2015 CCGS *Amundsen* Expedition

LEG 3b GEOTRACES/ARCTICNET
September 4 – October 1, 2015
Sachs Harbour – Resolute

CONTENT

1 – Cruise synopsis
2 – Parameters measured or sampled in the water column
3 – Parameters measured or sampled in underway
4 – Cruise participants
5 – Cruise reports by group
5.1 GEOTRACES
5.1.1 Measuring the spatial distribution of geochemical tracers in the Canadian Basin and Canadian Arctic Archipelago: Trace metal rosette sampling operations CCGS Amundsen 2015 Leg 3b
5.1.2 Particulate trace metals
5.1.3 Contaminants in a changing Arctic
5.1.4 ^{230}Th, ^{231}Pa, Nd isotopes, Cr isotopes and REE
5.1.5 Large volume in-situ operations for particulate ^{230}Th, ^{231}Pa, Nd isotopes, Cr isotopes and Si isotopes.
5.1.6 Anthropogenic Uranium, Iodine, and Cesium Analysis in the Arctic Ocean
5.1.7 Measurement of pH, alkalinity, δ^{13}C-DIC, δ^{18}O-water
5.1.8 Ocean Carbonate Chemistry and Boundary Exchange Tracers: Dissolved Inorganic Carbon, Alkalinity, Radium Isotopes, and Dissolved Barium
5.1.9 Organic Chemistry of the Beaufort Sea and Arctic Archipelago *and* Identification of Marine Organic Cu^{2+} Ligands in the Arctic Ocean
5.1.10 Aerosol sampling: Measurement of atmospheric fluxes of trace elements and isotopes in the Canadian Basin and the Canadian Arctic Archipelago during CCGS Amundsen 2015 Leg 3b
5.1.11 Moving Vessel Profiler and CTD mesoscale and mixing survey: Wellington, Maury, and Perry Channels

5.2 ArcticNet

5.2.1 ArcticNet CTD/Rosette
5.2.2 Carbon and Nutrients fluxes
5.2.3 Biogeochemical cycling of methane in Canadian Arctic Seas
5.2.4 Microbial hydrocarbon biodegradation and hydrocarbon analysis in marine sediment
5.2.5 Project: Benthic diversity and functioning across the Canadian Arctic
5.2.6 Zooplankton and Fish Ecology / Acoustic
5.2.7Dynamics and thermodynamics of the ocean-sea ice-atmosphere coupling
5.2.8 Mooring Program
5.2.9 Seabed Mapping

1. Cruise synopsis

Leg 3b of the 2015 CCGS *Amundsen* expedition was shared between ArcticNet and the Canadian Arctic GEOTRACES project: "*A biogeochemical and tracer study of a rapidly changing Arctic Ocean*". As part of the international GEOTRACES program (www.geotraces.org), the principal mandate of the Canadian Arctic GEOTRACES project was the study input, removal and cycling of trace elements and isotopes in the water column, and to use this information to document, monitor, and predict the evolution of physical and biogeochemical processes in the Arctic Ocean. On this leg, the Canadian GEOTRACES project was complemented by a 4-day process study in Penny Strait, using a Moving Vessel Profiler to study mesoscale mixing in Wellington, Maury and Perry Channels and assess the impact of these physical processes on the supply of nutrients to surface waters. The ArcticNet program included sea ice work, box coring, net casts, and a mooring deployment in Queen Maud Gulf

Sampling operations consisted of:

- seawater sampling with ArcticNet's 24 x 12 L rosette – CTD (Niskin-type bottles)
- seawater sampling under trace metal clean conditions with GEOTRACES' 12 x 12 L rosette – CTD (Go-Flo bottles)
- particle sampling with 6 McLane large volume in-situ pumps
- Box coring
- zooplankton and fish sampling with a Net Vertical Sampler (NVS), a Double Square Net (DSN), a Isaac-Kidd Midwater Trawl (IKMT), a Hydrobios, and a Benthic Beam Trawl
- aerosol sampling with a volumetric flow controlled high volume sampler

Additional planned activities included:

- seafloor mapping with a multibeam sonar and a CHIRP sub-bottom profiler
- mooring deployment in Queen Maud Gulf
- Moving Vessel Profiler and CTD mesoscale and mixing survey in Wellington, Maury, and Perry Channels

The CCGS *Amundsen* sailed from Sachs Harbour on September 4th to reach our first station (CB1) in McClure Strait (Fig. 1.1) where we conducted GEOTRACES (hydrocasts and pump casts) and ArcticNet (net casts, box cores) operations (Table 1.1) before crossing Canada Basin to reach station CB4. The latter station was the location chosen for a cross-over station for intercalibration with the US Arctic GEOTRACES program. The US cruise occupied the same station one week after our own occupation. However, because of bad weather, they could not deploy their trace metal clean system and could only measure hydrography and sample the non-contamination prone key trace elements and isotopes (e.g. Nd, Th, Pa). For contamination-prone elements, our US partners have taken replicate samples at 4 depths at a nearby station (73.5N, 158.6W) that will be exchanged between relevant PIs from each cruise. In addition, they bracketed the 75°N crossover station with stations to the North and South with full water column profiles of the key TEIs that will facilitate intercalibration for the Canadian 75°N data set and the US data sets via the Carina GO-SHIP interpolation routine recently published (Lauvset and Tanhua; Limnology and Oceanography: Methods, in press).

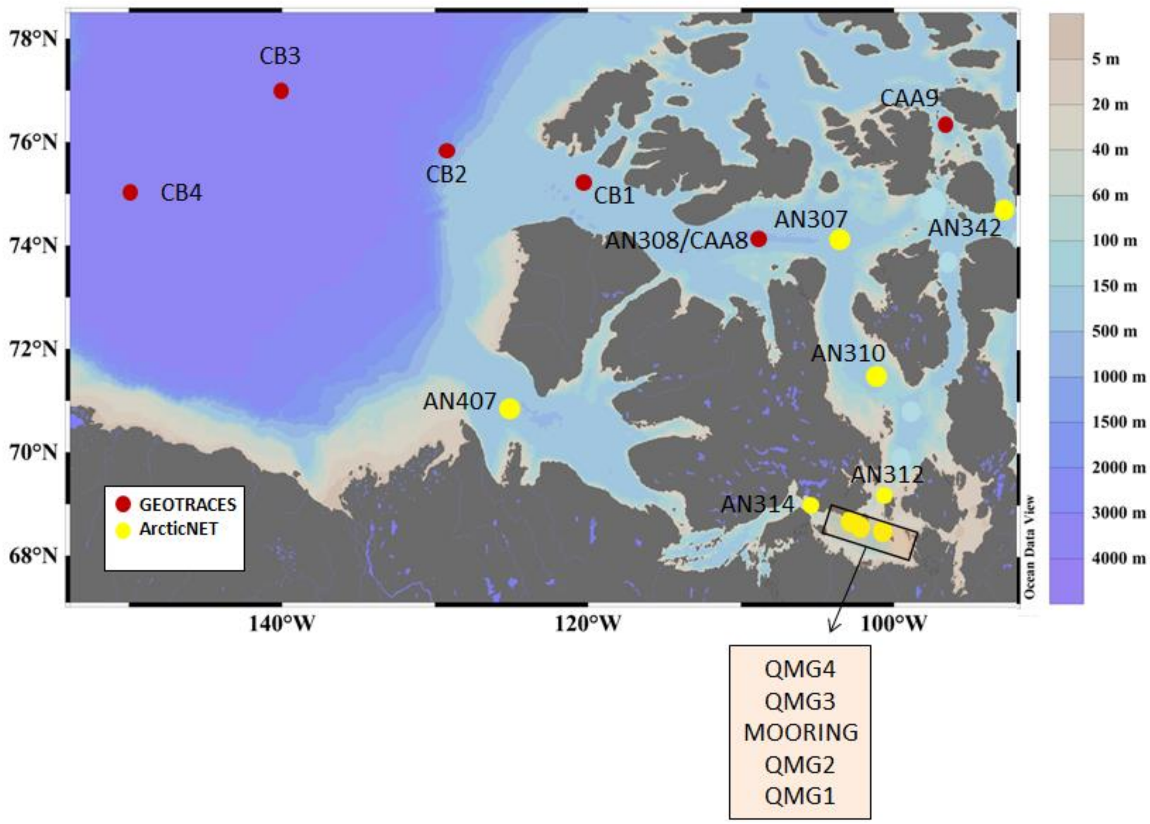

Fig. 1.1: Station locations during leg 3b. Red circles show the location of the shared GEOTRACES-ArcticNet stations. Yellow circles are stations for ArcticNet operations.

After completion of the work in Canada Basin (which also included sea ice work at CB2), we sailed to Amundsen and Queen Maude Gulf to conduct benthic work, net casts and to deploy a mooring. We then proceeded to McClintock and Perry channel to occupy time-series ArcticNet stations and one GEOTRACES station that was missed during leg 2 (CAA8). The leg ended with a MVP survey around Cornwallis Island.

At the end of leg 3b, we had occupied 15 stations and completed 141 operations (Table 1.1):

- 32 hydrocasts with ArcticNet's CTD-rosette
- 21 hydrocasts with GEOTRACES' trace metal clean CTD- rosette
- 13 casts with GEOTRACES' six large volume pumps
- 54 deployments with ArcticNet's nets
- 21 box cores (ArcticNet)

In addition, twenty-four hours of ship time were devoted to sea ice work and the deployments of three on ice met towers and 10 ice tracking beacons to study the dynamics and thermodynamics of the ocean-sea ice-atmosphere coupling, and 96 hours for the deployment of the Moving Vessel Profiler in Wellington, Maury and Penny Strait. Finally, seabed mapping and sub-bottom stratigraphy were conducted during transit between stations, using a multibeam sonar and a CHIRP sub-bottom profiler.

Table 1.1 Daily event log book – Leg 3b

DATE	TIME (CMT)	TIME (UTC)	Time Code	STATION	CAST TYPE	EVENT No.	Lat Deg	Lat Min		Lon Deg	Lon Min		BOTTOM DEPTH
5-Sep-15	13:32	18:32	IN	Test	TMROS	400	73˚	51'643	N	129˚	44'595	W	1226
6-Sep-15	16:18	21:18	IN	CB1	ANROS-RADS	401	75˚	07'35	N	120˚	38'466	W	463
6-Sep-15	16:48	21:48	OUT				75˚	07'365	N	120˚	38'231	W	465
7-Sep-15	17:00	22:00	IN	CB1	TMROS 1	402	75˚	06'812	N	120˚	38'503	W	465
7-Sep-15	-	-	OUT				-	-	N	-	-	W	-
6-Sep-15	18:42	23:42	IN	CB1	LVP 1	403	75˚	07'08	N	120˚	36'89	W	466
6-Sep-15	22:05	07/09/2015 3:05	OUT				75˚	06'73	N	120˚	35'59	W	457
6-Sep-15	22:30	07/09/2015 3:30	IN	CB1	ANROS 1	404	75˚	06'404	N	120˚	31'103	W	430
6-Sep-15	23:38	07/09/2015 4:38	OUT				75˚	06'353	N	120˚	31'162	W	430
6-Sep-15	23:52	08/09/2015 4:52	IN	CB1	TUCKER	405	75˚	06'03	N	120˚	31'163	W	429
7-Sep-15	0:13	5:13	OUT				75˚	05'941	N	120˚		W	419
7-Sep-15	10:10	08/09/2015 3:10	IN	CB1	TMROS 2	406	75˚	07'042	N	120˚	37'998	W	460
7-Sep-15	-	-	OUT				-	-	N	-	-	W	-
7-Sep-15	1:20	6:20	IN	CB1	ANROS 2	407	75˚	06'113	N	120˚	33'80	W	437
7-Sep-15	1:58	6:58	OUT				75˚	06'114	N	120˚	33'584	W	435
7-Sep-15	3:14	8:14	IN	CB1	LVP 2	408	75˚	05'592	N	120˚	33'455	W	431
7-Sep-15	6:05	11:05	OUT				75˚	05'65	N	120˚	33'3	W	431
7-Sep-15	6:42	11:42	IN	CB1	MONSTER	409	75˚	05'6	N	120˚	33'16	W	431
7-Sep-15	7:13	12:13	OUT				75˚	05'57	N	120˚	33'28	W	431
7-Sep-15	8:35	13:35	IN	CB1	HYDROBIOS	410	75˚	05'46	N	120˚	33'09	W	430
7-Sep-15	9:01	14:01	OUT				75˚	05'4	N	120˚	33'10	W	430
7-Sep-15	11:22	16:22	IN	CB1/4 MILES EAST	BOX CORE	411	75˚	06'75	N	120˚	21'4	W	407
7-Sep-15	11:42	16:42	OUT				75˚	06'73	N	120˚	21'26	W	409
7-Sep-15	12:42	17:42	IN	CB1/4 MILES EAST	BOX CORE	412	75˚	06'84	N	120˚	22'055	W	409
7-Sep-15	13:01	18:01	OUT				75˚	06'818	N	120˚	22'013	W	408
7-Sep-15	13:12	18:12	IN	CB1/4 MILES EAST	AGASSIZ	413	75˚	06'81	N	120˚	21'446	W	408
7-Sep-15	13:53	18:53	OUT				75˚	07'693	N	120˚	20'91	W	408
7-Sep-15	14:19	19:19	IN	CB1/4 MILES EAST	BEAM TRAWL	414	75˚	07'151	N	120˚	19'627	W	408
7-Sep-15	15:20	20:20	OUT				75˚	07'406	N	120˚	13'796	W	404
8-Sep-15	18:02	23:02	IN	CB2	ANROS-RADS	415	75˚	49.24	N	129˚	13.08	W	1373
8-Sep-15	18:40	23:40	OUT				75˚	49.28	N	129˚	13.41	W	1371
8-Sep-15	20:27	09/09/2015 1:27	IN	CB2	TMROS 1	416	75˚	48.88	N	129˚	13.16	W	1365
8-Sep-15	20:56	09/09/2015 1:56	OUT				75˚	48.81	N	129˚	12.92	W	1361
8-Sep-15	21:27	09/09/2015 2:27	IN	CB2	LVP1	417	75˚	49.11	N	129˚	14.34	W	1382
9-Sep-15	0:56	6:56	OUT				75˚	48.426	N	129˚	13.522	W	1356
9-Sep-15	1:24	6:24	IN	CB2	ANROS 1	418	75˚	48.466	N	129˚	14.073	W	1356
9-Sep-15	2:56	7:56	OUT				75˚	48.088	N	129˚	14.035	W	1343
9-Sep-15	3:15	8:15	IN	CB2	TMROS2	419	75˚	47.913	N	129˚	14.821	W	1346
9-Sep-15	4:13	9:13	OUT				75˚	47.92	N	129˚	14.84	W	1346
9-Sep-15	4:45	9:45	IN	CB2	ANROS 2	420	75˚	48.5	N	129˚	11.8	W	1344
9-Sep-15	5:53	10:53	OUT				75˚	48.35	N	129˚	11.52	W	1335
9-Sep-15	6:28	11:28	IN	CB2	LVP2	421	75˚	49.95	N	129˚	13.23	W	1383
9-Sep-15	10:44	15:44	OUT				75˚	49.21	N	129˚	14.3	W	1382
9-Sep-15	SEA ICE WORK			CB2									
9-Sep-15	23:12	10/09/2015 4:12	IN	CB2	TUCKER	422	75˚	53.64	N	129˚	28.63	W	1606
9-Sep-15	23:37	10/09/2015 4:37	OUT				75˚	53.46	N	129˚	25.09	W	1571
10-Sep-15	0:13	5:13	IN	CB2	MONSTER	423	75˚	53.264	N	129˚	25.13	W	1565
10-Sep-15	1:19	6:19	OUT				75˚	53.052	N	129˚	25.802	W	1563
10-Sep-15	2:40	7:40	IN	CB2	ANROS 3	424	75˚	47.108	N	129˚	17.443	W	1356
10-Sep-15	3:40	8:40	OUT				75˚	46.908	N	129˚	16.819	W	1344
10-Sep-15	4:08	9:08	IN	CB2	HYDROBIOS	425	75˚	46.84	N	129˚	16.71	W	1342
10-Sep-15	5:23	10:23	OUT				75˚	46.66	N	129˚	16.92	W	1346
10-Sep-15	5:45	10:45	IN	CB2	BOX CORE	426	75˚	47.03	N	129˚	17.08	W	1350
10-Sep-15	6:12	11:12					75˚	47.13	N	129˚	17.45	W	1355
10-Sep-15	6:36	11:36	OUT			~~427~~	75˚	47.17	N	129˚	17.58	W	1357
10-Sep-15	6:56	11:56	IN				75˚	47.14	N	129˚	17.5	W	1357
10-Sep-15	7:21	12:21		CB2	BOX CORE	428	75˚	47.12	N	129˚	17.54	W	1356
10-Sep-15	7:43	12:43	OUT				75˚	47.12	N	129˚	17.68	W	1359

