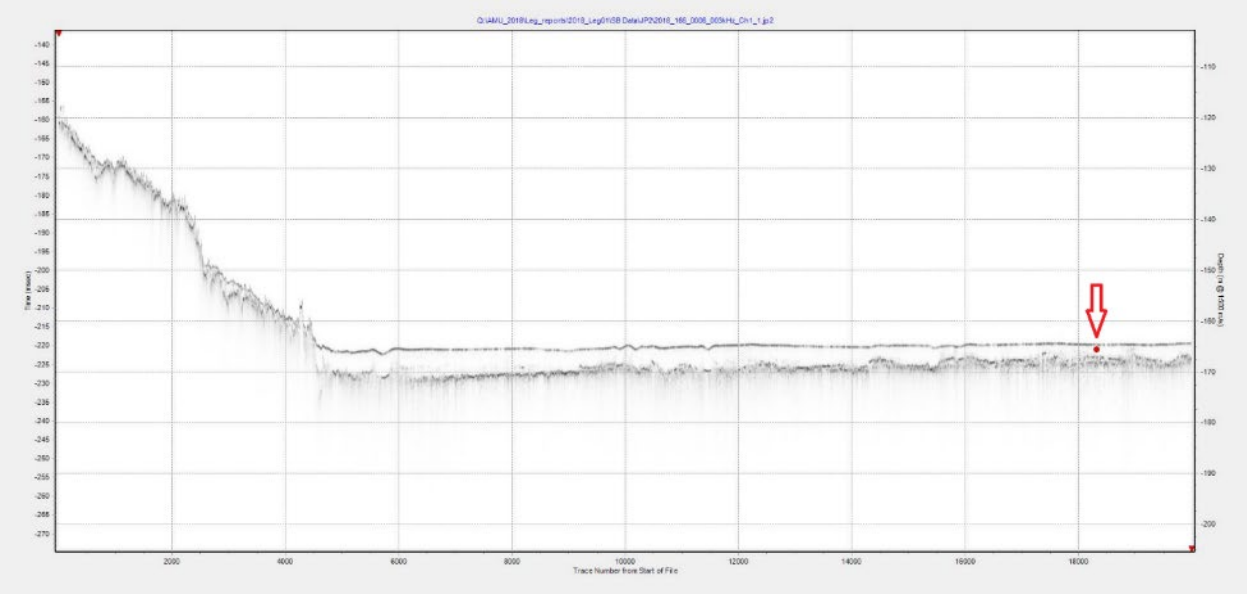

Figure 43 Location of the core site of near Rankin Inlet on the acoustic subbottom profile

Recommendations for Future Cruises

Given the performance of the MVP, this instrument could be deployed more often to acquire underway data for oceanographic studies, and also to get proper sound velocity correction for the multibeam sonar.

Appendix A

Station Type Definitions

Nutrient

- Station with 1 Rosette Cast for nutrient sampling
- May include 1 or 2 additional on deck operations if time permitted (ex., niskin bottle sampling; vertical or horizontal nets etc.)

Basic

- Station with open water-based sampling operations
    - 2 Rosettes
    - Horizontal Nets
    - Vertical Nets
    - Beam Trawls
    - Agassiz Trawls
    - Box Cores
    - Optical Instrument Suite
- Some ice operations were conducted where possible.

Full

- Station with all sampling operations including open water, ice, and remote.
    - 2 Rosettes
    - On-ice Operations via Cage
    - Skippy Boat/Zodiac Operations
    - Helicopter Survey and Sampling Operations
    - Vertical Nets
    - Horizontal Nets
    - Beam Trawl
    - Agassiz Trawl
    - Box Cores
    - Optical Instrument Suite

