BaySys 2017 Fall Cruise Report
-Turnaround of Moorings-

The recovery of BaySys mooring from CCGS "Henry Larsen barge. Three oceanographic moorings were recovered and re-deployed on 21-31 October, 2017. Water samplings and CTD casts were executed at each mooring position to determine the vertical thermohaline and hydrochemical structure.

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BaySys 2017 Mooring Program Cruise Report

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1. Introduction

BaySys is a 4-year collaboration among industry partner Manitoba Hydro (Hydro Québec and Ouranos) and the Universities of Manitoba, Northern British Columbia, Québec à Rimouski, Alberta, Calgary, Laval and Trent to conduct research on Hudson Bay. The overarching goal of the project is to understand the role of freshwater in Hudson Bay marine and coastal systems, and in particular, to create a scientific basis to distinguish climate change effects from those of hydroelectric regulation of freshwater on physical, biological and biogeochemical conditions in Hudson Bay.

In late September 2016, five oceanographic moorings were deployed in the eastern Hudson Bay and at the entrance to James Bay (Figure 1). These moorings were supposed to be recovered in summer 2017 during the BaySys cruise onboard CCGS *Amundsen* or *White Diamond* - a vessel refurnished in 2017 for the Churchill Marine Observatory. Later, a decision on turning the moorings from *White Diamond* instead of recovery was made. Unfortunately, the slow progress of ship's inspection from Transport Canada caused multiple delays of ship's departure from Prince Edward Island and the 2017 cruise was cancelled. Because of the critical role of these moorings for the scientific objectives of oncoming *Amundsen* cruise in spring 2018, the opportunistic cruise onboard CCGS *Henry Larsen* was conducted in October 26 – November 1, 2017 in order to maintain the uninterrupted measurements. The goals for this short cruise were to retrieve and re-deploy as many BaySys moorings as possible accompanied with the concurrent CTD and water sampling.

Figure 0. The array of BaySys mooring deployed in September 2016 and the initial turnaround plan

2. Mooring Operations

2.1. Mooring recovery

Despite the fact that the late autumn is usually very windy in the Hudson Bay region, the last days of October 2017 were relatively calm with a relatively light wind speed. Such a good weather allowed us using the ship's barge for NE02 and NE03 mooring recoveries (Figure 2). The barge was equipped with two small winches that were used to pull the mooring line and instruments onboard. Taking into account the relatively short length of all moorings, the recovery of NE03 and NE02 took approximately 30-40 minutes after the mooring's release. The heavy Trawl Resistant Bottom Mount (TRBM) at NE02 was the only element which could not be lifted on the barge's deck and it was drawn to the ship for lifting with a crane (Figure 3). For AN01 mooring, the zodiac boat was used to assist the recovery that was made with a crane from the ship's foredeck.

Figure 2. Onboard the barge with a recovered mooring.

Figure 3. Lifting the TRBM (NE02) onboard Henry Larsen.

2.2. The configuration of recovered moorings

The information from all instruments was examined after recoveries to determine if all equipment worked properly and recorded the reliable data. We also examined the pressure records from all available sensors to adjust the depths of moored instruments and prepare the final schemes of moorings' configurations (Figure 4). In general, all recovered instruments worked well and provided the year-long records of temperature, salinity, current velocities, ice thickness/waves etc. However, due to the loss of the buoyant tubes the surface ~27 m layer was unresolved at NE02 and NE03 positions in terms of thermohaline properties. It is difficult to say what the reasons of loss were but the wearing of weak links is mainly suspected for both moorings. Although the surface tubes at AN01 mooring persisted until recovery, the rope connecting the tubes with an anchor tangled around the major mooring line in 5 days after deployment, and the tubes became clung at the depth 30-40 m for the rest of measuring period. As a result, no surface layer records are available from all three locations and a new strategy needs to be developed for the surface layer measurements throughout the seasonal cycle under the sea ice.

