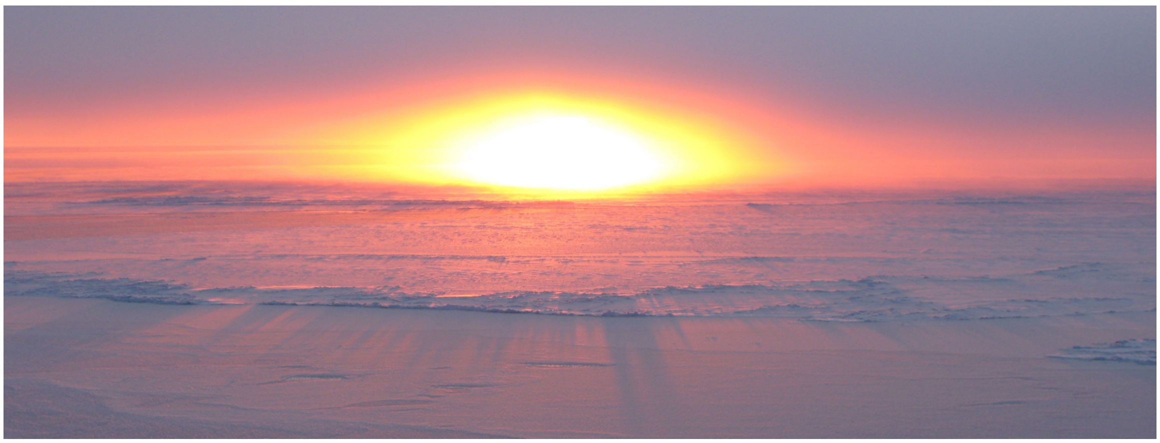
Joint Ocean Ice Study (JOIS) 2010
Cruise Report



Report on the Oceanographic Research Conducted aboard the *CCGS Louis S. St-Laurent,* September 15 to October 15, 2010

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1. OVERVIEW

The Joint Ocean Ice Study (JOIS) in 2010 involved the collaboration of Fisheries and Oceans Canada researchers with colleagues primarily from the U.S.A and Japan. This program forms an important Canadian contribution to international climate research programs and is comprised of two ongoing programs: the Beaufort Gyre Exploration Project (BGEP), a collaboration with Woods Hole Oceanographic Institution scientists and the Pan-Arctic Climate Investigation (PACI), a collaboration with Japan Agency for Marine-Earth Science and Technology (JAMSTEC) scientists. In 2010 JOIS also included ancillary programs carried out by researchers from: the International Arctic Research Center (IARC) in Fairbanks Alaska; Tokyo University of Marine Science and Technology (TUMSAT), Japan; Kitami Institute of Technology (KIT), Japan.

Research questions sought to understand the impacts of global change on the physical environment and corresponding biological responses by tracking and linking decadal scale perturbations in the Arctic atmosphere to interannual basin-scale changes in freshwater content, water mass properties, water mass distribution, ocean circulation and biota distribution in the Beaufort Gyre of the Canada Basin. In particular to:

- Understand the impacts of global change on sea ice and other fresh water products by utilizing a suite of stable isotopes and geochemical markers to quantify freshwater components and investigate water mass pathways.
- Investigate physical processes such as ice formation and gas exchange, turbulence and heat transfer, thermohaline intrusions, ventilation, boundary currents, and geothermal heating**.**
- Investigate distribution of phytoplankton and zooplankton.

2. CRUISE SUMMARY

The JOIS science program onboard the *CCGS Louis S St-Laurent* began September 15^{th} and finished October 15^{th}, 2010. The research was conducted in the Canada Basin from the Beaufort Shelf in the south to 80°N by a research team of 23 people. Full depth CTD casts with water samples were conducted, measuring biological, geochemical and physical properties of the seawater. The deployment of expendable temperature and salinity probes increased the spatial resolution of CTD measurements. Moorings and ice-buoys were serviced and deployed in the deep basin for daily time-series. Underway ice observations were taken and on-ice surveys conducted. Zooplankton net tows, phytoplankton and bacteria measurements were collected to examine distributions of the lower trophic level. Underway measurements were made of the surface water. Daily dispatches were posted to the web.

The goals of the JOIS program, led by Bill Williams of Fisheries & Oceans Canada (DFO), were met during the successful four-week program. However, this year, as last year, the late season ship schedule meant that science operations were less efficient and significant difficulties were encountered due to cold weather and the limited hours of daylight. In addition, we expected the refueling of the Louis to take place prior to 15 September, before we boarded the ship. This did not occur and a delay of 4 days (with 350 additional nm of steaming) was incurred at the beginning of the cruise for refueling. Our science program was completed despite these delays and winter conditions thanks to:

a) Efficiency and multitasking of the Captain and crew in their support of science.

b) Relatively light ice conditions leading to faster transit times.

c) Minimizing the science program:

  i) the ORV Mirai from the JAMSTEC conducted the southern end of the 150W line near Barrow Canyon.

  ii) no additional projects that might require wire-time were brought on board.

  iii) minimal geographic extent of the science stations.

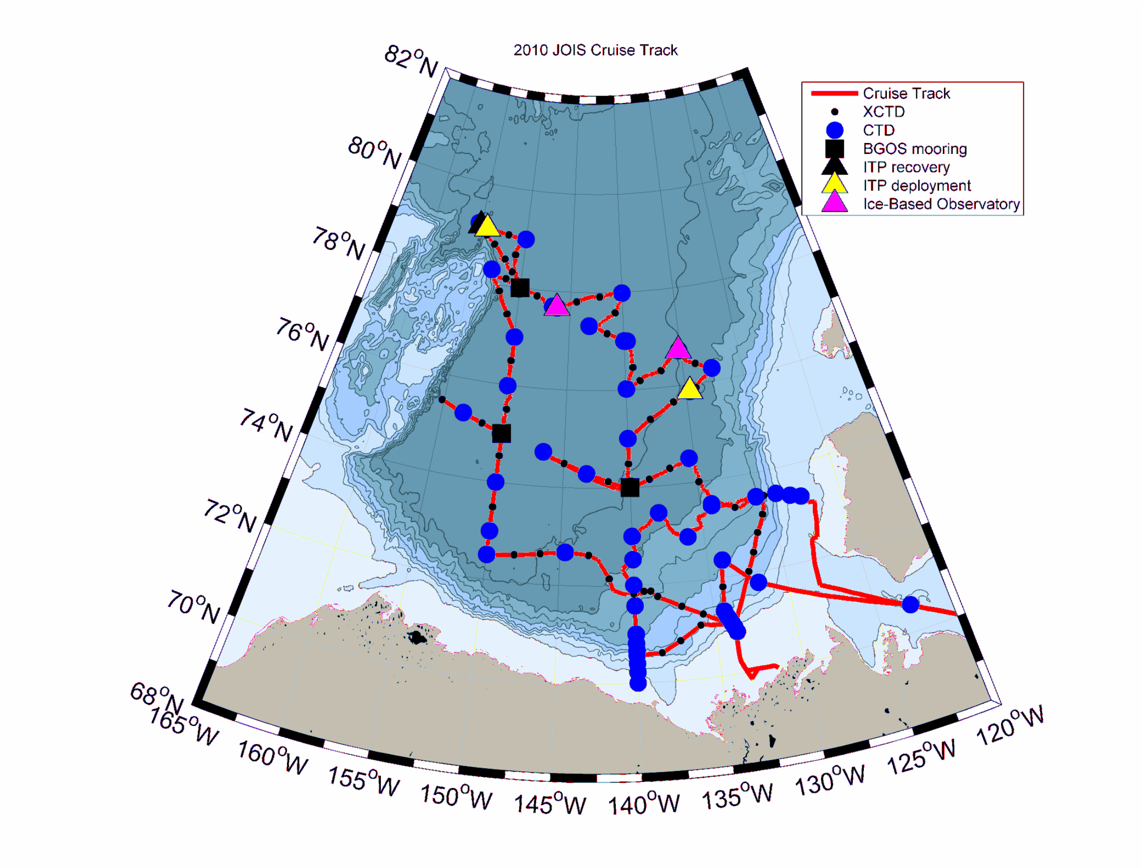

Figure 1.The JOIS-2010 cruise track showing the location of science stations.

- **PROGRAM COMPONENTS**

Distance Covered: 4964nm (Kugluktuk to Kugluktuk)

Measurements:

- At CTD/Rosette Stations:
  - 72 CTD/Rosette Casts at 56 Stations (DFO) with 1728 water samples collected for hydrography, geochemistry and pelagic biology (bacteria and phytoplankton) analysis (IOS, UBC, BIO and KOPRI).
    - At all stations: Salinity, Oxygen, Nutrients, Barium, ^{18}O, Bacteria, Alkalinity, Dissolved Inorganic Carbon (DIC, at surface only), Coloured Dissolved Organic Matter (CDOM), Chlorophyll-a.
    - At selected stations: Ammonium, DIC (full profile), $DI^{13}C$.
  - Upper ocean current measurements from Acoustic Doppler Current Profiler during most CTD casts (DFO)
  - 100 Vertical Net Casts at 24 select Rosette stations typically to 100m with occasional casts up to 1000m deep (DFO)
- 59 XCTD (expendable temperature, salinity and depth profiler) Casts typically to 1100m depth (JAMSTEC, WHOI , Tokyo University,)
- Mooring and buoy operations
  - 3 Mooring Recoveries (3 deep basin (WHOI))
  - 3 Mooring Deployments (3 deep basin (WHOI))
  - 2 Ice-Based Observatories (IBO, WHOI), the first consisting of :

    1 Ice Tethered Profiler (ITP, WHOI)
    1 Ice Mass Balance Buoy (IMBB, CRREL)
    1 Flux buoy

    and the second:

    1 Ice Tethered Profiler (ITP, WHOI)
    1 Ice Mass Balance Buoy (IMBB, CRREL)
    1 Flux buoy
    1 O-buoy (Bigelow, UAF)
  - 4 Ice Tethered Profilers deployments (ITP, WHOI)
  - 1 Ice Tethered Profiler recovery (ITP, WHOI)
  - NOTE: The CABOS mooring was not recovered and redeployed this year, owing to funding constraints. It remains in the water, collecting data, for another year.
- Ice Observations
  - Ice Observations (IARC)

    Hourly visual observations from bridge and automated fixed-camera photos.
    Opportunistic aerial observations during helicopter flights
    On-ice observations of ice-depth transects and ice-cores
  - Ice Observations (KIT)

Underway measurements of ice thickness from passive microwave sensor, an electromagnetic inductive sensor (EM-31), and a fixed camera.
On-ice observations of snow composition.

- Underway collection of meteorological, depth, near-surface seawater, and navigation data with 152 water samples collected from the underway seawater loop for: Salinity, Oxygen, Nutrients, Barium, ^{18}O, DIC/Alkalinity, Particulate Organic Carbon (POC), and CDOM. (DFO,UBC)
- Drift Bottles deployed at 1 site (DFO)
- Daily dispatches to the web (WHOI)

Other:

- Fuel (~2000m³ litres) loaded by barge near Tuktoyaktuk and McKinley Bay. The total loss to the program for refuelling was 4 days and 350nm of steaming.

3. COMMENTS ON OPERATION

3.1 Ice conditions

We had a substantial amount of open water in our study area again this year since our cruise was timed during the sea ice minimum and 2010 had low summer ice extent, similar to 2007, 8 and 9. The southern region and the 150W line north to 77N were mostly ice free and our return along the 140W contained a lot of new ice. The thickest multiyear ice was generally to the east of the 140W near the northwestern boarder of the Canadian Arctic Archipelgo. We encountered some of this ice when heading east from BGOS site D towards Banks Island. In general, ice was not a constraint during our program. Instead it was a challenge to find ice thick enough to install the ice-buoys in the northern area.

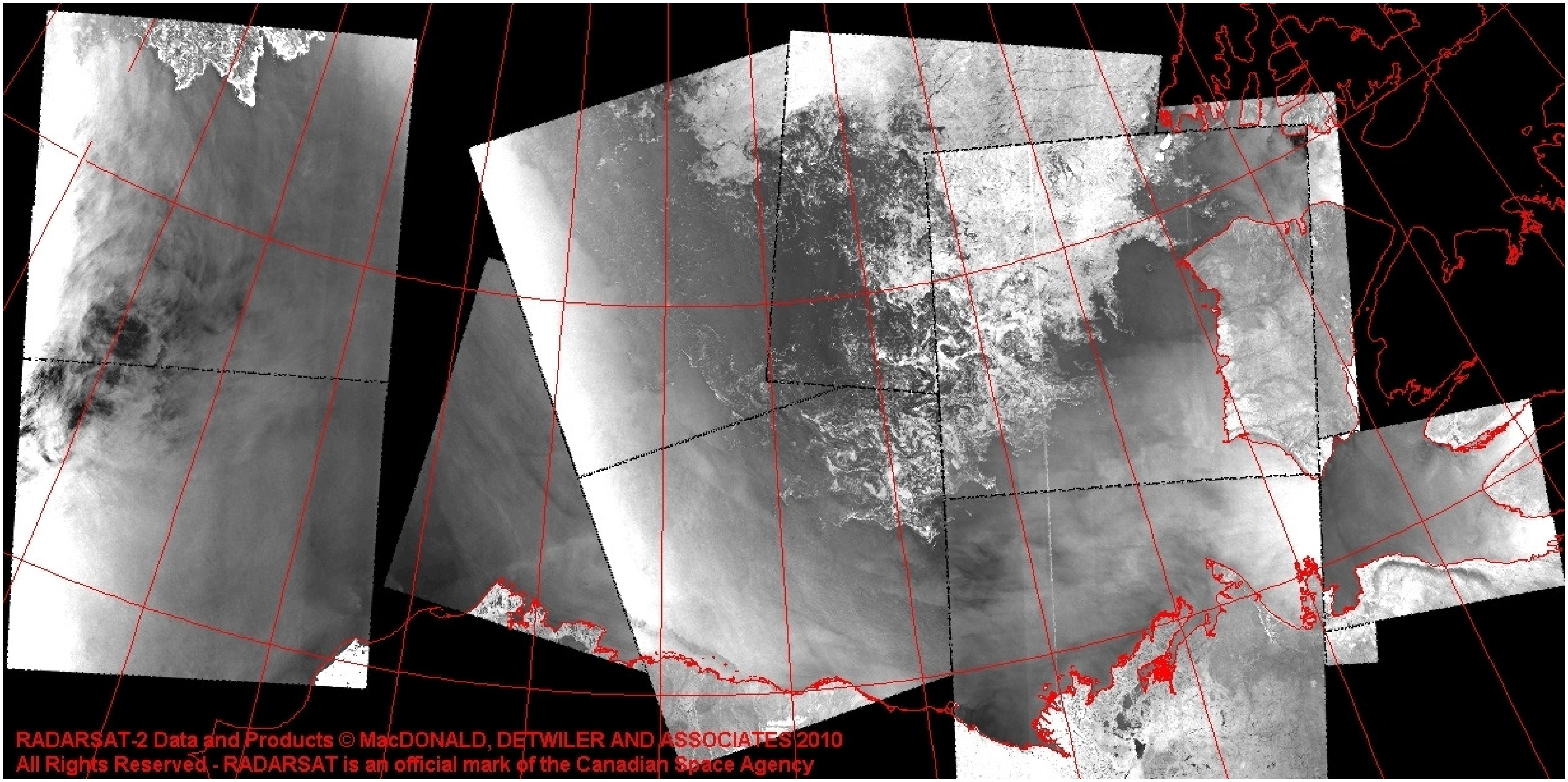

Figure 2. RADARSAT-2 mosaic from 13-16 September 2010 (created by Erik Thibault, Canadian Ice Service) showing ice conditions at the beginning of the expedition.

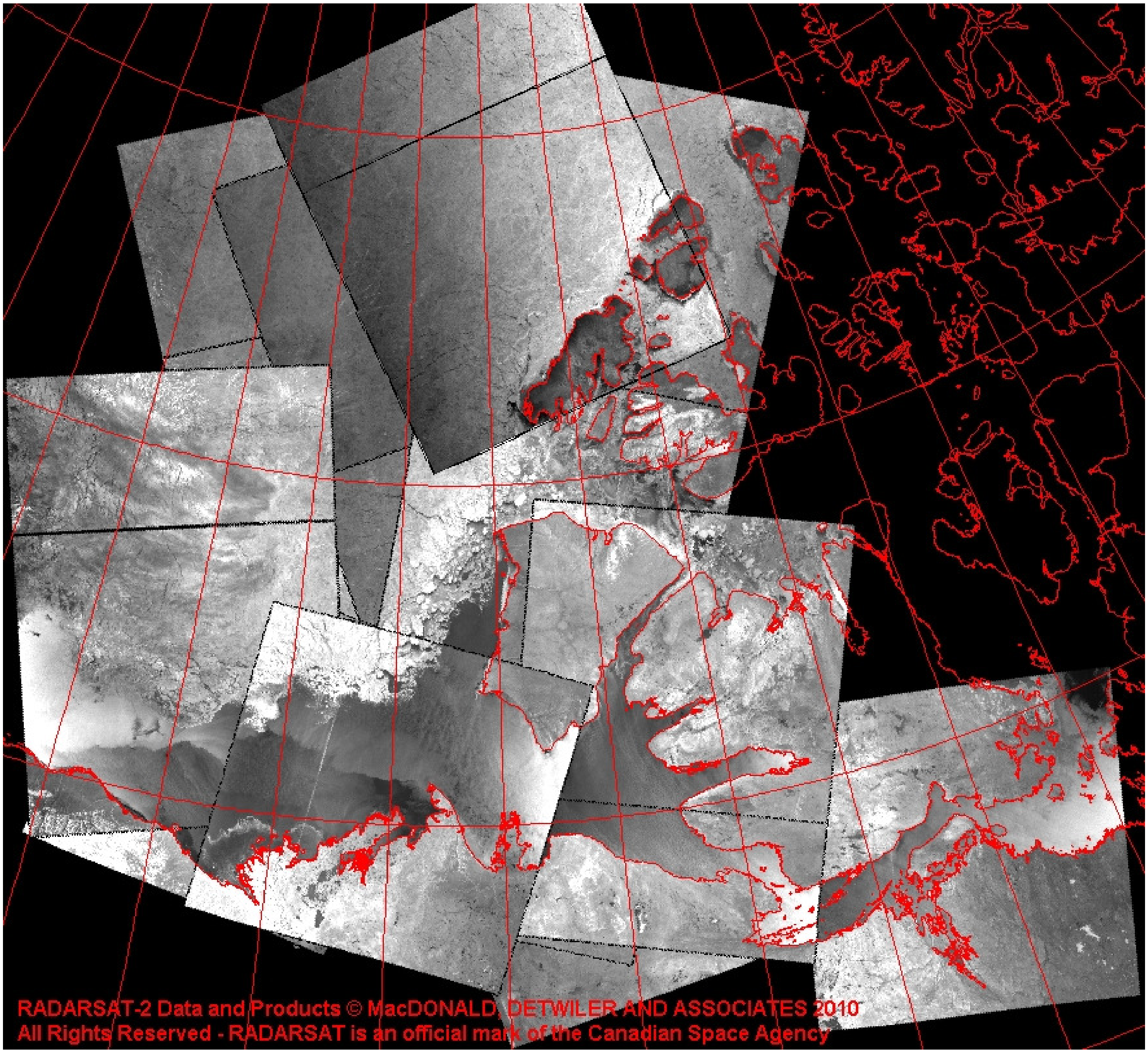

Figure 3. RADARSAT-2 mosaic from 12-14 October 2010 (created by Erik Thibault, Canadian Ice Service) showing ice conditions at the end of the expedition.