Appendix B

Complete Station List – Leg 1

Station ID	Alt. ID	Activity Collection Start Date	Location Name	Site Description	Sample Depth (m)	Lat. Decimal Degrees	Long. Decimal Degrees	Site Location Country
1	356	31/05/2018	Hudson Bay	Nutrient	328.75	60.8133	-64.5334	Canada
2	354	31/05/2018	Hudson Bay	Nutrient	571.13	60.9735	-64.7734	Canada
3	352	01/06/2018	Hudson Bay	Nutrient	430.12	61.1502	-64.8087	Canada
4	HN01	01/06/2018	Hudson Bay	Nutrient	285	62.0405	-69.6133	Canada
5	FB01(A)	02/06/2018	Hudson Bay	Nutrient	233.03	64.2865	-78.2308	Canada
6	FB01(B)	03/06/2018	Hudson Bay	Nutrient	276.08	64.2236	-78.6244	Canada
7	FB02	03/06/2018	Hudson Bay	Nutrient	270	64.0653	-79.0624	Canada
8	M19	03/06/2018	Hudson Bay	Nutrient	320.34	63.9494	-79.5646	Canada
9	FB03	03/06/2018	Hudson Bay	Basic	103	63.7302	-79.9264	Canada
10		04/06/2018	Hudson Bay	Nutrient	201.58	63.4474	-79.4428	Canada
11		04/06/2018	Hudson Bay	Full/Ice	320.87	62.8651	-78.8984	Canada
12		05/06/2018	Hudson Bay	Nutrient	85.78	63.3958	-81.2244	Canada
13		05/06/2018	Hudson Bay	Nutrient	148.03	63.2646	-81.6708	Canada
14		05/06/2018	Hudson Bay	Nutrient	-9999	63.1967	-81.8557	Canada
15	CMO-C	05/06/2018	Hudson Bay	Basic	187.93	63.1934	-81.9231	Canada
16		06/06/2018	Hudson Bay	Full/Ice	136.81	62.2794	-85.9089	Canada
17		07/06/2018	Hudson Bay	Basic	88.43	63.1846	-90.0357	Canada
18	CMO-D	08/06/2018	Hudson Bay	Full/Ice	115.61	63.7137	-88.4168	Canada
19		09/06/2018	Hudson Bay	Full/Water	74.89	61.8468	-92.1129	Canada
20		10/06/2018	Hudson Bay	Nutrient	112.15	61.3743	-90.9420	Canada
21		10/06/2018	Hudson Bay	Full/Ice	149.58	60.9102	-89.3595	Canada
22		11/06/2018	Hudson Bay	Full/Water	239.9	60.4231	-94.0023	Canada

23	M6	12/06/2018	Hudson Bay	Nutrient	110.52	60.9221	-91.7809	Canada
24		12/06/2018	Hudson Bay	Full/Ice	189.39	61.6960	-87.7618	Canada
25		13/06/2018	Hudson Bay	Full/Ice	148.19	62.0218	-87.0086	Canada
26		14/06/2018	Hudson Bay	Nutrient	131.46	62.2042	-88.3775	Canada
27		14/06/2018	Hudson Bay	Nutrient	61.02	62.5836	-90.9228	Canada
28		15/06/2018	Hudson Bay	Basic	163.63	62.4155	-89.8339	Canada
29	CMO-B	16/06/2018	Hudson Bay	Full	176.99	61.7698	-84.3091	Canada
31	NE02	18/06/2018	Hudson Bay	Nutrient	47.4	57.5001	-91.7953	Canada
32		19/06/2018	Hudson Bay	Full/Ice	32.97	56.9840	-88.1158	Canada
33		20/06/2018	Hudson Bay	Ice Sampling	47.49	56.6114	-87.0904	Canada
34		21/06/2018	Hudson Bay	Full/Ice	43.78	56.4998	-86.8688	Canada
35		22/06/2018	Hudson Bay	Nutrient	61.46	57.1798	-86.4995	Canada
36		22/06/2018	Hudson Bay	Full/Ice	128.34	57.7741	-86.0313	Canada
37		23/06/2018	Hudson Bay	Nutrient	169.68	58.4689	-86.2255	Canada
38		23/06/2018	Hudson Bay	Full/Ice	181.31	58.7224	-86.3050	Canada
39		24/06/2018	Hudson Bay	Nutrient	182.66	58.4748	-87.4385	Canada
40		24/06/2018	Hudson Bay	Basic	90.62	58.2326	-88.5635	Canada
41		25/06/2018	Hudson Bay	Nutrient	71.08	58.0189	-9999	Canada
42	NE03	25/06/2018	Hudson Bay	Mooring Recovery	53.82	57.8278	-90.8759	Canada
43	Repeat 15	27/06/2018	Hudson Bay	Basic	192.62	63.1917	-81.9668	Canada
44	CMO-A AN01	28/06/2018	Hudson Bay	Basic	106.59	59.9747	-91.9506	Canada
45		30/06/2018	Hudson Bay	Basic	16.66	57.2230	-91.9554	Canada
46		01/07/2018	Hudson Bay	Basic	41.2	57.5032	-91.8129	Canada
Remote Stations	**Alt. ID**	**Activity Collection Start Date**	**Location Name**	**Site Description**	**Sample Depth (m)**	**Lat. Decimal Degrees**	**Long. Decimal Degrees**	**Site Location Country**
FB05-H		02/06/2018	Hudson Bay	Hudson Strait Heli				Canada
M.I. H1		04/06/2018	Hudson Bay	Mansel Island Heli		62.2439	-78.3126	Canada
M.I. H2		04/06/2018	Hudson Bay	Mansel Island Heli		62.2429	-78.5166	Canada