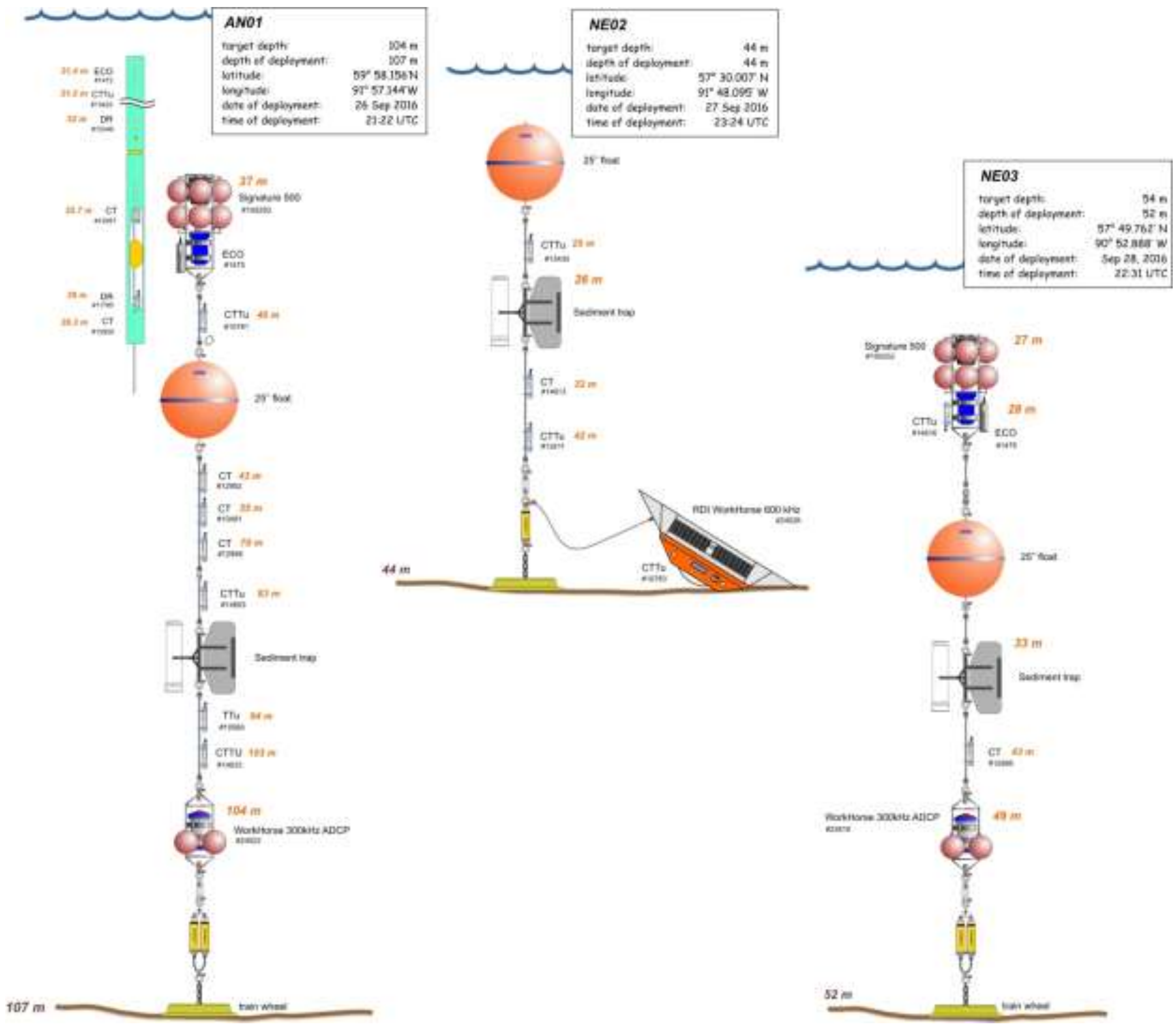
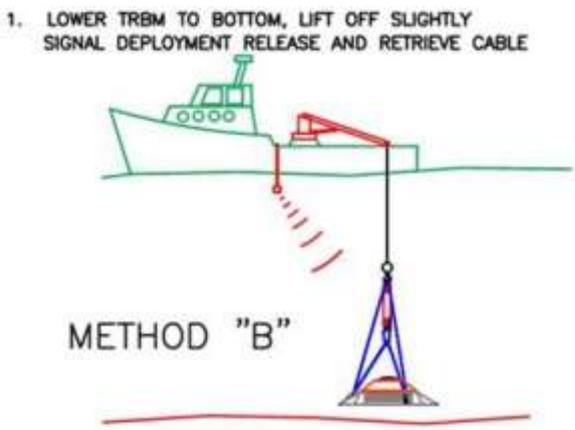


Figure 4. AN01 (Churchill shelf), NE02 (Nelson Outer Estuary) and NE03 (Nelson River outer shelf) mooring configurations as recovered

It was also found that the TRBM at NE02 flipped upside-down during deployment (Figure 4). The large cross-sectional area makes TRBM very unstable during free-fall deployment and its positioning on the sea-floor has to be done with precautions. Although the recommended method of deployment was used (Figure 5, left) and the bottom mount was released approximately 10m above the sea floor, the platform seems to have been initially tilted as the ship was drifting during deploying. This could further initialize the flipping as soon as the slip-lines had been released. An alternative approach (Figure 5, right) was used to deploy the TRBM at NE01 mooring with helicopter. The floats were rigged above the platform acting to raise the height of the center of buoyancy and keep any external force from flipping the unit, although the success of that operation will remain unknown until recovery next year.