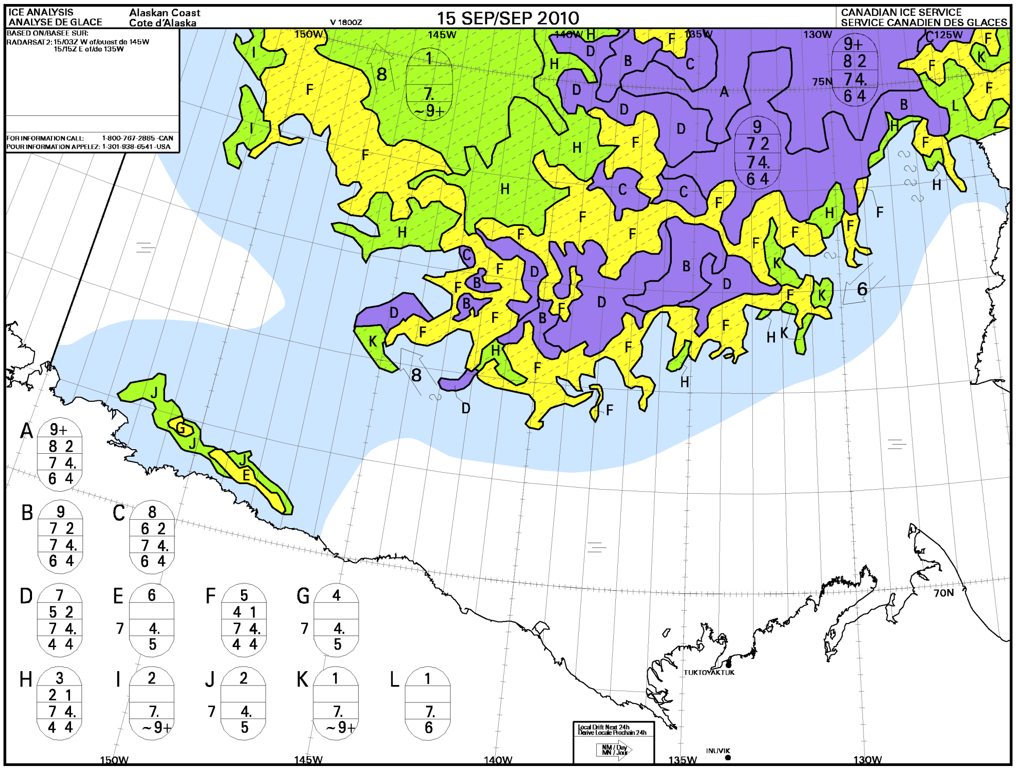

Figure 4. Ice concentration at the start of the program

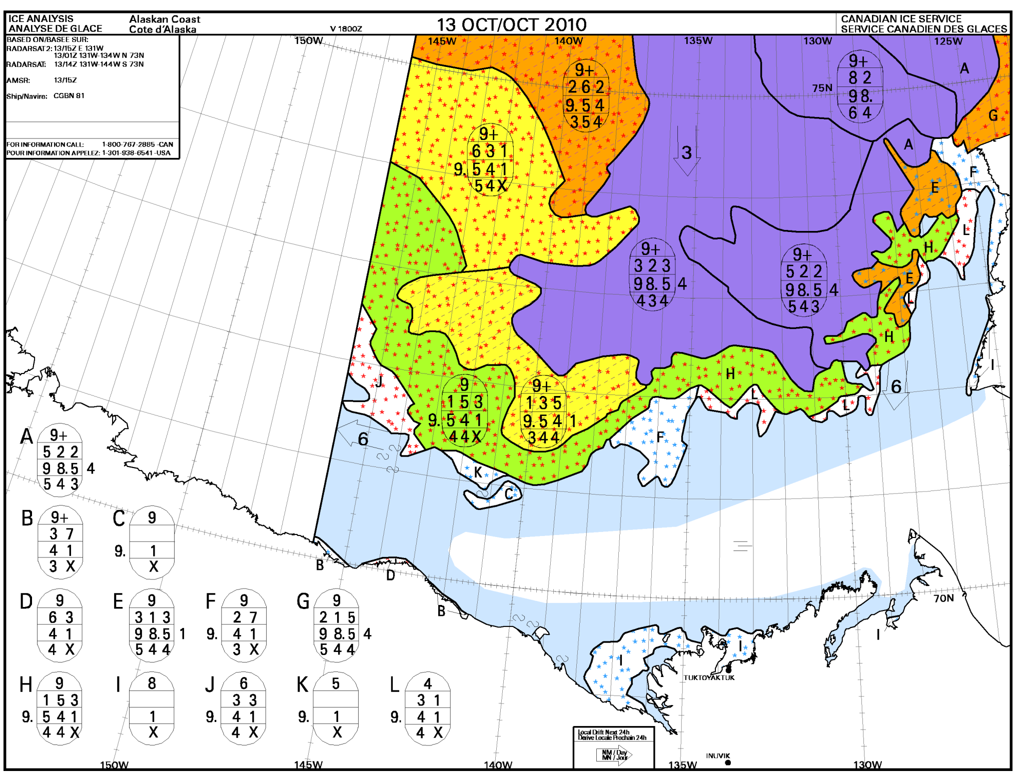

Figure 5. Ice concentration at the end of the program

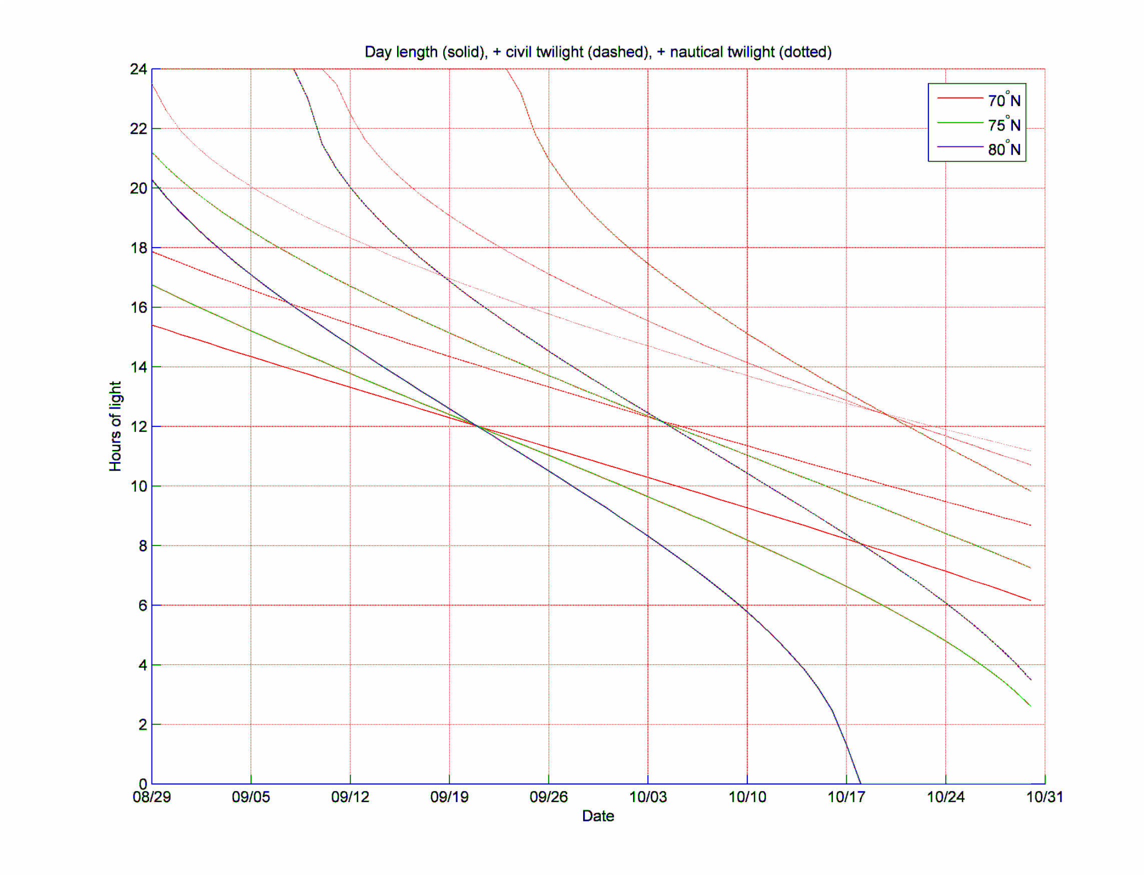

Figure 6. Hours of daylight dependant on latitude and day of year during the JOIS cruise.

3.2 Completion of planned activities

All primary objectives were met.

3.3 Ship improvements completed for 2010

We are very appreciative that all items identified last year for improvement were addressed. Through discussion and prioritising funds, decisions were made regarding what was feasible and could be improved. Some of the highlighted outcomes of last winter's efforts are listed below.

Suggestions for 2011

A list of suggested improvements to and comments about the ship's equipment and lab spaces will be sent separately. In the event next year's cruise is conducted in late September and October it would be beneficial to have additional lighting of the work decks and the ability to keep plumbing (including water from fire-mains) and winches from freezing.

ACKNOWLEDGMENTS

The science team would like to thank the Coast Guard for their support, particularly Captain Marc Rothwell and the crew of the *CCGS Louis S. St-Laurent*. At sea, we were very grateful for everyone's top-notch performance and assistance with the program. We'd like to thank Erik Thibault and the Canadian Ice Service for their assistance with ice images and weather information as well as Chris Swannell, the helicopter pilot for his and Steve Lloyd the helicopter mechanic's valuable help with ice reconnaissance flights, support on the ice and transport. Importantly, we'd like to acknowledge DFO, NSF and JAMSTEC for their continued support of this program.

4. PROGRAM COMPONENT DESCRIPTIONS

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

4.1 Rosette/CTD Casts:

PI: Bill Williams (DFO-IOS)
Mike Dempsey, Jane Eert, Sarah Zimmermann (DFO-IOS)

The primary CTD system used on board was a Seabird SBE9+ CTD s/n 0756, configured with a 24- position SBE-32 pylon with 10 litre Niskin bottles fitted with internal stainless steel springs in an ice-strengthened rosette frame. The data were collected real-time using the SBE 11+ deck unit and computer running Seasave V7 acquisition software. The CTD was set up with two temperature sensors, two conductivity sensors, two oxygen sensors, fluorometer, transmissometer, CDOM fluorometer and altimeter. In addition, an ISUS nitrate sensor and PAR sensor was used on select casts shallower than 1100 m. These sensors have 0-5v analogue output which is included in the CTD data string. Note that early on in the cruise the pressure housing for the battery pack of the ISUS leaked and resisted repair for the remainder of the cruise so that we have little ISUS or PAR data.

On all rosette casts we collected water samples for Salinity, Dissolved Oxygen, Nitrate (NO3), Silicate (SiO4), Phosphate (PO4), Chlorophyll-a (filtered at 0.7 µm with chlorophyll-a and phaeopigment values for each), Colored Dissolved Organic Matter (CDOM), Alkalinity, surface Dissolved Inorganic Carbon (DIC), ^{18}O, Barium, and Bacteria. On selected casts we sampled Ammonium and full profile DIC.

Prior to each deployment of the CTD/Rosette package the transmissometer and CDOM sensor windows were sprayed with deionised water and wiped with a DI water-soaked lens cloth to prevent sensor drift due to window fouling during the month-long cruise.

At the beginning of each CTD cast, the package was lowered to 5m to cool the system to ambient sea water temperature, remove bubbles from the sensor's plumbing and equilibrate the oxygen sensor. The pumps for the T/C/DO_2 ducts were manually turned on when the CTD/Rosette package was lowered into the water. The sensors were soaked for 3 minutes at 5m and at the end of the soak the package was then brought up to just below the surface, to begin a clean cast. For the cast, the package was lowered at 30m/min down to 300 or 500m deep and then lowered to within 8-10m of the bottom at 60m/min. Niskin bottles were closed during the upcast either by stopping the package, waiting 30 seconds then closing the bottle or closing the bottle 'on the fly' without slowing down ascent of the package. At the beginning of the cruise, in open water with waves, we closed bottles by stopping the package but relatively quickly changed to closing the bottles without a stop. During a CTD/Rosette cast, the instrumented sheave (Brook Ocean Technology) read out data to the winch operator, CTD operator and bridge, allowing all three to monitor cable out, wire angle and CTD depth.

In the upper 400m, the sample depths were chosen to match a set of salinity values. During the downcast, the depths of the salinity values were noted so that on the upcast the bottle could be closed at the pre-determined depths.

Figure 7. Bringing the full rosette in the sampling room.

Data/Performance notes:

The SBE9+ CTD overall performance was very good.

The primary oxygen sensor, a SBE-43, performed well. There were shifts in the readings requiring calibration but no issues with the membrane.

Due to the colder temperatures (0 to -20C) resulting from the timing of this years cruise:

Problems were encountered with icing up of the Brooke Ocean technology (BOT) block. A pneumatic air blower (the "de-icer") was clipped onto the wire to dry the wire as it came in. Results were very good and after a few deployments, the installation required only an extra couple of minutes for each cast.

Effort was made to reduce the time of the Rosette on deck to prevent freezing of the sensor. The Rosette lab's doors would remain closed until the bridge gave

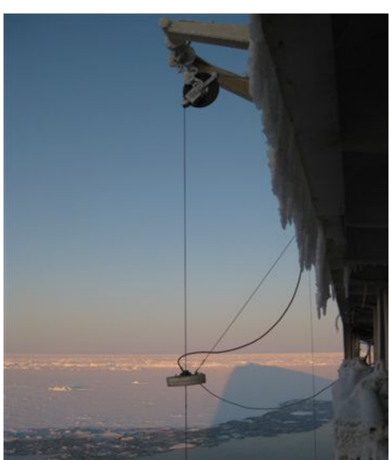

Figure 8. The 'de-icer' attached to the CTD wire.

permission to start the cast. The Rosette was then brought out and lowered into the water as quickly as possible. This step was repeated in reverse at the end of the cast. Between CTD casts, the T/C/DO_2 sensors and ducts are kept full of distilled water. When air temperatures are below freezing, the residual distilled water in these ducts can freeze, especially at the intake by the temperature thermistor, and this changes the temperature and salinity readings in the water until the ice melts. In freezing conditions we take care to remove as much water as possible from the ducts, including dabbing the end of the ducts with a kim wipe, before putting the package in the water. Once in the water, the dual T/C sensors will disagree during the 3 minute soak if there is freezing in the ducts. If this is the case, a longer soak is used and if necessary the CTD is lowered into warmer water (either the subsurface temperature max or the warm Atlantic Water) until the ice melts and the dual sensors agree. A suggestion for future cruises is to have a light mounted on the rail on the deck above to illuminate the working deck and to have a light mounted on outboard, aft, corner of the rosette lab, illuminating the water surface.

The 72 CTD/Rosette cast locations are listed in the appendix

Sampling took place immediately after each cast in the heated rosette room. The order of sampling was fixed, based on sampling water most susceptible to gas exchange or temporal changes first. Dissolved Oxygen, Nutrients, Salinity, and Ammonium were analysed on board. All other samples were prepared as required and stored for analysis on shore.

4.2 Side-of-ship ADCP
PI: Svein Vagle (DFO-IOS)

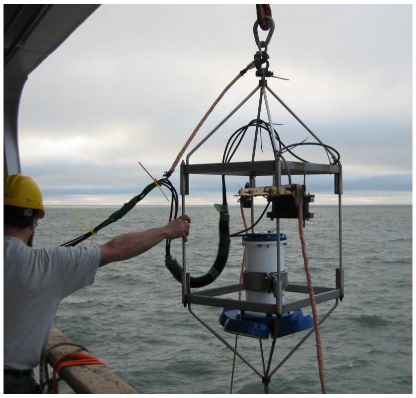

Figure 2. ADCP being lowered to 5m during rosette cast.

In conjunction with the CTD/Rosette Casts, an RDI acoustic doppler current profiler (ADCP) measuring currents in the upper waters and two backscatter transducers looking for layers of zooplankton were lowered over the side. The package was lowered by crane from the boatdeck to approximately 5m beneath the surface and left in place until the completion of the CTD cast. The ship's heading and location, recorded using the SCS data collection system, provides ADCP orientation information so the velocity of surface currents can be determined.