M.I. H3		04/06/2018	Hudson Bay	Mansel Island Heli		62.2419	-78.7206	Canada
M.I. H4		04/06/2018	Hudson Bay	Mansel Island Heli		62.2408	-78.9246	Canada
M.I. H5		04/06/2018	Hudson Bay	Mansel Island Heli		62.2398	-79.1286	Canada
Northwest HB 1		06/06/2018	Hudson Bay	Northwest HB Heli		62.0798	-85.3600	Canada
Northwest HB 2		06/06/2018	Hudson Bay	Northwest HB Heli		62.3279	-85.2619	Canada
Northwest HB 3		06/06/2018	Hudson Bay	Northwest HB Heli		62.3604	-85.2203	Canada
R.W.S H1		08/06/2018	Hudson Bay	Roes Welcome Sound Heli		64.0049	-87.0154	Canada
R.W.S H2		08/06/2018	Hudson Bay	Roes Welcome Sound Heli		64.0739	-87.1999	Canada
R.W.S H3		08/06/2018	Hudson Bay	Roes Welcome Sound Heli		64.1391	-87.3856	Canada
R.W.S H4		08/06/2018	Hudson Bay	Roes Welcome Sound Heli		64.2236	-87.5592	Canada
R.W.S H5		08/06/2018	Hudson Bay	Roes Welcome Sound Heli		64.2920	-87.7409	Canada
C.I. H1		08/06/2018	Hudson Bay	Chesterfield Inlet Heli		63.4752	-90.8744	Canada
C.I. H2		08/06/2018	Hudson Bay	Chesterfield Inlet Heli		63.5688	-90.5472	Canada
C.I. H3		08/06/2018	Hudson Bay	Chesterfield Inlet Heli		63.2368	-90.6563	Canada
F.R. River Station		09/06/2018	Hudson Bay	Ferguson River Heli		62.0723	-93.351	Canada
F.R. Landfast 1		09/06/2018	Hudson Bay	Ferguson River Heli		61.8796	-92.8451	Canada
F.R. Landfast 2		09/06/2018	Hudson Bay	Ferguson River Heli		61.8173	-92.7918	Canada
Wil.R. River Station		09/06/2018	Hudson Bay	Wilson River Heli		62.3380	-93.1128	Canada
Wil.R. Landfast 1		09/06/2018	Hudson Bay	Wilson River Heli		62.1260	-92.4869	Canada
Wil.R. Landfast 2		09/06/2018	Hudson Bay	Wilson River Heli		62.1183	-92.4522	Canada
Wil.R. Z1		09/06/2018	Hudson Bay	Wilson River Zodiac		62.0574	-92.4729	Canada
Wil.R. Z2		09/06/2018	Hudson Bay	Wilson River Zodiac		61.9853	-92.3349	Canada
Wil.R. Z3		09/06/2018	Hudson Bay	Wilson River Zodiac		61.9211	-92.2151	Canada
T.R. River Station		11/06/2018	Hudson Bay	Thlewiaza River Heli		60.4851	-94.8167	Canada
T-A.R. River Station		11/06/2018	Hudson Bay	Tha-anne River Heli		60.5461	-94.8292	Canada