10-Sep-15	?	?	IN	CB2	NET	429	?	?		?	?		?
10-Sep-15	?	?	OUT				?	?		?	?		
10-Sep-15	SEA ICE WORK												
11-Sep-15	14:50	19:50	IN	CB3	ANROS-RADS	430	76˚	58.826	N	140˚	2.739	W	3728
11-Sep-15	15:53	20:53	OUT				76˚	58.79	N	140˚	2.288	W	3720
11-Sep-15	17:00	22:00	IN	CB3	TMROS-shal	431	76˚	58.828	N	140˚	2.279	W	3731
11-Sep-15	17:19	22:19	OUT				76˚	58.836	N	140˚	2.059	W	3731
11-Sep-15	17:34	22:34	IN	CB3	LVP	432	76˚	58.83	N	140˚	1.83	W	3731
11-Sep-15	21:37	12/09/2015 2:37	OUT				76˚	58.53	N	140˚	2.87	W	3729
11-Sep-15	21:57	12/09/2015 2:57	IN	CB3	ANROS 2	433	76˚	59.53	N	140˚	3.87	W	3735
11-Sep-15	23:15	12/09/2015 4:15	OUT				76˚	60.53	N	140˚	4.87	W	3736
12-Sep-15	0:21	5:21	IN	CB3	TMROSmeso	434	76˚	59.477	N	140˚	1.901	W	3729
12-Sep-15	1:25	6:25	OUT				76˚	49.41	N	140˚	2.187	W	3729
12-Sep-15	1:43	6:43	IN	CB3	MONSTER	435	76˚	59.405	N	140˚	2.189	W	3729
12-Sep-15	2:49	7:49	OUT				76˚	59.316	N	140˚	2.228	W	3729
12-Sep-15			IN	CB3	ANROS 1	436							
12-Sep-15			OUT										
12-Sep-15	4:48	9:48	IN	CB3	TUCKER	437	76˚	59.85	N	139˚	53.97	W	3965
12-Sep-15	5:07	10:07	OUT				76˚	59.57	N	139˚	52.13	W	3729
12-Sep-15	6:09	11.09	IN	CB3	LVP	439	76˚	59.48	N	139˚	52.13	W	3729
12-Sep-15	11:15	16:15	OUT				76˚	58.31	N	139˚	52.07	W	3729
12-Sep-15	SEA ICE WORK												
12-Sep-15	13:11	18:11	IN	CB3	TMROS 1	438	76˚	59.986	N	140˚	5.719	W	3731
12-Sep-15	15:10	20:10	OUT				76˚	59.942	N	140˚	5.71	W	?
12-Sep-15	ZODIAK					440	76˚	59.44	N	140˚	5.3	W	3732
12-Sep-15	18:12	23:12	IN	CB3	TMROS 2	441	77˚	1.15	N	140˚	2.71	W	3732
12-Sep-15	20:22	13/09/2015 1:22	OUT				77˚	0.86	N	140˚	2.58	W	3734
12-Sep-15	20:43	13/09/2015 1:43	IN	CB3	LVP	442	77˚	0.78	N	140˚	3.58	W	3734
13-Sep-15	1:08	6:08	OUT				76˚	59.613	N	140˚	4.911	W	3733
13-Sep-15	1:26	6:26	IN	CB3	HYDROBIOS	443	77˚	0.003	N	140˚	7.474	W	3733
13-Sep-15	3:25	8:25	OUT				76˚	59.841	N	140˚	9.451	W	3734
13-Sep-15	4:33	9:33	IN	CB3	TMROSdeep	444	76˚	59.6	N	140˚	4.26	W	3658
13-Sep-15	6:43	11:43	OUT				76˚	59.24	N	140˚	5.75	W	3731
13-Sep-15	8:05	13:05	IN	CB3	ANROS 1	436	76˚	59.42	N	140˚	2.61	W	3730
13-Sep-15	9:34	14:34	OUT				76˚	59.22	N	140˚	2.95	W	3730
14-Sep-15	15:12	20:12	IN	CB4	ANROS-RADS	445	74˚	59.977	N	149˚	59.493	W	3828
14-Sep-15	16:16	21:16	OUT				74˚	59.91	N	150˚	0.38	W	3830
14-Sep-15	16:47	21:47	IN	CB4	TMROSshal	446	74˚	59.81	N	150˚	0.08	W	3826
14-Sep-15	17:12	22:12	OUT				74˚	59.714	N	150˚	1.196	W	3820
14-Sep-15	18:07	23:07	IN	CB4	MONSTER	453	74˚	59.62	N	150˚	1.83	W	3829
14-Sep-15	19:18	15/09/2015 0:18	OUT				74˚	59.54	N	150˚	2.96	W	3831
14-Sep-15	19:47	15/09/2015 0:47	IN	CB4	ANROS 2	452	75˚	0.13	N	150˚	0.02	W	3831
14-Sep-15	20:53	15/09/2015 1:53	OUT				75˚	0	N	150˚	0.36	W	3829
14-Sep-15	21:10	15/09/2015 2:10	IN	CB4	TUCKER	449	74˚	59.92	N	150˚	1.04	W	3830
14-Sep-15	21:33	15/09/2015 2:33	OUT				74˚	59.05	N	150˚	0.39	W	3826
14-Sep-15	22:10	15/09/2015 3:10	IN	CB4	TMROSmeso	448	75˚	0.064	N	150˚	0.217	W	3828
14-Sep-15	23:17	15/09/2015 4:17	OUT				74˚	59.984	N	149˚	59.999	W	3828
15-Sep-15	0:33	5:33	IN	CB4	LVP 1	447							
15-Sep-15			OUT										
15-Sep-15	4:45	9:45	IN	CB4	ANROS 1	454	74˚	59.99	N	149˚	59.43	W	3830
15-Sep-15	6:20	11:20	OUT				75˚	0.09	N	150˚	0.03	W	3828
15-Sep-15	7:34	12:34	IN	CB4	TMROSdeep	451	75˚	0.11	N	150˚	0.01	W	3829
15-Sep-15	9:51	14:51	OUT				74˚	59.94	N	149˚	59.63	W	3829
15-Sep-15	10:28	15:28	IN	CB4	LVP 2	450	75	0.06	N	150˚	0.19	W	3828
15-Sep-15	15:51	20:51	OUT				74˚	59.83	N	150˚	1.506	W	3829
15-Sep-15	17:04	22:04	IN	CB4	HYDROBIOS	458	75˚	0.23	N	149˚	59.873	W	3830
15-Sep-15	19:00	16/09/2015 0:00	OUT				74˚	59.88	N	149˚	59.04	W	3828
15-Sep-15	19:21	16/09/2015 0:21	IN	CB4	ANRa-shal	460	74˚	59.98	N	149˚	59.45	W	3830
15-Sep-15	19:36	16/09/2015 0:36	OUT				74˚	59.94	N	149˚	59.48	W	3824
15-Sep-15	19:55	16/09/2015 0:55	IN	CB4	LVP 3	456	74˚	59.94	N	149˚	59.39	W	3829
16-Sep-15	0:05	5:05	OUT				74˚	59.7	N	149˚	59.4	W	3829

16-Sep-15	1:08	6:08	IN	CB4	ANRa-deep	462	74˚	59.215	N	150˚	0.091	W	3824
16-Sep-15	1:32	6:32	OUT				74˚	59.867	N	149˚	59.727	W	3827
16-Sep-15	2:14	7:14	IN	CB4	LVP 4	463	75˚	0.621	N	150˚	2.08	W	3828
16-Sep-15	6:34	11:34	OUT				75˚	0.03	N	150˚	0.81	W	3830
16-Sep-15	7:34	12:34	IN	CB4	TMROS 1	455	75˚	1.03	N	150˚	0.81	W	3830
16-Sep-15	9:37	13:37	OUT				75˚	2.03	N	150˚	0.81	W	3830
16-Sep-15	12:12	17:12	IN	CB4	TMROS 2	457	75˚	0.33	N	150˚	0.98	W	3827
16-Sep-15	14:12	19:12	OUT				75˚	0.095	N	149˚	59.521	W	3827
16-Sep-15	17:06	22:06	IN	CB4.1	TM-Cs	461	74˚	42.253	N	148˚	46.525	W	3811
16-Sep-15	19:14	17/09/2015 0:14	OUT				74˚	42.21	N	148˚	45.62	W	3811
16-Sep-15	20:17	17/09/2015 1:17	IN	CB4.2	TM-intercal	459	74˚	35.578	N	148˚	12.713	W	3799
16-Sep-15	21:05	17/09/2015 2:05	OUT				74˚	35.57	N	148˚	12.483	W	3800
18-Sep-15	8:22	13:22	IN	AN407	ANROS	464	71˚	0.33	N	126˚	4.56	W	390
18-Sep-15	9:04	14:04	OUT				71˚	0.53	N	126˚	5.08	W	390
18-Sep-15	9:48	14:48	IN	AN407	BOX CORE	465	70˚	59.6	N	126˚	3.28	W	398
18-Sep-15	10:09	15:09	OUT				70˚	59.64	N	126˚	3.56	W	395
18-Sep-15	10:20	15:20	IN	AN407	BOX CORE	466	70˚	59.66	N	126˚	3.74	W	397
18-Sep-15	10:40	15:40	OUT				70˚	59.7	N	126˚	3.86	W	394
20-Sep-15	11:09	16:09	IN	AN314	ANROS	-	68˚	58.2	N	105˚	28.89	W	77
20-Sep-15	11:30	16:30	OUT				68˚	58.1	N	105˚	28.9	W	76
20-Sep-15	12:12	17:12	IN	AN314	MONSTER	-	68˚	58.198	N	105˚	28.233	W	77
20-Sep-15	12:17	17:17	OUT				68˚	58.17	N	105˚	28.399	W	77
20-Sep-15	12:43	17:43	IN	AN314	TUCKER	-	68˚	58.262	N	105˚	28.256	W	81
20-Sep-15	13:02	18:02	OUT				68˚	58.233	N	105˚	28.834	W	77
20-Sep-15	13:22	18:22	IN	AN314	BOX CORE	-	68˚	58.256	N	105˚	28.251	W	81
20-Sep-15	13:41	18:29	OUT				68˚	58.291	N	105˚	28.415	W	78
20-Sep-15	13:50	18:50	IN	AN314	BOX CORE	-	68˚	58.193	N	105˚	28.505	W	80
20-Sep-15	14:04	19:04	OUT				68˚	58.181	N	105˚	28.643	W	73
20-Sep-15	14:11	19:11	IN	AN314	BOX CORE	-	68˚	58.208	N	105˚	28.348	W	81
20-Sep-15	14:20	19:20	OUT				68˚	58.186	N	105˚	28.474	W	77
20-Sep-15	14:28	19:28	IN	AN314	AGASSIZ	-	68˚	58.164	N	105˚	28.634	W	75
20-Sep-15	14:50	19:50	OUT				68˚	58.366	N	105˚	28.886	W	74
20-Sep-15	15:04	20:04	IN	AN314	BEAM TRAWL	-	68˚	58.38	N	105˚	29.18	W	75
20-Sep-15	15:42	20:42	OUT				68˚	58.236	N	105˚	29.498	W	81
20-Sep-15	20:19	21/09/2015 1:19	IN	QMG4	ANROS	-	68˚	29.0	N	103˚	25.48	W	71
20-Sep-15	20:38	21/09/2015 1:38	OUT				68˚	28.93	N	103˚	25.52	W	69
20-Sep-15	20:52	21/09/2015 1:52	IN	QMG4	MONSTER	-	68˚	28.95	N	103˚	25.56	W	69
20-Sep-15	20:58	21/09/2015 1:58	OUT				68˚	28.98	N	103˚	25.63	W	69
20-Sep-15	21:21	21/09/2015 2:21	IN	QMG4	TUCKER	-	68˚	29.09	N	103˚	25.75	W	71
20-Sep-15	21:45	21/09/2015 2:45	OUT				68˚	28.06	N	103˚	25.61	W	66
20-Sep-15	22:14	21/09/2015 3:14	IN	QMG4	BOX CORE	-	68˚	29.06	N	103˚	25.71	W	67
20-Sep-15	22:20	21/09/2015 3:20	OUT				68˚	30.06	N	103˚	25.76	W	69
20-Sep-15	22:31	21/09/2015 3:31	IN	QMG4	AGASSIZ	-	68˚	29.08	N	103˚	25.67	W	68
20-Sep-15	22:48	21/09/2015 3:48	OUT				68˚	28066	N	103˚	26.39	W	76
20-Sep-15	23:17	21/09/2015 4:17	IN	QMG4	BEAM TRAWL	-	68˚	29.68	N	103˚	23.67	W	77
20-Sep-15	23:58	21/09/2015 4:58	OUT				68˚	28.032	N	103˚	24.536	W	61
21-Sep-15	2:05	7:05	IN	QMG3	ANROS	-	68˚	19.77	N	102˚	36.398	W	64
21-Sep-15	2:26	7:26	OUT				68˚	19.675	N	102˚	36.402	W	60
21-Sep-15	2:39	7:39	IN	QMG3	TUCKER	-	68˚	19.67	N	102˚	36.53	W	61
21-Sep-15	2:56	7:56	OUT				68˚	19.447	N	102˚	34.786	W	73
21-Sep-15	3:17	8:17	IN	QMG3	MONSTER	-	68˚	39.674	N	102˚	36.677	W	62
21-Sep-15	3:25	8:25	OUT				68˚	19.707	N	102˚	36.962	W	62
21-Sep-15	3:50	8:50	IN	QMG3	BOX CORE	-	68˚	19.801	N	102˚	36.545	W	67
21-Sep-15	3:54	8:54	OUT				68˚	19.81	N	102˚	36.4	W	67
21-Sep-15	4:04	9:04	IN	QMG3	AGASSIZ	-	68˚	19.75	N	102˚	36.47	W	63
21-Sep-15	4:17	9:17	OUT				68˚	19.46	N	102˚	36.47	W	62
21-Sep-15	4:39	9:39	IN	QMG3	BEAM TRAWL	-	68˚	19.73	N	102˚	36.35	W	63
21-Sep-15	7:17	12:17	OUT				68˚	19.02	N	102˚	36.41	W	64
21-Sep-15	9:06	14:06	IN	MOORING	MOORING	-	68˚	14.49	N	101˚	48.34	W	97
21-Sep-15	9:15	14:15	OUT				68˚	14.46	N	101˚	48.35	W	97
21-Sep-15	9:47	14:47	IN	MOORING	CTD	-	68˚	14.54	N	101˚	47.55	W	107

21-Sep-15	9:55	14:55	OUT				68˚	14.54	N	101˚	47.71	W	103
21-Sep-15	10:29	15:29	IN	MOORING	TUCKER	-	68˚	14.62	N	101˚	43.15	W	103
21-Sep-15	10:45	15:45	OUT				68˚	14.21	N	101˚	44.38	W	101
21-Sep-15	11:10	16:10	IN	MOORING	MONSTER	-	68˚	14.18	N	101˚	44.82	W	107
21-Sep-15	11:19	16:19	OUT				68˚	14.23	N	101˚	45.01	W	108
21-Sep-15	12:47	17:47	IN	MOORING	IKMT	-	68˚	13.759	N	101˚	45.722	W	107
21-Sep-15	13:15	18:15	OUT				68˚	13.459	N	101˚	44.53	W	97
21-Sep-15	13:39	18:39	IN	MOORING	ANROS	-	68˚	14.803	N	101˚	43.057	W	107
21-Sep-15	14:05	19:05	OUT				68˚	14.701	N	101˚	43.103	W	104
21-Sep-15	14:19	19:19	IN	MOORING	BOX CORE	-	68˚	14.654	N	101˚	43.039	W	100
21-Sep-15	14:24	19:24	OUT				68˚	14.633	N	101˚	43.043	W	100
21-Sep-15	14:36	19:36	IN	MOORING	AGASSIZ	-	68˚	14.583	N	101˚	43.347	W	105
21-Sep-15	14:54	19:54	OUT				68˚	14.176	N	101˚	42.732	W	98
21-Sep-15	15:08	20:08	IN	MOORING	BEAM TRAWL	-	68˚	14.673	N	101˚	43.785	W	106
21-Sep-15	15:51	20:51	OUT				68˚	14.069	N	101˚	42.668	W	115
21-Sep-15	17:44	22:44	IN	QMG2	TUCKER	-	68˚	18.82	N	100˚	48.01	W	53
21-Sep-15	18:03	23:03	OUT				68˚	18.55	N	100˚	48.11	W	54
21-Sep-15	18:26	23:26	IN	QMG2	MONSTER	-	68˚	18.81	N	100˚	47.88	W	55
21-Sep-15	18:31	23:31	OUT				68˚	18.82	N	100˚	47.86	W	55
21-Sep-15	18:54	23:54	IN	QMG2	ANROS	-	68˚	18.81	N	100˚	47.99	W	54
21-Sep-15	19:09	22/09/2015 0:09	OUT				68˚	18.74	N	100˚	47.97	W	59
21-Sep-15	19:23	22/09/2015 0:23	IN	QMG2	BOX CORE	-	68˚	18.72	N	100˚	47.89	W	59
21-Sep-15	19:28	22/09/2015 0:28	OUT				68˚	18.73	N	100˚	47.92	W	59
21-Sep-15	19:39	22/09/2015 0:39	IN	QMG2	AGASSIZ	-	68˚	18.77	N	100˚	47.88	W	59
21-Sep-15	19:53	22/09/2015 0:53	OUT				68˚	18.56	N	100˚	47.9	W	74
21-Sep-15	20:14	22/09/2015 1:14	IN	QMG2	BEAM TRAWL	-	68˚	18.76	N	100˚	48.2	W	63
21-Sep-15	20:58	22/09/2015 1:58	OUT				68˚	17.08	N	100˚	46.77	W	?
21-Sep-15	23:02	22/09/2015 4:02	IN	QMG1	ANROS	-	68˚	29.63	N	99˚	53.44	W	35
21-Sep-15	23:17	22/09/2015 4:17	OUT				68˚	29.57	N	99˚	53.44	W	36
21-Sep-15	23:31	22/09/2015 4:31	IN	QMG1	MONSTER	-	68˚	29.52	N	99˚	53.54	W	39
21-Sep-15	23:35	22/09/2015 4:35	OUT				68˚	29.52	N	99˚	53.62	W	42
22-Sep-15	0:12	5:12	IN	QMG1	BOX CORE	-	68˚	29.469	N	99˚	54.091	W	48
22-Sep-15	0:19	5:19	OUT				68˚	29.497	N	99˚	54.276	W	45
22-Sep-15	9:01	14:01	IN	AN312	ANROS	-	69˚	10.33	N	100˚	4106	W	65
22-Sep-15	9:25	14:25	OUT				69˚	10.32	N	100˚	41.43	W	66
22-Sep-15	9:34	14:34	IN	AN312	TUCKER	-	69˚	10.27	N	100˚	41.25	W	65
22-Sep-15	9:51	14:51	OUT				69˚	9.92	N	100˚	39.5	W	58
22-Sep-15	10:11	15:11	IN	AN312	MONSTER	-	69˚	10.11	N	100˚	42.11	W	65
22-Sep-15	10:20	15:20	OUT				69˚	10.1	N	100˚	42.07	W	65
22-Sep-15	10:46	15:46	IN	AN312	BOX CORE	-	69˚	10.22	N	100˚	41.7	W	64
22-Sep-15	10:53	15:53	OUT				69˚	10.23	N	100˚	41.56	W	64
22-Sep-15	11:07	16:07	IN	AN312	AGASSIZ	-	69˚	10.11	N	100˚	42.25	W	64
22-Sep-15	11:17	16:17	OUT				69˚	9.94	N	100˚	41.78	W	60
22-Sep-15	11:32	16:32	IN	AN312	BEAM TRAWL	-	69˚	10.18	N	100˚	41.45	W	64
22-Sep-15	12:07	17:07	OUT				69˚	10.025	N	100˚	37.438	W	47
22-Sep-15	12:08	17:08		AN312	SONAR	-	69˚	10.026	N	100˚	37.437	W	47
23-Sep-15	1:41	6:41	IN	AN310	ANROS	-	71˚	27.411	N	101˚	16.734	W	163
23-Sep-15	2:15	7:15	OUT				71˚	27.142	N	101˚	16.756	W	163
23-Sep-15	2:31	7:31	IN	AN310	TUCKER	-	71˚	27.02	N	101˚	16.862	W	161
23-Sep-15	2:47	7:47	OUT				71˚	26.959	N	101˚	15.487	W	163
23-Sep-15	3:11	8:11	IN	AN310	MONSTER	-	71˚	27.242	N	101˚	17.404	W	162
23-Sep-15	3:24	8:24	OUT				71˚	27.264	N	101˚	17.368	W	161
23-Sep-15	4:00	9:00	IN	AN310	BOX CORE	-	71˚	26.98	N	101˚	17.54	W	158
23-Sep-15	4:05	9:05	OUT				71˚	26.95	N	101˚	17.58	W	157
23-Sep-15	4:35	9:35	IN	AN310	AGASSIZ	-	71˚	27.53	N	101˚	16.2	W	166
23-Sep-15	5:00	10:00	OUT		CANCELLED		71˚	26.75	N	101˚	17.64	W	158
23-Sep-15	21:36	24/09/2015 2:36	IN	AN308/CAA8	ANROS	465	74˚	8.32	N	108˚	50.08	W	565
23-Sep-15	22:08	24/09/2015 3:08	OUT				74˚	8.34	N	108˚	49.61	W	562
23-Sep-15	22:28	24/09/2015 3:28	IN	AN308/CAA8	TMROS shallow	466	74˚	8.31	N	108˚	50.39	W	564
23-Sep-15	22:48	24/09/2015 3:48	OUT				74˚	8.33	N	108˚	50.27	W	569
23-Sep-15	23:06	24/09/2015 4:06	IN	AN308/CAA8	LVP	467	74˚	8.31	N	108˚	50.25	W	569