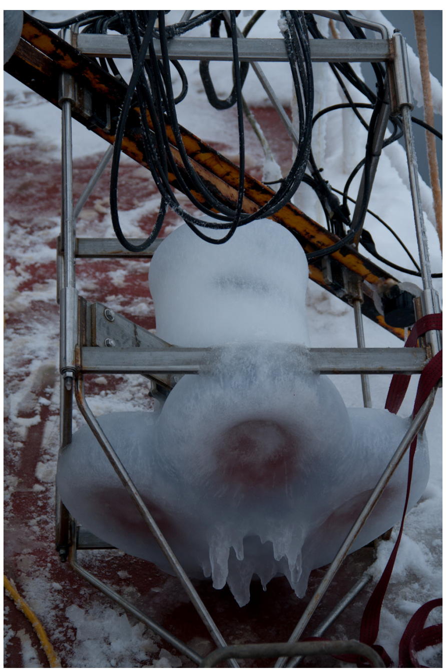

Figure 11. Ice accumulated on the ACDP during the cruise *(Photo by Jeffrey Charters)***.**

4.3 XCTD Profiles

PIs: Motoyo Itoh (JAMSTEC), Andrey Proshutinsky (WHOI), Kohei Mizobata, Koji Shimada, (TUMSAT)

XCTD (expendable conductivity, temperature and depth profiler, Tsurumi-Seiki Co., Ltd.) probes provided by JAMSTEC, WHOI and Tokyo University of Marine Science and Technology were deployed from the ship's stern with temperature, salinity and depth data acquired by computer located in the stern (AVGAS) hold. The data converter, MK-130 and Mk150 (Tsurumi-Seiki Co., Ltd.) were used for XCTD deployment and data conversion from original binary to ascii data.

The casts took approximately 5 minutes or 10 minutes for the released probe to reach its final depth of 1100m or 2000m. In open water, we deployed XCTD-3, which can be deployed when ship steams at 15Knot but in heavy ice the ship had to stop for deployment, because probe's wire can easily break due to ice.

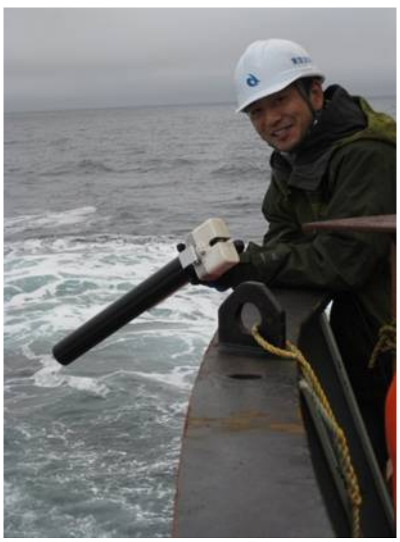

Figure 1: Kohei Mizobata deploying XCTD probe from the ship's stern

The locations of XCTD deployment were determined 1) to increase the spatial resolution of CTD data and 2) to make all cross-section data comparable deploying a certain isobaths Typically 1 probe was deployed between CTD casts.

According to the manufacturer's nominal specifications, the range and accuracy of parameters measured by the XCTD are as follows;

Parameter	Range	Accuracy
Conductivity	0 ~ 60 [mS/cm]	+/- 0.03 [mS/cm]
Temperature	-2 ~ 35 [deg-C]	+/- 0.02 [deg-C]
Depth	0 ~ 1000 [m]	5 [m] or 2 [%] (either of them is major)

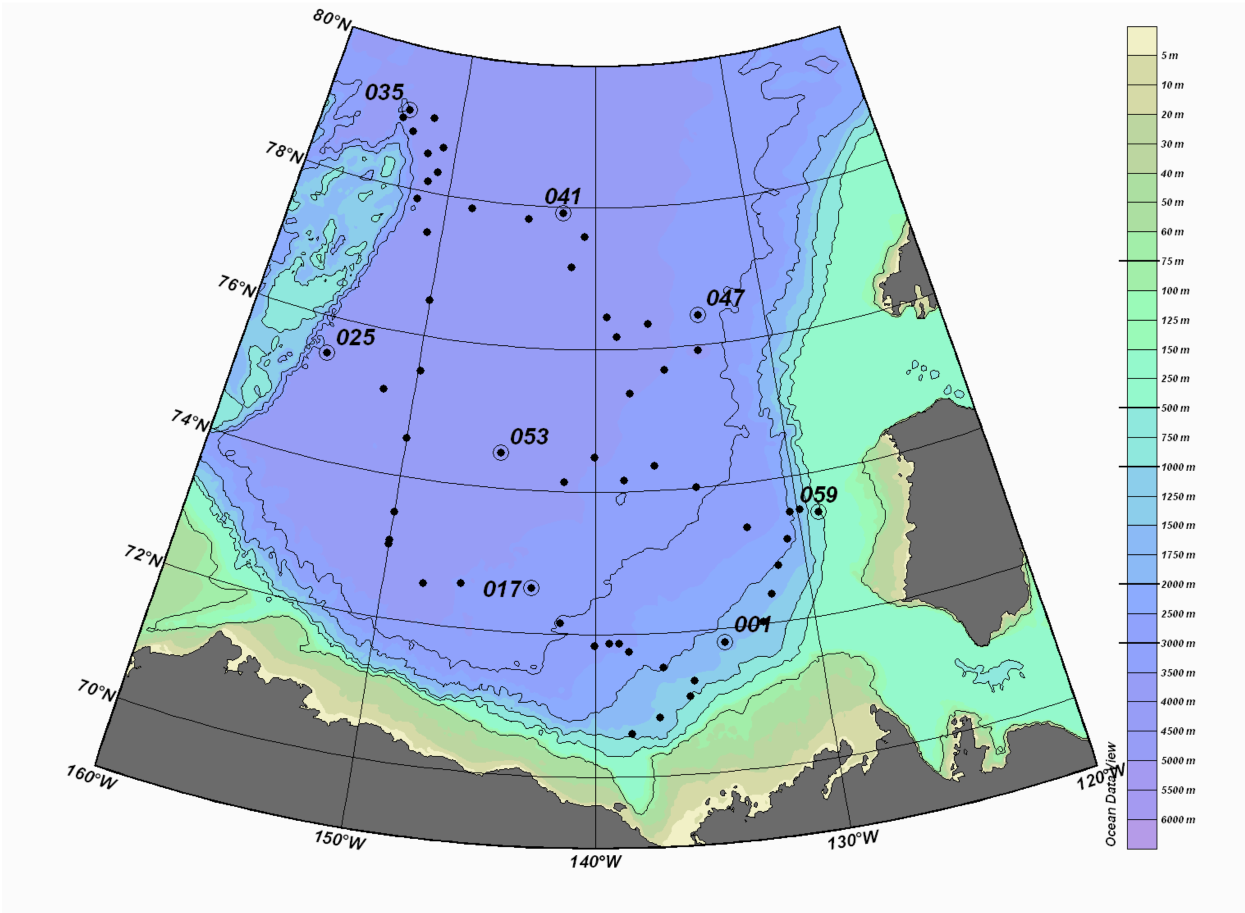

Figure 2: XCTD stations of the JOIS2010-07 cruise

During this cruise, 58 XCTDs were successfully launched, and 2 failed. 1 of the working XCTDs had shortened profiles (700m) presumably due to broken wires which was resulted from heavy sea ice. Two XCTD-2 probes, which reached 2000m, were deployed for seeking eddy structure along the 150^{o} W Line, while three XCTD-2 probes were deployed at Northwind Ridge area.

After each deployment, binary raw data was immediately converted to 1-m interval data. To make it comparable to CTD data, temperature data was converted using a following equation,

t=temp*1.00024 : [ITS68-->ITS90];

Table 1. XCTD deployment locations.

Stn	Filename	Time				Lat			Lon			Bottom Depth	Comments
1	201000-XCTD-001	2010	9	18	20:12	71	48.35	N	134	12.22	W	1448	
2	201000-XCTD-002	2010	9	19	22:00	71	5.11	N	135	55.15	W	1024	
3	201000-XCTD-003	2010	9	19	0:01	70	48.74	N	137	15.38	W	1470	
4	201000-XCTD-004	2010	9	20	1:44	70	35.81	N	138	27.04	W	1155	SST >6℃, foggy
5	201000-XCTD-005	2010	9	23	14:57	73	22.48	N	132	33.93	W	2652	Open water in ice area
6	201000-XCTD-006	2010	9	23	22:38	73	7.97	N	130	43.32	W	2187	Open water
7	201000-XCTD-007	2010	9	24	0:09	72	47.28	N	131	18.89	W	1953-1927	Ice conc. 10%
8	201000-XCTD-008	2010	9	24	1:47	72	24.19	N	131	49.73	W	1664	
9	201000-XCTD-009	2010	9	24	3:24	72	2.05	N	132	22.25	W	1438	
10	201000-XCTD-010	2010	9	26	7:59	71	18.33	N	135	40.95	W	N/A	Open Water
11	201000-XCTD-011	2010	9	26	9:52	71	30.44	N	136	59.83	W	N/A	Open Water
12	201000-XCTD-012	2010	9	26	12:01	71	44.79	N	138	29.96	W	N/A	Open Water
13	201000-XCTD-013	2010	9	26	13:34	71	51.84	N	138	56.02	W	N/A	Ice conc. 50% Swelling
14	201000-XCTD-014	2010	9	26	14:42	71	52.28	N	139	22.36	W	N/A	Ice conc. 80% Multi-year
15	201000-XCTD-015	2010	9	26	16:19	71	49.85	N	140	3.41	W	2664	Ice conc. 90%
16	201000-XCTD-016	2010	9	26	19:53	72	8.84	N	141	38.50	W	2993	Open Water
17	201000-XCTD-017	2010	9	26	23:08	72	37.53	N	143	2.00	W	4243	Ice conc. 90%
18	201000-XCTD-018	2010	9	27	8:17	72	37.54	N	146	21.63	W	N/A	Open Water
19	201000-XCTD-019	2010	9	27	10:31	72	33.75	N	148	6.78	W	N/A	Open Water
20	201000-XCTD-020	2010	9	27	22:02	73	2.08	N	149	59.61	W	3736	Open Water
21	201000-XCTD-021	2010	9	27	22:37	73	5.46	N	150	0.17	W	3743	Open Water
22	201000-XCTD-022	2010	9	28	0:17	73	29.31	N	149	59.62	W	3796	Open Water
23	201000-XCTD-023	2010	9	28	8:08	74	32.51	N	149	59.37	W	3808	Open Water
24	201000-XCTD-024	2010	9	29	1:02	75	9.44	N	151	40.28	W	3838	Ice conc. 5%
25	201000-XCTD-025	2010	9	29	8:13	75	28.64	N	155	10.32	W	3846	Open Water
26	201000-XCTD-026	2010	9	30	2:18	75	30.24	N	149	52.25	W	3831	Ice conc. 100%
27	201000-XCTD-027	2010	9	30	11:23	76	30.17	N	149	59.93	W	3847	Ice conc. 100%
28	201000-XCTD-028	2010	9	30	20:14	77	26.16	N	150	55.62	W	3828	Ice conc. 100% 10cm
29	201000-XCTD-029	2010	9	30	23:24	77	52.63	N	151	58.88	W	3835	Ice conc. 100% 10cm
30	201000-XCTD-030	2010	10	1	10:04	78	8.77	N	151	32.29	W	N/A	Ice conc. 100% 10cm~20cm
31	201000-XCTD-031	2010	10	1	23:55	78	18.17	N	150	59.93	W	3831	Ice conc. 100% 10cm~20cm
32	201000-XCTD-032	2010	10	2	2:26	78	32.30	N	151	55.38	W	3830	Ice conc. 100% 10cm~30cm
33	201000-XCTD-033	2010	10	2	6:13	78	48.14	N	153	15.52	W	3828	Ice conc. 100% 10cm~30cm
34	201000-XCTD-034	2010	10	2	8:07	78	57.48	N	154	13.38	W	3666	Ice conc. 100%
35	201000-XCTD-035	2010	10	3	4:15	79	5.05	N	153	51.46	W	3579	Ice conc. 100% 10cm~100cm
36	201000-XCTD-036	2010	10	3	6:45	79	2.28	N	151	56.50	W	3836	Ice conc. 100% 10cm~200cm
37	201000-XCTD-037	2010	10	3	15:43	78	39.41	N	150	54.73	W	3829	Ice conc. 100% 10cm~200cm
38	201000-XCTD-038	2010	10	4	10:02	77	52.52	N	148	16.54	W	3819	Ice conc. 100% 10cm~200cm
39	201000-XCTD-039	2010	10	5	4:32	77	48.35	N	144	24.80	W	3798	Ice conc. 100% 100cm~200cm
40	201000-XCTD-040	2010	10	5	9:38	77	54.64	N	142	10.43	W	3781	Ice conc. 100% 100cm~200cm Heavy Ice XCTD cast was shorten (700m) due to ice
41	201000-XCTD-041	2010	10	5	9:47	77	54.64	N	142	10.43	W	3781	second trial

42	201000-XCTD-042	2010	10	5	20:00	77	34.99	N	140	43.92	W	3750	Ice conc. 100% 100cm~200cm
43	201000-XCTD-043	2010	10	6	8:49	77	9.52	N	141	31.40	W	3751	Ice conc. 100% 100cm~200cm
44	201000-XCTD-044	2010	10	7	2:56	76	27.26	N	139	18.88	W	3672	Ice conc. 100% 100cm~200cm
45	201000-XCTD-045	2010	10	7	11:58	76	10.54	N	138	46.21	W	3645	Ice conc. 100% 100cm
46	201000-XCTD-046	2010	10	7	15:05	76	20.69	N	136	54.50	W	3588	Ice conc. 100% 30cm
47	201000-XCTD-047	2010	10	8	6:49	76	24.64	N	133	52.44	W	3367	Ice conc. 100% 100cm
48	201000-XCTD-048	2010	10	8	17:31	75	55.39	N	134	6.89	W	3339	Ice conc. 100% 100cm
49	201000-XCTD-049	2010	10	9	4:50	75	40.88	N	136	7.20	W	3530	Ice conc. 100% 10cm-30cm
50	201000-XCTD-050	2010	10	9	8:35	75	22.39	N	138	7.85	W	3555	Ice conc. 100% 10cm-50cm
51	201000-XCTD-051	2010	10	9	17:33	74	29.14	N	140	3.54	W	3643	Ice conc. 100% 10cm-30cm
52	201000-XCTD-052	2010	10	10	6:36	74	8.01	N	141	37.71	W	3635	Ice conc. 100% 10cm-50cm
53	201000-XCTD-053	2010	10	10	15:46	74	29.65	N	144	58.93	W	3737	Ice conc. 100% 10cm-100cm
54	201000-XCTD-054	2010	10	12	1:10	74	8.99	N	138	32.05	W	3426	Ice conc. 100% 10cm-50cm, relative warm air temperature
55	201000-XCTD-055	2010	10	12	4:46	74	20.41	N	136	56.64	W	3300	Ice conc. 100% 10cm-50cm
56	201000-XCTD-056	2010	10	12	8:24	74	0.11	N	134	53.20	W	3066	Ice conc. 100% 10cm-30cm
57	201000-XCTD-057	2010	10	13	10:36	73	30.08	N	130	22.10	W	N/A	Ice conc. 100% heavy ice, 100-300cm
58	201000-XCTD-058	2010	10	13	12:05	73	31.15	N	129	51.78	W	1367	Ice conc. 100%
59	201000-XCTD-059	2010	10	13	18:13	73	26.19	N	128	57.97	W	573	Ice conc. 100%

4.4 Zooplankon vertical net haul.

Kelly Young, Kenny Scozzafava (DFO-IOS)
PI: John Nelson(DFO-IOS)
Day Watch: Chelsea Stanley, Zoe Sandwith (DFO-IOS)
Honorary members: Peter Peterson (UAF) & Bill Williams (DFO-IOS)

Summary

A total of 100 bongo net hauls were completed at 47 stations. Bongos were harnessed and deployed in the same manner as the 2009-20 JOIS cruise. Standard, duplicate tows to 100m were sampled at all stations except where weather and time restraints limited the deployment to one 100m tow (CB-2, CB-2a, CB-10, CB-65, MK-3a). In addition to the routine tows, additional tows to depths of 500 and 1000m were conducted at select stations (Table 1). Samples were preserved following the method in 2009-20, with the following additions for the deep tows:

Cast 1 (100m):
- 236 µm into buffered formalin (10%)
- 150 µm into buffered formalin (10%)
- both 53 µm combined to single buffered formalin (10%) sample

Cast 2 (100m):
- 236 µm 95% ethanol
- 150 µm frozen in whirl-pak at -80°C
- both 53 µm combined 95% ethanol

Deep Casts (500 & 1000m):
- 236 µm 95% ethanol
- 150 µm into buffered formalin (10%)
- both 53 µm combined to single buffered formalin (10%) sample

Table 1. Summary of the number of samples taken at each station, based on net mesh size (53, 150 or 236 μm) and tow depth (100, 500 or 1000m).