T-A.R. Z1		11/06/2018	Hudson Bay	Tha-anne River Zodiac		60.4712	-94.5673	Canada
T-A.R. Z2		11/06/2018	Hudson Bay	Tha-anne River Zodiac		60.4592	-94.4156	Canada
T-A.R. Z3		11/06/2018	Hudson Bay	Tha-anne River Zodiac		60.4434	-94.2228	Canada
Seal.R. River Station		28/06/2018	Hudson Bay	Seal River Heli		59.0739	-94.8344	Canada
K.R. River Station		28/06/2018	Hudson Bay	Knife River Heli		58.8831	-94.7031	Canada
C.R. River Station		28/06/2018	Hudson Bay	Churchill River Heli		58.6781	-94.2033	Canada
N.R. River Station		18/06/2018	Hudson Bay	Nelson River Heli		56.9659	-92.6305	Canada
H.R. Station		18/06/2018	Hudson Bay	Hayes River Heli		56.9955	-92.2924	Canada
Sev.R. River Station		19/06/2018	Hudson Bay	Severn River Heli		55.9603	-87.7081	Canada
Win.R. River Station		21/06/2018	Hudson Bay	Winisk River Heli		55.2218	-85.2068	Canada
34_HeliA		20/06/2018	Hudson Bay	Helicopter Ice Sampling		56.6833	-86.9083	Canada
34_HeliB		20/06/2018	Hudson Bay	Helicopter Ice Sampling		56.5867	-86.8968	Canada
34_HeliC		21/06/2018	Hudson Bay	Helicopter Ice Sampling		56.1072	-84.5633	Canada
34_HeliD		21/06/2018	Hudson Bay	Helicopter Ice Sampling		56.4099	-85.8918	Canada
36_HeliA		22/06/2018	Hudson Bay	Helicopter Ice Sampling		57.8781	-84.22	Canada
36_HeliB		22/06/2018	Hudson Bay	Helicopter Ice Sampling		57.8291	-85.1337	Canada
36_HeliC		22/06/2018	Hudson Bay	Helicopter Ice Sampling		58.2978	-87.6056	Canada
36_HeliD		22/06/2018	Hudson Bay	Helicopter Ice Sampling		58.0513	-86.8623	Canada
38_HeliA		23/06/2018	Hudson Bay	Helicopter Ice Sampling		58.7909	-84.2376	Canada
38_HeliB		23/06/2018	Hudson Bay	Helicopter Ice Sampling		58.7916	-85.1604	Canada
38_HeliC		23/06/2018	Hudson Bay	Helicopter Ice Sampling		59.2654	-87.9881	Canada
38_HeliD		23/06/2018	Hudson Bay	Helicopter Ice Sampling		59.0165	-87.1095	Canada
N.E. South Tran 1		29/06/2018	Hudson Bay	Nelson Estuary		57.1842	-91.811	Canada
N.E. South Tran 2		29/06/2018	Hudson Bay	Nelson Estuary		57.2081	-91.8711	Canada
N.E. South Tran 3		29/06/2018	Hudson Bay	Nelson Estuary		57.2176	-91.9585	Canada
N1a		29/06/2018	Hudson Bay	Nelson River		57.0543	-92.5351	Canada
N1b		29/06/2018	Hudson Bay	Nelson River		57.0558	-92.5313	Canada

N2		29/06/2018	Hudson Bay	Nelson River		57.1191	-92.4165	Canada
BN3a		29/06/2018	Hudson Bay	Nelson River		57.1358	-92.4118	Canada
BN3b		30/06/2018	Hudson Bay	Nelson River		57.1311	-92.4174	Canada
BN4a		30/06/2018	Hudson Bay	Nelson River		57.1660	-92.3519	Canada
BN4b		30/06/2018	Hudson Bay	Nelson River		57.1615	-92.3673	Canada
BN5a		30/06/2018	Hudson Bay	Nelson River		57.1731	-92.3411	Canada
BN5b		30/06/2018	Hudson Bay	Nelson River		57.1628	-92.3574	Canada
BN6a		30/06/2018	Hudson Bay	Nelson River		57.2078	-92.2868	Canada
BN6b		30/06/2018	Hudson Bay	Nelson River		57.2019	-92.308	Canada
BN7a		30/06/2018	Hudson Bay	Nelson River		57.2500	-92.2216	Canada
BN7b		30/06/2018	Hudson Bay	Nelson River		57.2579	-92.237	Canada
N3		30/06/2018	Hudson Bay	Nelson River		57.2059	-92.2825	Canada
N4		30/06/2018	Hudson Bay	Nelson River		57.2221	-92.2939	Canada
IB13		19/06/2018	Hudson Bay	Ice Beacon Deployment Via Heli		56.6173	-87.4002	Canada
IB17		18/06/2018	Hudson Bay	Ice Beacon Deployment Via Heli		58.4802	-89.2547	Canada
IB18		22/06/2018	Hudson Bay	Ice Beacon Deployment Via Heli		58.3499	-87.4718	Canada
IB19		19/06/2018	Hudson Bay	Ice Beacon Deployment Via Heli		57.7233	-88.2824	Canada
IB20		23/06/2018	Hudson Bay	Ice Beacon Deployment Via Heli		59.3507	-87.8543	Canada
IB21		21/06/2018	Hudson Bay	Ice Beacon Deployment Via Heli		56.4220	-85.4002	Canada
IB22		23/06/2018	Hudson Bay	Ice Beacon Deployment Via Heli		58.8122	-84.3463	Canada
IB23		19/06/2018	Hudson Bay	Ice Beacon Deployment Via Heli		57.0884	-88.4002	Canada
IB25		22/06/2018	Hudson Bay	Ice Beacon Deployment Via Heli		57.8789	-84.1463	Canada

IB26		21/06/2018	Hudson Bay	Ice Beacon Deployment Via Heli		56.2193	-84.5491	Canada