24-Sep-15	3:05	8:05	OUT				74˚	8.321	N	108˚	50.223	W	569
24-Sep-15	3:25	8:25	IN	AN308/CAA8	ANROS	468	74˚	8.348	N	108˚	50.275	W	563
24-Sep-15	4:21	9:21	OUT				74˚	8.37	N	108˚	50.25	W	563
24-Sep-15	4:32	9:32	IN	AN308/CAA8	TMROS deep	469	74˚	8.34	N	108˚	50.19	W	563
24-Sep-15	5:06	10:06	OUT				74˚	8.38	N	108˚	50.13	W	563
24-Sep-15	5:50	10:50	IN	AN308/CAA8	LVP	470	74˚	8.36	N	108˚	50.12	W	564
24-Sep-15	9:53	14:53	OUT				74˚	8.33	N	108˚	50.12	W	564
24-Sep-15	10:05	15:05	IN	AN308/CAA8	ANROS	471	74˚	8.32	N	108˚	50.14	W	563
24-Sep-15	10:54	15:54	OUT				74˚	8.31	N	108˚	50.18	W	567
24-Sep-15	11:00	16:00	IN	AN308/CAA8	TUCKER	472	74˚	8.52	N	108˚	50.03	W	565
24-Sep-15	11:11	16:11	OUT				74˚	8.66	N	108˚	51.03	W	563
24-Sep-15	12:13	17:13	IN	AN308/CAA8	MONSTER	473	74˚	9.66	N	108˚	52.03	W	566
24-Sep-15	12:51	17:51	OUT				74˚	10.66	N	108˚	53.03	W	570
24-Sep-15	13:12	18:12	IN	AN308/CAA8	HYDROBIOS	474	74˚	8.329	N	108˚	50.069	W	565
24-Sep-15	13:44	18:44	OUT				74˚	8.333	N	108˚	50.031	W	564
24-Sep-15	14:15	19:15	IN	AN308/CAA8	BOX CORE	475	74˚	8.356	N	108˚	50.193	W	563
24-Sep-15	15:30	19:52	OUT				74˚	8.352	N	108˚	50.429	W	564
24-Sep-15	15:52	20:52	IN	AN308/CAA8	AGASSIZ	478	74˚	8.242	N	108˚	49.705	W	563
24-Sep-15	16:42	21:42	OUT				74˚	8.89	N	108˚	52.48	W	561
24-Sep-15	17:07	22:07	IN	AN308/CAA8	BEAM TRAWL	479	74˚	8.4	N	108˚	50.049	W	564
24-Sep-15	18:24	23:24	OUT				74˚	8.25	N	108˚	59.02	W	562
25-Sep-15	2:52	7:52	IN	AN307	ANROS	-	74˚	6.675	N	103˚	7.454	W	357
25-Sep-15	3:44	8:44	OUT				74˚	2.019	N	103˚	7.666	W	352
25-Sep-15	4:09	9:09	IN	AN307	MONSTER	-	74˚	6.71	N	103˚	6.69	W	355
25-Sep-15	4:34	9:34	OUT				74˚	6.94	N	103˚	6.17	W	351
25-Sep-15	5:00	10:00	IN	AN307	BOX CORE	-	74˚	6.98	N	103˚	6.0	W	350
25-Sep-15	5:20	10:20	OUT				74˚	7.12	N	103˚	5.45	W	349
25-Sep-15	20:49	26/09/2015 1:49	IN	AN342	ANROS	-	74˚	47.67	N	92˚	46.86	W	137
25-Sep-15	21:21	26/09/2015 2:21	OUT				74˚	47.62	N	92˚	46.95	W	138
25-Sep-15	21:33	26/09/2015 2:33	IN	AN342	TUCKER	-	74˚	47.63	N	92˚	46.86	W	137
25-Sep-15	21:57	26/09/2015 2:57	OUT				74˚	47.58	N	92˚	43.49	W	128
25-Sep-15	22:26	26/09/2015 3:26	IN	AN342	MONSTER	-	74˚	47.66	N	92˚	47.3	W	137
25-Sep-15	22:36	26/09/2015 3:36	OUT				74˚	47.66	N	92˚	47.63	W	140
25-Sep-15	23:04	26/09/2015 4:04	IN	AN342	BOX CORE	-	74˚	47.65	N	92˚	48.63	W	138
25-Sep-15	23:13	26/09/2015 4:13	OUT				74˚	47.63	N	92˚	49.63	W	138
25-Sep-15	23:33	26/09/2015 4:33	IN	AN342	BOX CORE	-	74˚	47.65	N	92˚	50.63	W	138
25-Sep-15	23:43	26/09/2015 4:43	OUT				74˚	47.59	N	92˚	51.63	W	137
26-Sep-15	0:10	5:10	IN	AN342	BEAM TRAWL	-	74˚	46.632	N	92˚	52.63	W	135
26-Sep-15	0:50	5:50	OUT				74˚	43.50	N	92˚	53.63	W	128
26-Sep-15	2:38	7:38	IN		MVP	-	74˚	47.21	N	92˚	11.635	W	78
26-Sep-15	21:00	27/09/2015 2:00	OUT				76˚	14.60	N	96˚	16.2	W	?
26-Sep-15	22:13	27/09/2015 3:13	IN	CAA9	ANROS	480	76˚	19.93	N	96˚	44.69	W	340
26-Sep-15	22:46	27/09/2015 3:13	OUT				76˚	19.60	N	96˚	43.74	W	347
27-Sep-15	0:02	5:02	IN	CAA9	TMROS shallow	481	76˚	20.01	N	96˚	45.206	W	334
27-Sep-15	0:16	5:16	OUT				76˚	19.98	N	96˚	45.376	W	333
27-Sep-15	0:32	5:32	IN	CAA9	ANROS	483	76˚	19.96	N	96˚	45.679	W	331
27-Sep-15	1:16		OUT				76˚	19.97	N	96˚	46.044	W	322
27-Sep-15	**(ET) (CMT+1)**												
27-Sep-15	3:11	8:11	IN	CAA9	MONSTER	482	76˚	19.91	N	96˚	45.161	W	337
27-Sep-15	3:36	8:36	OUT				76˚	20.03	N	96˚	44.856	W	336
27-Sep-15	5:00	10:00	IN	CAA9	TMROSdeep	485	76˚	19.82	N	96˚	45.40	W	336
27-Sep-15	5:23	10:23	OUT				76˚	19.83	N	96˚	45.21	W	336
27-Sep-15	5:36	10:36	IN	CAA9	BOX CORE	486	76˚	19.83	N	96˚	45.24	W	338
27-Sep-15	5:53	10:53	OUT				76˚	19.81	N	96˚	45.38	W	336
27-Sep-15	7:17	12:17	IN	CAA9	CTD	-	76˚	25.46	N	96˚	26.94	W	278
27-Sep-15	7:30	12:30	OUT				76˚	25.42	N	96˚	26.95	W	276
27-Sep-15	9:42	14:42	IN	-	CTD	-	76˚	34.84	N	96˚	42.62	W	216
27-Sep-15	10:06	15:06	OUT				76˚	34.65	N	96˚	42.37	W	217
27-Sep-15	10:54	15:54	IN	PS1	CTD	-	76˚	40.03	N	96˚	51.12	W	230
27-Sep-15	11:07	16:07	OUT				76˚	39.93	N	96˚	50.32	W	208
27-Sep-15	11:39	16:39	IN	PS2	CTD	-	76˚	37.16	N	96˚	51.34	W	188

27-Sep-15	11:49	16:49	OUT				76˚	37.01	N	96˚	50.85	W	188
27-Sep-15	13:31	18:31	IN	PS3	CTD	-	76˚	36.37	N	97˚	1.472	W	153
27-Sep-15	13:41	18:41	OUT				76˚	36.32	N	97˚	1.028	W	149
27-Sep-15	14:27	19:27	IN	PS4	CTD	-	76˚	33.00	N	97˚	5.583	W	141
27-Sep-15	14:36	19:36	OUT				76˚	33.07	N	97˚	5.643	W	141
26-30 Sept					MVP		74°-76.5°		N	92°-97°		W	100-450

2. Parameters measured or sampled in the water column

Stations CB1, 2, 3, 4, and CAA 8, 9:
Sixty-three parameters (Table 2.1) were measured on board or sampled for later analysis for GEOTRACES. ArcticNet sampling consisted of net casts, box coring (CB1, CB2, CAA8, CAA9) and sea ice work (CB2, CAA9)

Table 2.1: List of parameters measured on board or sampled for later analysis for the GEOTRACES program

Hydrography/CTD sensors	**Biological parameters**	**Trace elements and isotopes**
Pressure	Particulate organic carbon	Dissolved and particulate trace metals
Temperature	Particulate organic nitrogen	Al, Mn, Fe, Cd, Zn, Cu, Pb, Ga, Ba, Cr, REE, Hg, MeHg
Salinity	Size fractionated chlorophyll a	Dissolved and particulate radioisotopes
Oxygen	Pigments	^{230}Th, ^{231}Pa, ^{228}Ra, ^{224}Ra, ^{223}Ra
Fluorescence	Particulate biogenic silica	Dissolved and particulate radiogenic isotopes
Light transmission	Genomics	Nd, Pb
Nutrients	Proteomics	Dissolved and particulate stable isotopes
Phosphate	Zooplankton, ichtyoplankton	$\delta^{18}O$ in water
Nitrate/Nitrite	Fish	$\delta^{13}C$ in DIC
Ammonia	**Biogenic trace gases**	$\delta^{15}N$ in nitrate
Silicate	CH4	$\delta^{30}Si$
	Chemical parameters	$\delta^{53}Cr$
	Dissolved inorganic carbon	$\delta^{56}Fe$
	Total alkalinity	Anthropogenic isotopes
	pH	^{129}I, ^{236}U, ^{137}Cs
	Dissolved organic carbon	**Large volume in-situ pumps**
	Fluorescent dissolved organic matter	Paticulate ^{230}Th, ^{231}Pa, ^{234}Th
	Coloured dissolved organic matter	Paticulate Si, Nd and Cr isotopes
	Thiols	
	Organic ligands	

Stations AN407 (ArcticNet)
Hydrocast and box cores

Stations AN314, QMG4, 1 (ArcticNet)
Hydrocast, alkalinity, DIC, pH, net casts and box cores

Mooring station (between QMG3 and QMG2)
Mooring deployment, hydrocast, alkalinity, DIC, pH, net casts and box cores

Stations QMG3, 2 (ArcticNet)
Hydrocast, net casts and box cores

Stations AN312, 310, 307, 342 (ArcticNet)
Hydrocast, alkalinity, DIC, pH, net casts and box cores

3. Participants

The science party consisted of 23 GEOTRACES (from 7 Canadian Universities and 2 partner foreign research institutions) and 17 ArcticNet scientists (Table 4).

The GEOTRACES group consisted of:

- 4 Principal Investigators (Francois, Tortell, Cullen, Thomas)
- 2 Research Technicians
- 4 Postdoctoral Fellows
- 9 PhD students
- 3 MSc students
- 1 BSc student

The ArcticNet group consisted of:

- 7 Professionals
- 3 Research Technicians
- 1 Postdoctoral Fellow
- 5 MSc students
- 1 BSc student

Table 3.1: List of participants

2015 CCGS Amundsen Expedition Leg 3b (04 September to 01 October)			
Name	**Position**	**Affiliation**	**From/To**
François, Roger	Chief Scientist	University of British Columbia	Sachs Harbour - Resolute
Orians, Kristin	Researcher/Professor	University of British Columbia	Sachs Harbour - Resolute
Klymak, Jody	Researcher/Professor	University of Victoria	Resolute - Resolute
Soon, Maureen	Research Staff	University of British Columbia	Sachs Harbour - Resolute
Fox, Rowan	Research Staff	University of Victoria	Sachs Harbour - Resolute
Guignard, Constance	Research Staff	McGill University	Kugluktuk - Resolute
Colombo, Manuel	PhD Student	University of British Columbia	Sachs Harbour - Resolute
Baconnais, Isabelle	PhD Student	University of Saskatchewan	Sachs Harbour - Resolute
Wang, Kang	PhD Student	University of Manitoba	Sachs Harbour - Resolute
Chandan, Priyanka	PhD Student	University of Toronto	Sachs Harbour - Resolute
Mol, Jacoba	PhD Student	Dalhousie University	Kugluktuk - Resolute
Hughes, Ken	PhD Student	University of Victoria	Kugluktuk - Resolute
Blanken, Hauke	PhD Student	University of Victoria	Kugluktuk - Resolute
Nixon, Richard	PhD Student	University of Victoria	Sachs Harbour - Resolute
Jackson, Sarah Louise	PhD Student	University of Victoria	Sachs Harbour - Resolute
Sauve, Daniel	MSc Student	University of Ottawa	Sachs Harbour - Resolute
Elliott, Ashley	MSc Student	University of Manitoba	Sachs Harbour - Resolute
Li, Jingxuan	MSc Student	University of British Columbia	Sachs Harbour - Resolute
Purdon, Kathryn	BSc Student	University of Victoria	Sachs Harbour - Resolute
Candlish, Lauren	Research Staff	University of Manitoba	Kugluktuk - Resolute
Aubry, Cyril	Research Staff	Université Laval	Sachs Harbour - Resolute
Parenteau, Marie	Research Staff	Université Laval	Sachs Harbour - Resolute
de Montety, Laure	Research Staff	Université du Quebec - Rimouski	Kugluktuk - Resolute
Provost, Roger	Professional	Canadian Ice Service	Kugluktuk - Resolute
Morisset, Simon	Professional	Université Laval	Kugluktuk - Resolute
Mireault, Callum	Professional	Université Laval	Kugluktuk - Resolute
Asselin, Olivier	Professional	Université Laval	Kugluktuk - Resolute
Meredyk, Shawn	Professional	Université Laval	Kugluktuk - Resolute
Deslongchamps, Gabrièle	Professional	Université Laval	Kugluktuk - Resolute
Yu, Heidi	Professional	Canadian Hydrographic Services	Kugluktuk - Resolute
DeGrandpré, Charles	Professional	Université Laval	Kugluktuk - Resolute
Geoffroy, Maxime	PhD Student	Université Laval	Kugluktuk - Resolute
Geng, Lantao	PhD Student	Université du Quebec - Rimouski	Kugluktuk - Resolute
Sun, Xiaoxu	PhD Student	Georgia Inst. of Technology	Kugluktuk - Resolute
Bourgeois, Solveig	PhD Student	Université of Aberdeen	Kugluktuk - Resolute
Dezutter, Thibaud	MSc Student	Université Laval	Kugluktuk - Resolute
Theriault, Nathalie	MSc Student	University of Manitoba	Kugluktuk - Resolute
Noël, Amy	MSc Student	University of Calgary	Kugluktuk - Resolute
Sabourin, Clément	Journalist	AFP	Kugluktuk - Resolute

2015 CCGS Amundsen Expedition			
Leg 3b: 4 September to 1 October (Sachs Harbour to Resolute))			
Name	**Position**	**Affiliation**	
François, Roger	Chief Scientist	University of British Columbia	
Orians, Kristin	Researcher/Professor	University of British Columbia	
Klymak, Jody	Researcher/Professor	University of Victoria	Resolute - Resolute
Soon, Maureen	Research Staff	University of British Columbia	
Guignard, Constance	Research Staff	McGill University	
Fox, Rowan	Research Staff	University of Victoria	
Colombo, Manuel	PhD Student	University of British Columbia	
Baconnais, Isabelle	PhD Student	University of Saskatchewan	
Wang, Kang	PhD Student	University of Manitoba	
Chandan, Priyanka	PhD Student	University of Toronto	
Mol, Jacoba	PhD Student	Dalhousie University	
Elliott, Ashley	MSc Student	University of Manitoba	
Hughes, Ken	MSc Student	University of Victoria	Kugluktuk-Resolute
Blanken, Hauke	MSc Student	University of Victoria	Kugluktuk-Resolute
Nixon, Richard	MSc Student	University of Victoria	
Jackson, Sarah Louise	MSc Student	University of Victoria	
Sauve, Daniel	MSc Student	University of Ottawa	
Li, Jingxuan	MSc Student	University of British Columbia	
Purdon, Kathryn	BSc Student	University of Victoria	
Candlish, Lauren	Research Staff	University of Manitoba	
Aubry, Cyril	Research Staff	Université Laval	
Provost, Roger	Professional	Canadian Ice Service	
Morisset, Simon	Professional	ArcticNet	
Mireault, Callum	Professional	ArcticNet	
Asselin, Olivier	Professional	ArcticNet	
Meredyk, Shawn	Professional	ArcticNet	Kugluktuk-Resolute
Deslongchamps, Gabrièle	Professional	Université Laval	
Yu, Heidi	Professional	Université Laval	
de Montety, Laure	Postdoctoral Fellow	Université du Quebec - Rimouski	
Geoffroy, Maxime	PhD Student	Université Laval	Kugluktuk-Resolute
Geng, Lantao	PhD Student	Université du Quebec - Rimouski	
Dezutter, Thibaud	MSc Student	Université Laval	
Noël, Amy	MSc Student	Univeristy of Calgary	
Parenteau, Marie	Student	Université Laval	
DeGrandpré, Charles	Student	Université Laval	
Theriault, Nathalie	Student	University of Manitoba	
Sun, Xiaoxu	Student	Université du Quebec - Rimouski	
Bourgeois, Solveig	Student	Aberdeen University	
Sabourin, Clément	Journalist	AFP	

5. Cruise reports by group

5.1 GEOTRACES

5.1.1 Measuring the spatial distribution of geochemical tracers in the Canadian Basin and Canadian Arctic Archipelago: Trace metal rosette sampling operations CCGS Amundsen 2015 Leg 3b

Principal Investigators: Kristin J. Orians[1], Roger Francois[1], Jay T. Cullen[2], Bridget Bergquist[3], Maite Maldonado[1], Feiyue Wang[4], Celine Guéguen[5] and Andrew Ross[6]
Cruise Participants: Kristin Orians[1], Manuel Colombo[1], Rowan Fox[2], Sarah Jackson[2], Kathryn Purdon[2], Priyanka Chandan[3], Ashley Elliott [4], Kang Wang [4], Jingxuan Li[1], Richard Nixon [6]

[1]*Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia*
[2]*School of Earth and Ocean Sciences, University of Victoria*
[3]*Department of Earth Sciences, University of Toronto*
[4]*Department of Environment and Geography, University of Manitoba*
[5]*Department of Chemistry, Trent University*
[6]*Department of Fisheries and Oceans, IOS, Sidney BC*

Introduction and objectives
The Trace Metal Rosette team was responsible for collecting trace element clean samples to characterize the distributions of dissolved and particulate trace elements, their isotopes, speciation and the ligands that bind them, in the Canadian Basin (Beaufort Sea) and the Canadian Arctic Archipelago from the CCGS Amundsen during Leg 3b. These samples were collected as part of the Arctic GEOTRACES program whose stated scientific objectives were to fill critical gaps in our understanding of fundamental physical and biogeochemical processes in the Canadian Arctic Ocean and their sensitivity to projected climate change and economic development. The geochemical tracer data, in conjunction with field-based process studies and numerical models will be used to address the following specific research questions:

1. How do Arctic waters flow from the Canadian Basin, through the CAA, and into the Atlantic? How are the physical, chemical and biological signatures of these water masses modified, and how might this change over the coming decades? In turn, how can geochemical tracer distribution provide additional constraints on circulation and mixing?
2. How will climate change and economic development alter the cycling of essential and toxic trace elements, and what are the likely impact upon planktonic community structure, marine productivity and contaminant fates?
3. What are the potential effects of climate change on the distribution of marine productivity, biological carbon sequestration, and distributions of climate-active trace gases (e.g. CO2, N2O, CH4 and dimethylsulfide - DMS) across different hydrographic regimes?