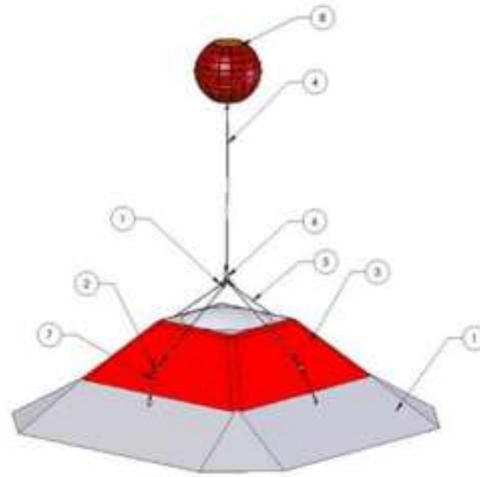


Figure 5. The deployment of TRBM with an acoustic release (left) and with a float (right)

2.3. Mooring re-deployment

The recovered moorings were re-deployed from the helicopter deck by using the crane at the starboard side of the ship (Figure 6). The relatively short length of all moorings allowed deploying them "anchor last" (Figure 7). Although all acoustic releases were found functioning well, we kept using two acoustic releases at each mooring to increase the mooring survivability in a case of one of releases failure. The moorings were deployed in the same positions (or in a close vicinity) as in 2016.

Figure 6. Mooring deployment from the helicopter deck

Figure 7. Approaching to the release of anchor

We kept the same configurations of moored instruments at all three moorings with the minor changes related to the removal of sediment traps and buoyant tubes near the surface. The TRBM at NE02 was also replaced with an in-line not-magnetic frame for carrying the upward-looking ADCP near the bottom. All mooring components were programmed for a one-year deployment with the suggested recovery in early summer 2018 from CCGS *Amundsen*. The mooring configurations, time of deployments, coordinates and the codes for acoustic releases are presented in Figure 8.