Depth	<100			100			500			1000			Total
Mesh	**53**	**150**	**236**	**53**	**150**	**236**	**53**	**150**	**236**	**53**	**150**	**236**	
AG-5				2	2	2							**6**
CABOS				2	2	2							**6**
CB-10				1	1	1							**3**
CB-12				2	2	2							**6**
CB-13				2	2	2							**6**
CB-15				2	2	2	1	1	1	1	1	1	**12**
CB-16				2	2	2	1	1	1				**9**
CB-17				2	2	2							**6**
CB-18				2	2	2							**6**
CB-19				2	2	2							**6**
CB-2				1	1	1							**3**
CB-21				2	2	2	1	1	1				**9**
CB-22				2	2	2							**6**
CB-23a				2	2	2							**6**
CB-27				2	2	2							**6**
CB-28aa	2	2	2										**6**
CB-28b				2	2	2							**6**
CB-29				2	2	2							**6**
CB-2a				1	1	1							**3**
CB-3				2	2	2							**6**
CB-31b				2	2	2							**6**
CB-4				2	2	2	1	1	1				**9**
CB-40				2	2	2							**6**
CB-5				2	2	2							**6**
CB-50				4	4	4							**12**
CB-51				4	4	4							**12**
CB-52				2	2	2							**6**
CB-53				2	2	2							**6**
CB-54				2	2	2							**6**
CB-6				2	2	2							**6**
CB-60				2	2	2							**6**
CB-61				2	2	2							**6**
CB-65	1	1	1										**3**
CB-7				2	2	2							**6**
CB-8				2	2	2							**6**
CB-9				2	2	2	1	1	1				**9**
CB-DW				2	2	2							**6**
MK-1				2	2	2							**6**
MK-2				2	2	2							**6**
MK-3				2	2	2							**6**
MK-3a				2	2	2							**6**
MK-4				1	1	1							**3**
MK-6				2	2	2							**6**
MK-7				2	2	2							**6**
PP-6				2	2	2							**6**
PP-7				2	2	2							**6**
STA-A				2	2	2							**6**
Total	**3**	**3**	**3**	**90**	**90**	**90**	**5**	**5**	**5**	**1**	**1**	**1**	**298**

New Additions

An RBR pressure/temperature sensor was provided by Svein Vagle to attach to the bongo frame which provided an accurate depth measurement for the net tows. This was important considering both the flowmeters and winch meter were often frozen (see *Challenges*, next section), making it impossible to get an accurate depth of tow or volume estimate. However, it was found that ice build-up on the pressure sensor would also cause the RBR sensor to fail. This was solved by immediately removing the sensor between casts to a warm place, either in the lab between stations or inside a jacket between casts.

Challenges

Similar problems occurred with the MF-315 flowmeters as in previous years. They froze up quickly, sometimes in between duplicate tows. To prevent the flowmeters from freezing between stations, they were removed immediately following the cast and brought inside the lab to defrost, and replaced immediately before the next cast. Occasional freezing up still occurred, especially for the multi-tow casts (deep tows) or on very chilly, windy days. The gears would also jam occasionally, and adjacent numbers would roll over out of sequence. Since similar problems were encountered last year, a TSK flowmeter was also used on one side of the large bongo frame. The TSK worked well in the cold for the first half of the cruise; however, once temperatures dipped below -10C the gears would seize up and the TSK was removed from the nets to prevent damage. Two TSK's were used at the start of the cruise, but TSK 5294 gears were constantly jamming and was replaced with a MF-315.

Two stations were not completed due to a frozen winch caused by a disconnected winch heater. This was eventually repaired. To avoid the winch from freezing up for a station, the winch and heater were turned on at least half an hour before the cast.

The winch counter flywheel was also frozen for most casts, making the wire-out meter readings unreliable. This seems to be caused by an excess of ice forming on the winch from the wet wire and freezing up the block.

The forward A-frame power switch started freezing up during the cold stations (-18°C), causing delays while the electrician was called to repair the switch. This was avoided by powering up the A-frame from the below-deck control panel.

Suggestions for next year

- The fire hose froze at the start of the cruise, and was no longer available to use. A cheap plastic garden hose was provided, which cracked in the cold weather and was unusable. Good quality hoses should be purchased and brought by IOS, preferably thick rubber hoses that resist icing or cracking in cold conditions.

- Currently samples have to be transported from the foredeck, to the main lab for sieving, then upstairs to the fumehood in the container lab beside the CTD operations, and back down to the main lab. It would be helpful if a container would be available on the foredeck for wet work (either a sink or just a drain) that has adequate ventilation so all the sample processing (including preservation with formalin and ethanol) could take place on the foredeck.

- An ice chummy for the forward winch cable may help prevent the meter block from freezing up.

- Spare cod ends for the 53um nets are needed (there are currently only 2).

- The bongo box is awkward to slide over the staples on the foredeck, and several times the staples slipped up between the bottom of the net box and the side. What may work better is a box with a sturdier frame with legs at the corners which raise the box up above the level of the foredeck staples. The frame for the bongos which sits inside the box needs reinforcing or replacement.

- It would have been great to have a microscope on board - perhaps a dissecting scope with a camera attachment in order to be able to show samples to media and other JOIS science participants.

- The handle on the forward container needs replacement.

4.4 Limacina helicina experiment

PIs: Michiyo Kawai (DFO-IOS), John Nelson (DFO-IOS)

In order to study the influence of ocean acidification and melting of seaice on shells of Pteropod, *Limacina helicina*, an experiment was performed during the 2010-07 JOIS cruise. L. helicina were collected and kept in 5 different seawaters with different aragonite-saturation states.

Water sampling

Seawater for the experiment were collected by CTD/R system with 10L-Niskin bottles at 450, 150, 50 and 5 m depths at station PP-7 (cast 56). Seawater was transferred from each Niskin bottle into a carboy. Seawater collected in carboys were sub-sampled for salinity, and nutrient analysis. The sampling was finished by 17:40 07 October (LTC). Then, carboys were kept in the walk-in cooler (4C).

Plankton sampling

Plankton samples were collected by a net tow from 100m deep to the surface at PP-7 on 7 October 2010 (19:00-19:30 LTC). Nets were not washed with water when came up board the ship. Codends with collected plankton and seawater were immediately put in a bucket filled with cold seawater (~0C) and brought the lab.

In the lab, all samples collected by 4 nets with different mesh size were filtered through the large mesh net to remove large plankton and then collected on 53um mesh. Samples collected on the 53um mesh were transferred into a glass jar filled with cold seawater (from ~50 m deep, seawater after filtered for Chl.a). Glass jar with sample was stored in the walk-in cooler (4C) until 01:45am 08 October.

Experiment

Seawater collected in a carboy was mixed and transferred into 250ml glass bottle for DIC/TA analysis and two 1L-brown glass bottles (for the experiment) following the sampling instruction for DIC. The leftover of seawater from 5m deep of ~3.8L was mixed with ~800ml of DMQ to make low-salinity, low-alkalinity seawater. This water (5m+DMQ) was also transferred into a DIC/TA bottle and two experiment bottles.

From the plankton sample kept in the glass jar, *Limacina helicina* was picked up using a pastur pipet and dropt into one of experiment bottles. ~5~10 of *L. helicina* were put in each bottle.

These were done in a walk-in cooler. Sampling was started at 01:00 and everything was done by 02:30 on 08 October.

Experiment bottles were kept in a box filled with iced seawater place in the 4C walk-in cooler until 17:45 of 13 October. Temperature was monitored using EasyLog USB, kept in the same box (USB-sensor was kept in a plastic bag , put in a glass bottle, and put in the box).

Experiment bottles were slowly mixed and opened to make sure there is no plankton left on the surface of the cap. This was done once a day.
After 6 days of experiment, DIC/TA and nutrient samples were taken from each experiment bottle (17:45-19:00, 13 October). Then, plankton samples were collected onto

53um mesh and stored in ethanol in 50ml glass bottles. Shells of *L. helicina* will be checked using SEM after the cruise if they had any damage by aragonite-undersaturated waters.

4.5 Underway Measurements

Jane Eert

PIs: Svein Vagle (DFO-IOS), Celine Gueguen (Trent University), Patricia Ramlal (DFO)

Seawater Loop

The ship's seawater loop system draws seawater from below the ship's hull at 9m, to the TSG lab, a small room just off the main lab ("aft lab"). This system allows measurements to be made of the sea surface water without having to stop the ship for sampling. The water is as unaltered as possible coming directly from outside of the hull through stainless steel piping without recirculation in a sea-chest. The manifold in the TSG has been insulated to minimize condensation. Flow rate is controlled to the lab by a Honeywell electronic system which has a data feed from a pressure sensor in the lab, and on one arm of the manifold, by a Kates mechanical flow rate controller. This arm also has a vortex debubbler so that the water provided to the TSG and other instruments is as bubble free as possible.

Autonomous measurements were made using:

- SBE38: Temperature.
  Sensor was installed in-line, approximately 4m from pump at intake. This is the closest measurement to actual sea-temperature.
- SBE21 Seacat Thermosalinograph: Temperature and Conductivity, Fluorescence and CDOM
  5 second sample rate, fed by water that has gone through the debubbler
  (Jane Eert, DFO)
- Blue Cooler: Total gas (Gas Tension Device) 40s sampling, Oxygen.
  5 second sample rate, fed by water that has gone through the debubbler
  (Svein Vagle, DFO)
- Black Box: Methane, Oxygen, pCO2.
  Hourly sample, run off the manifold in the main lab
  (Patricia Ramlal, DFO)

Part of the system, but not attached to the seawater loop:

- SBE48: Temperature was also measured through the hull using a temperature sensor mounted on the ship's hull, inside, aft of the pump approximately 15m, starboard side. Sampling rate is once per minute

Discreet Water Samples drawn for calibration of sensors:

- Salinity, Chlorophyll-a, Dissolved Oxygen (these 3 analysed on board), and CDOM (samples sent back to Celine Gueguen at Trent University)

Figure 1. Seawater loop system providing uncontaminated seawater from 9m depth to the science lab for underway measurements.

Figure 2. Pump for seawater loop at intake in engine room.

Some of the instruments were self-contained; others were connected to a single data storage computer. The data storage computer provided a means to pass ship's GPS for integration into sensor files, to pass the SBE38 data from the engine room to the TSG instrument, and to pass the TSG and SBE48 data to the ship's data collection system (SCS).

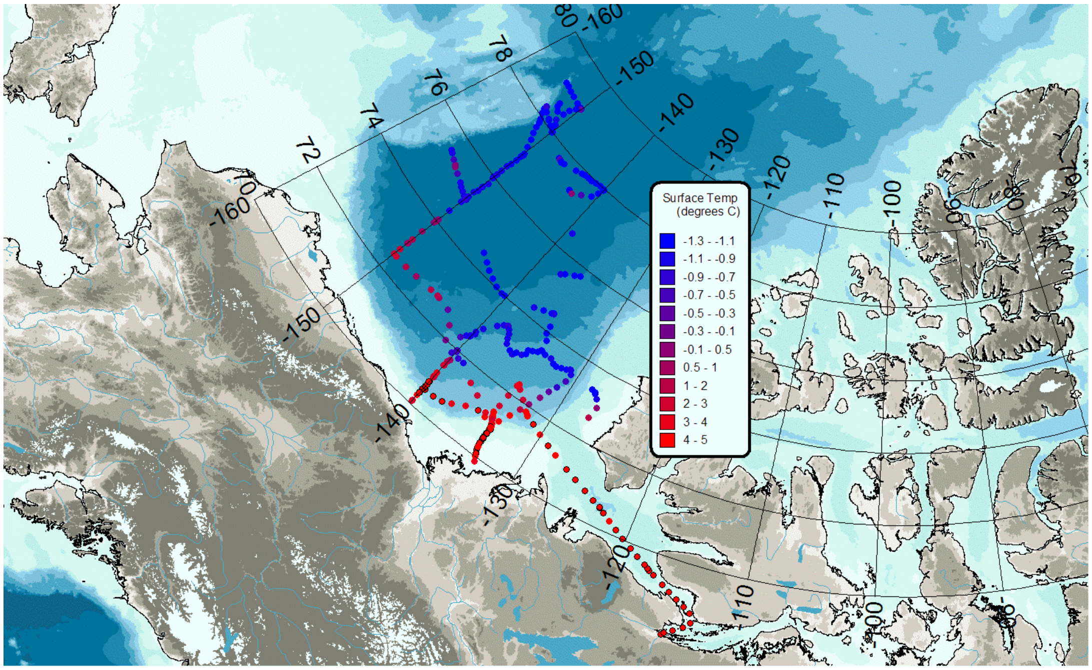

Figure 3. Underway sea surface Temperature.

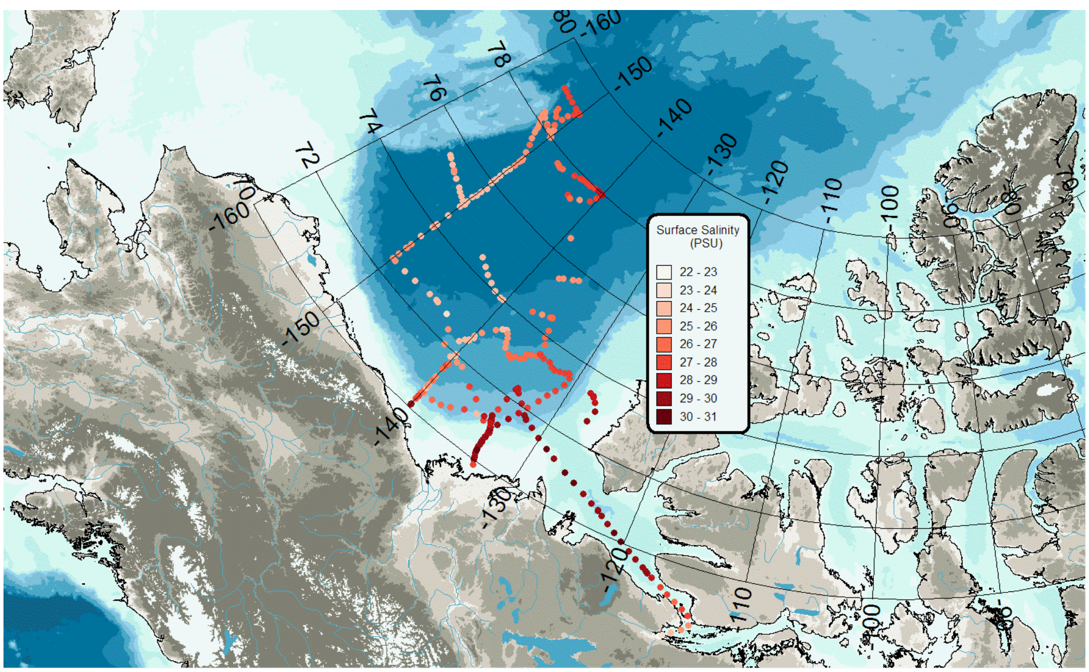

Figure 4. Underway sea surface Salinity.

PAR Data

Photosynthetically available radiation (PAR) was measured continuously. Location was on the hanger top aft of the stack in the most unobstructed spot possible.

However, the PAR sensor was seldom wiped clean and it was dark and snowed in a lot of the time….

Ice Cameras

Ice Cameras mounted on above the bridge took pictures every 5 to 30minutes depending on ice conditions. Two cameras were installed, one looking forward, the other looking aft along the side of the ship to observe upturned ice. See the complete report on this system by Alice Orlich.

SCS Data Collection System

The ship uses the Shipboard Computer System (SCS) written by the National Oceanographic and Atmospheric Administration (NOAA), to collect and archive underway measurements. This system takes data arriving via the ship's network (LAN) in variable formats and time intervals and stores it in a uniform ASCII format that includes a time stamp. Data saved in this format can be easily accessed by other programs or displayed using the SCS software.

The SCS system on a shipboard computer called the "NOAA server" collects:

- Location, speed over ground and course over ground as well as information about the quality of GPS fixes from the ship's GPS (GPGGA and GPRMC sentences)
- Heading from the ship's gyro (HEHDT sentences)
- Depth sounding from the ship's Knudsen sounder (SDDBT sentences)
- Air temperature, apparent wind speed, apparent and relative wind direction, barometric pressure, relative humidity, and apparent wind gusts from the ship's AVOS weather data system (AVRTE sentences). SCS derives true wind speed (see note on true wind speed below).
- Sea surface temperature, conductivity, salinity, CDOM and fluorescence from the ship's SBE 21 thermosalinograph and ancillary instruments
- Sea surface temperature from the SBE48 hull mounted temperature sensor

The RAW files were set to contain a day's worth of data, restarting around midnight. The ACO and LAB files grew until they were moved out of the datalog/compress directory for archiving.

We experienced few problems this year with the system losing data. Major gaps in the TSG records are due to the system being turned off in ice. There was one gap of about 6 hours when the system was accidentally shut down by other users of the NOAA computer.

Ship Notes on the Sea Water Plumbing
Engineering Dept

<u>SW SAMPLING SYSTEM FOR THERMAL SALINOGRAPH</u>

ABOARD THE LOUIS S. ST. LAURENT

SEA SUCTION

This consists of a 4” diameter suction fitting fitted flush with the hull. It is located between Frame 179 and Frame 180 and 5’ 3” to Port of the ship’s centerline. The 4” dia. stainless steel suction plate is press fit into the opening and fastened by 4 – ½” stainless steel countersunk screws. The suction plate has a cross pattern across it of 3/8” width yielding 4 quadrants open for suction.

A 4” stainless steel angle globe valve with de-icing connection is directly bolted to the flush fitting at the hull using 8 – 5/8” steel cadmium plated studs on 7 ½” PCD. The valve is fitted with a lazy rod supported by a deck stand at tank top level to allow operation of the valve above the tank top by 10” hand wheel.

PIPING TO PUMP

From the 4” outlet of the valve is a 4” 90^0 stainless steel elbow connected to a 4” to 2” stainless steel concentric reducer.

Height from the hull plating to the end of the concentric reducer is 1’ 10”.

From concentric reducer, pipe continues vertically via 2” stainless steel, schedule 40 pipe to the tank top. This is a distance of 4 ft..

From the tank top, 2” stainless steel schedule 40 pipe continues 6’ 7” to a 2” – 150# flanged stainless steel ball valve and directly into the 2” Hayward 6036 (CF8M) stainless steel duplex basket strainer c/w changeover cock, 5/32” basket perforations. There is another identical flanged ball valve on the outlet of the strainer.

From the outlet valve, 2” stainless steel schedule 40 piping leads another 6” 5” to a 2” to 3” concentric bushing to a flanged 3” connection on the pump suction.