4. What is the chemical buffering capacity of Arctic waters against ocean acidification, and how will acidification affect marine productivity and biogeochemical cycles?

The trace metal rosette was used to collect samples for elements that are prone to contamination where collection with standard water sampling rosettes compromise sample integrity. These contamination prone elements include, but are not limited to:

- Dissolved trace metal concentrations: Fe, Al, Mn, Ga, Cu, Zn, Cd, Pb, Hg, Ag
- Fe and Pb isotopes
- Particulate trace elements and their isotopes
- The chemical speciation of Fe
- The organic ligands that bind Cu and Fe

Underlined samples are core parameters dictated by the international GEOTRACES program (www.geotraces.org). These geochemical tracers are key towards achieving the research goals of the Arctic GEOTRACES project on Leg 2 and Leg 3b.

Operations conducted during the Leg / Methodology
Collection of seawater was performed using a trace metal rosette system that consists of a 12 position, powder coated rosette frame equipped with 12 L, Teflon coated GO-FLO (General Oceanics, Miami, USA) bottles and a SeaBird 911 CTD/SBE 43 Oxygen sensor instrument package. In addition to the rosette a dedicated winch with 5000 meters of non-metallic conducting sea cable and an 8ft clean sampling container were installed on the starboard foredeck. The rosette was deployed using the winch and starboard crane over the side of the ship. Details of this operation are outlined in the leg 2 field report.

We collected trace metal clean water samples from 4 stations in the Canadian Basin (CB1, CB2, CB3 and CB4) and two stations in the Canadian Arctic Archipelago (CAA8 and CAA9). A map of the station locations is presented in Figure 1, and a summary of at TMR casts in Table 1. Station CB4 also serves as a cross-over station with the US GEOTRACES expedition, an important part of the GEOTRACES inter-calibration exercise. And lacking a cross-over station with the European groups involved in the GROTRACES program (i.e. GEOVIDE), we collected samples for them for an inter-calibration at both CB4 and CAA8.

The TM rosette was also used for all samples collected deeper than 1500m, since the ArcticNet rosette cable was not long enough to sample the deeper waters in the Canadian basin. The rosette was deployed on a total of 21 occasions and travelled almost 65 vertical kilometers during leg 3b.

Samples for dissolved metals were filtered in our clean sampling van, directly from the Go Flo bottles, through Acropak Supor capsule filters (both Supor 500 or 1500) as recommended by the GEOTRACES Standard and Intercalibration Committee, Cruise and Methods Manual (CookBook, p. 53) <http://www.geotraces.org/science/intercalibration>.

Samples were either acidified to pH $\leq$ 1.7 within 5 days using Seastar HCl (500 µl HCl per 250 ml sw), or frozen for later analysis (samples and speciation and/or ligand analysis

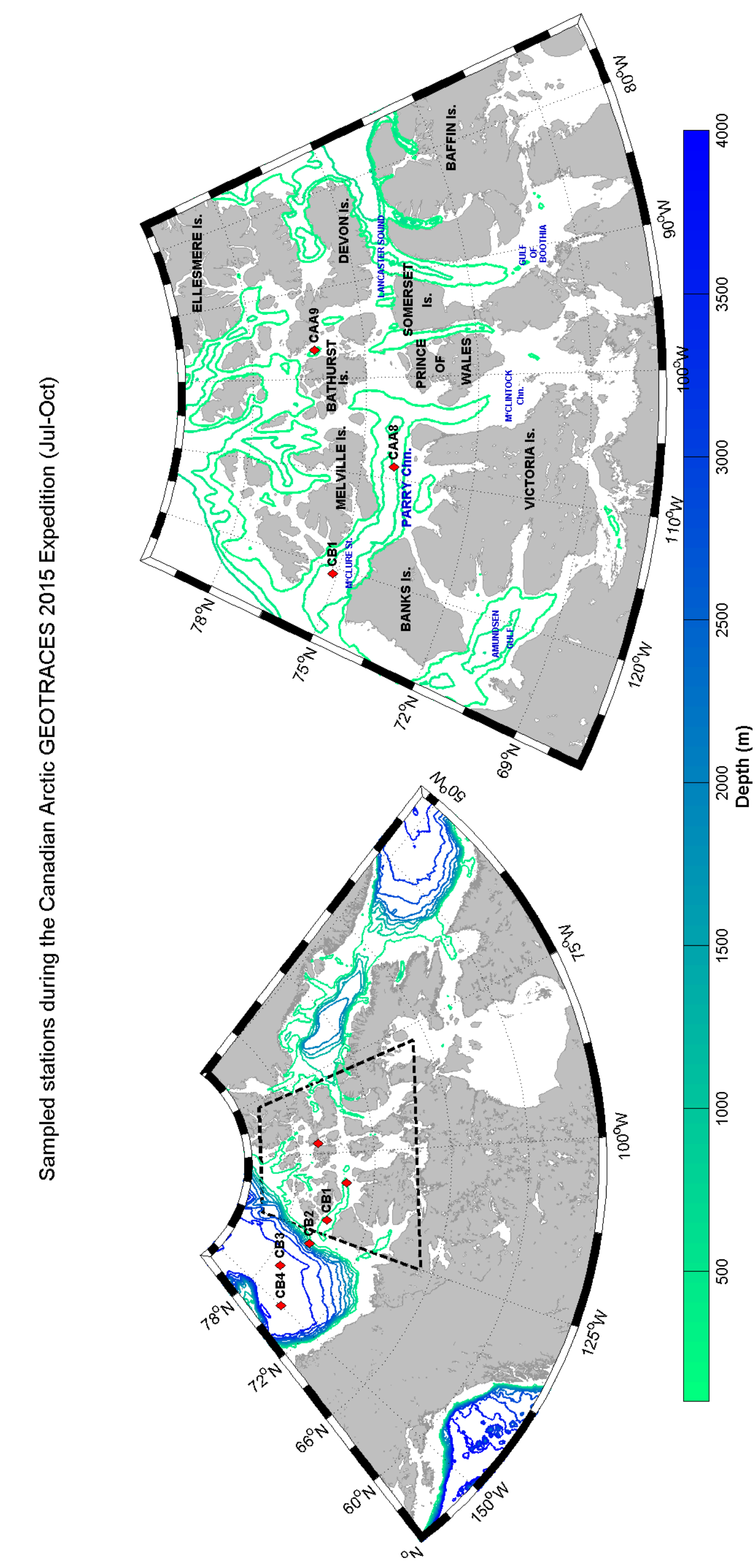

Figure 5.1.1.1 Location of stations where the Trace Metal Rosette was deployed on Leg 3b.

Daily Event Log Book

EVENT No. initially entered as 200, 201...208

LOOK AT DATA\ROSETTE\BTL

DATE	TIME (CMT)	TIME (UTC)	Time Code	STATION	CAST TYPE	Sampling team	EVENT No.	Lat Deg	Lat Min		Lon Deg	Lon Min		BOTTOM DEPTH	MAX DEPTH	SAMPLE NUMBERS	No. of BOTTLES	WATCH	COMMENTS
5-Sep-15	13:32	18:32	IN	Test	TMROS	N/A	400	73˚	51'643	N	129˚	44'595	W	1226	1000	-	-	RF	TEST
7-Sep-15	17:00	22:00	IN	CB1	TMROS 1	A	402	75˚	06'812	N	120˚	38'503	W	465	75	2019-2030	12	RF	CAST DELAYED DUE TO CABLE FAILURE
7-Sep-15	-	-	OUT					-	-	N	-	-	W	-					
7-Sep-15	10:10	15-09-08 3:10	IN	CB1	TMROS 2	B	406	75˚	07'042	N	120˚	37'998	W	460	400	2060-2071	12	RF	CAST DELAYED DUE TO CABLE FAILURE
7-Sep-15	-	-	OUT					-	-	N	-	-	W	-					
8-Sep-15	20:27	15-09-09 1:27	IN	CB2	TMROS 1	A	416	75˚	48.88	N	129˚	13.16	W	1365	200	2126-2137	12	RF	
8-Sep-15	20:56	15-09-09 1:56	OUT					75˚	48.81	N	129˚	12.92	W	1361					
9-Sep-15	3:15	8:15	IN	CB2	TMROS2	B	419	75˚	47.913	N	129˚	14.821	W	1346	1200	2168-2179	12	RF	
9-Sep-15	4:13	9:13	OUT					75˚	47.92	N	129˚	14.84	W	1346					
11-Sep-15	17:00	22:00	IN	CB3	TMROS-shal	B	431	76˚	58.828	N	140˚	2.279	W	3731	200	2248-2259	12	RF	
12-Sep-15	0:21	5:21	IN	CB3	TMROSmeso	A	434	76˚	59.477	N	140˚	1.901	W	3729	1400	2284-2295	12	RF	
12-Sep-15	1:25	6:25	OUT					76˚	49.41	N	140˚	2.187	W	3729					
12-Sep-15	13:11	18:11	IN	CB3	TMROS 1	N/A	438	76˚	59.986	N	140˚	5.719	W	3731	3500	2320-2331	12	RF	ORDER OF OPERATION FOR LVP AND TMROS DIFFERENT FROM ORDEF
12-Sep-15	15:10	20:10	OUT					76˚	59.942	N	140˚	5.71	W	?					
12-Sep-15	18:12	23:12	IN	CB3	TMROS 2	N/A	441	77˚	1.15	N	140˚	2.71	W	3732	3500	2338-2349	12	RF	
12-Sep-15	20:22	15-09-13 1:22	OUT					77˚	0.86	N	140˚	2.58	W	3734					
13-Sep-15	4:33	9:33	IN	CB3	TMROSdeep	A	444	76˚	59.6	N	140˚	4.26	W	3658	3500	2356-2367	12	RF	
13-Sep-15	6:43	11:43	OUT					76˚	59.24	N	140˚	5.75	W	3731					
14-Sep-15	16:47	21:47	IN	CB4	TMROSshal	B	446	74˚	59.81	N	150˚	0.08	W	3826	220	2344-2355	12	RF	Intercal bottles 3 (150m) and 10 (10m)
14-Sep-15	17:12	22:12	OUT					74˚	59.714	N	150˚	1.196	W	3820					
14-Sep-15	22:10	15-09-15 3:10	IN	CB4	TMROSmeso	A	448	75˚	0.064	N	150˚	0.217	W	3828	1400	2362-2373	12	RF	Intercal bottle 1 (1400m)
14-Sep-15	23:17	15-09-15 4:17	OUT					74˚	59.984	N	149˚	59.999	W	3828					
15-Sep-15	7:34	12:34	IN	CB4	TMROSdeep	B	451	75˚	0.11	N	150˚	0.01	W	3829	3500	2380-2391	12	RF	
15-Sep-15	9:51	14:51	OUT					74˚	59.94	N	149˚	59.63	W	3829					
16-Sep-15	7:34	12:34	IN	CB4	TMROS 1	A	455	75˚	1.03	N	150˚	0.81	W	3830	3500	2435-2446	12	RF	bears
16-Sep-15	9:37	13:37	OUT					75˚	2.03	N	150˚	0.81	W	3830					
16-Sep-15	12:12	17:12	IN	CB4	TMROS 2	B	457	75˚	0.33	N	150˚	0.98	W	3827	3500	2447-2458	12	RF	Part Hg
16-Sep-15	14:12	19:12	OUT					75˚	0.095	N	149˚	59.521	W	3827					
16-Sep-15	17:06	22:06	IN	CB4.1	TM-Cs	A	461	74˚	42.253	N	148˚	46.525	W	3811	3500	2480-2491	12	RF	
16-Sep-15	19:14	15-09-17 0:14	OUT					74˚	42.21	N	148˚	45.62	W	3811					
16-Sep-15	20:17	15-09-17 1:17	IN	CB4.2	TM-intercal	B	459	74˚	35.578	N	148˚	12.713	W	3799	1000	2465-2476	12	RF	Part TM intercalibration
16-Sep-15	21:05	15-09-17 2:05	OUT					74˚	35.57	N	148˚	12.483	W	3800					
23-Sep-15	22:28	15-09-24 3:28	IN	AN308/CAA8	TMROS shallow	B	466	74˚	8.31	N	108˚	50.39	W	564	120	2530-2541	12	RF	Intercal bottle 2 (90m)
23-Sep-15	22:48	15-09-24 3:48	OUT					74˚	8.33	N	108˚	50.27	W	569					
24-Sep-15	4:32	9:32	IN	AN308/CAA8	TMROS deep	A	469	74˚	8.34	N	108˚	50.19	W	563	450	2572-2583	12	RF	Intercal bottles 1 (450m), 7 (250m), and 8 (200m speciation only)
24-Sep-15	5:06	10:06	OUT					74˚	8.38	N	108˚	50.13	W	563					
27-Sep-15	0:02	5:02	IN	CAA9	TMROS shallow	B	481	76˚	20.01	N	96˚	45.206	W	334	90	2638-2649	12	RF	
27-Sep-15	0:16	5:16	OUT					76˚	19.98	N	96˚	45.376	W	333					
27-Sep-15	5:00	10:00	IN	CAA9	TMROSdeep	A	485	76˚	19.82	N	96˚	45.40	W	336	350	2669-2678	10	RF	
27-Sep-15	5:23	10:23	OUT					76˚	19.83	N	96˚	45.21	W	336					

Table 5.1.1.1 TM rosette sampling log summary (leg 3b)

User Experience

The Captain and Crew of CCGS Amundsen were outstanding and demonstrated considerable skill and coordination to deploy the Trace Metal Rosette, following the methods documented in the video posted from leg 2. The video was very useful for transferring knowledge on this difficult procedure to the new teams involved in the deployment on leg 3b. See report from leg 2 for details on how this was done. As noted in that report, it is not an ideal method for deploying a rosette, and we did need to re-termination on two occasions again on leg 3b due to kinks or water breaches (water was found to have entered the cable and travelled 75 m up the sheath). Between the UVic and ArcticNet technicians onboard, this was done with minimal down time. One suggestion, if the rosette will be deployed off the starboard bow again in the future, is to have a block that fits the cable better, and doesn't allow the cable to rotate in the block. Ideally, it would be deployed using a dedicated A-frame on the ship.

An additional challenge we faced on leg 3b was freezing of the sensors and trigger pins, due to the low temperatures during sampling at two of the stations (CB4 and CAA9 were both sampled at temperatures of -5 to -12 °C. Application of hot water would melt the ice, but the water would re-freeze before deployment in most cases. Some possible solutions would be a steamer or a shelter with heat lamps (the latter would be challenging in the location we deployed from on this cruise).

Additional comments from Rowan Fox and members of the Amundsen crew:

- the winch is not safe (operator has to sit behind drum) – order a remote pendant? Or install steel shield for operator
- make-shift display for depth and cable rate (worked in the end, but would be good to have a better way to do this)
- level wind sensors froze sometimes – needs checking and a replacement part (needs a grease nipple, but it is too rusted for that)

Preliminary Results
No at sea analyses for TEI were performed on leb 3b by the TM group.
(Hg analysis is covered in "Contaminants" report)
Our measurements will be made upon return of samples to the respective home laboratories after CCGS Amundsen's return to Quebec later this year.

Five questions

a) From the perspective of one of the PI's involved in TMR operations the process was straightforward once CCGS Amundsen was determined to be our platform for Arctic GEOTRACES. *4. Satisfied*

b) We were very satisfied with the quantity, timing and quality of the information provided to us during the planning and mobilization stage of the research expedition. *5. Very Satisfied*

c) Everything the TMR team required was available to us and found to be in working order. Our experience with the ships technicians found them to world class in skill and easy and agreeable to work with. *4. Satisfied*

d) We were satisfied with the safety of the ship. Our concerns about TMR deployment are expressed above. All other aspects of operations and the ship were very satisfying. *4. Satisfied*

e) The TMR team is satisfied with operations this year. Despite minor incidents with the rosette we were able to accomplish our core scientific objectives. The CCGS Amundsen is a unique and special ship that allows world class scientific operations to be conducted in a friendly and collegial atmosphere. *5. Very Satisfied*

5.1.2 Trace metal-phytoplankton interactions, particulate trace metals and Fe uptake by phytoplankton

Principal Investigator: Maite Maldonado[1], Andrew Ross[2]
Cruise Participants: Dave Semeniuk[1] and Jingxuan Li[1]

[1]Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia
[2] Institute of Ocean Science, Sydney BC

Introduction and objectives

Bioactive metals, such as Fe, Cu and Zn, are essential for phytoplankton growth and may potentially limit primary productivity in the sea. Indeed, Fe availability controls primary productivity in 30-40% of the global ocean. Phytoplankton may, in turn, influence trace metal concentrations and speciation in the ocean by; (a) taking up trace elements to fulfill their growth requirements, (b) releasing organic complexes to enhance or prevent metal acquisition, and (c) altering trace metal redox speciation through enzymatic activity (reductases & oxidases) at their cell surface. To gain a better understanding of the biogeochemical cycles of essential trace elements in the global ocean, it is therefore imperative to investigate the interactions between primary producers and the distribution and speciation of bioactive trace elements.

During the 2 Arctic cruises in the summer of 2015, we aimed to investigate how micronutrient supply and speciation affects primary productivity, photosynthetic efficiency (in collaboration with Dr. Tortell), species composition and trace metal elemental composition of phytoplankton. In order to achieve this, we collected samples to determine vertical profiles of particulate bioactive metals at all the stations, as well as samples to determine trace metal speciation (in collaboration with Andrew Ross at IOS). In the euphotic zone and the chlorophyll maximum, the speciation data and the particulate metal data will be combined with HPLC pigment data (which we collected also) to determine how phytoplankton community composition affects particulate metals in the water column. We will also examine our data in the context of dissolved metals data (J. Cullen and K. Orians) to establish how dissolved metals affect the trace metal composition of particles in the water column.

Operations conducted during the Leg / Methodology

After collecting sample for salinity and nutrients (if applicable), the GOFLO bottle (approximately 10 L water remaining) was drained to a cubitainer through a piece of masterflex tubing and a spigot, which replaced the cap of cubitainer. Then the water was filtered off-line through 0.45 micrometer poresize SUPOR filter, which was dried afterwards. Filtrate was collected for volume measurement. Filtration was done in a clean 'bubble' built in Aft lab in leg2 and forward filtration lab in leg3b.