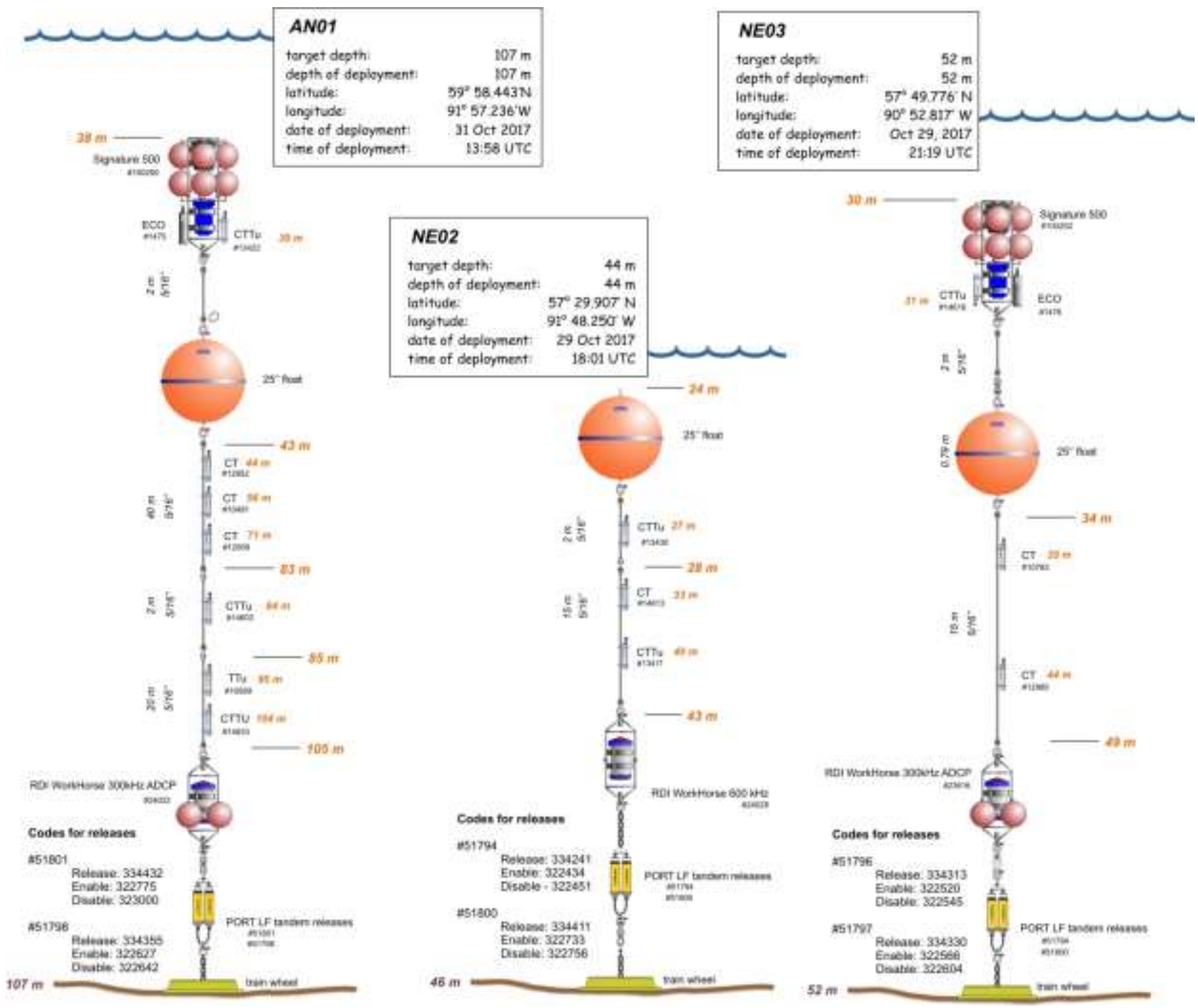


Figure 8. The new configuration of AN01, NE02 and NE03 moorings

2.4. Sediment Traps

The Sediment traps on moorings AN01, NE02 and NE03 were successfully recovered and were not redeployed. Mooring JB02 was not recovered during this operation. Once on board the traps were dismantled, first removing the PVC tube that houses an asymmetrical funnel, the stabilising fins and then the sample vials from the rosette (Figure 9). The samples were placed into a vial rack numbered from 1 to 10 (Figure 10). The vials were then emptied into labeled amber jars which were then packed and stored in cooler on the deck. The sediment traps were then reassembled, cleaned with freshwater and then packed in their respective boxes for transport. The samples collected have been placed in cold storage (-4°C) and are yet to be analyzed.

Figure 9: The rosette of the sediment traps being filed with density gradient solution before deployment.

Figure 10: The vials from the sediment traps in the vial rack.

2.5. Early results

The CT sensors deployed at different depths captured the seasonal changes in vertical thermohaline structure at all three positions. These changes correspond to the impact of different processes such as: the vertical mixing and redistribution of heat from the surface to the deeper layers in autumn; cooling of water column and the following salinity increase due to the sea ice growth in winter; the freshening and warming associated with sea ice melting/river runoff and solar heating in summer (Figure 11).

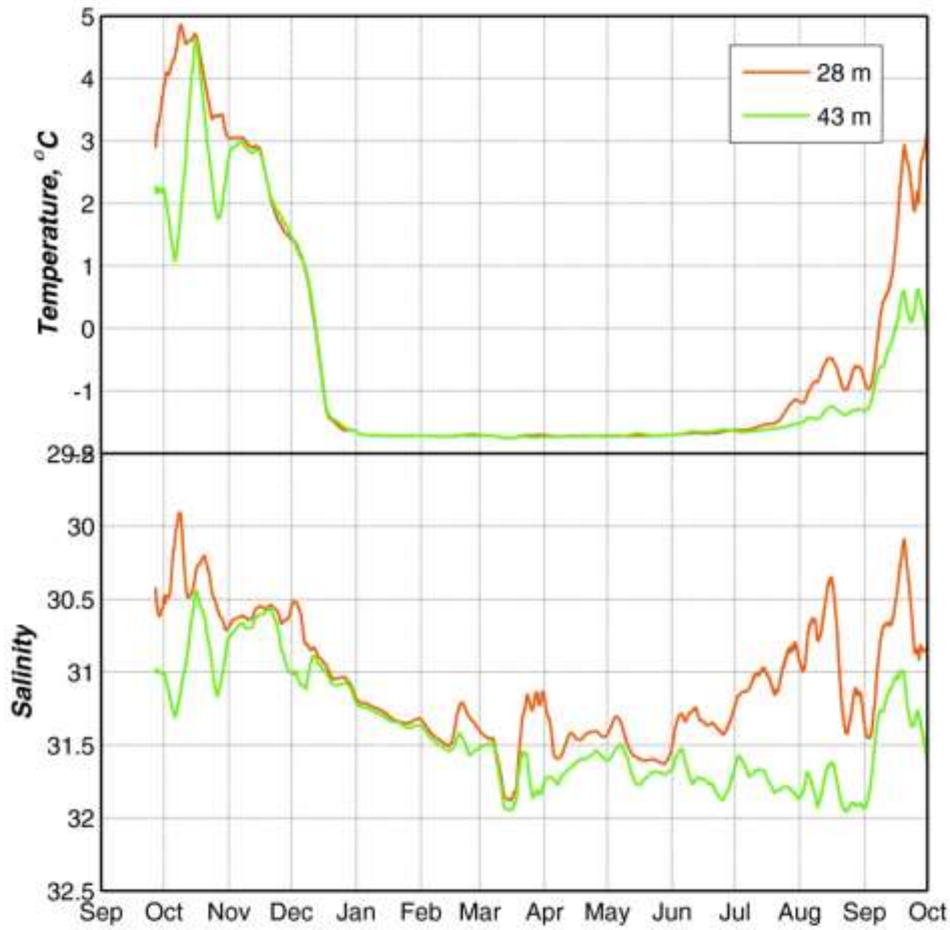


Figure 11. The one-year evolution of vertical thermohaline structure at NE03 mooring

The effect of atmospheric circulation on vertical thermohaline structure and freshwater content is clearly seen in CT data at NE02. The altering wind forcing led to the shift of the frontal zone formed by fresher coastal water (diluted by rivers' discharge) and saltier basin water. For instance, the considerable freshening observed at NE02 mooring on March 8 and September 3 was associated with low atmospheric pressure systems passing over the Hudson Bay. The storm winds resulted in on-shore water transport that blocked riverine waters near the shore and caused abrupt salinity decrease by 1.5-2.0 (Figure 12).