SW PUMP

The pump is a 3” Moyno Progressive Cavity pump Model #2L6SSQ3SAA, customized seal arrangement, L-frame pump, L6 drive frame. This pump is driven by a geared motor. The pump rated flowrate is 10 GPM. It is composed of a stainless steel rotor and nitrile rubber stator and has a John Crane carbon/ceramic single mechanical seal.

The pump is controlled by a ACTech Model #1450C variable speed controller and gets it’s setpoint from a Honeywell UDC Controller mounted in Lab 426B.

The gearbox is an SEW Eurodrive Type RX67. The motor is an SEW Eurodrive Type RX76DT10044, 5 HP motor.

An Akron Electric (Delta Corporation)VS5100 Flowswitch acts as a drypipe sensor to shut down the pump via the VFD should the duplex basket strainers become clogged with ice.

A pressure transmitter is also fitted in the pipe on the outlet of the pump to provide a pressure alarm signal to the SIMOS system in the Machinery Control Room.

PUMP OUTLET TO LAB 426B

From the pump outlet, 1 ½" sch. 40 stainless steel pipe continues another 12' to a 1 ½" SS ball valve. From here it continues another 16" via 1 ½" pipe to a 1 ½" "T" where the flow can then be diverted to the SBE 38 via 24" of 1" sch. 40 stainless steel pipe or continue in 1 ½" another 11' to the 19' flat of the engine room.(Boiler Flat)

An RTD for measuring temperature is installed just prior to the SBE branch connection.

From the 19' Flat the 1 ½" pipe continues vertically 16' 6" to the Incinerator Deck.

From the Incinerator Deck the 1 ½" pipe continues on a 26' vertical run to the Main Deck.

The same pipe then runs horizontally 85' along the Main Deck Stbd Alleyway.

From the alleyway to Lab 426B is another 8' horizontally (athwartships) and 14" vertically.

In Lab 426B, another 6" of 1 1/2"' pipe, then a 1 ½" stainless steel, flanged, ball valve, then a 4' run of 1 ½" pipe to the 3" pipe manifold.

Manifold has 4 – 1" NPT process connections along it's length and 1 – 1" threaded process connection at the end to provide a pressure signal from the Honeywell ST 3000 Smart Pressure Transmitter to the Honeywell UDC Controller.

Louis NOAA SCS system, October 2010

The SCS system on the NOAA server collects data from

-the Ship's GPS (GPGGA and GPRMC sentences)
-the Ship's gyro (HEHDT sentences)
-the Knudsen sounder (SDDBT sentences)
-the AVOS weather data system (AVRTE sentences)
-the thermosalinograph, and
-the SBE48 hull mounted temperature sensor.

Variables derived from each sentence are:

GPGGA:

time-UTC, HHMMSS
LAT, dd.ddddd
LONG, ddd.ddddd
Quality, 1=gps 2=dgps
#-of-Sats
HDOP, horizontal dilution of precision

GPRMC:

SOG, Knots
COG, degrees

HEHDT:

Gyro-Heading, Deg

SDDBT:

depth, Meters

AVRTE:

time, HHMMSS
date, YYMMDD
apparent-wind-speed, knots
apparent-wind-direction, degrees
relative-wind-direction, degrees
barometric-pressure, mmhg
air-temp, C
relative-humidity, %
apparent-wind-gust, knots

TSG:

SBE21-T, Degrees-C
SBE21-S, PSU
SBE38-T, Degrees-C

SBE48:

Hull-Temp, Degrees-C

As well, the SCS system derives true wind speed based on the AVRTE ***apparent*** wind speed and direction and the GPRMC speed over ground and course over ground. ***Note on true wind speed: Since this system was set up in 2006, true wind speed has been derived from ***apparent*** wind speed and direction along with the ship's COG and SOG. It turns out that this is incorrect, and the direction that should be used in this calculation is the ***relative*** wind direction. The error was noticed and corrected on October 1 at 1330 UTC. All true wind data before this should be recalculated.

***Editorial comment: I think that SCS should be calculating true wind speed from apparent wind direction and not relative wind direction. Or if it wants to use the relative wind direction, it should take into account the ships heading. As it is now, the calculation assumes that the ship is moving (COG) in the same direction the bow is heading. In practical terms, it unlikely that large errors are introduced by making this assumption since the times when one usually has a large mismatch between ships head and COG are when the ship is moving slowly.

Data for each type of sentence is stored in 3 types of files:

RAW: a comma separated file, each record starts with a timestamp, followed by the sentence received at that time.

ACO: a comma separated file, each record starts with a timestamp (year, decimal Julian day, integer Julian day, fractional Julian day) followed by the variables extracted from each record.

LAB: a blank separated file, each record is as for ACO, but decimated in time, so the LAB files are about 1/10th the size of the ACO files.

Setup in 2010: The RAW files were set up to contain a day's worth of data, restarting at 10 minutes past midnight, UTC. They are named, for example, GPGGA-Parent_20070821-100257.RAW, and stored in the main SCS datalog directory. The ACO and LAB files grow until they are moved out of the datalog/compress directory for archiving. The files were restarted at the beginning of the 2010 filed season. Naming for these files is like GPGGA-Parent.ACO. As well, there are template files, named like GPGGA-Parent.TPL which contain a list of the variables derived for each sentence. .

Timestamps: The timestamps generated by SCS are based on the time settings in Windows.

***Note on SCS timestamps: This year (unlike some previous years) the NOAA server stayed in UTC. However, this computer's clock does not keep very accurate time; if you need to synchronize data across the files, use the timestamp, but if you are trying to synchronize with outside data that is properly keeping UTC, then use the time of day found in the GPGGA sentence. At worst on this cruise, the NOAA server clock was ahead by 8 minutes; this was corrected on October 12, 2010.

Gaps: There are gaps in the data collection, some of which can be filled by post processing from independent records.

SDDBT: The sounder depth is recorded but not the sound speed used to calculate the depth. An external log of sound speed was kept and is included here:

Date	Time (UTC)	Sound Speed (m/s)
start		1500
17/09/2010	1:28:45	1448
21/09/2010	7:01	1455
21/09/2010	9:20	1465
22/09/2010	7:27	1470
27/09/2010	14:36:00	1473
12/10/2010	10:14:30	1470
13/10/2010	14:08	1455
13/10/2010	14:41:30	1445

Note: The Knudsen Sound speed is the assumed average sound speed from surface to sea floor. We change it during the cruise so that the sounder reports reasonably accurate depths which can be used to predict the bottom of a rosette cast.

4.6 BGOS Field Operations

Rick Krishfield, Kris Newhall, and Jim Dunn (WHOI)
PI: Andrey Proshutinsky (WHOI)

As part of the Beaufort Gyre Observing System (BGOS; http://www.whoi.edu/beaufortgyre), three bottom-tethered moorings deployed in 2009 were recovered, data was retrieved from the instruments, refurbished, and redeployed at the same locations in September-October 2010 from the *CCGS Louis S. St. Laurent* during the JOIS 2010 Expedition. In addition, four Ice-Tethered Profiler (ITP; http://www.whoi.edu/itp) buoys were deployed, one in combination with an Arctic Ocean Flux Buoy (AOFB), and Ice Mass Balance (IMBB) and one with an AOFB, IMBB, and atmospheric chemistry O-Buoy. One ITP was also recovered.

Summary of BGOS 2010 field operations.

Mooring Designation	Depth (m)	2009 Location	2010 Recovery	2010 Deployment	2010 Location
BGOS-A	3825	75° 0.002'N 150° 0.005'W	28-Sep 15:58 UTC	29-Sep 22:10 UTC	74° 59.913'N 149° 59.800'W
BGOS-B	3821	78° 0.081'N 149° 59.949'W	1-Oct 17:05 UTC	4-Oct 02:20 UTC	77° 59.3'N 149° 58.2'W
BGOS-D	3509	73° 59.744'N 139° 59.698'W	9-Oct 22:15 UTC	11-Oct 22:20 UTC	73° 59.87'N 139° 58.98'W
ITP35			2-Oct 20:30		79° 7.91'N 155° 1.13'W
ITP41				3-Oct 02:30	79° 5.3'N 154° 16.9'W
ITP42/AOFB/IMBB				4-Oct 23:40	77° 39.8'N 149° 15.5'W
ITP43/AOFB/IMBB/ O-Buoy				8-Oct 23:00	76° 42.9'N 135° 11.7'W
ITP44 (w/ MAVS)				9-Oct 1:15	75° 51.6'N 134° 39.7'W

Moorings:

The centerpiece of the BGOS program are the bottom-tethered moorings which have been maintained at 3 or 4 locations since 2003. The moorings are designed to acquire long term time series of the physical properties of the ocean for the freshwater and other studies described on the BG webpage. Previous years, the top floats were positioned approximately 45 m below the surface to avoid ice ridges, but this year the floats were brought up to 35 m due to thinner ice conditions and to increase the scope of the underwater instruments. The instrumentation on the moorings include an Upward Looking Sonar mounted in the top flotation sphere for measuring the draft (or thickness) of the sea ice above the moorings, a vertical profiling CTD and velocity instrument which samples the water column from 50 to 2050 m twice every two days, sediment traps for collecting vertical fluxes of particles (on two moorings), and a Bottom Pressure Recorder mounted on the anchor of the mooring which determines variations in height of the sea surface with a resolution better than 1 mm. One mooring (D) also includes a number of discrete temperature and salinity devices clamped to one deep segment of the mooring wire.

The moorings are deployed anchor first, rather than top float first (as is typical in lower latitudes), because of the presence of the ice pack. This requires the use of a dual capstan winch system to safely handle the heavy loads. Typically it takes around 5 hours to deploy the 3800 m long system.

Recovering the moorings in pack ice is extremely tricky, so that the top float does not surface under an icefloe, where we cannot access it. However, in this case, we do have backup floatation at the bottom of the mooring, which we can also recover the moorings from. First the locations of the moorings have to be pinpointed by triangulating acoustically on the releases at the bottom of the mooring. Then the Captain of the icebreaker creates a pond in the ice over the mooring, and acoustic release commands are sent to the release instruments just above anchor, which let go of the anchor, so that the floatation on the mooring can bring the system to the surface. Then the floatation, wire rope, and instruments are hauled back on board. Data is dumped from the scientific instruments, batteries, sensors, and other hardware are replaced as necessary, and then the systems are subsequently redeployed for another year.

So far, 7 years of data have been acquired by our mooring systems, which document the state of the ocean and ice cover in the BG. The seasonal and interannual variability of the ice draft, ocean temperature, salinity and velocity, and sea surface height in the deep Canada Basin are being documented and analyzed to discern the changes in the heat and freshwater budgets. Trends in the data show an increase in freshwater in the upper ocean in the 2000s, some of which can be accounted for by the observed decrease in ice thickness, but Ekman (surface driven) forcing is also a significant contributor.

Buoys:

Because the moorings only extend up to about 30 m from the ice surface, we use automated ice-tethered buoys to sample the upper ocean and sea ice. On this cruise, we deployed 4 Ice-Tethered Profiler buoys (or ITPs), and assisted with the deployments of two Naval Postgraduate School Arctic-Ocean Flux Buoys, two US Army CRREL Ice-Mass Balance buoys, and an O-Buoy. The combination of multiple platforms at one location is called an Ice Based Observatory (IBO).

The ITPs obtain profiles of seawater temperature and salinity from 7 to 760 m twice each day and broadcast that information back by satellite telephone. The flux buoys measure the fluxes of heat, salt, and momentum at the ice ocean interface, and the ice mass balance buoys measure the variations in ice and snow thickness, and obtain surface meteorological data. Most of these data are made available in near-real time on the different project websites.

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

Operations:

The mooring deployment and recovery operations were conducted from the foredeck using a dual capstan winch as described in WHOI Technical Report 2005-05 (Kemp et al., 2005). Before each recovery, an hour long precision acoustic survey was performed using an Edgetech 8011A release deck unit connected to the ship's transducer and MCal software in order to fix the anchor location to within ~10 m. The mooring top transponder (located beneath the sphere at about 45 m) was also interrogated to locate the top of the mooring. In addition, at every station the sphere was located by the ship's 400 khz fish finder. All top spheres successfully released into open water.

All of the mooring recovery and deployment operations were conducted without incident. The actual recovery operations varied from between 3.5 and 5 hours after release. The deployment operations normally entailed an hour of deck preparation once on site, followed by a 4 to 5 hour anchor first deployment. The extra instrumentation devices clamped to a deep segment of the wire on mooring D added less than half an hour to that operation.

Complete year long data sets with good data were recovered from all MMPs, 2 out 3 ULSs, every BPR, and all of the temperature and salinity loggers. Unfortunately, the ULS on mooring B had a low battery problem, so it is unclear whether any data from that instrument will be recovered, but further attempts will be made back in our laboratory.

The ITP deployment operations were conducted with the aid of helicopter transport to and from each site according to procedures described in a WHOI Technical Report 2007-05 (Newhall et al., 2007). ITPs 41, 42, 43 (with dissolved oxygen sensor), and 44 (with prototype MAVS current sensor) were deployed on 2.5, 2.4, 2.5, and 1.6 m thick ice floes respectively. Not including the time to reconnaissance, drill and select the ice floes, the deployment operations took between 3 and 8 hours each (depending on the number of systems installed in each IBO) including transportation of gear and personnel each way to the site. Ice analyses were also performed by others in the science party, while the ITP deployment operations took place.

Since deployment, all of the ITPs have begun profiling and transmitting data. However, ITP 41 seems to be returning corrupted data, which we will attempt to resurrect back in our laboratory. In addition, after the first down profile, ITP 44 appears to have a problem communicating with the surface package. A similar problem occurred with ITP 35 (deployed in 2009), which was recovered this cruise using helicopter support, and provided information on 1357 more profiles that were taken while the profiler was unable to communicate with the surface package. This unit will be examined back in our laboratory to determine the cause of the failure.

4.7 O-buoy 2 Deployment

Peter Peterson, Geophysical Institute, University of Alaska Fairbanks;
Carlton Rauschenberg, Bigelow Laboratory for Ocean Sciences
PIs: Patricia Matrai, Bigelow Laboratory for Ocean Sciences;
Bill Simpson, University of Alaska Fairbanks

Pre-deployment Assembly and Testing 9/15-10/6

Soon after arrival on-board, the deck crew moved the various buoy pieces into the hanger so assembly and testing could begin.
The instrument tray was then pulled out of the buoy casing and the standards for the CO_2 sensor were set. An inspection was also made of the instrumentation for any damage during shipping. The tray was then slid back into casing.

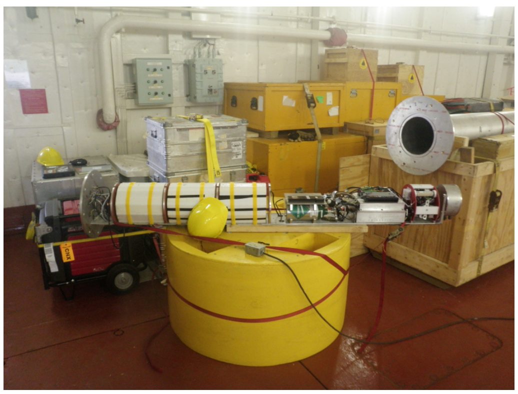

Figure 1: The instrumentation for the O-buoy. Starting from the left of the picture the tray holds: 3 Li battery packs for power during winter months when the solar array does not work, CO_2 tanks used as standards for the CO_2 sensor, the ozone detector and supervisory computer which controls buoy operations, the CO_2 sensor, and finally the spectrometer for the differential optical absorption spectroscopy done by the buoy to detect BrO

The next step was the assembly of the mast with two gas inlets, the scanhead for the spectrometer, communication components and meteorological sensors shown in Figure 2.
After assembly the buoy was hoisted up to the top of the hanger deck using the ships crane and oriented at a thirty degree angle with the deck to facilitate iridium data transmission. The buoy was switched into deployment mode while project members back on land examined the transmitted data to ensure the buoy was working properly. A problem was found with the CO_2 inlet tube, so the buoy was moved back into the hanger for troubleshooting. The length of the CO_2 tubing was examined and a kink was found in a section of tubing on the mast designed to dry the incoming sample. This was corrected and the CO_2 readings indicated the instrument had returned to normal function. During this time a horizon alignment was performed on the scan head to verify the instrument could properly detecting the horizon for data collection. The flotation collar was attached to the buoy and the Li batteries

were changed out in preparation for deployment. The deck gang hoisted it back onto the top of the hanger so it could send data back to others to verify proper function of the CO_2 instrument. This was the conclusion of pre-deployment testing. The day prior to deployment the buoy was hoisted down and the mast removed in preparation for being transported via chopper to the deployment site. Temporary covers were made for all connections while transport was taking place.

Figure 2: Assembled mast minus the scan head for the UV/Vis spectrometer and wind sensor.

Deployment

Date: 7 October 2010
Location: 76 42.950N 135 11.702 W The site was a multi-year ice floe roughly 25m across. The buoy was deployed in a thin section adjacent to a ridge to avoid having to melt a hole. A picture of the site can be seen in Figure 3.

Figure 3: Completed ice buoy observation(IBO) site. Photo by Rick Krishfield

Weather: Clear skies, sunny, Occasional wind gusts, and temps ranging from -10 to -20 C.

11:00am (ship time): Scouting for floes begins, with Kris Newhall and and Rick Krishfield(WHOI) going in the helicopter to pick out a site. This is day three of looking for suitable locations so they settle for a smaller floe, but one that is still substantially bigger than anything around so it can be made to work for this four buoy IBO given the cruise time constraints.

12:30pm: The helicopter started shuttling people and gear to the chosen site. The WHOI team preps the site for deployment of the O-buoy by chainsawing a 30 cm deep hole in the ice. This is less ice then ideal for deployment but with the loss of daylight and late start to the day, there is no time to melt an ideal hole. The buoy is then slung out to the floe via chopper and guided into position by the WHOI team.