Table 5.1.2.1: List of particulate trace metal samples

Depth	Gofl	Sampl	Statio	Event info	Depth	Gofl	Sampl	Statio	Event info
Tmin	2	2020		402 – Sept 7	Tmin	2	2345		446 – Sept 14
Tmax	4	2022		TM rosette	150m	4	2347		
Chlma	7	2025		2200h	Chlma	7	2350		TM rosette
Partma	9	2027		75.06.80N	25m	11	2354		2147h - 2212h
10m	11	2029		120.38.51W	1400	2	2363		448 – Sept 15
400m	2	2060		406 – Sept 8	800m	4	2365		
350m	4	2062	**CB-1**	TM rosette	Tmax2	7	2368	**CB-4**	TM rosette
300m	6	2064		0310h	10m	11	2372		0310h - 0417h
				75.07.04N					[illegible]
250m	7	2067		120.37.89W	2500m	4	2383		451 – Sept 15
200m	10	2068			2000m	7	2386		TM rosette
150m	12	2070			3500m	11	2381		
									1234h - 1451h
200m	2	2127		416 – Sept 9	1000m	1	2465		459 – Sept 17
Tmin	4	2129		TM rosette	1000m	2	2466		TM rosette
Tmax	6	2131			300m	3	2467		
Chlma	7	2132		01h - 0156h	300m	4	2468		0014h - 0117h
10m	11	2136		75.48.88N	71m	5	2469		
1200m	2	2169		419 – Sept 10	71m	6	2470	**CB 4.2**	74.35.57N
800m	4	2171			10m	11	2475	**pMe**	148.12.60W
400m	7	2174		TM rosette	10m	12	2476	**interc**	
25m	12	2179	**CB-2**	0815h - 0913h	90m	3	2532		466 – Sept 24
200m	2	2249		431 – Sept 11	Chlma	7	2536		
Tmin	4	2251		TM rosette	Partma	9	2538		TM rosette
Chlma	7	2254			Mld	11	2540		0328h - 0348h
25m	9	2256		2200h - 2219h	450m	2	2573		469 – Sept 24
1400m	2	2285		434 – Sept 12	350m	4	2575		TM rosette
800m	4	2287		TM rosette	250m	6	2577		
480m	7	2290			200m	9	2580		0932h - 1006h
Mld	11	2294		0521h - 0625h	150m	11	2582	**CAA 8**	
2500m	5	2360	**CB-3**	444 – Sept 13	120m	12	2583		74.08.36N
									108.50.16W
3500m	11	2357			90m	2			481 – Sept 27
2000m	7	2362		TM rosette	70m	3			
				0933h -	Chlma	9			TM rosette
				01143h	Mld	11			0512h - 0516h
						4	2672		485 – Sept 27
				76.59.60N		6	2674		

140.04.26W	9	2676	**CAA 9**	TM rosette
	10	2677		1000h - 1023h
				76.19.82N
				96.45.30W

5.1.3 Canadian Arctic GEOTRACES: Contaminants in a changing Arctic

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Section A—Total and Methylated Mercury in Seawater

Introduction and Objectives:
Mercury (Hg) in the Arctic marine ecosystem is a hot topic due to its high toxicity and biomagnification in the food web, and the main culprit of both features is monomethylmercury (MMHg). While major progress has been made with respect to the Hg distribution and speciation in the atmosphere and biota, much less is known about the source and distribution of Hg species (MMHg in particular) in the Arctic seawater, which is the primary Hg exposure pathway to marine biota.

Though release of sediment produced methylated Hg (MeHg, sum of MMHg and dimethylmercury) was postulated as the primary seawater MeHg source (Hammerschmidt and Fitzgerald, 2006), sub-surface peak of MeHg recently observed in different oceans suggest water column Hg methylation is a more important source in seawater. In addition, the subsurface MeHg peak always shows up in the depth where nutrient are high and dissolved oxygen is low, suggesting the association of in-situ MeHg production and organic matter (OM) reminerallization.

Considering the knowledge gap in distribution and source of MeHg in the Arctic Ocean, the objectives of this project are set as: 1) to map the distribution of total Hg (Hg_T) and MeHg as well as particulate Hg (Hg_P) in the Canadian Arctic seawater; 2) to identify the mechanisms of Hg methylation in water column, and how it is associated with OM remineralization.

Operations conducted during the Leg / Methodology
Seawater samples were collected via Trace metal Rosette from all the GEOTRACES stations along the route of Amundsen during Leg3 (Table 1). Samples of Hg_T and MeHg are included in all the stations, while large volume (up to 11L) of seawater were filtered to get the data of particulate Hg (Hg_P) in Station CB4.

Both Hg_T and MeHg are acidified immediately upon collection, and refrigerated before being analyzed onboard the ship at the Portable In-Situ Laboratory for Mercury Speciation (PILMS). The instrument used is a Tekran 2600 for Hg_T analysis and a Brooks Rand MERX for MeHg. On the other hand, the filters for Hg_P are frozen for shipment to Winnipeg for analysis at University of Manitoba.

To study the mechanism of Hg methylation in water column, incubation experiments are carried out onboard. Isotopic enriched Hg and MMHg were spiked to newly collected seawater to start the incubation, which were stopped after certain period of time by acidification. The samples for incubation will be shipped to University of Manitoba for analysis.

Table 5.1.3.1. Stations sampled during Leg 3b.

Station	Location	Coordinates	Bottom Depth	Samples Collected
CB1	Beaufort Sea	75°N 120°W	465 m	Hg_T, MeHg
CB2	Beaufort Sea	75°N 129°W	1365 m	Hg_T, MeHg
CB3	Beaufort Sea	76°N 140°W	3500 m	Hg_T, MeHg
CB4	Beaufort Sea	75°N 150°W	3830 m	Hg_T, Hg_P, MeHg inter-calibration
CAA8	Parry Channel	74°N 108°W	560 m	Hg_T, MeHg
CAA9	Penny Strait	76°N 96°W	340 m	Hg_T, MeHg

Preliminary results.
While HgT concentrations in most of the seawater samples are in the range of 0.4-2.0 pM, some samples in mixed layer are showing value as high as ~4pM, which might be reflecting the atmospheric Hg deposition in surface seawater.

Section B—Atmospheric Mercury

Introduction and objectives
Mercury is one of the primary contaminants of concern in the Arctic marine ecosystem. It can be transported to the Arctic via long-range atmospheric transport. Gaseous elementary mercury (GEM) is the main mercury species in the atmosphere since it has a long residence time (up to two years) and is relatively stable (Stephen et al., 2008). In the presence of strong oxidants in the air (e.g. halogen atoms), GEM can be rapidly oxidized into reactive gaseous mercury (RGM), which then can be adsorbed onto aerosols to become to particulate mercury (PHg). Both RGM and PHg are much more reactive than GEM, and can readily deposit onto the surface environment (e.g., snow, ice and seawater). In the springtime Arctic, the oxidation and deposition processes are accelerated by photolytically produced reactive halogens, resulting in the so-called mercury depletion events. In the summer time, on the other hand, the open ocean can be a

source of atmospheric mercury and release mercury into the air. Previous model studies suggest that 30-40% mercury deposited to the ocean is re-emitted. Much less is known about the oxidation process of GEM during the Arctic summer.

The objective of the atmospheric mercury project is to analyze three different species of mercury in the air: GEM, RGM and PHg. Together with our complementary project measuring mercury species in seawater, the results of this project will improve our understanding of Hg redox reactions and exchange between the atmosphere and the ocean in the Arctic summer.

Operations conducted during the Leg/Methodology

An automated Tekran atmospheric mercury speciation system measured mercury throughout the Leg 3 transect. Two outdoor atmospheric samplers, the 1130 and 1135 modules, were installed on the starboard bow on a stand fabricated by the Amundsen engineers during mobilization in Quebec City. The outdoor sampling units fed into the starboard dry lab container, where two additional units, the pump module and the 2537B mercury detector unit, measured real-time GEM, RGM and PHg during the ship transects in the Canadian Arctic. The placement of the atmospheric sampling units was selected in order to obtain air samples that were not contaminated by exhaust from the ship engines and to measure as close to the water surface as possible to best determine exchange between the atmosphere and ocean.

Discrete GEM measurements were obtained every 5 minutes. Analysis of PHg and RGM samples occurred after 2-hour collection periods.

During the first week of sampling in leg 3a the two outdoor sampling units were exposed to water and were damaged. Following this event it was only possible to sample GEM throughout the remaining transects. Continuous monitoring of GEM was carried out with measurements every 5 minutes.

Preliminary results

Analysis of the collected data is ongoing. However, initial review of the data show that GEM concentrations in the air range from 0.8 to 1.6 ng m^{-3} during Leg 3b.

User Experience.

a) The process to gain access to the vessel and request ship time for our team's project was clear and easy to follow.

5. Very satisfied √

Comments: As a joint project between ArcticNet and GEOTRACES, the mercury team members were involved early in the process of cruise planning and therefore found access and ship time requests were well met. In addition, we very much appreciate the ease with which we were able to make changes to our team members for this leg.

b) The annual Amundsen expedition was effectively planned and organized (e.g., planning meeting, vessel scheduling, dissemination of information, mobilization, etc.).

5. Very satisfied √

Comments: The expedition was well planned and involved the cooperation of many. We were fortunate to execute sampling at all stations in the original plan as well as adding an

additional station at the end to use up extra ship time available. This extra station is of interest and we believe it was a good use of ship time. We are thankful that the chief scientist and ship captain were flexible in allowing opportunistic sampling of sea ice and water when time was available and conditions were suitable.
c) The Amundsen's central pool of equipment (e.g., scientific winches, CTD Rosette system, MVP system, onboard laboratories, sonars, piston corer, Remotely Operated Vehicle, etc.) was properly maintained and operational at sea.
10. Very satisfied √
Comments: We were very pleased with the assistance from the ship's engineering departments to help changing gas cylinders timely.
d) Safety in the workplace (i.e. were you satisfied with the overall safety of the science operations conducted on and from the Amundsen?)
4. Satisfied √
Comments:
e) What is your overall level of satisfaction regarding your experience conducting research on board the Amundsen this year?
5. Very satisfied √
Comments:

5.1.4 ^{230}Th, ^{231}Pa, Nd isotopes, Cr isotopes and REE

Principal Investigators: Roger Francois[1], Chris Holmden[2]
Cruise participants: Isabelle Baconnais[2]

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Introduction and objectives
Climate-driven alterations of the Arctic Ocean (*e.g.* sea ice cover, water masses circulation) strongly influence local biological productivity, ecosystem structure, air-sea exchange of climate-active gases, and the distribution of contaminants (*e.g.* Hg, Pb). At the moment, our ability to evaluate the full impact of these rapid changes and predict their future trajectory is limited by a poor understanding of the interacting chemical, physical and biological processes which shape the functional characteristics and resiliency of Arctic waters. To bridge this critical knowledge gap, a pan-Arctic field study (Arctic-GEOTRACES, http://www.geotraces.org) is being coordinated between Canada (this present expedition), US, Germany and France to generate a quasi-synoptic database of biogeochemical tracers of circulation, ecosystem structure and productivity, as well as a sea ice state.

The need for a basic understanding of the water masses circulation in the CAA and the adjacent need of understanding the distribution and cycle of toxic/essential trace elements in this area is a major opportunity for the development of non-traditional stable isotope tracers such as Chromium.

Chromium in seawater is found under two oxidation states, both bearing different isotope signatures and properties: Cr(III) and Cr(VI) (Ellis et al. 2002). Cr(III) is a micronutrient for higher mammals (Mertz, 1993), with concentration and isotopic composition of the Cr(III) species potentially able to trace supply fluxes from shelf sediment and groundwater (Frei et al. 2014), whereas Cr(VI) is a toxic element easily absorbed by living organisms (Richard and Bourg, 1991; Standeven and Wetterhahn, 1991), which species' concentration and isotopic composition are thought to trace circulation and removal fluxes to the sediment (Bonnand et al. 2013).

During the IPY-GEOTRACES cruise in 2009, the very first dataset of total Cr isotopes in these waters was determined, resulting in the identification of a unique signature for Pacific source water (~1.5‰; Scheiderich et al. 2015, IPY Conference abstract, 2012). These measurements will add to future results for Cr isotopes and cross-parameters (*e.g.* Nutrients, Salinity, Pa/Th) from this cruise to potentially: 1) observe the gradual changes in Cr-isotope signature of Pacific source water as it traverses the CAA and therefore trace the evolution of the Pacific water as it moves to the Atlantic Ocean; 2) relate these changes to a range of potential addition and removal processes affecting TEIs in these waters, helping on documenting their cycle in the archipelagos.

For analytical efficiency reasons, the sampling for Cr and Nd isotopes, as well as Pa-Th and REE concentration measurements were combined during this cruise. Nd isotopes measurement's main purpose is as a water mass tracer (Pacific *vs* Atlantic water in the Canada Basin and CAA; Denmark Strait Overflow water *vs* Baffin Bay in the Labrador Sea). Another potential outcome, particularly in the CAA, is in identifying exchange of trace elements between bottom waters and shelf sediments, complementing Cr isotopes observations. The REE patterns will provide further constraints on the processes (*e.g.* scavenging, lithogenic sources) that govern isotope exchanges. Finally, ^{230}Th and ^{231}Pa measurements will help developping novel tracers of deep and intermediate water circulation (*e.g.* ^{129}I, Nd). The likely outcome of this project will be the cross-comparison of all these new tracers for the quantification of exchange of trace elements between waters and shelf sediments, with implications for biological productivity and contaminant dispersion, as well as the documentation on water masses chemical evolution in the Canadian Archipelagos.

Operations conducted during the Leg / Methodology
The operations conducted in the leg 3b echo the ones conducted during the leg 2b by Mélanie Grenier (UBC).

As in the leg 2b, the Amundsen rosette, which is dedicated to most of the ArcticNet samplings (AN), is used to retrieve seawater samples above 1400m, while deeper samples are collected from the Trace-Metal rosette (University of Victoria; PI: Jay Cullen). Because of the limited volume of the Niskin/GoFlo bottles, each seawater sample is simultaneously collected from two Niskin bottles (or Go-Flo bottles when collected from the TM rosette) closed at same depths.
Using Teflon tubings pre-contaminated with the sample, seawater is retrieved in acid-cleaned 20L jerricans (also pre-contaminated by three rinses with the sample) and

brought back to the on-board lab in a hermetic plastic bag. There, the seawater is filtered through a one-use-only 0.45µm-filter cartridge (AquaPrep®) mounted on an acid-cleaned tubing system connected to a peristaltic pump, operating at ~250mL/min. The filtered seawater is divided into three containers in the following order: a 1L acid-cleaned Nalgene® bottle for REE concentration measurement, a 20L acid-cleaned cubitainer for Nd isotopes determination, and a 4L trace-clean cubitainer dedicated to Cr isotopes measurement. Each container is rinsed three times with the seawater before being filled. All samples are then acidified to pH~2 using 6N HCl EG (made on-board under the fume hood of the Nutrient lab with concentrated HCl EG and milli-Q® water coming from the on-board Arctic Net system). The 1L bottles and 4L cubitainers are then stored away in UBC and Usask coolers.

Except for the stations CB1, AN-407 and CAA9, all 20L cubitainers are spiked for the measurement of ^{230}Th and ^{231}Pa concentrations. The spike solution is a mixture of 0.5mL of ^{233}Pa at ~0.4788pmol/g, 0.2mL of ^{229}Th at ~1.5dpm, and 2mL of $FeCl_3$ at ~50mg/mL, prepared before the cruise and conditioned in the form of a precipitate into 15mL test tubes (one per cubitainer). The 20L cubitainers are accurately weighed empty and with the sample before the addition of the spike solution on an industrial scale. The acidification and the spiking of the seawater for Pa/Th and REE measurements are done in one shot, with the dissolution of the spike solution with ~10mL of 6N HCl EG, which is then poured into the cubitainer. The test tube containing the spike solution is then rinsed 3 times with ~10mL of 6N HCl EG to ensure a complete transfer of the spike into the sample, leading to a total use of ~40mL of 6N HCl EG to acidify the sample at pH~2. The pH is checked for every sample using pH-paper.

For the 20L-samples from stations CB1 and AN-407, ~40mL of 6N HCL EG are added for acidification, and 2mL of FeCl3 are added separately for trace-elements' pre-concentration.
For all 20L-seawater samples, they are stored ~24H to allow the equilibration of the spikes and the iron solution with the seawater. After 24H, the pH is raised to 8.0-8.5 using ~25mL of concentrated NH_4OH to engage the Fe co-precipitation. The pH is checked for every sample using pH-paper. After 48H of settling, most of the supernatant is drained using an acid-clean tubing system connected to a peristaltic pump. The remaining seawater and co-precipitate are poured into 1L acid-cleaned transparent bottles (Figure 1). The cubitainer is rinsed twice with Milli-Q® water 18.2MΩ to collect all the precipitate. After 12H, as the precipitate and the seawater/Milli-Q® water 18.2MΩ separated again into two phases, the supernatant is poured and discarded, and the precipitate is poured into a 50mL acid-cleaned centrifugation tube. The 1L bottle is rinsed twice with Milli-Q® water 18.2MΩ and the sample is centrifuged. The sample is finally stored in the centrifugation tubes after the removal of any remains of supernatant (i.e. seawater or Milli-Q® water 18.2MΩ).

For the station CAA9, as the short time before the end of the leg did not allow the completion of the procedure for Pa/Th and REE measurement, and as no containers were left for the collection for Cr isotopes measurement, the seawater was filtered from one jerrican to another, with three rinses of the sample beforehand, and collection of 1L for

REE concentration measurement. Jerricans and bottles were acidified with 6N HCl EG to pH~2. An aliquot of 3L will be later collected from the jerricans at UBC for Cr measurement at USask. In order to monitor any contamination from the storage of the seawater in the jerricans, a blank was done with the collection of Milli-Q® water 18.2MΩ, acidified to pH~2, into an analogue jerrican.

During the leg 3b, 2 total procedural blanks are realised. A 20L jerrican is rinsed three times with Milli-Q® water 18.2MΩ and filled directly at the on-board Millipore system. Both are then filtered in the same conditions as for normal seawater samples, with the collection of three aliquots for REE concentration blanks, Nd blanks and Cr blanks. The 1L Nalgene® bottles for REE concentration measurement and 4L cubitainers for Cr isotopes measurement are acidified and stored away. The first 20L blank is acidified with addition of 2mL of $FeCl_3$. The 2nd procedural blank is spiked for Pa/Th blank measurement. Both consequently follow the same procedure as described above for normal seawater samples (i.e. pH-rising, discard of supernatant, centrifugation).

Table 5.1.4.1 Log of the samples collected during Leg3b, all valid for Nd isotopes samples (PWW:Pacific Winter Water; PSW: Pacific Summer Water; SCM: Surface Chl a Max).