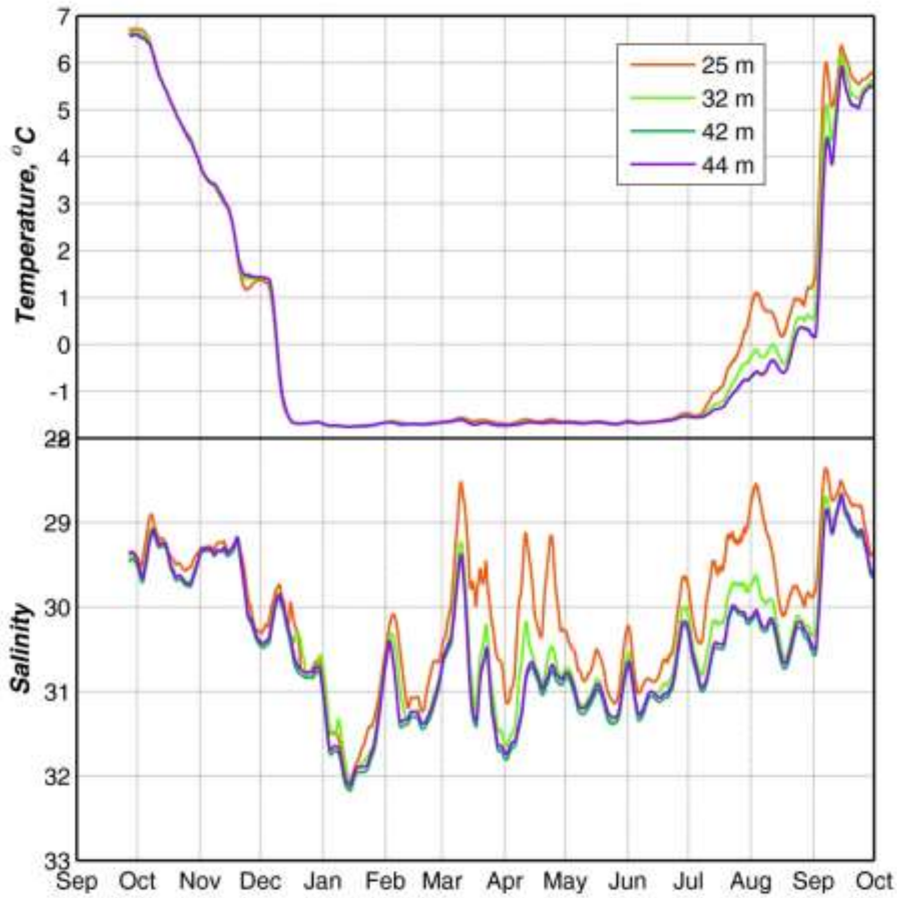


Figure 12. The one-year evolution of vertical thermohaline structure at NE02 mooring

Another piece of important information has been received from the combination of two upward-looking ADCPs : WorkHorse 300 kHz by RDI deployed near the sea floor and Signature 500 kHz by Nortek at AN01 and NE03. Both instruments provided the continual records of water dynamic in entire water column with 15 min recording interval. Moreover, Signature 500 was equipped with 5th vertical beam that allowed measuring the wave heights and directions as well as the draft of ice throughout the full seasonal cycle (Figure 13).