1:30pm: The deployers and various buoy pieces make it onto the ice. The mast is slung out attached to another crate going out minus the windbird and DOAS scanhead. The solar panels, lead acid batteries, windbird, scanhead, and charge controller are put in the back of the chopper along with our tools. We wait for a break in flight ops and then get to work making the mast connections, attaching the DOAS scanhead, and bolting the mast to the buoy body with the assistance of Miranda Corkum from IOS

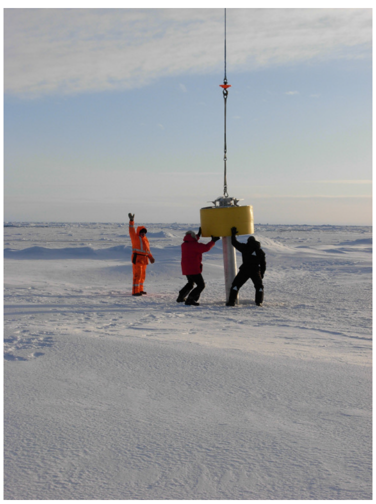

Figure 4: Kris Newhall(R) and Jim Dunn(L) guide the buoy into position. Photo by Rick Krishfield

Next the solar panels were installed and wired to the charge controller which lit up to indicate the panels were connected properly. The rechargeable batteries were placed in the flotation collar and hooked up to the solar array.

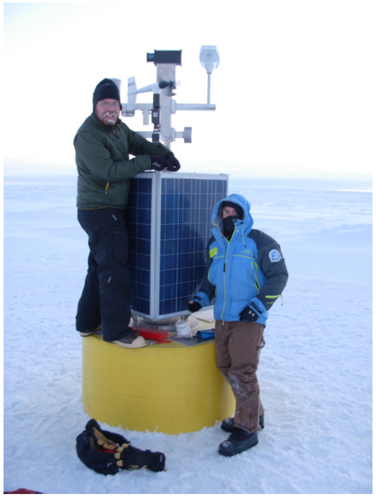

Figure 5: Peter(L) and Carlton(R) pause for a photo-op during assembly. Photo by Rick Krishfield

5:30pm: Pictures were taken for later determination of the buoy azimuth and direction of the scan- head. GPS marks were also taken for this purpose, but may not work well due to the small size of the floe. Visibility was dropping so the chopper started bringing people home. With the assistance of Jeffery Charters(IOS) we finished bolting down the solar array and turned the buoy on. Due to time constraints there was no time to connect to the buoy via RS-232, so we waited for the sounds of scanhead operation to verify that the buoy had in fact come on.
6:15pm: Boarded the helicopter and returned to the ship. The buoy made its first transmission home soon after and other members of the O-buoy team looked at the data set and verified a

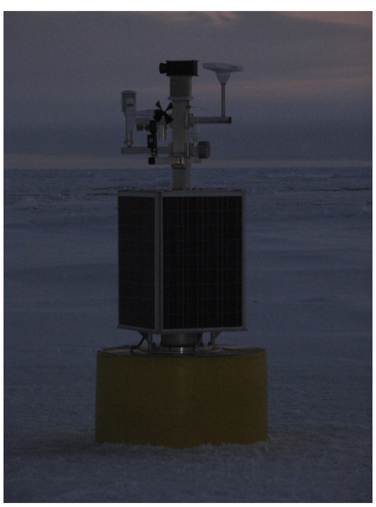

Figure 6: Completed O-Buoy. Photo by Rick Krishfield

4.8 Ice Observations

PI: Kazutaka Tataeyama, Kitami Institute of Technology, Japan
Kohei Mizobata, TUMSAT

Measurements:

- Ice Observations
    - Ice Observations (KIT)

      Underway measurements of ice thickness from an electromagnetic induction sensor, Passive microwave Radiometers(PMR), and fixed forward-looking camera.

Underway measurements

Underway measurements of ice thickness were made using, an Electromagnetic induction (EM) sensor, Passive Microwave Radiometers (PMR) and a forward looking camera. These data will be used to help interpret satellite images of sea ice which have the advantage of providing extensive area and thickness but lack the groundtruthing of just what the images represent. The EM sensor was deployed from the foredeck's crane on the port side, collecting data while underway. The passive microwave sensor was mounted one deck higher also on the ship's port side looking out over the EM's measurement area and collected data continuously.

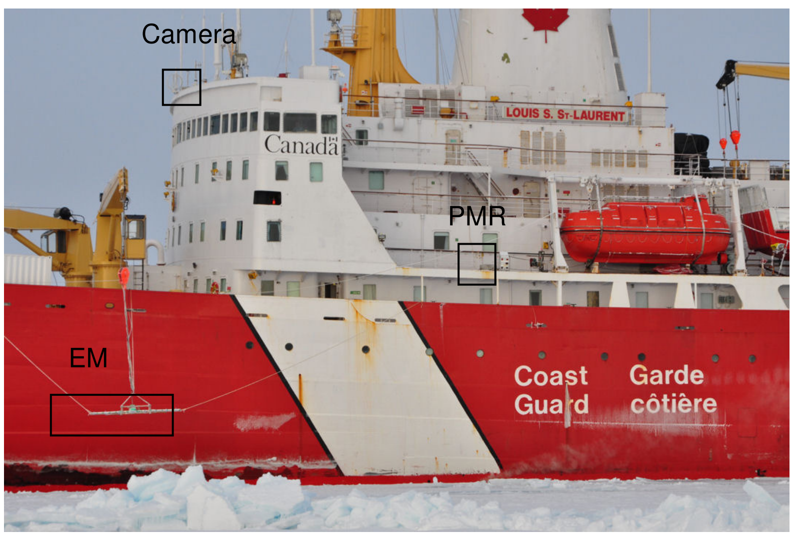

Figure 1. Pictures of EM , PMR and forward-looking camera.

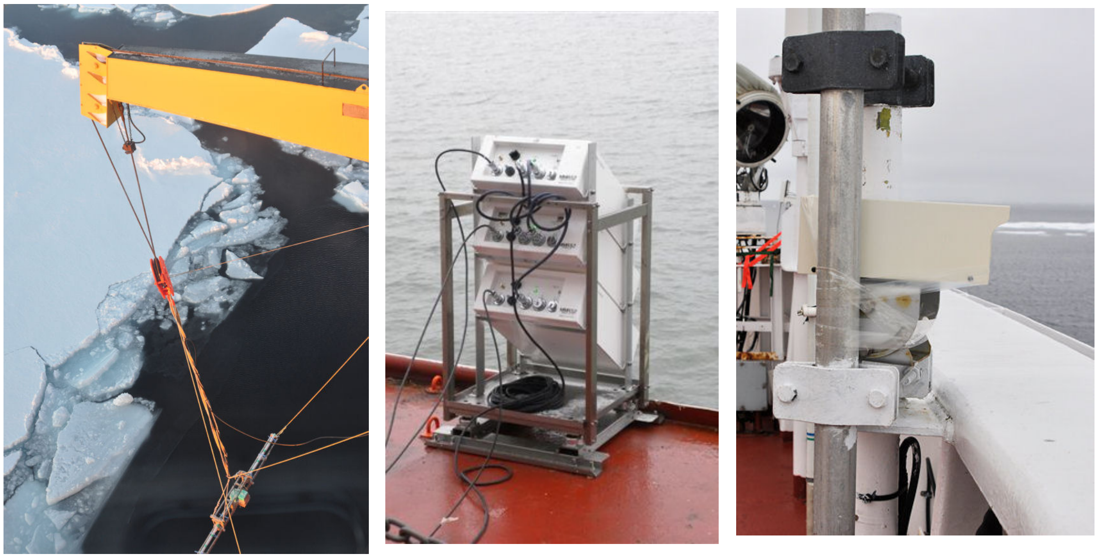

Figure 2. Pictures of EM, PMR and forward-looking camera.

EM ice thickness profiles and PMR observation

An Electro-Magnetic induction device EM31/ICE (EM) and laser altimeter LD90 will be used for sea-ice thickness sounding. EM provides apparent conductivities in mS/m which can be converted to a distance between the instrument and sea water at sea-ice bottom (H_E) by using inversion method. LD90 provides a distance between the instrument and snow/sea-ice surface (H_L). The total thickness of snow and sea-ice (H_T) can be derived by subtracting H_L from H_E. Ice concentration can be measured by EM system.

To develop new algorithm for estimation of the Arctic snow/sea-ice total thickness by using satellite-borne passive microwave radiometer (PMR), snow/sea-ice brightness temperatures and surface temperature measurements will be conducted. The portable PMR, called MMRS2A, which is newly developed by Mitsubishi Tokki System Co. Ltd., Japan, have 5 channels which are the vertically polarized 6GHz, 18GHz and 36GHz, the horizontally polarized 6GHz and 36GHz with radiation thermometers and CCD cameras. The radiation thermometers IT550, which are developed by HORIBA Corp., Japan, were used. Those sensors were mounted on the port side below the bridge in 55 incident angle which is same angle as the satellite-borne passive microwave radiometer AQUA/AMSR-E. All data are collected every 1 second continuously except CTD stations and maintenance.

EM ice thickness observation started at 29 September and ended at 13 October. 12 ice thickness profiles are observed as shown in figure 4 and summarized in table 1. The total distance of 12 profiles are 7,919 km. EM was calibrated twice on Oct. 1 and Oct 13 over open water and nilas, respectively.

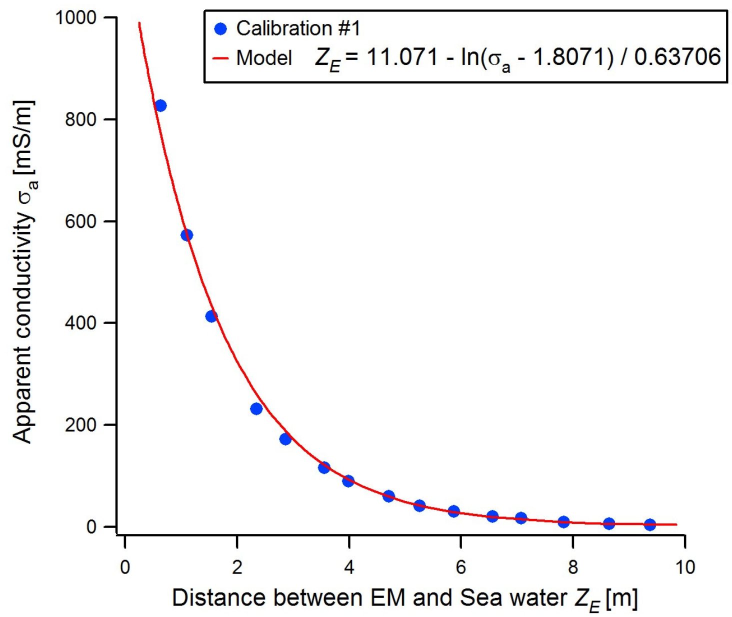

Figure 3. Result of EM calibration over open water.

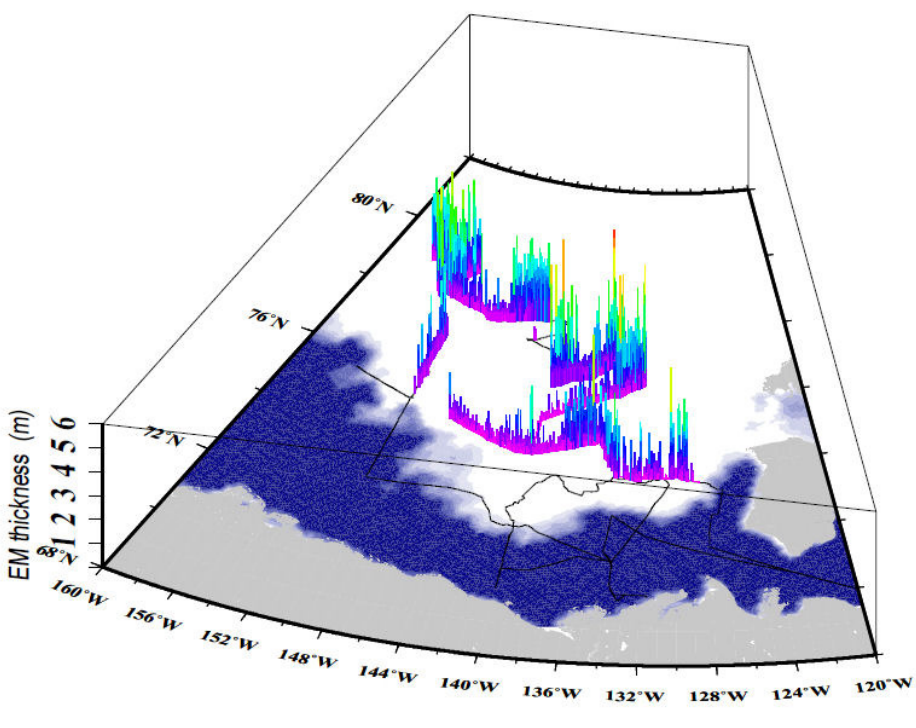

Figure 4. EM thickness profile during 29 Sep. – 13 Oct., 2010. Background image is sea ice concentration on 7 Oct., 2010 derived from AMSR-E.

Table 1. EM and PMR observation log.

Profile Number	Start Time(UTC)	Start Position	End Time(UTC)	End Position	Length of profile [km]
1	Sep. 30 01:02	75.36058N 149.9227W	Sep. 30 16:22	76.99203N 149.9022W	273.82
2	Sep. 30 16:38	76.99263N 149.8889W	Oct. 1 04:26	78.28362N 153.077W	415.92
3	Oct 1 05:15	78.28047N 153.0698W	Oct. 1 15:41	78.0093N 149.9918W	434.16
4	Oct 1 21:06	77.99005N 150.0956W	Oct. 2 16:14	79.15653N 155.2464W	724.86
5	Oct 2 21:55	79.10118N 154.5471W	Oct. 3 20:55	77.99942N 149.9973W	803.87
6	Oct 4 03:10	77.97948N 150.0831W	Oct. 5 10.47	77.9332N 141.6666W	976.43
7	Oct 6 23:16	78.98383N 139.6039W	Oct. 8 02:17	76.71253N 135.1826W	794.82
8	Oct 8 03:33	76.70915N 135.1832W	Oct. 9 12:51	75.00415N 140.0134W	1174.89
9	Oct 9 14:16	74.98305N 140.0327W	Oct. 9 19:39	74.07478N 140.1222W	102.37
10	Oct 10 03:35	73.98072N 139.9978W	Oct. 10 19:24	74.71073N 146.6217W	750.93
11	Oct 10 22:09	74.6962N 146.6156W	Oct. 11 07:50	74.02882N 139.9895W	746.16
12	Oct 13 00:00	73.49852N 134.1779W	Oct. 13 22:22	73.37783N 128.4495W	720.83

A looking-forward digital camera on upper bridge will be set to record sea ice condition in ice covered area. These images will be used for calculation of concentrations of open water, melt pond, and ice.

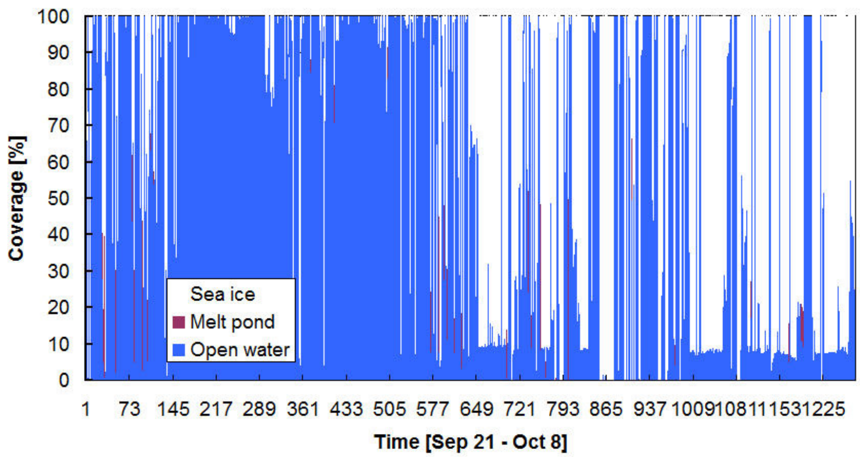

Figure 4. Result of automated ice-pond-water detection from camera images.

Ice station measurements

Snow depth, skin temperature, internal temperature, density, salinity, strategy(crystal type and size) measured in ice stations 2-4. Sampling intervals are 1cm and 3cm for internal temperature and density/salinity, respectively. Snow strategy was recorded in each snow layers.

Those snow properties will be compared with PMR brightness temperatures in order to validate general microwave radiation transfer model for satellite remote sensing. Those data will be used for evaluation of snow and sea-ice conditions in the end of melting and the begging of freezing periods with ice core data.

The total thickness of snow and ice distributions were investigated representative sea-ice morphology by drilling and using EM31SH which is shorter than EM31/ICE. Apparent conductivities (mS/m) of the Vertical Magnetic Dipole (VMD) and Horizontal Magnetic Dipole (HMD) modes were collected every 2 m in order to synchronize drill-hole (every 10m).