Date	Latitude [°N]	Longitude [°W]	Station-Cast [#]	Event [#]	Sample Nb [#]	Niskin/Go-Flo bottle Nb [#]	Depth [m]	Filtration	REE (1L)	^{230}Th-^{231}Pa spiking	Cr (3L)	Comments
Leg 3b (Sept. 4th, 2015-Oct. 1st, 2015)												
Sept. 06, 2015	75°07.35	120°38.50	CB1-AN (RADS)	401	2008-2009	B8-9	350	YES	YES	NO	YES	
Sept. 07, 2015	75°06.095	120°33.569	CB1-AN1	407	2072-2073	B1-2	Bottom	YES	YES	NO	YES	
Sept. 07, 2015	75°06.095	120°33.569	CB1-AN1	407	2077-2078	B6-7	250	YES	YES	NO	YES	
Sept. 07, 2015	75°06.095	120°33.569	CB1-AN1	407	2080-2081	B9-10	200	YES	YES	NO	YES	
Sept. 07, 2015	75°06.095	120°33.569	CB1-AN1	407	2082-2083	B11-12	150	YES	YES	NO	YES	
Sept. 07, 2015	75°06.095	120°33.569	CB1-AN1	407	2086-2087	B15-16	75	YES	YES	NO	YES	PWW (water mass)
Sept. 07, 2015	75°06.095	120°33.569	CB1-AN1	407	2088-2089	B17-18	65	YES	YES	NO	YES	PSW (water mass)
Sept. 07, 2015	75°06.095	120°33.569	CB1-AN1	407	2094-2095	B23-24	10	YES	YES	NO	YES	
Sept. 08, 2015	75°49.28	129°13.08	CB2-AN (RADS)	415	2106-2107	B5-6	700	YES	YES	YES	LOST	
Sept. 08, 2015	75°49.28	129°13.08	CB2-AN (RADS)	415	2108-2109	B7-8	500	YES	YES	YES	YES	
Sept. 08, 2015	75°49.28	129°13.08	CB2-AN (RADS)	415	2114-2115	B13-14	400	YES	YES	YES	YES	
Sept. 09, 2015	75°48.35	129°11.52	CB2-AN1	420	2180-2181	B1-2	Bottom	YES	YES	YES	YES	
Sept. 09, 2015	75°48.35	129°11.52	CB2-AN1	420	2183-2184	B4-5	1000	YES	YES	YES	YES	
Sept. 09, 2015	75°48.35	129°11.52	CB2-AN1	420	2186-2187	B7-8	800	YES	YES	YES	YES	
Sept. 09, 2015	75°48.35	129°11.52	CB2-AN1	420	2189-2190	B10-11	400	YES	YES	YES	YES	
Sept. 09, 2015	75°48.35	129°11.52	CB2-AN1	420	2191-2192	B12-13	200	YES	YES	YES	YES	
Sept. 09, 2015	75°48.35	129°11.52	CB2-AN1	420	2195-2196	B16-17	140	YES	YES	YES	YES	
Sept. 09, 2015	75°48.35	129°11.52	CB2-AN1	420	2197-2198	B18-19	65	YES	YES	YES	YES	
Sept. 09, 2015	75°48.35	129°11.52	CB2-AN1	420	2202-2203	B23-24	10	YES	YES	YES	YES	
Sept. 11, 2015	76°58.791	140°02.288	CB3-AN (RADS)	430	2224-2225	B1-2	1400	YES	YES	YES	YES	
Sept. 11, 2015	76°58.791	140°02.288	CB3-AN (RADS)	430	2226-2227	B3-4	1000	YES	YES	YES	YES	
Sept. 11, 2015	76°58.791	140°02.288	CB3-AN (RADS)	430	2240-2241	B17-18	600	YES	YES	YES	YES	
Sept. 11, 2015	76°58.791	140°02.288	CB3-AN (RADS)	430	2246-2247	B23-24	400	YES	YES	YES	YES	
Sept. 11, 2015	76°58.40	140°03.24	CB3-AN2	433	2266-2267	B1-2	1400	YES	YES	YES	YES	
Sept. 11, 2015	76°58.40	140°03.24	CB3-AN2	433	2271-2272	B6-7	250	YES	YES	YES	YES	
Sept. 11, 2015	76°58.40	140°03.24	CB3-AN2	433	2274-2275	B9-10	140	YES	YES	YES	YES	
Sept. 11, 2015	76°58.40	140°03.24	CB3-AN2	433	2277-2278	B12-13	65	YES	YES	YES	YES	
Sept. 11, 2015	76°58.40	140°03.24	CB3-AN2	433	2281-2282	B16-17	10	YES	YES	YES	YES	
Sept. 12, 2015	76°59.644	140°04.711	CB3-TM1	438	2321-2322	B2-3	3500	YES	YES	YES	YES	
Sept. 12, 2015	76°59.644	140°04.711	CB3-TM1	438	2324-2325	B5-6	3000	YES	YES	YES	YES	
Sept. 12, 2015	76°59.644	140°04.711	CB3-TM1	438	2327-2328	B8-9	2500	YES	YES	YES	YES	
Sept. 12, 2015	76°59.644	140°04.711	CB3-TM1	438	2330-2331	B11-12	2000	YES	YES	YES	YES	
Sept. 14, 2015	74°59.91	150°00.38	CB4-AN1	445	2320-2321	B1-2	1400	YES	YES	YES	YES	
Sept. 14, 2015	74°59.91	150°00.38	CB4-AN1	445	2322-2323	B3-4	1000	YES	YES	YES	YES	
Sept. 14, 2015	74°59.91	150°00.38	CB4-AN1	445	2336-2337	B17-18	600	YES	YES	YES	YES	
Sept. 14, 2015	74°59.91	150°00.38	CB4-AN1	445	2342-2343	B23-24	400	YES	YES	YES	YES	
Sept. 14, 2015	75°00.00	150°00.36	CB4-AN3	452	2392-2393	B1-2	1400	YES	YES	YES	YES	
Sept. 14, 2015	75°00.00	150°00.36	CB4-AN3	452	2397-2398	B6-7	300	YES	YES	YES	YES	

Sept. 14, 2015	75°00.00	150°00.36	CB4-AN3	452	2399-2400	B8-9	220	YES	YES	YES	YES	
Sept. 14, 2015	75°00.00	150°00.36	CB4-AN3	452	2403-2404	B12-13	71	YES	YES	YES	YES	
Sept. 14, 2015	75°00.00	150°00.36	CB4-AN3	452	2407-2408	B16-17	10	YES	YES	YES	YES	
Sept. 16, 2015	75°00.24	149°57.65	CB4-TM1	455	2436-2437	B2-3	3500	YES	YES	YES	YES	
Sept. 16, 2015	75°00.24	149°57.65	CB4-TM1	455	2439-2440	B5-6	3000	YES	YES	YES	YES	
Sept. 16, 2015	75°00.24	149°57.65	CB4-TM1	455	2442-2443	B8-9	2500	YES	YES	YES	YES	
Sept. 16, 2015	75°00.24	149°57.65	CB4-TM1	455	2445-2446	B11-12	2000	YES	YES	YES	YES	
Sept. 18, 2015	71°00.53	126°05.08	AN-407	464	2499-2500	B5-6	Bottom	YES	YES	NO	YES	
Sept. 18, 2015	71°00.53	126°05.08	AN-407	464	2502-2503	B8-9	300	YES	YES	NO	YES	
Sept. 18, 2015	71°00.53	126°05.08	AN-407	464	2505-2506	B11-12	200	YES	YES	NO	YES	Tmin
Sept. 18, 2015	71°00.53	126°05.08	AN-407	464	2508-2509	B14-15	71	YES	YES	NO	YES	SCM
Sept. 18, 2015	71°00.53	126°05.08	AN-407	464	2514-2515	B20-21	10	YES	YES	NO	YES	
Sept. 24, 2015	74°08.37	108°50.25	CAA 8-AN1	468	2549-2550	B2-3	Bottom	YES	YES	YES	NO	
Sept. 24, 2015	74°08.37	108°50.25	CAA 8-AN1	468	2552-2553	B5-6	450	YES	YES	YES	YES	
Sept. 24, 2015	74°08.37	108°50.25	CAA 8-AN1	468	2556-2557	B9-10	350	YES	YES	YES	YES	
Sept. 24, 2015	74°08.31	108°50.18	CAA 8-AN2	471	2590-2591	B1-2	Bottom	YES	YES	YES	YES	
Sept. 24, 2015	74°08.31	108°50.18	CAA 8-AN2	471	2595-2596	B6-7	250	YES	YES	YES	YES	
Sept. 24, 2015	74°08.31	108°50.18	CAA 8-AN2	471	2598-2599	B9-10	200	YES	YES	YES	YES	
Sept. 24, 2015	74°08.31	108°50.18	CAA 8-AN2	471	2600-2601	B11-12	150	YES	YES	YES	YES	
Sept. 24, 2015	74°08.31	108°50.18	CAA 8-AN2	471	2605-2606	B16-17	75	YES	YES	YES	YES	33.1/Tmin
Sept. 24, 2015	74°08.31	108°50.18	CAA 8-AN2	471	2607-2608	B18-19	60	YES	YES	YES	YES	31.8/Tmax
Sept. 24, 2015	74°08.31	108°50.18	CAA 8-AN2	471	2612-2613	B23-24	10	YES	YES	YES	YES	
Sept. 25, 2015			BLANK 1					YES	YES	NO	YES	
Sept. 25, 2015			BLANK 2					YES	YES	YES	YES	
Sept. 26, 2015	76°19.60	096°43.74	CAA 9-AN1	480	2614-2615	B1-2	Bottom	YES	YES	NO	NOT YET	
Sept. 26, 2015	76°19.60	096°43.74	CAA 9-AN1	480	2619-2620	B6-7	250	YES	YES	NO	NOT YET	
Sept. 26, 2015	76°19.60	096°43.74	CAA 9-AN1	480	2622-2623	B9-10	200	YES	YES	NO	NOT YET	
Sept. 26, 2015	76°19.60	096°43.74	CAA 9-AN1	480	2624-2625	B11-12	150	YES	YES	NO	NOT YET	
Sept. 26, 2015	76°19.60	096°43.74	CAA 9-AN1	480	2628-2629	B15-16	120	YES	YES	NO	NOT YET	
Sept. 26, 2015	76°19.60	096°43.74	CAA 9-AN1	480	2631-2632	B18-19	90	YES	YES	NO	NOT YET	33.1/Tmin
Sept. 26, 2015	76°19.60	096°43.74	CAA 9-AN1	480	2634-2635	B21-22	45	YES	YES	NO	NOT YET	SCM
Sept. 27, 2015	76°19.971	096°46.044	CAA 9-AN2	483	2658-2659	B9-10	50	YES	YES	NO	NOT YET	Tmax
Sept. 27, 2015	76°19.971	096°46.044	CAA 9-AN2	483	2662-2663	B13-14	15	YES	YES	NO	NOT YET	max part.
Sept. 27, 2015	76°19.971	096°46.044	CAA 9-AN2	483	2666-2667	B17-18	10	YES	YES	NO	NOT YET	mixed layer
Sept. 27, 2015			CAA 9-BLANK					NO	NO	NO	NOT YET	

Preliminary results
Samples were filtered and acidified on-board, and will be further processed in the on-land Stable Isotope laboratory at the University of Saskatchewan (Saskatoon, Canada). Therefore, no results can be presented yet.

User experience

a) The process to gain access to the vessel and request ship time for our team's project was clear and easy to follow

Very satisfied.

b) The annual *Amundsen* expedition was effectively planned and organized (e.g., planning meeting, vessel scheduling, dissemination of information, mobilization, etc.).

Very satisfied.

c) The *Amundsen's* central pool of equipment (e.g., scientific winches, CTD-Rosette system, MVP system, onboard laboratories, sonars, piston corer, Remotely Operated Vehicle, etc.) was properly maintained and operational at sea.

Very satisfied.

d) Safety in the workplace (i.e. were you satisfied with the overall safety of the science operations conducted on and from the *Amundsen*?)

Very satisfied.

e) What is your overall level of satisfaction regarding your experience conducting research on board the *Amundsen* this year?

Very satisfied.

5.1.5 Large volume in-situ operations for particulate ^{230}Th, ^{231}Pa, Nd isotopes, Cr isotopes and Si isotopes.

Principal Investigators: Roger Francois
Cruise Participants: Maureen Soon

[1] *Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia*

Introduction and objectives

Analysis of particles is essential for the interpretation of ^{230}Th, ^{231}Pa, Nd isotopes, Cr isotopes and Si isotopes measured in the water column. Particulate ^{230}Th, ^{231}Pa provide information on the mean sinking rates of particles and the influence of particle composition on $^{231}Pa/^{230}Th$ ratio, which is used in paleoceanography to determine past changes in circulation and/or particle flux. Particulate Nd isotopes document the exchange of Nd isotopes between seawater and the lithogenic or authigenic phases of particles. Si isotopes provide information on Si isotopic fractionation during the formation of biogenic silica.

Sampling/Methodology

Because of the large seawater volumes that need to be filtered to collect enough particles to make these measurements, large volume in-situ pumps were used to filter hundreds of liter of water at fixed depths (Table 5.1.5.1)

Table 5.1.5.1 Large volume pump samples for ^{230}Th, ^{231}Pa, Nd isotopes, Cr isotopes and Si isotopes on Leg 3b

Geotraces 2015 Leg 3b LVP

STN	EVENT #	Target Depth	LVP #	Samp #	Nd-Pa-Th (Supor)	Si isotopes	STN	EVENT #	Target Depth	LVP #	Samp #	Nd-Pa-Th (Supor)	Si isotopes
CB1	403	10	1	2031	x		CB3	442	10	1	2350		x
CB1	403	75	2	2032	x		CB3	442	58	2	2351		x
CB1	403	150	3	2033	x		CB3	442	180	3	2352		x
CB1	403	250	4	2034	x		CB3	442	400	4	2353		x
CB1	403	400	5	2035	x		CB3	442	600	5	2354	x	
CB1	403	435	6	2036	x		CB3	442	1400	6	2355		x
CB1	408	10	1	2096		x	CB4	447	15	1	2356	x	
CB1	408	40	2	2097		x	CB4	447	71	2	2357	x	
CB1	408	75	3	2098		x	CB4	447	220	3	2358	x	
CB1	408	150	4	2099		x	CB4	447	350	4	2359	x	
CB1	408	250	5	2100		x	CB4	447	500	5	2360	x	
CB1	408	400	6	2101		x	CB4	447	800	6	2361	x	
CB2	417	10	1	2138	x		CB4	450	1000	1	2374	x	
CB2	417	140	2	2139	x		CB4	450	1250	2	2375	x	
CB2	417	400	3	2140	x		CB4	450	1500	3	2376	x	
CB2	417	700	4	2141	x		CB4	450	2000	4	2377	x	
CB2	417	1000	5	2142	x		CB4	450	2500	5	2378	x	
CB2	417	bottom	6	2143	x		CB4	450	3000	6	2379	x	
CB2	421	10	1	2204			CB4	456	15	1	2459		x
CB2	421	58	2	2205		x	CB4	456	71	2	2460		x
CB2	421	140	3	2206		x	CB4	456	220	3	2461		x
CB2	421	400	4	2207		x	CB4	456	350	4	2462		x
CB2	421	800	5	2208		x	CB4	456	500	5	2463		x
CB2	421	1200	6	2209		x	CB4	456	1000	6	2464		x
CB3	432	10	1	2260	x		CB4	463	1500		2492		
CB3	432	58	2	2261	x		CB4	463	2000		2493		
CB3	432	180	3	2262	x		CB4	463	2500		2494		
CB3	432	250	4	2263	x		CAA8	467	15	1	2542	x	
CB3	432	480	5	2264	x		CAA8	467	90	2	2543	x	
CB3	432	600	6	2265	x		CAA8	467	150	3	2544	x	
CB3	439	1000	1	2332	x		CAA8	467	250	4	2545	x	
CB3	439	1400	2	2333	x		CAA8	467	450	5	2546	x	
CB3	439	2000	3	2334	x		CAA8	467	bottom	6	2547	x	
CB3	439	2000	4	2335		x	CAA8	470	15	1	764		x
CB3	439	2500	5	2336	x		CAA8	470	45	2	765		x
CB3	439	2500	6	2337		x	CAA8	470	90	3	766		x
							CAA8	470	250	4	767		x
							CAA8	470	450	5	768		x
							CAA8	470	bottom	6	769		x

5.1.6 Anthropogenic Uranium, Iodine, and Cesium Analysis in the Arctic Ocean

Principle Investigator: Jack Cornett
Cruise Participant: Daniel Sauvé

Department of Earth Sciences, University of Ottawa

Background / summary

There are two basic tracer applications of radionuclides ^{129}I and ^{137}Cs in the Arctic Ocean:

(1) Measurements of ^{129}I and ^{137}Cs, separately provide evidence for Atlantic-origin water labeled by discharges from European reprocessing plants; and

(2) Measurements of ^{129}I and ^{137}Cs, together can be used to identify a given year of transport through the Norwegian Coastal Current (NCC) thereby permitting the determination of a transit time from the NCC to the sampling location (Smith et al., 1998).

(3) Recently the use of ^{236}U released from nuclear reprocessing plants in France and the UK has been proposed as a potential label for Atlantic Sea Water entering the Arctic. (Christl et al., 2012)

Sampling/Methodology

^{137}Cs:

Sea water samples were collected from multiples depths at stations CB 1 through 4 and placed in 20L cubitainers for further workup. Samples were acidified using 25ml of concentrated nitric acid to reduce the pH to 1 to 2 and around 4g of ammonium molybdophosphate (AMP) was added as a Cesium sorbent. The supernatant was then removed and stored for later use and the AMP was collected and stored for later analysis at the University of Ottawa via gamma spectrometer.

^{129}I:

Samples were collected in 1L and 500mL Nalgene bottles based on availability and stored for transport back to the University of Ottawa where the Iodine will be extracted and analyzed on the new Accelerator Mass Spectrometer (AMS) for ^{129}I concentration. Samples were collected from stations CB 2-4 as well as from CAA7.

^{236}U:

20L samples were collected from the same stations and depths as for 137Cs and stored in 20L cubitainers. The water was then acidified using 25mL of concentrated nitric acid, after which 100 Furthermore the left over supernatant from the ^{137}Cs samples was used to extract U. As the water was already acidic from the ^{137}Cs samples no more acid was added, 1000fg of ^{233}U spike was added to the samples as a yield tracer. 10ml of 45mg/ml ferric chloride was then added to act as a sorbent for uranium. The samples were then bubbled with nitrogen gas for approximately 25 minutes to remove carbonate from the sample as ferric chloride preferentially sorbs carbonates before uranium. After bubbling 30ml of Ammonium Hydroxide was added to raise the pH of the sample to 9 to precipitate the ferric chloride and sorb the uranium to it. Samples were left to settle overnight and afterwards the supernatant was discarded and the precipitate was collected for later analysis via AMS at the University of Ottawa.

Preliminary Results

On this cruise a slightly different methodology was used in terms of using 20L cubitainers for sample storage and chemistry work. On previous cruises plastic bag lined buckets were used for storage and chemistry work. It seems that the method of using cubitainers for this work is much more efficient than the previously used bucket method and will continue to be used for future work as it seems much more of the precipitate can be collected much more conveniently than the previous methodology.