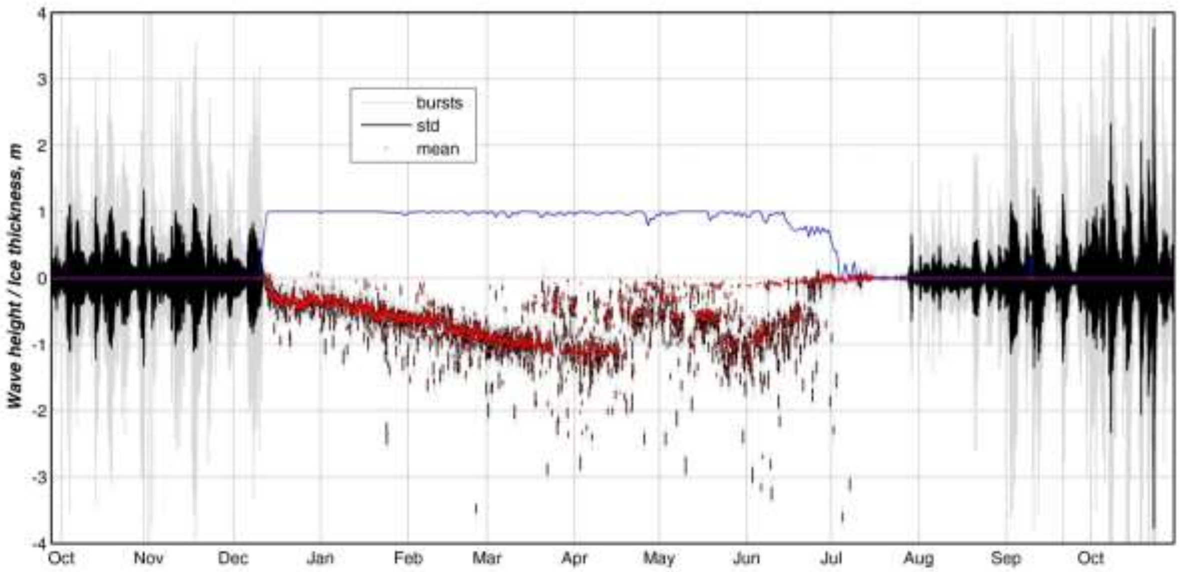


Figure 13. The sea-level heights and ice thicknesses recorded by upward-looking Nortek ADCP at AN01 mooring. Blue line shows AMSR2 sea ice concentration in the mooring position.

3. CTD

For the hydrological measurements, we used SBE 19plusV2 CTD profiler with a set of various sensors (see Table 1) mounted on a frame. CTD casts were made from the starboard side of foredeck with an assistance of ship's crane and winch (Figure 14). The depth of each cast was limited by ~10 m above the sea floor from the safety considerations, although the maximum distance to the bottom at each station could be higher taking into account the tilt of the rope because of current and ship's drift. Totally, 4 CTD casts were made at the mooring positions and one cast was made in between NE02 and NE01 positions (Table 2).

Table 1. CTD sensors

Instrument	Manufacturer	Type & Properties	Serial Number	Date of calibration
Data Logger	SeaBird	SBE-19plus V2 Sampling rate : 4 Hz	6989	
Temperature	SeaBird	Range: -5°C to + 35°C Accuracy: 0.005	6989	6 July 2016
Pressure	SeaBird	Accuracy: 0.1% of full range Range 1000 m	3525364	1 July 2016
Conductivity	SeaBird	Range: 0 to 9 S/m Accuracy: 0.0005	6989	6 July 2016
Oxygen	SeaBird	SBE-43 Range: 120% of saturation	2244	7 July 2016

		Accuracy: 2% of saturation		
PAR	Biospherical/Licor		70392	3 October 2011
Fluorometer	Seapoint		3491	3 April 2014
Turbidity	Seapoint		13052	3 April 2014

Figure 14. CTD cast from the foredeck

3.1. Preliminary results of thermohaline stratification in the mooring positions from CTD profiles

Temperature and salinity profiles were recorded at the mooring locations either before the mooring recovery (AN01, NE03, and NE02) and after re-deployment (AN01). The vertical CTD profiles collected at AN01 position show the freshened (~2 psu) surface layer with a pycnocline located at 30-35 m (Figure 15). The fresher surface waters there seem to be mostly associated with a local melt of sea ice in summer. The melt of 1.5m ice with a salinity of 4 would result in diluting of surface 30 m layer by 1.4 that is reasonably close to the observed salinity anomalies. In the Nelson area, the only station showing the presence of vertical stratification is HL17-04, where the salinity at surface ~3 psu lower compared to the bottom layer. The vertical stratification at the stations located further off-shore is absent. This fact is likely attributed to the intensive wind-driven vertical mixing initiated by several sequential strong storms in mid-October with an average wind speed exceeding 20 m/s. The thermal stratification matches, in general, the salinity profiles. The surface waters were well above freezing point and ranged from 1° C in AN01 position to 3-4° C north-east of Nelson mouth (Figure 15).