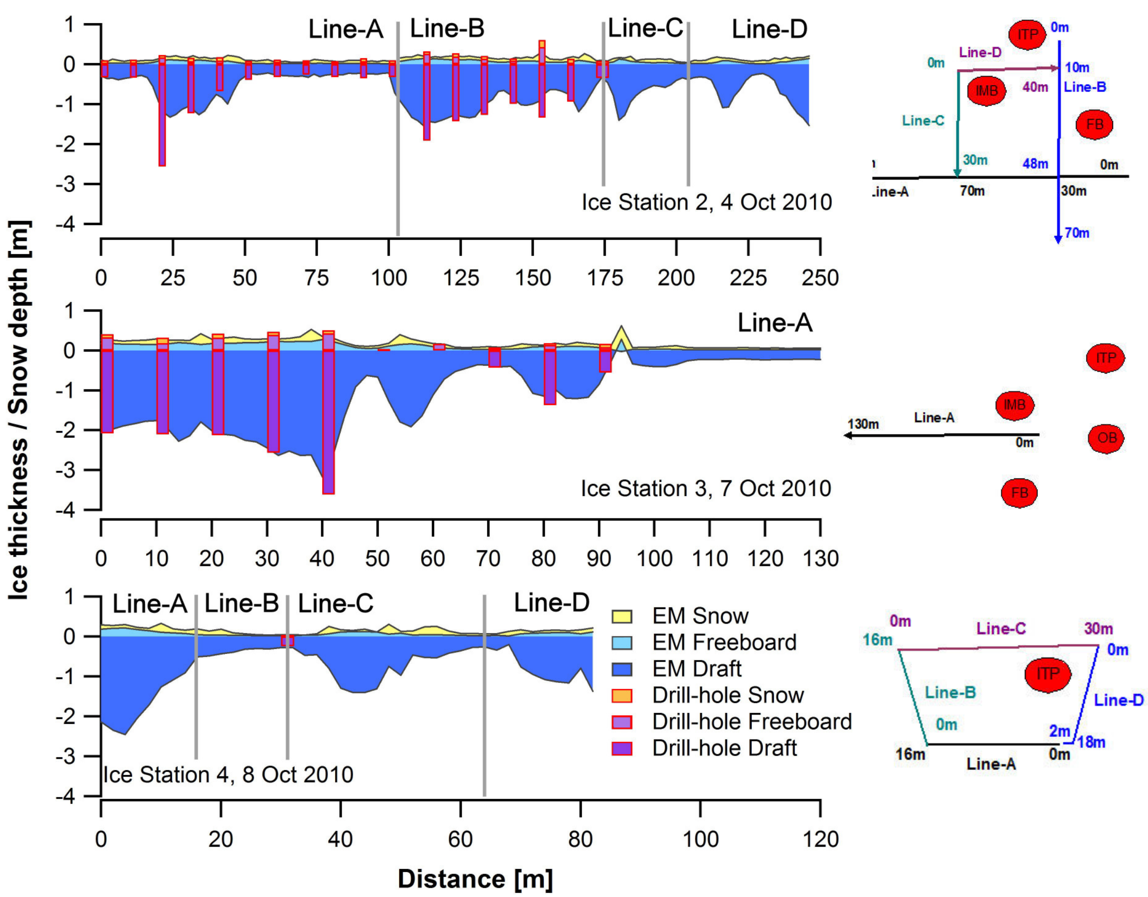

Figure 5. Transects of EM 31SH and drill-holes on the ice station 2-4. Maps of profiles are shown in right side.

Table 2. Summery of snow depth and ice thickness on the ice station 2-4.

Station name	Lat Lon	Line name	Length of profile [m]	Snow depth [m]		Ice thickness [m]	
				mean	std	mean	std
St.2	77.66441N 146.29408W	Line-A	100	0.07	0.03	0.54	0.40
		Line-B	70	0.09	0.03	1.11	0.32
		Line-C	30	0.06	0.03	0.71	0.35
		Line-D	40	0.08	0.02	0.73	0.43
St.3	76.71900N 135.19353W	Line-A	130	0.09	0.09	1.35	0.98
St.4	75.8566N 134.65028W	Line-A	16	0.10	0.05	1.85	0.73
		Line-B	16	0.05	0.05	0.43	0.13
		Line-C	30	0.09	0.08	0.92	0.43
		Line-D	20	0.07	0.03	0.94	0.45

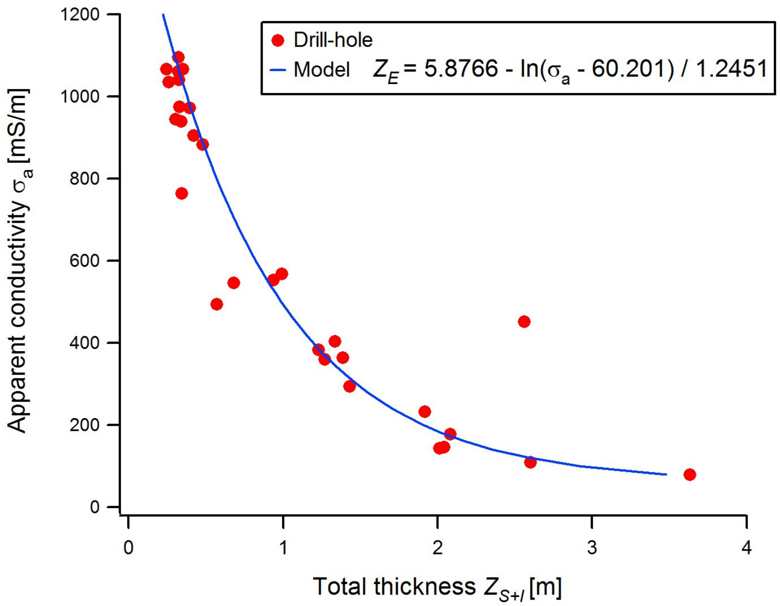

Figure 6. Comparison of total thicknesses between drill-hole and EM31SH.

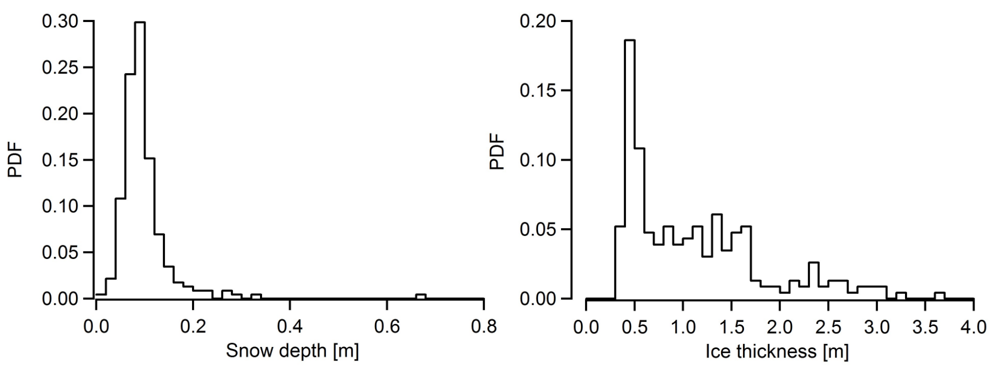

Figure 7. PDF of snow and ice thickness observed by EM31SH.

APPENDIX A: Participants

Table 1. Cruise Participants

Name	Affiliation	Role
Bill Williams	DFO	Chief Scientist
Jane Eert	DFO	Co-Chief Scientist, CTD Watch
Michiyo Kawai	DFO	Principal Chemist, Alkalinity Anaysis
Linda White	DFO	Nutrients Analyis, Lab Supervisor
Miranda Corkum	DFO	Oxygen Analysis
Nes Sutherland	DFO	CFC Analysis
Rick Nelson	DFO	CFC, Cs, I Analysis
Mike Dempsey	DFO	CTD Watch, Chief Technician
Sarah Zimmermann	DFO	CTD Watch, Data Analysis
Kelly Young	DFO	CTD Watch, Zooplankton Analysis
Kenny Scozzafava	DFO	CTD Watch
Chelsea Stanley	DFO	CTD Watch
Jeffrey Charters	DFO	CTD Watch, Ammonium Analysis
Zoe Sandwith	DFO	CTD Watch
Rick Krishfield	WHOI	Moorings and ITP Buoys
Kris Newhall	WHOI	Moorings and ITP Buoys
Jim Dunn	WHOI	Moorings and ITP Buoys
Carlton Rauschenberg	CRREL	O-Buoy
Peter Peterson	CRREL	O-Buoy
Alice Orlich	IARC	Ice observation
Heidi Isernhagen	IARC	Ice observation
Kohei Mizobata	TUMSAT	Ice observation
Kazu Tateyama	KIT	Ice observation

Table 2. Principal Investigators not on-board ship

Name	Affiliation
Fiona McLaughlin	DFO-IOS
Eddy Carmack	DFO-IOS
John Nelson	DFO-IOS
Svein Vagle	DFO-IOS
John Smith	DFO-BIO
Bill Li	DFO-BIO
Andrey Proshutinsky	WHOI
Motoyo Itoh	JAMSTEC
Koji Shimada	TUMSAT
Chris Guay	Pacific Marine Sciences and Technology
Celin Gueguen	Trent University
Don Perovich	CRREL
Jennifer Hutchings	IARC

Table 3. Affiliation Abbreviation

CRREL	Cold Regions Research Laboratory, New Hampshire
DFO	Department of Fisheries and Oceans, Canada
IARC	International Arctic Research Center, Alaska
JAMSTEC	Japan Agency for Marine-Earth Science Technology, Japan
KIT	Kitami Institute of Technology, Japan
WHOI	Woods Hole Oceanographic Institution, Massachusetts
TUMSAT	Tokyo University of Marine Science and Technology

APPENDIX B: Science Station Locations

Table 4. Rosette/CTD Casts

Cast #	Station	CAST START TIME (UTC)	Lat Deg	Lat Min	N	Lon Deg	Lon Min	W	Uncorrected Water Depth (m)	Cast Depth (m)	Sample #'s
1	AG-5	9/17/2010 0:26	70	33.22	N	122	54.62	W	660	636	Jan-22
2	CABOS	9/17/2010 14:12	71	46.91	N	131	51.9	W	1113	1109	23-44
3	CB-31b	9/17/2010 19:23	72	20.91	N	133	59.95	W	2039	2062	45-68
4	CB-60	9/18/2010 2:20	71	18.71	N	134	19.48	W	977	976	69-91
5	CB-61	9/19/2010 1:11	71	12.15	N	134	11.94	W	700	673	92-114
6	CB-62	9/19/2010 4:34	71	7.48	N	134	3.69	W	500	442	115-116
7	CB-63	9/19/2010 6:02	71	2.16	N	133	56.54	W	270	259	117-118
8	CB-64	9/19/2010 7:19	70	57.12	N	133	48.8	W	83	74	119-120
9	CB-65	9/19/2010 8:21	70	51.61	N	133	42.19	W	78	68	121-122
10	MK3	9/20/2010 3:55	70	34.3	N	140	0.4	W	771	759	123-146
11	MK3	9/20/2010 5:07	70	34.25	N	140	0.44	W	771	756	147-169
12	MK2	9/20/2010 8:13	70	23.95	N	139	59.84	W	502	490	170-191
13	MK1	9/20/2010 10:41	70	13.5	N	139	59.93	W	227	214	192-203
14	CB28aa	9/20/2010 12:34	70	0.26	N	140	0.84	W	58	50	204-209
15	MK3a	9/20/2010 16:20	70	39.9	N	140	0.1	W	1319	1307	210-233
16	MK-4	9/20/2010 20:37	70	48.53	N	140	0.85	W	1461	1426	235-258
17	MK-6	9/21/2010 1:24	71	34.88	N	140	0.19	W	2449	2467	259-282
18	CB-28b	9/21/2010 6:38	70	59.79	N	140	0.12	W	2057	1001	283-302
19	CB-28b	9/21/2010 9:35	71	0.11	N	140	0.42	W	2085	2076	303-326
20	CB-29	9/21/2010 16:45	72	0.26	N	140	2.11	W	2685	2676	327-350
21	MK-7	9/21/2010 23:08	72	31.54	N	140	0.99	W	3001	3000	351-374
22	CB-27	9/22/2010 6:01	72	59.99	N	140	0.68	W	3197	3200	375-398
23	CB-22	9/22/2010 13:16	73	26.99	N	138	2.21	W	3118	3113	399-422
24	CB-23a	9/22/2010 21:28	72	54.37	N	136	7.65	W	2777	2764	423-446
25	CB-50	9/23/2010 7:23	73	29.23	N	134	9.89	W	2872	1002	447-469
26	CB-50	9/23/2010 9:06	73	28.92	N	134	12.36	W	2878	2870	470-493
27	CB-51	9/23/2010 18:40	73	30.6	N	130	56.97	W	2511	2497	494-517
28	Sta-A	9/27/2010 1:54	72	40.68	N	144	39.86	W	3451	1001	518-541
29	Sta-A	9/27/2010 3:39	72	40.66	N	144	38.9	W	3451	3454	542-565
30	CB-2a	9/27/2010 13:14	72	30.53	N	149	58.98	W	3705	3712	566-589
31	CB-2	9/27/2010 18:37	72	59.5	N	149	59.82	W	3735	3737	590-613
32	CB-3	9/28/2010 3:11	73	59.88	N	149	59.67	W	3812	3815	614-637
33	CB-4	9/28/2010 11:32	74	59.01	N	150	1.57	W	3825	1002	638-661
34	CB-4	9/28/2010 20:22	75	0.23	N	150	6.06	W	3825	3817	662-685
35	CB-5	9/29/2010 3:18	75	18.14	N	153	17.45	W	3844	3832	686-709
36	CB-7	9/30/2010 5:29	75	59.18	N	150	0.84	W	3832	3819	710-733
37	CB-8	9/30/2010 15:03	76	59.3	N	149	57.58	W	3832	3805	734-757
38	CB-10	10/01/2010 3:28	78	17.25	N	153	5.38	W	2829	1002	758-781
39	CB-10	10/01/2010 4:59	78	16.87	N	153	4.32	W	2954	3087	782-805
40	CB-70	10/02/2010 11:39	79	10.1	N	155	18.22	W	3819	3806	806-829
41	CB-70	10/02/2010 16:24	79	9.35	N	155	14.66	W	3819	351	830-853
42	CB-11	10/03/2010 9:58	78	59.79	N	150	2.44	W	3825	3809	854-877
43	CB-9	10/04/2010 3:10	77	58.77	N	150	4.99	W	3824	1002	878-901
44	CB-9	10/04/2010 4:35	77	58.77	N	150	4.98	W	3825	3813	902-925
45	CB-12	10/04/2010 12:40	77	41.34	N	146	42.4	W	3809	1001	926-949

46	CB-12	10/04/2010 14:13	77	41.2	N	146	42.15	W	3809	256	na
47	CB-12	10/04/2010 14:42	77	41.18	N	146	42.17	W	3809	3801	950-973
48	CB-12a	10/04/2010 23:04	77	40.01	N	146	15.93	W	3809	350	974-997
49	CB-16	10/05/2010 14:05	77	58.81	N	140	0.66	W	3753	3743	998-1021
50	CB-13	10/06/2010 1:31	77	19.05	N	143	11.18	W	3780	1001	1022-1045
51	CB-13	10/06/2010 3:06	77	18.86	N	143	9.7	W	3780	3770	1046-1069
52	CB-15	10/06/2010 12:09	77	0.05	N	140	0.74	W	3727	500	1070 - 1093
53	CB-15	10/06/2010 14:01	76	59.91	N	139	57.78	W	3727	1002	1094-1117
54	CB-15	10/06/2010 18:58	76	59.58	N	139	43.51	W	3722	3712	1118-1141
55	CB-17	10/07/2010 7:07	76	1.27	N	139	57.38	W	3695	3686	1142-1165
56	PP-7	10/07/2010 22:18	76	43.2	N	135	10.74	W	3568	1002	1166-1189
57	PP-7	10/08/2010 0:50	76	42.93	N	135	11	W	3567	3553	na
58	PP-6	10/08/2010 9:49	76	15.69	N	132	31.47	W	3061	1002	1214-1237
59	PP-6	10/08/2010 12:01	76	16.13	N	132	31.5	W	3069	3050	1238-1261
60	CB-DW	10/08/2010 21:47	75	51.41	N	134	39.74	W	3417	2165	1262-1285
61	CB-18	10/09/2010 12:24	75	0.22	N	140	0.5	W	3628	2204	1286-1309
62	CB-19	10/10/2010 9:45	74	17.58	N	143	15.06	W	3697	3684	1310-1333
63	CB-6	10/10/2010 19:25	74	42.64	N	146	37.32	W	3779	3769	1334-1357
64	CB-21	10/11/2010 8:03	74	1.64	N	139	59.03	W	3525	1004	1358-1381
65	CB-21	10/11/2010 9:58	74	1.14	N	139	59.92	W	3524	500	1382-1405
66	CB-21	10/11/2010 13:26	74	0.56	N	140	1.04	W	3527	3511	1406-1429
67	CB-40	10/12/2010 9:04	74	30.21	N	135	23.91	W	3266	3244	1430-1453
68	CB-50	10/12/2010 20:06	73	31.15	N	134	11.46	W	2881	2873	1454 - 1477
69	CB-51	10/13/2010 7:01	73	30.81	N	130	56.62	W	2511	2491	1478-1501
70	CB-52	10/13/2010 14:10	73	29.68	N	129	29.51	W	987	991	1502-1525
71	CB-53	10/13/2010 19:12	73	23.58	N	128	32.25	W	401	398	1526-1544
72	CB-54	10/14/2010 0:58	73	19.29	N	127	47.55	W	205	194	1550-1559