User Experience

I found my experience aboard the Amundsen to be one of the best of the cruises I have participated on. I found the sampling process to be pain free and had adequate space for my work. I found the crew easy to work with as well as friendly and willing to help along with my fellow scientific staff. I found that the science meetings were informative in keeping up with current operations and that changes in the plan were clearly posted and updated regularly. The food was also some of the best I have had on a coast guard ship, my compliments to the chefs.

a) The process to gain access to the vessel and request ship time for our team's project was clear and easy to follow.
5. Very satisfied
b) The annual Amundsen expedition was effectively planned and organized (e.g., planning meeting, vessel scheduling, dissemination of information, mobilization, etc.).
5. Very satisfied
c) The Amundsen's central pool of equipment (e.g., scientific winches, CTDRosette system, MVP system, onboard laboratories, sonars, piston corer, Remotely Operated Vehicle, etc.) was properly maintained and operational at sea.
5. Very satisfied
d) Safety in the workplace (i.e. were you satisfied with the overall safety of the science operations conducted on and from the Amundsen?)
5. Very satisfied
e) What is your overall level of satisfaction regarding your experience conducting research on board the Amundsen this year?
5. Very satisfied

References

Smith, J.N., Ellis, K.M. and Kilius, L.R. 1998. 129I and 137Cs tracer measurements in the Arctic Ocean. Deep-Sea Research I. 45(6):959-984.

Christl, M., Lachner, J., Vockenhuber, C., Lechtenfeld, O., Stimac, I., van der Loeff, M. R., & Synal, H.-A. (2012). A depth profile of uranium-236 in the Atlantic Ocean. *Geochimica et Cosmochimica Acta*, *77*, 98–107. doi:10.1016/j.gca.2011.11.009

5.1.7 Measurement of pH, alkalinity, δ^{13}C-DIC, δ^{18}O-water

Principal Investigator: Alfonso Mucci
Cruise Participants: Constance Guignard

Department of Earth & Planetary Sciences, McGill University

Introduction

Since the beginning of the industrial period in the late 18th century, humans have emitted large quantities of CO_2 into the atmosphere, mainly as a result of fossil-fuel burning, but also because of changes in land-practices (e.g., deforestation). Whereas atmospheric concentrations oscillated between 180 and 280 ppm over much of the past 400,000 years, current atmospheric concentrations have now reached 403 ppm, diverging wildly from the very reproducible, eleven last glacial-interglacial cycles. Hence, it is hard to argue that anthropogenic activities are unrelated to this increase in atmospheric CO_2 concentration and the associated rise in global temperatures.

The impact of climate change is disproportionately large in the high latitudes. Rapid warming in the northern polar region has resulted in significant glacial and sea-ice melt, affecting the fresh water budget and circulation of the Arctic Ocean and feeding back on Earth's radiation balance. Likewise, the uptake of anthropogenic CO_2 is accelerated in high latitude waters because the solubility of CO_2 in water increases with decreasing water temperature and salinity. Consequently, high latitude waters are more susceptible to ocean acidification.

Objectives-

A study of large-scale processes that modulate the spatial and temporal variability of the pH in surface waters, the pCO_2 gradient at the air-sea interface, and exchange of CO_2 with sub-thermocline waters and across oceanic basins. In addition to measurements of carbonate parameters (pH, TA), the stable carbon isotope composition, $\delta^{13}C(DIC)$, of dissolved inorganic carbon (DIC) will be determined to differentiate between inorganic (atmospheric CO_2 uptake, alkalinity exclusion, ikaite precipitation/ dissolution) and metabolic processes (photosynthesis, microbial degradation of allochtonous and autochtonous organic matter) in the ice and water column to CO_2 exchange. These results will be combined with historical data acquired since 2003 (i.e., CASES, IPY-CFL, IPY-Geotraces, Malina) to construct time-series of the saturation state of the waters with respect to aragonite in order to evaluate the impact of increasing atmospheric CO_2 concentrations, physical and biological processes on Arctic water acidification.

In order to elucidate the role physical mixing of various source waters, the stable oxygen isotope composition, $\delta^{18}O(H_2O)$, of water will be combined to other conservative (e.g., S_P, T, TA) and non-conservative tracers (e.g., O_2, Ba, nutrients) to quantify the relative contribution of freshwater inputs (river, sea-ice melt, snow and glacier melt) and oceanic water masses (Pacific, Atlantic) to the vertical structure of the water column and the transfer of heat, salt and carbon between the North Pacific and North Atlantic through the Canadian Arctic Archipelago. Results of this water mass analysis will also serve as a template for the interpretation of the distribution of trace elements and their isotopes that are measured by other researchers involved in the Geotraces program.

Sampling and analytical methods

pH samples (list in annexe 1) were collected from the rosette using a rubber tube and stored in LDPE 125 ml bottles. While sampling the Niskin bottle, with a low water flow, the air was carefully removed from the sampling tube which was held at the bottom of the bottle. The water was then allowed to overflow at about the same volume as the bottle before the tube was slowly removed from it, in order to leave enough water at the neck of the bottle to avoid having air inside while putting the cap on or having as little air as possible. The bottle was then closed air tight. The samples were, right after the sampling, equilibrated at 25 C, in a Digital One Rte 7 temperature controlled water bath, and analyzed immediately by colorimetry, using a UV-VIS spectrophotometer, model HP 8453 from Agilent Technology, using two pH indicators: phenol red and cresol purple. The sample was poured in a 50 mm quartz cell and used to measure the blank. Absorbance measurements were taken after adding the pH indicator to the sample. The method is described in Baldo, Morris and Byrne (1985) and in Clayton and Byrne (1993). TRIS buffers, prepared in our laboratory with the method described in Millero & al (1993), of salinities 35 and 25 were used to calibrate the spectrophotometer.

Alkalinity analyses were performed by titration, using an automatic titrator, model TTT865 titration manager, titralab, from Radiometer Analytical. The samples were collected from the Niskin bottles, using a rubber tube, and, stored in 250 ml glass bottles. They were poisoned, right after they were collected, with 250 microliters of a mercuric chloride saturated solution as a preservative. Apiezon grease was put on the glass stoppers before closing the bottles and they were then clipped to keep them air tight. The samples were equilibrated at 25 C in a Digital One Rte 7, controlled temperature water bath, and then, titrated with a 0.03N hydrochloric acid solution. The titrant was standardized using Dickson water, which is a reference material for oceanic CO2 measurements, and also a reference for alkalinity measurements. The reference material was purchased from Scripps Institution of Oceanography, in La Jolla, California, USA. Samples, even though poisoned, were analyzed no more than two days after they were collected.

Samples for O18 and C13 were also collected. The C13 samples were collected in 30ml amber glass bottles and poisoned with mercuric chloride for preservation. The O18 samples were collected in 13 ml plastic test tubes with no special treatment. Those samples will be analyzed at Geotop, UQAM further in time.

Notes

Since the beginning of leg 2, a new identification system for sample, proper to this mission, has been implemented, with the adding of event numbers and a number assigned to each sample. However made with the best of intentions, this system became a source of extra work for me, along with many participants, without, at the end, proving of being of any benefit to us, and, at the same time, making the access to the needed information more difficult. Its rigidity made any correction to the pre-cast rosette sheets quite confusing, since the sample numbers, and, sometimes event numbers, were automatically changed every time a correction was made, and the participants who had already prepared their sampling bottles had to redo it.

For my data handling, I need the information provided by the bottle files, which are identified by the number of the rosette cast. A file containing the correspondence between the event numbers and the actual cast numbers was supposed to be made, but, at the end, was not, so I had to take the time to get the information myself as I had to do at the end of leg 2.

The geochem rosette sheets final redaction, which is usually the rosette operator's task, was undertaken by someone else for the purpose of including them in a big file along with a lot of other data. However, because of the overload of work, the file stopped being updated after station LS2 during leg 2. At the end of leg 3b, we still do not have that file, so, we still do not have access to the updated geochem rosette sheets of leg 2. Therefore, it might have been best to leave the redaction of the rosette sheets to the rosette operator; this would not have stopped the redaction of that file and the participants would have had access to completed rosette sheets right away.

As I mentioned earlier in the report, I need the data included in the bottle files in order to complete my data entries. It appears that there is no such information available for the deep casts that were done with the TM rosette. The files resulting of those casts still have to be processed in order to produce the bottle file we need.

I was approached, at the end of leg 2, with a request to perform the oxygen titrations for leg 3b. I had to decline, having been given more than a full task by my supervisor. I believe that the issue of not having anyone responsible O2 analysis should have been discussed at the ArcticNet meeting last winter, since it was known back then, and someone should have been found prior to the cruise; otherwise, there is always the risk that no one on board has enough time to take the task, as luck lasts only for so long.

Table 5.1.7.1 Sampling depths

Station	**Position**		**Depths sampled (m)**
	Lat(N)	**Lon(W)**	
CB1	75^{o} 6.412	120^{o} 31.113	Bot, 300, 200, 100, 75, 60, 50, 45, 25, 10, Surface
CB2	75^{o} 48.261	129^{o} 13.941	Bot, 1000, 800, 600, 400, 300, 200, 140, 100, 75, 65, 58, 40, 25, Surface
CB3	76^{o} 59.930	140^{o} 2.892	3500, 3000, 2500, 2000, 1500, 1200 1000, 800, 600, 480, 300, 180, 100, 75, 58, 40, 25, Surface
CB4	75^{o} 0.013	149^{o} 59.838	3500, 3000, 2500, 2000, 1500, 1200 1000, 800, 600, 500, 400, 300, 220,

			100, 75, 71, 50, 25, 10, Surface
314	68° 58.174	105° 28.910	Bot, 60, 10, Surface
QMG4	68° 28.969	103° 25.490	Bot, 60, 50, 40, 30, 20, 10, Surface
QMG	68° 14.757	101° 43.023	Bot, 70, 50, 30, 20, 10, Surface
QMG1	68° 29.753	099° 53.441	Bot, 20, 10, Surface
312	69° 10.322	100° 41.489	Bot, 40, 10, Surface
310	71° 27.345	101° 16.910	Bot, 100, 70, 50, 30, 20, 10, Surface
CAA8/308	74° 8.375	108° 50.358	Bot, 450, 300, 200, 100, 75, 65, 50, 40, 25, 14, 10
307	74° 6.762	103° 7.614	Bot, 200, 100, 70, 50, 30, 20, 10, Surface
342	74° 47.653	092° 46.882	Bot, 100, 70, 50, 30, 20, 10, Surface
CAA9	76° 19.943	096° 45.641	Bot, 200, 90, 70, 50, 40, 30, 17, 10, Surface

5.1.8 Ocean Carbonate Chemistry* and Boundary Exchange Tracers: Dissolved Inorganic Carbon, Alkalinity, Radium Isotopes, and Dissolved Barium

Principle Investigator: Helmuth Thomas
Cruise Participants: Jacoba Mol

Department of Oceanography, Dalhousie University

*Ocean carbonate chemistry was carried out in collaboration with Dr. Alfonso Mucci and Constance Guignard, McGill University, Montreal, QC, Canada

Objectives:

a: One of the primary objectives is to characterize the marine carbonate system at the stations sampled during the GEOTRACES expedition. Dissolved inorganic carbon (DIC) and Alkalinity (A_T) have been chosen, since for these two parameters certified reference materials are available, which are used internationally to warrant world class quality and comparability in time and space of the data. From these parameters, all relevant species of the carbonate system can be computed, anchored to the reference material. The data will be used to investigate carbonate system and pH conditions in dependence of water masses encountered at the various stations. In particular attention is devoted to the spreading of the water mass, originating from the Pacific Ocean, which is channelled through the Canadian Arctic Archipelago via different routes. Furthermore the data complement data from earlier expedtions into the region, e.g., CFL and ArcticNet, carried out by Dr Mucci's and Dr Miller's groups, which will facilitate investigations of the spatiotemporal variability of the carbonate system and ocean acidification (see for example Shadwick et al., 2013, 2011a, b).

b: Radium isotopes can be used as a tracer for exchanges of matter across the sediment-water (i.e. vertical) and the land-ocean (horizontal) boundaries (e.g. Burt et al., 2013, 2014). At selected stations within the Canadian Arctic Archipelago we determined Ra activities in the deep water column, with a spacing of 5-10m between the samples, as well as at mid-depths and in the surface waters. Lateral gradients in the surface waters, as well as vertical gradients above the seafloor and throughout the water column, if observed, will allow us to establish lateral and vertical diffusion coefficients, which in turn will be used to obtain diffusive transports of, for example, carbonate system species, nutrients or oxygen. We further will explore, by sampling of the mid-depths water column, whether the distribution of the long-lived isotope ^{228}Ra can be used to shed light on the different spreading routes of the different water masses throughout the Canadian Arctic Archipelago.

c: Ba is mainly released from the North American continent and can therefore be used as a tracer for terrestrial freshwater input as well as a tracer for export production (e.g., Thomas et al., 2011). Together with A_T and ^{18}O, tracers for different freshwater sources (rivers, precipitation, ice melt), all freshwater sources to the Arctic can be quantified.

Methods

a: Rosette sampling for DIC, A_T and Ba was conducted in vertical profiles at all stations as shown in Table 1. DIC and A_T were analyzed onboard using a dual VINDTA 3C system. In case of a longer delay (>12hours) between sampling and analysis, samples were poisoned with 250µl saturated $HgCl_2$ solution. DIC was determined by coulometric titration and A_T by potentiometric titration from the same sample simultaneously. Details are provided for example by Shadwick et al. (2011a).

b: Ra isotopes were collected onto MnO_2-coated acrylic fibers from surface waters (5 m) at 14 stations as shown in Table 1. Water column samples were taken from the rosette at 10 stations, with near-bottom vertical profiles and mid-depths samples, four depths in total, and one surface water sample. For surface samples, the sample volume of individual samples was between 200L and 210L, for roestte samples between 100L and 130L. ^{224}Ra and ^{223}Ra activities were obtained using the Radium Delayed Continuous Counting system (RaDeCC) system. All samples were initially counted within 2 days of sample collection to avoid significant ^{224}Ra and ^{223}Ra decay. Samples need to be recounted between 7-13 days after collection to determine activities of supported ^{228}Th and ^{227}Ac, which is then subtracted to obtain excess ^{224}Ra and ^{223}Ra activities. Following ^{224}Ra and ^{223}Ra analysis, fibers have to age for > 36 months before recounting on the RaDeCC. After this aging time, a significant amount of the original ^{228}Ra will have decayed to ^{228}Th, and the ^{228}Ra -^{228}Th and ^{228}Th-^{220}Rn isotope pairs will have reached secular equilibrium. Therefore, recounting fibers on the RaDeCC yields the extent of ^{228}Th in growth, which, using the various decay constants, can be used to back calculate for the activity of ^{228}Ra at the time of sampling. More detailed methods for Ra isotope collection and analysis of ^{224}Ra and ^{223}Ra are described by Burt et al. (2013, 2014), or originally Moore (1987) and Moore and Arnold (1996).

c: Samples for dissolved Ba were taken from the rosette parallel to samples for DIC and A_T. 30 ml nalgene bottles were rinsed three times, then filled and spiked with 15 µl concentrated HCl. Sample bottles were sealed with parafilm and taken for later analysis using isotope dilution mass spectrometry (see for details Thomas et al., 2011).

Table 5.1.8.1: Station locations and sample dates for dissolved inorganic carbon (DIC), alkalinity (A_T), barium, and radium isotope samples. DIC, A_T and Ba were sampled at every station. Radium samples were taken at the highlighted stations only.

Station	**Latitude**	**Longitude**	**Date Sampled**
405	70.60784	-123.03556	23 August 2015
407	71.01118	-126.08194	24 August 2015
437	71.79826	-126.50489	24 August 2015
412	71.56200	-126.92322	25 August 2015
408	71.30816	-127.59881	25 August 2015
418	71.16352	-128.17146	25 August 2015
420	71.05261	-128.51243	25 August 2015
434	70.17700	-133.55449	26 August 2015
432	70.39444	-133.60216	26 August 2015
435	71.07918	-133.63572	27 August 2015
428	70.79157	-133.68736	29 August 2015
421	71.42792	-134.00774	30 August 2015
535	73.41236	-128.17610	31 August 2015
518	74.57194	-121.43702	2 September 2015
514	75.10320	-120.62944	2 September 2015
CB1	75.10674	-120.51954	7 September 2015
CB2	75.80416	-129.23238	9 September 2015
CB3	76.98976	-140.04842	13 September 2015
CB4	75.00033	-149.99513	15 September 2015
314	68.96948	-105.48184	20 September 2015
QMG4	68.48288	-103.42484	21 September 2015

QMG3	68.32940	-102.60620	21 September 2015
QMG	68.24598	-101.71696	21 September 2015
QMG2	68.31312	-100.79976	21 September 2015
QMG1	68.49356	-99.89056	22 September 2015
312	69.17210	-100.69153	22 September 2015
310	71.45578	-101.28309	23 September 2015
CAA8/308	74.13962	-108.83916	24 September 2015
342	74.79420	-92.78140	26 September 2015
CAA9	76.33238	-96.76082	27 September 2015

Preliminary Results
No results are available at this time.

User Experience
a) The process to gain access to the vessel and request ship time for our team's project was clear and easy to follow.
4. Satisfied
b) The annual *Amundsen* expedition was effectively planned and organized (e.g., planning meeting, vessel scheduling, dissemination of information, mobilization, etc.).
4. Satisfied
c) The *Amundsen's* central pool of equipment (e.g., scientific winches, CTDRosette system, MVP system, onboard laboratories, sonars, piston corer, Remotely Operated Vehicle, etc.) was properly maintained and operational at sea.
5. Very satisfied
d) Safety in the workplace (i.e. were you satisfied with the overall safety of the science operations conducted on and from the *Amundsen*?)
4. Satisfied
e) What is your overall level of satisfaction regarding your experience conducting research on board the *Amundsen* this year?
4. Satisfied

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5.1.9 Organic Chemistry of the Beaufort Sea and Arctic Archipelago *and* Identification of Marine Organic Cu^{2+} Ligands in the Arctic Ocean

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Introduction and Objectives
Expanding on previous work in the field (10-12), my MSc project focuses on structural characterization of low molecular weight organic compounds which form complexes with copper(II) in the marine environment. Samples collected during the GEOTRACES program aboard the CCGS Amundsen will support my efforts to extract small molecules with affinity for Cu^{2+} by immobilized metal-ion affinity chromatography for analysis by electrospray ionization mass spectrometry. I hope to produce data elucidating the structure of Cu(II) ligands, and moreover, correlative results relating the presence of such ligands to oceanographic and chemical features (eg. depth, algal productivity).

Copper(II) speciation in the marine environment is of biochemical interest as Cu^{2+} can act as both a nutrient and a toxicant: copper is a required cofactor for algae but becomes inhibitory to their growth at low levels (7). More than 99% of copper in the ocean is organically complexed, unable to exert toxic effects as only free cupric ions are readily bioavailable (1,2). Numerous studies have identified two broad classes of marine copper-binding ligands, a high-affinity low-concentration surface-water class, L_1, and a moderate-affinity high-concentration depth-invariant class, L_2 (1-5). Correlative data have related the concentration of L_1-type ligands as coincident with maxima in primary production (4,5) while algal culturing studies have demonstrated biogenic ligand exudation (6,7,9). Developing a full understanding of marine copper speciation represents an important facet of oceanographic biology, with critical implications for aquaculture and remediation efforts.