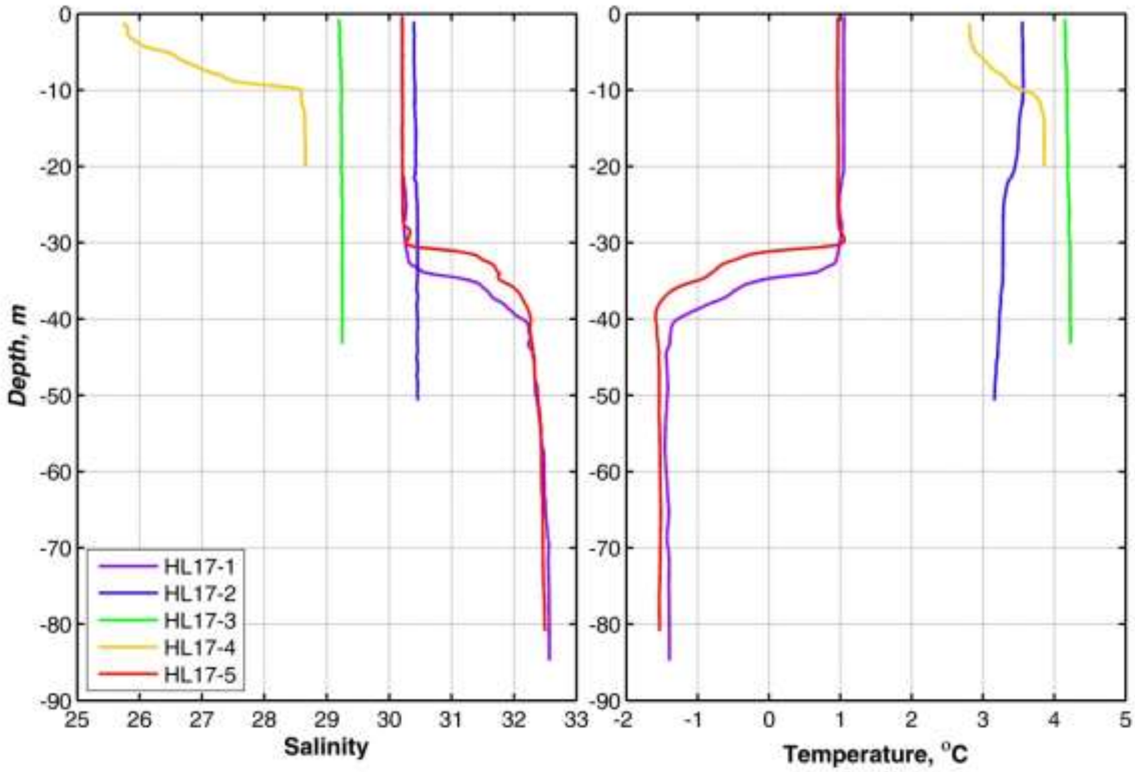


Figure 15. Temperature and salinity profiles collected during the cruise

Table 2. The positions of CTD stations, water sampling and moorings

Date	CTD cast	Mooring position	LAT (N) DD MM.SS	LON (W) DD MM.SS	Operation	Time (UTC)	Water depth (m)	Comments
27-Oct	HL17-01	*AN01*	59 57.7	091 56.9	CTD	08:17	107	
27-Oct		*AN01*	59 57.7	091 56.9	Water sampling		107	Surface, 20m, 40m, 100m
28-Oct	HL17-02	*NE03*	57 49.6	090 52.6	CTD	08:59	54	
28-Oct		*NE03*	57 49.6	090 52.6	Water sampling		54	Surface, 20m, 30m, 50m
28-Oct		*NE03*	57 49.8	090 52.9	Mooring recovery		54	
28-Oct	HL17-03	*NE02*	57 30.1	091 47.9	CTD	13:51	44	
28-Oct		*NE02*	57 30.1	091 47.9	Water sampling		44	Surface, 5m, 15m, 40m
28-Oct		*NE02*	57 30.0	091 48.1	Mooring recovery		44	
29-Oct	HL17-04		57 23.5	092 00.1	CTD	08:44	?	CTD cast to 20 m
29-Oct			57 23.5	092 00.1	Water sampling		?	Surface, 5m, 15m, 20m

29-Oct		*NE02*	57 29.907	091 48.250	Mooring deployment	18:01	44	
29-Oct		*NE03*	57 49.776	090 52.817	Mooring deployment	21:19	54	
30-Oct		*AN01*	59 58.2	091 57.1	Mooring recovery		107	
31-Oct		*AN01*	59 58.443	091 57.236	Mooring deployment	13:58	107	
31-Oct	HL17-04	*AN01*	59 57.7	091 56.9	CTD	14:24	107	

4. Water Sampling

The second objective of our shipboard fieldwork was to characterize the physical and chemical properties in the water column such as oxygen isotopes and nutrients. The water was sampled in the same location as the CTD casts using a Niskin bottle. At all stations 4 depths were sampled, at the surface, above the pycnocline, below the pycnocline and the bottom. The depths of the pycnocline samples were determined by looking at the CTD casts. The Niskin bottle was lowered over the side of the ship using a marked rope by hand to the approximate depths. The Niskin bottle was triggered using a messenger and then retrieved. The samples were then sub sampled for the properties shown in Table 3.

Table 3. Water sampling parameters collected during cruise

CTD	Conductivity temperature depth probe of two manufacturers (Seabird, Idronaut)
CDOM	Colored dissolved organic matter
O18	Oxygen Isotopes
NO^3, NO^2, Si, PO^4	Nitrite, nitrate, orthophosphate and orthosilicic acid
Salinity	

All subsamples were stored in a cooler on the deck in order to remain cool, apart from the nutrient samples which were frozen. All information of Niskin bottle and CTD casts can be found in table 2.