Table 5. XCTD Casts

XCTD Cast #	Time				Latitude (N)		Longitude (W)		Uncorrected Water Depth (m)	Probe Type	Comments
1	2010	9	18	20:12	71	48.35	134	12.22	1448	XCTD-3	
2	2010	9	19	22:00	71	5.11	135	55.15	1024	XCTD-3	
3	2010	9	19	0:01	70	48.74	137	15.38	1470	XCTD-3	
4	2010	9	20	1:44	70	35.81	138	27.04	1155	XCTD-3	SST >6℃, foggy
5	2010	9	23	14:57	73	22.48	132	33.93	2652	XCTD-1	Open water in ice area
6	2010	9	23	22:38	73	7.97	130	43.32	2187	XCTD-3	Open water
7	2010	9	24	0:09	72	47.28	131	18.89	1953-1927	XCTD-3	Ice conc. 10%
8	2010	9	24	1:47	72	24.19	131	49.73	1664	XCTD-3	
9	2010	9	24	3:24	72	2.05	132	22.25	1438	XCTD-3	
10	2010	9	26	7:59	71	18.33	135	40.95	N/A	XCTD-3	Open Water
11	2010	9	26	9:52	71	30.44	136	59.83	N/A	XCTD-3	Open Water
12	2010	9	26	12:01	71	44.79	138	29.96	N/A	XCTD-3	Open Water
13	2010	9	26	13:34	71	51.84	138	56.02	N/A	XCTD-1	Ice conc. 50% Swelling
14	2010	9	26	14:42	71	52.28	139	22.36	N/A	XCTD-1	Ice conc. 80% Multi-year
15	2010	9	26	16:19	71	49.85	140	3.41	2664	XCTD-1	Ice conc. 90%
16	2010	9	26	19:53	72	8.84	141	38.5	2993	XCTD-3	Open Water
17	2010	9	26	23:08	72	37.53	143	2	4243	XCTD-1	Ice conc. 90%
18	2010	9	27	8:17	72	37.54	146	21.63	N/A	XCTD-3	Open Water
19	2010	9	27	10:31	72	33.75	148	6.78	N/A	XCTD-3	Open Water
20	2010	9	27	22:02	73	2.08	149	59.61	3736	XCTD-2	Open Water
21	2010	9	27	22:37	73	5.46	150	0.17	3743	XCTD-1	Open Water
22	2010	9	28	0:17	73	29.31	149	59.62	3796	XCTD-3	Open Water
23	2010	9	28	8:08	74	32.51	149	59.37	3808	XCTD-3	Open Water
24	2010	9	29	1:02	75	9.44	151	40.28	3838	XCTD-2	Ice conc. 5%
25	2010	9	29	8:13	75	28.64	155	10.32	3846	XCTD-2	Open Water
26	2010	9	30	2:18	75	30.24	149	52.25	3831	XCTD-1	Ice conc. 100%
27	2010	9	30	11:23	76	30.17	149	59.93	3847	XCTD-1	Ice conc. 100%
28	2010	9	30	20:14	77	26.16	150	55.62	3828	XCTD-1	Ice conc. 100% 10cm
29	2010	9	30	23:24	77	52.63	151	58.88	3835	XCTD-2	Ice conc. 100% 10cm
30	2010	10	1	10:04	78	8.77	151	32.29	N/A	XCTD-2	Ice conc. 100% 10cm~20cm
31	2010	10	1	23:55	78	18.17	150	59.93	3831	XCTD-1	Ice conc. 100% 10cm~20cm
32	2010	10	2	2:26	78	32.3	151	55.38	3830	XCTD-1	Ice conc. 100% 10cm~30cm
33	2010	10	2	6:13	78	48.14	153	15.52	3828	XCTD-1	Ice conc. 100% 10cm~30cm
34	2010	10	2	8:07	78	57.48	154	13.38	3666	XCTD-1	Ice conc. 100%
35	2010	10	3	4:15	79	5.053	153	51.46	3579	XCTD-1	Ice conc. 100% 10cm~100cm
36	2010	10	3	6:45	79	2.28	151	56.5	3836	XCTD-1	Ice conc. 100% 10cm~200cm
37	2010	10	3	15:43	78	39.41	150	54.73	3829	XCTD-1	Ice conc. 100% 10cm~200cm
38	2010	10	4	10:02	77	52.52	148	16.54	3819	XCTD-1	Ice conc. 100% 10cm~200cm
39	2010	10	5	4:32	77	48.35	144	24.8	3798	XCTD-1	Ice conc. 100% 100cm~200cm

40	2010	10	5	9:38	77	54.64	142	10.43	3781	XCTD-1	Ice conc. 100% 100cm~200cmHeavy Ice XCTD cast was shorten (700m) due to ice
41	2010	10	5	9:47	77	54.64	142	10.43	3781	XCTD-3	second trial
42	2010	10	5	20:00	77	34.99	140	43.92	3750	XCTD-1	Ice conc. 100% 100cm~200cm
43	2010	10	6	8:49	77	9.52	141	31.4	3751	XCTD-1	Ice conc. 100% 100cm~200cm
44	2010	10	7	2:56	76	27.26	139	18.88	3672	XCTD-1	Ice conc. 100% 100cm~200cm
45	2010	10	7	11:58	76	10.54	138	46.21	3645	XCTD-3	Ice conc. 100% 100cm
46	2010	10	7	15:05	76	20.69	136	54.5	3588	XCTD-1	Ice conc. 100% 30cm
47	2010	10	8	6:49	76	24.64	133	52.44	3367	XCTD-1	Ice conc. 100% 100cm
48	2010	10	8	17:31	75	55.39	134	6.89	3339	XCTD-1	Ice conc. 100% 100cm
49	2010	10	9	4:50	75	40.88	136	7.2	3530	XCTD-1	Ice conc. 100% 10cm-30cm
50	2010	10	9	8:35	75	22.39	138	7.85	3555	XCTD-3	Ice conc. 100% 10cm-50cm
51	2010	10	9	17:33	74	29.14	140	3.54	3643	XCTD-3	Ice conc. 100% 10cm-30cm
52	2010	10	10	6:36	74	8.01	141	37.71	3635	XCTD-1	Ice conc. 100% 10cm-50cm
53	2010	10	10	15:46	74	29.65	144	58.93	3737	XCTD-1	Ice conc. 100% 10cm-100cm
54	2010	10	12	1:10	74	8.99	138	32.05	3426	XCTD-1	Ice conc. 100% 10cm-50cm, relative warm air temperature
55	2010	10	12	4:46	74	20.41	136	56.64	3300	XCTD-1	Ice conc. 100% 10cm-50cm
56	2010	10	12	8:24	74	0.11	134	53.2	3066	XCTD-1	Ice conc. 100% 10cm-30cm
57	2010	10	13	10:36	73	30.08	130	22.1	N/A	XCTD-3	Ice conc. 100% heavy ice, 100-300cm
58	2010	10	13	12:05	73	31.15	129	51.78	N/A	XCTD-1	Ice conc. 100%

Table 6. Vertical Net Hauls

Station	Net #	Date (Local)	Time (UTC)	Latitude (N)		Longitude (W)		Bottom Depth (m)	Max Depth (m)	Wire Angle	RBR Depth (m)	Notes
AG5	1	16-Sep-10	1:20	70	33.59	122	54.78	647	100	15	97.9	15 deg wire angle at bottom, increased to almost 45 deg near surface
AG5	2	16-Sep-10	1:36	70	33.62	122	54.5	646	100	0	100.8	
CABOS	3	17-Sep-10	14:39	71	46.9	131	51.94	1100	100	0	100.7	
CABOS	4	17-Sep-10	14:55	71	46.88	131	51.94	1100	100	0	101.2	flowmeter removed, rinsed and zeroed
CB31b	5	17-Sep-10	19:53	72	21.19	133	59.85	2052	100	0	98.5	
CB31b	6	17-Sep-10	20:09	72	21.2	133	59.86	2052	100	0	101	
CB-60	7	17-Sep-10	2:53	71	18.75	134	19.81	1036	100	0	98.8	
CB-60	8	17-Sep-10	3:13	71	18.74	134	19.88	1036	100	0	98	
CB-61	9	18-Sep-10	3:50	71	11.03	134	12.14	701	100	0	100.9	net sat at 100m for 9 minutes
CB-61	10	18-Sep-10	4:04	71	11.98	134	12.23	701	100	0	99.9	
CB-65	11	19-Sep-10	8:48	70	51.59	133	42.14	77	65	0	65.3	un-scheduled net, snuck one in
MK-3	12	19-Sep-10	5:27	70	34.16	140	0.41	1305	100	0	102.1	
MK-3	13	19-Sep-10	5:42	70	34.1	140	0.56	1305	100	0	101.4	
MK-2	14	20-Sep-10	8:33	70	23.92	140	0.06	507	100	0	100.7	cod-end weight line broke during tow, but net didn't tangle. juvenile Arctic cod removed and froze @ -80 separately
MK-2	15	20-Sep-10	8:55	70	23.87	140	0.25	507	100	0	102.4	
MK-1	16	20-Sep-10	11:00	70	13.52	140	0.14	225	100	0	100.5	euphausiids in sample
MK-1	17	20-Sep-10	11:14	70	13.51	140	0.06	225	100	0	99.3	
CB-28aa	18	20-Sep-10	12:51	70	0.2	140	0.95	56	48	0	47.6	Samples full of algae, preserved in 250 ml jars
CB-28aa	19	20-Sep-10	13:04	70	0.16	140	1.28	59	49	0	49	Samples full of algae, preserved in 250 ml jars
MK-3a	20	20-Sep-10	16:40	70	39.84	140	0.3	1305	100	0	103.8	
MK-3a	21	20-Sep-10	16:56	70	39.8	140	0.5	1315	100	0	101.5	
MK-4	22	20-Sep-10	21:03	70	48.54	140	1.42	1437	100	0	102.6	2nd net tow cancelled due to snapped cod end lines
MK-6	23	20-Sep-10	1:35	71	34.88	140	0.33	2476	100	0	102.8	
MK-6	24	20-Sep-10	1:45	71	34.88	140	0.33	2476	100	0	104.9	
CB-28b	25	21-Sep-10	8:20	71	0.56	140	0.06	2100	100	0	108.6	
CB-28b	26	21-Sep-10	8:39	71	0.56	140	0.06	2100	100	0	115.4	
CB-29	27	21-Sep-10	16:57	72	0.17	140	2.35	2690	100	0	100.6	In ice!
CB-29	28	21-Sep-10	17:19	71	59.91	140	2.97	2693	100	0	98.1	In ice!
MK-7	29	21-Sep-10	23:37	72	31.54	140	1.58	2998	100	0	100.4	
MK-7	30	21-Sep-10	23:52	72	31.55	140	0.63	2998	100	0	100.5	
CB-27	31	21-Sep-10	6:29	72	59.69	140	1.34	3195	100	60	82.1	60 deg. Wire angle - ship backing up to avoid ice
CB-27	32	21-Sep-10	6:42	72	59.63	140	1.53	3195	100	10	95.9	10 deg wire angle
CB-22	33	22-Sep-10	13:42	73	26.88	138	2.52	3118	100	0	100.7	

CB-22	34	22-Sep-10	14:00	73	26.88	138	2.62	3119	100	0	100.7	
CB-23a	35	22-Sep-10	22:09	72	54.2	136	8.15	2774	100	0	100	
CB-23a	36	22-Sep-10	22:22	72	54.14	136	8.37	2774	100	0	100.1	
CB-50	37	23-Sep-10	7:28	73	29.22	134	10.14	2873	100	0	101.6	cod ends full of slush
CB-50	38	23-Sep-10	7:53	73	29.23	134	10.14	2874	100	0	101.5	
CB-51	39	23-Sep-10	19:15	73	30.61	130	56.91	2513	100	0	100.6	TSK 5294 switched out for MF-315 #4
CB-51	40	23-Sep-10	19:32	73	30.58	130	57.11	2513	100	0	100.7	
STA-A	41	26-Sep-10	3:10	72	40.65	144	38.99	3478	100	0	125.6	
STA-A	42	26-Sep-10	3:25	72	40.65	144	38.99	3478	100	0	123.3	
CB2a	43	27-Sep-10	16:11	72	30.92	149	59.73		100	0	109.6	2nd net tow cancelled due to rough weather
CB2	44	27-Sep-10	16:25	72	59.01	149	59.1	3739	110	30	112.3	2nd net tow cancelled due to rough weather. juvenile Arctic cod removed and froze @ -80 separately
CB-3	45	27-Sep-10	2:44	73	59.65	150	0.34	3811	100	0	120.5	
CB-3	46	27-Sep-10	2:59	73	59.79	150	0.15	3811	100	0	126.8	
CB-4	47	28-Sep-10	11:18	74	58.9	150	1.05	3825	100	0	100.7	
CB-4	48	28-Sep-10	11:50	74	59.13	150	2.03	3825	500	0	497	
CB-4	49	28-Sep-10	12:18	74	59.32	150	2.35	3825	100	0	100.6	
CB-5	50	28-Sep-10	3:48	75	18.13	153	17.6	3841	100	0	101.3	
CB-5	51	28-Sep-10	3:52	75	18.11	153	17.72	3841	100	0	101	
CB7	52	29-Sep-10	5:55	75	59.13	150	0.47	3828	100	0	98.6	
CB7	53	29-Sep-10	6:09	75	59.13	150	0.35	3828	100	0	101.5	
CB8	54	30-Sep-10	15:51	76	59.44	149	55.63	3824	100	0	97.8	high winds, around 25knts. Flowmeters not windmilling tho
CB8	55	30-Sep-10	16:07	76	59.48	149	54.85	3824	100	15	100.2	high winds, around 25knts. Flowmeters not windmilling tho
CB-10	56	30-Sep-10	5:17	78	16.82	153	4.17	2990	100	0	101.2	cod ends full of slush, only one net done due to freeze
CB-9	57	03-Oct-10	5:20	77	58.81	150	4.59	3825	100	0	99.8	flowmeter frozen
CB-9	58	03-Oct-10	6:07	77	58.86	150	4.34	3825	500	0	533.5	flowmeter frozen
CB-9	59	03-Oct-10	6:30	77	58.84	150	4.01	3825	100	0	101.6	flowmeter frozen
CB-12	60	04-Oct-10	14:39	77	41.17	146	42.17	3809	100	0	101.8	flowmeter frozen
CB-12	61	04-Oct-10	14:58	77	41.16	146	42.14	3809	100	0	-	flowmeter frozen
CB-16	62	05-Oct-10	15:03	77	58.68	139	59.72	3751	100	0	-	flowmeter frozen
CB-16	63	05-Oct-10	15:34	77	58.63	139	59.08	3751	500	0	513.3	stopped at 20m for bubbler to clear ice on upcast
CB-16	64	05-Oct-10	16:00	77	58.58	139	58.68	3751	100	0	108.8	
CB-13	65	05-Oct-10	1:57	77	18.99	143	10.77	3780	100	0	121.9	
CB-13	66	05-Oct-10	2:12	77	18.9	143	10.58	3780	100	0	-	
CB-15	67	06-Oct-10	12:39	77	0.05	140	0.18	3727	100	0	-	winch counter frozen at start of tow, read -58m at end
CB-15	68	06-Oct-10	13:17	77	0	139	59.5	3727	500	0	502.3	
CB-15	69	06-Oct-10	13:45	76	59.92	139	58.2	3727	100	0	100	stopped at 10m for bubbler
CB-15	70	06-Oct-10	14:37	76	59.86	139	56.74	3727	1000	15	-	removed RBR for cast
CB-17	71	07-Oct-10	7:46	76	1.14	139	56.72	3695	100	0	107.7	
CB-17	72	07-Oct-10	8:03	76	1.06	139	56.4	3695	100	0	104.8	

PP-7	73	07-Oct-10	0:08					3568	100	0	-	flowmeter froze
PP-7	74	07-Oct-10	0:27					3568	100	0	-	flowmeter froze
PP-7	75	07-Oct-10	2:09					3568	100	0	-	for Michiyo for Limacina
PP-6	76	08-Oct-10	11:33	76	16.04	132	31.5	3067	100	0	-	
PP-6	77	08-Oct-10	11:49	76	16.1	132	31.51	3067	100	0	-	winch counter frozen at start of tow, read -67m at end
CB-DW	78	08-Oct-10	0:53	75	51.34	134	41.4	2164	100	0	-	
CB-DW	79	08-Oct-10	1:10	75	51.35	134	41.26	2164	100	0	-	
CB-18	80	09-Oct-10	12:57	75	0.26	140	0.87	3629	100	0	-	winch counter not working, read -50.7 at end of tow
CB-18	81	09-Oct-10	13:14	75	0.24	140	1.06	3629	100	0	-	winch counter not working, read -22.3 at end of tow
CB-19	82	10-Oct-10	10:27	74	17.3	143	14.93	3697	100	20	-	winch counter not working, Stopped at 85m, read -31 at end
CB-19	83	10-Oct-10	10:48	74	17.19	143	14.9	3697	100	20	-	flowmeter frozen
CB-6	84	10-Oct-10	20:08	74	42.52	146	37.21	3778	100	0	-	
CB-6	85	10-Oct-10	20:20	74	42.59	146	37.32	3778	100	0	-	
CB-21	86	11-Oct-10	9:39	74	1.22	139	59.9	3524	100	0	-	winch counter not working - read -22m at surface
CB-21	87	11-Oct-10	10:07	74	1.11	139	59.97	3524	500	0	673.2	winch counter not working - read -159m at surface
CB-21	88	11-Oct-10	10:36	74	0.99	140	0.19	3524	100	0	-	winch counter not working - read 17m at bottom, -118m at surface. RBR removed for cast
CB-40	89	12-Oct-10	9:35	74	30.02	135	23.98	3266	100	0	100.7	flowmeter frozen
CB-40	90	12-Oct-10	9:50	74	29.91	135	24.02	3266	100	0	101.8	flowmeter frozen
CB-50	91	12-Oct-10	23:17	73	30.72	134	11.56	2882	100	0	100.8	flowmeter frozen
CB-50	92	12-Oct-10	23:31	73	31.13	134	11.56	2882	100	0	-	flowmeter frozen
CB-51	93	13-Oct-10	8:11	73	30.41	130	56.71	2510	100	0	102	flowmeter frozen
CB-51	94	13-Oct-10	8:25	73	30.33	130	56.79	2510	100	0	-	flowmeter frozen
CB-52	95	13-Oct-10	14:39	73	29.53	129	29.61	1000	100	0	116.7	
CB-52	96	13-Oct-10	14:54	73	29.44	129	29.61	1000	100	0	104.9	winch reading -19m at surface
CB-53	97	13-Oct-10	21:51	73	22.65	128	33.26	401	100	0	133.8	flowmeter frozen
CB-53	98	13-Oct-10	22:03	73	22.65	128	33.31	401	100	0	-	flowmeter frozen
CB-54	99	13-Oct-10	1:23	73	19.17	127	47.47	204	100	0	106.4	
CB-54	100	13-Oct-10	1:37	73	19.05	127	47.47	204	100	0	105.5	