5. Acknowledgements

The BaySys teams would like to thank the CCG for their extraordinary collaboration to make this happen and the Captain and crew of the CCGS Henry Larsen for their commitment to this field project and ensuring safe deployment and recovery of the moorings. We would like to acknowledge Manitoba Hydro for their extensive logistical and in-kind support to this field program. Lastly, we are grateful to the Natural Sciences and Engineering Research Council of Canada (NSERC).

6. Appendix

Mooring	Instrument	Depth, m	Start time	End time	Frequency	Data status	Notes
AN01	Signature 500	37	27 Sep, 2016	30 Oct, 2017	15 min	OK	
	WorkHorse 300	104	27 Sep, 2016	30 Oct, 2017	15 min	OK	
	ECO	38	26 Sep, 2016	30 Oct, 2017	30 min	OK	
	RBR CTTu	40	27 Sep, 2016	01 Oct, 2017	15 min	OK	
	RBR CT	43	27 Sep, 2016	01 Oct, 2017	15 min	OK	
	RBR CT	55	27 Sep, 2016	01 Oct, 2017	15 min	OK	
	RBR CT	70	27 Sep, 2016	01 Oct, 2017	15 min	OK	
	RBR CTTu	83	27 Sep, 2016	01 Oct, 2017	15 min	OK	
	RBR TTu	94	27 Sep, 2016	01 Oct, 2017	15 min	OK	
	RBR CTTu	103	27 Sep, 2016	01 Oct, 2017	15 min	OK	
	Sediment trap	84	04-Oct-16 08-Nov-16 13-Dec-16 17-Jan-17 21-Feb-17 28-Mar-17 02-May-17 06-Jun-17 11-Jul-17 15-Aug-17	08-Nov-16 13-Dec-16 17-Jan-17 21-Feb-17 28-Mar-17 2-May-17 06-Jun-17 11-Jul-17 15-Aug-17 19-Sep-17	35 days 35 days 35 days 35 days 35 days 35 days 35 days 35 days 35 days 35 days	OK	
AN01 surface tubes	ECO	31.4	26 Sep, 2016	30 Oct, 2017	30 min	OK	
	RBR CTTu	31.5	20 Jun, 2016	20 Jun, 2016			No data recorded. Wrong timing
	RBR TD	32	27 Sep, 2016	01 Oct, 2017	15 min	OK	
	RBR CT	35.7	27 Sep, 2016	01 Oct, 2017	15 min	OK	
	RBR TD	39	27 Sep, 2016	01 Oct, 2017	15 min	OK	
	RBR CTTu	39.2	27 Sep, 2016	01 Oct, 2017	15 min	OK	
NE03	Signature 500	27	28 Sep, 2016	28 Oct, 2017	15 min	OK	
	WorkHorse 300	49	28 Sep, 2016	28 Oct, 2017	15 min	OK	
	ECO	28	28 Sep, 2016	28 Oct, 2017	30 min	OK	
	RBR CTTu	28	27 Sep, 2016	01 Oct, 2017	15 min	OK	
	RBR CT	43	27 Sep, 2016	01 Oct, 2017	15 min	OK	

	Sediment trap	33	04-Oct-16 08-Nov-16 13-Dec-16 17-Jan-17 21-Feb-17 28-Mar-17 02-May-17 06-Jun-17 11-Jul-17 15-Aug-17	08-Nov-16 13-Dec-16 17-Jan-17 21-Feb-17 28-Mar-17 2-May-17 06-Jun-17 11-Jul-17 15-Aug-17 19-Sep-17	35 days 35 days 35 days 35 days 35 days 35 days 35 days 35 days 35 days 35 days	OK	
NE03 surface tubes	Lost						
NE02	WorkHorse 600	44					The platform was flipped over during deployment. No data recorded.
	RBR CTTu	25	27 Sep, 2016	01 Oct, 2017	15 min	OK	
	RBR CT	32	27 Sep, 2016	01 Oct, 2017	15 min	OK	
	RBR CTTu	42	27 Sep, 2016	01 Oct, 2017	15 min	OK	
	RBR CTTu	44	27 Sep, 2016	01 Oct, 2017	15 min	OK	
	Sediment trap	26	01-Oct-17 26-Oct-17 21-Nov-17 16-Dec-17 11-Jan-18 05-Feb-18 03-Mar-18 28-Mar-18 23-Apr-18 18-May-18	26-Oct-17 21-Nov-17 16-Dec-17 11-Jan-18 05-Feb-18 03-Mar-18 28-Mar-18 23-Apr-18 18-May-18 13-Jun-18	25.5 days 25.5 days 25.5 days 25.5 days 25.5 days 25.5 days 25.5 days 25.5 days 25.5 days 25.5 days	OK	
NE02 surface tubes	Lost						