A lucid understanding of organic copper speciation could be of great ecological benefit on a local or global scale, but despite decades of study, no groups have published data confirming the structural identity of marine copper-binding ligands. With the looming threat of ocean acidification (and concomitant rise in Cu^{2+}), anthropogenic methods of sequestering free cupric ions may become necessary to protect aquatic ecosystems. Marine cupric ion levels (currently around 1pM) are expected to increase 30% by 2100 (8), which poses an aquacultural risk as fish are unable to detoxify metal ions taken up through the gills and an ecological risk in the form of depleted algae populations. Studies into copper speciation are a step towards a sustainable future for our oceans; the GEOTRACES program offers a rare opportunity to develop our understanding of this important but understudied biogeochemical enigma.

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Operations conducted during Leg 3B

Hansell – **DOC** – *Table 1*

1x60mL samples were collected by the TM team in amber vials (rinsed thrice with sample water) at select depths from the TM rosette, no filtration. Stored at 4ºC in the heli-deck fridge (tote 3).

Gueguen – **CDOM** – *Table 1*

1x60mL samples were collected by the TM team in amber vials (rinsed thrice with sample water) at each selected depth from the TM rosette. Samples were filtered by gravity filtration through a capsule filter for all depths 200m and shallower. Samples at depth greater than 200m were not filtered. Samples stored at 4ºC in the heli-deck fridge (tote 3).

Gueguen – **Thiols** – *Table 1*

2x60mL samples were collected by the TM team in amber vials (rinsed thrice with sample water) at each selected depth from the TM rosette. Samples were gravity filtered through a capsule filter for all depths 200m and shallower. Samples at depth greater than 200m were not filtered. All samples were acidified with 50µL 10N HCl before storage at 4ºC in the heli-deck fridge (tote 2).

Table 5.1.9.1. Samples taken for DOC (Hansell), CDOM and thiol (Gueguen) analysis. UTC-5 time. Event 402/406 are recorded on labels as 202/206. Coordinates given are when cast began.

Depth	**Gofl o**	**Samp le**	**Stati on**	**Event info**	**Depth**	**Gofl o**	**Samp le**	**Stati on**	**Event info**
Tmin	1	2019		402 - Sept	Tmin	1	2344		446 – Sept
Tmax	3	2021		7	150m	3	2346		14
Chlmax	5	2023		TM rosette	Tmax	5	2348		TM rosette
Partmax	8	2026	**CB-1**	1652h - 1710h	Chlmax	6	2349		1647h - 1712h
10m	10	2028		75.06.80N 120.38.51	10m	10	2353		74.59.81N 150.00.08

				W
400m	1	2060		406 – Sept 7
350m	3	2062		TM rosette
300m	5	2064		2208h -
250m	8	2067		2225h 75.07.04N
200m	9	2068		120.37.89
150m	11	2070		W
200m	1	2126		416 – Sept 9
Tmin	3	2128		TM rosette
Tmax	5	2130	**CB-2**	2027h - 2056h
Chlmax	9	2134		75.48.88N 129.13.16
10m	10	2135		W
1200m	1	2168		
1000m	3	2170		419 – Sept 10
800m	5	2172		TM rosette
400m	6	2173		0315h -
300m	8	2175		0413h
100m	9	2176		75.47.91N
40m	10	2177		129.14.82
25m	11	2178		W
200m	1	2248		431 – Sept 11
Tmin	3	2250		TM rosette 1700h -
Tmax	5	2252	**CB-3**	1719h
Chlmax	6	2253		76.58.828N
10m	10	2257		140.02.279W
1400m	1	2284		
1000m	3	2286		434 – Sept 12
800m	5	2288		TM rosette

				W
1400m	1	2362		448 – Sept
1000m	3	2364	**CB-4**	15 TM
800m	5	2366		rosette
Tmax2	6	2367		0020h - 0406h
300m	8	2369		74.00.168
100m	10	2371		N
40m	12	2373		150.00.017W
3500m	1	2380		
3000m	3	2382		451 – Sept 15
2500m	5	2384		TM rosette
2000m	6	2385		0734h - 0951h
1600m	8	2387		75.00.11N 150.00.01
1200m	9	2388		W
600m	10	2389		
250m	2	2390		
150m	12	2391		
Tmin	2	2531		466 – Sept 23
Tmax	4	2533		TM
Chlmax	5	2534		rosette
Partmax	8	2537	**CAA-8**	2228h - 2248h
10m	10	2539		74.08.31N 108.50.39 W
450m	1	2572		
350m	3	2574		469 – Sept 24
300m	5	2576		TM rosette
250m	7	2578		0432h - 0506h
200m	8	2579		74.08.34N 108.50.19
150m	10	2581		W

Tmax 2	6	2289		0021h - 0125h	120m	12	2583		
300m	8	2291		76.59.477 N	Tmin	1	2638		481 – Sept 27
100m	10	2293		140.01.90 W	Tmax	4	2641		TM rosette
40m	12	2295			Chlmax	5	2642	**CAA-9**	0002h - 0016h
3500m	1	2356			Partmax	8	2645		76.20.006 N
3000m	3	2358		444 – Sept 13	10m	10	2647		96.45.206 W
2500m	5	2360		TM rosette	Bottom	1	2669		485 – Sept 27
2000m	6	2361		0433h - 0643h	250m	3	2671		TM rosette
1600m	8	2363		76.59.60N 140.04.26 W	200m	5	2673		0500h - 0523h
1200m	9	2364			150m	8	2675		76.19.82N 96.45.40 W
600m	10	2365			120m	12	2678		
250m	2	2357							
150m	12	2367							

Gueguen – underway – *Table 2*
60mL samples were collected approximately three times per day in amber vials (rinsed thrice with sample water), no filtration, from the underway sampling system in the engine room. Samples stored at 4ºC in the heli-deck fridge (tote 4).

Table 5.1.9.2. Underway samples collected for Gueguen. Data for time sampled is correct (UTC-5) but coordinates were unavailable at the source and reflect our location 3 minutes after sampling.

Loop	**Latitude (deg N)**	**Longitude (deg W)**	**Date and time**	**Loop**	**Latitude (deg N)**	**Longitude (deg W)**	**Date and time**
51	73.51.493	129.44.686	Sept 5 – 1448hrs	*88*	71.04.613	134.30.720	Sept 17 – 2003hrs
52	74.06.494	127.44.030	Sept 5 – 2100hrs	*89*	71.25.737	131.02.692	Sept 18 – 0058hrs
55	75.05.972	120.30.876	Sept 6 – 2351hrs	*90*	70.50.992	124.49.874	Sept 18 – 1309hrs
56	75.05.719	120.33.251	Sept 7 – 0515hrs	*91*	70.06.083	120.26.732	Sept 18 – 2001hrs
57	75.06.816	120.21.993	Sept 7 – 1242hrs	*92*	69.42.905	118.16.922	Sept 18 – 2353hrs
58	75.06.878	120.38.544	Sept 7 – 1612hrs	*93*	68.01.916	114.28.767	Sept 19 – 1349hrs

59	75.07.003	120.42.472	Sept 7 – 2129hrs
60	75.19.193	127.46.720	Sept 8 – 1326hrs
61	75.49.179	129.12.945	Sept 8 – 1850hrs
62	75.48.768	129.13.571	Sept 8 – 2345hrs
63	75.49.384	129.13.526	Sept 9 – 0905hrs
64	75.53.154	129.20.240	Sept 9 – 1126hrs
65	76.07.196	129.19.576	Sept 9 – 1830hrs
65	75.51.080	129.25.558	Sept 10 – 0106hrs
66	76.165.053	129.06.093	Sept 10 – 1526hrs
67	75.52.933	128.53.788	Sept 10 – 1842hrs
68	75.53.151	131.14.382	Sept 10 – 2358hrs
69	76.27.700	136.58.950	Sept 11 – 0826hrs
70	76.44.819	138.34.170	Sept 11 – 1216hrs
71	76.58.789	140.01.635	Sept 11 – 1826hrs
72	76.58.501	140.02.970	Sept 11 – 2142hrs
73	76.59.445	139.56.474	Sept 12 – 0426hrs
74	77.00.179	140.05.035	Sept 12 – 1154hrs
75	77.01.662	140.02.541	Sept 12 – 1730hrs
76	76.59.920	140.00.242	Sept 13 – 0714hrs
77	75.44.374	146.34.340	Sept 13 – 2014hrs
78	75.03.625	149.18.680	Sept 14 – 1342hrs
79	75.00.007	150.00.411	Sept 14 – 2044hrs
80	74.59.983	149.59.968	Sept 14 – 2315hrs
94	68.12.926	113.47.003	Sept 19 – 1901hrs
95	68.28.362	111.20.733	Sept 19 – 2337hrs
96	69.01.861	106.22.022	Sept 20 – 0913hrs
97	68.35.771	103.55.350	Sept 20 – 1905hrs
98	68.29.485	103.24.125	Sept 20 – 2322hrs
99	68.13.430	101.44.417	Sept 21 – 1317hrs
100	68.18.720	100.47.965	Sept 21 – 1913hrs
101	68.29.565	99.53.700	Sept 21 – 2345hrs
102	69.05.290	101.00.047	Sept 22 – 0811hrs
103	69.53.160	99.28.594	Sept 22 – 1610hrs
104	71.16.678	100.38.567	Sept 22 – 2350hrs
105	72.53.760	103.10.612	Sept 23 – 1152hrs
106	74.05.283	107.50.828	Sept 23 – 2004hrs
107	74.08.313	108.50.178	Sept 23 – 2352hrs
108	74.08.343	108.49.972	Sept 24 – 0732hrs
109	74.08.294	108.50.209	Sept 24 – 1212hrs
110	74.08.902	108.52.121	Sept 24 – 1729hrs
111	74.06.662	103.59.516	Sept 25 – 0118hrs
112	74.14.190	97.45.442	Sept 25 – 1251hrs
113	74.31.767	93.26.343	Sept 25 – 1850hrs
114	74.47.584	92.46.142	Sept 26 – 0014hrs
115	75.20.177	93.22.934	Sept 26 – 0952hrs
116	76.19.777	96.44.226	Sept 26 – 2021hrs

81	75.00.055	149.59.946	Sept 15 – 0845hrs	*117*	76.25.464	96.27.296	Sept 27 – 0707hrs
82	74.59.803	150.02.202	Sept 15 – 1510hrs	*118*	76.38.595	96.56.426	Sept 27 – 0951hrs
83	74.59.748	149.59.424	Sept 15 – 2057hrs	*119*	76.08.067	95.50.125	Sept 27 – 1837hrs
84	75.00.209	149.57.432	Sept 16 – 0940hrs	*120*	75.37.176	94.09.676	Sept 28 – 0420hrs
85	74.44.794	148.56.746	Sept 16 – 1627hrs	*121*	75.41.864	95.01.495	Sept 28 – 1752hrs
86	74.11.846	146.38.272	Sept 16 – 2332hrs	*122*	75.36.726	93.47.536	Sept 29 – 0107hrs
87	71.46.086	138.20.942	Sept 17 – 1345hrs	*123*	75.22.573	92.40.263	Sept 29 – 0656hrs

Varela – **bSiO2 and δ^{30}Si(OH)$_2$** – *Table 5.1.9.3*

4L (+/-100mL) samples were collected in plastic jugs (rinsed once with 1.2N HCl, thrice with ultrapure water, and thrice with sample water) and stored at 4ºC until filtration. Funnels and collection flasks were rinsed once with 1.2N HCl and thrice with ultrapure water before inserting a 0.6μm filter into each of four parallel channels of the vacuum filtration apparatus. 50mL of initial flow-through was collected in clean centrifuge tubes, while the next 100mL was used to rinse collection flasks. All further filtrate (~3L per depth) was collected and stored along with 50mL tubes at 4ºC in the heli-deck fridge. Filtrate containers were rinsed once with filtrate. Filters were folded with clean forceps (rinsed once with acid, thrice with ultrapure water between each sample), placed in 15mL centrifuge tubes, and dried in a ~55ºC oven for at least 48 hours.

Table 5.1.9.3. Samples taken for $bSiO_2$ and $\delta^{30}Si(OH)_2$ (Varela). Note that event 404 is recorded on labels as event 204.Coordinates given reflect position when each rosette was cast. UTC-5 time.

Depth	Bottle	Sample	Event info	Vol	Time filtered
400m	2	2038			
350m	3	2039	Stn CB-1		Sept 7 1100h
300m	4	2040	AN rosette		
250m	5	2041	Event 404		
200m	7	2043	Sept 6	4L	Sept 7 1330h
150m	10	2046	2235h-2338h		
Tmin	14	2050	75.06.41N		Sept 7 0300h
Tmax	15	2051	120.31.10W		
Chlmax	19	2055			
10m	22	2058			
Bottom	1	2144			Sept 9 2330h
1200m	3	2146	Stn CB-2		
800m	5	2148	AN rosette		Sept 9 1900h
400m	8	2151	Event 418		
200m	11	2154	Sept 9	4L	

Tmin	14	2157	0122-0254h		
Tmax	18	2161	75.48.466N		Sept 9 0500
Chlmax	19	2162	129.14.073W		
25m	22	2165			
1400m	2	2297			
800m	5	2300	Stn CB-3		Sept 14 1905h
Tmax2	7	2302	AN rosette	4L	
250m	10	2305	Event 436		
200m	11	2306	Sept 13		Sept 13 1615h
Tmin	13	2308	0805h-0934h	2.1L	
100m	16	2311	76.59.42N		Sept 13 1120h
Chlmax	19	2314	140.02.61W	4L	
25m	22	2317			
3500m	1	2320	Stn CB-3 Event 438; TM		
2500m	7	2326	rosette	4L	Sept 13 1615h
2000m	10	2329	Sept 12 1311h-1510h		
			76.59.94N 140.05.71W		
1400m	2	2412			Sept 15 2120h
800m	5	2415	Stn CB-4	4L	
Tmax2	7	2417	AN rosette		Sept15 1910h
Tmin	11	2421	Event 454	3.55L	
150m	14	2424	Sept 15		
100m	16	2426	0445h-0620h	4L	
Chlmax	19	2429	74.59.99N		Sept 15 1620h
25m	22	2432	149.59.43W	3.2L	
10m	23	2433		4L	
3500m	1	2435	Stn CB-4 Event 455; TM		
2500m	7	2441	rosette	4L	Sept 16 1915h
2000m	10	2444	Sept 16 0734h-0937h		
			75.00.03N 149.59.60W		
Bottom	1	2548			Sept 25 0015h
250m	13	2560	Stn CAA-8		
200m	14	2561	AN rosette		
150m	15	2562	Event 468		Sept 24 1745h
100m	16	2563	Sept 24	4L	
Tmin	17	2564	0325h-0421h		
Tmax	18	2565	74.08.348N		
Chlmax	20	2567	108.50.275W		Sept 24 0830
Partmax	22	2569			
10m	24	2571			
300m	4	2593	CAA-8; AN; 471; Sept 24 1005h-1054h	4L	Sept 25 0015h
Bottom	1	2650			Sept 27 1859h
250m	2	2651			(1759h)
200m	3	2652	Stn CAA-9		
150m	4	2653	AN rosette		Sept 27 0830h

120m	5	2654	Event 483		(0730h)
Tmin	6	2655	Sept 27	4L	
Tmax	7	2656	0032h-0116h		
Chlmax	11	2660	76.19.956N		Sept 27 0420h
Partmax	15	2664	96.45.679W		(0320h)
10m	16	2665			

Maldonado – **POC –** *Table 4*

Large volumes (~10L) of unfiltered seawater were collected in cubitainers (rinsed thrice with sample water) typically from the Amundsen rosette. Pre-combusted filters were placed, using ethanol-cleaned forceps, into each funnel of a vacuum filtration system with five parallel channels. POC was collected on filters; filtrate was discarded. Filtration continued until flow rate significantly decreased and/or brown colouration appeared on filters. Sample volumes measured with calibrated bottles; listed volume accounts for small spills and leftovers. Filters folded with ethanol-cleaned forceps and placed in tinfoil. Filters were stored at -20ºC, then dried at ~60ºC.

Table 5.1.9.4. Samples taken for POC analysis (Maldonado). Event 402 recorded as 202 on labels. Times given are UTC-5, coordinates given are when cast began.

Depth	**Bottle**	**Sample**	**Event info**	**Volume**	**Time filtered**
300m	4	2075	Stn CB-1	2830mL	
250m	5	2076	AN rosette	3750mL	Sept 7 1430h
200m	8	2079	Event 407	3230mL	
150m	13	2084	Sept 7	4160mL	
Tmax	19	2090	0115h-0158h	3180mL	Sept 7 0830h
Chlmax	20	2091	75.06.110N	2100mL	
10m	22	2093	120.33.842W	2080mL	
Tmin	2	2020	CB-1; TM rosette; 402	1275mL	
Partmax	9	2027	Sept 7, 1652h-1710h	2150mL	Sept 8 0000h
400m	2	2061	CB-1; TM rosette; 406	2000mL	
350m	4	2063	Sept 7, 2208h-2225h	2080mL	
1200m	3	2182		4200mL	
800m	6	2185	Stn CB-2	4100mL	Sept 9 2330h
400m	9	2188	AN rosette	5000mL	
200m	14	2193	Event 420	4220mL	
Tmin	15	2194	Sept 9	3120mL	
Tmax	20	2199	0445h-0553h	2040mL	
Chlmax	21	2200	75.48.50N	2020mL	Sept 9 0940h
25m	22	2201	129.11.80W	2120mL	
10m	23	2202		1695mL	
1400m	3	2268	Stn CB-3	4200mL	Sept 13 0945h
800m	4	2269	AN rosette	750mL	
200m	8	2273	Event 433	5100mL	
Tmin	11	2276	Sept 11	5200mL	
Chlmax	14	2279	2157h-2315h	4200mL	Sept 12 0040h
25m	15	2280	76.58.51N	2980mL	

10m	18	2283	140.03.09W	3050mL	
3500m	1	2338	CB-3; AN rosette; 441	5250mL	
2500m	6	2344	Sept 12 1812h-2022h	5150mL	Sept 13 0945h
2000m	12	2349	77.01.15N 140.05.702W	5200mL	
1400m	3	2394	Stn CB-4	3080mL	Sept 15 2115h
800m	4	2395	AN rosette	3140mL	
Tmin	10	2401	Event 452	3000mL	
Chlmax	14	2405	Sept 14 1947h-2053h	4200mL	Sept 14 2345h
25m	15	2406	75.00.13N	4060mL	
10m	18	2409	150.00.02W	4100mL	
150m	12	2391	CB-4; TM; 451; Sept 15	4090mL	Sept 15 2115h
3500m	1	2447	CB-4; TM; Event 457;	5200mL	
2500m	3	2449	Sept 16 1212h-1412h	6200mL	Sept 16 1845h
2000m	4	2450	75.00.33N 150.00.98W	5200mL	
Bottom	1-3	2548-50	Stn CAA-8; AN rosette	4150mL	
450m	4	2551	Event 468 – Sept 24	6175mL	Sept 24 0615h
350m	8	2555	0325h-0421h	6325mL	
Partmax	23	2570	74.08.31N 108.50.275W	2775mL	
300m	4	2593		2040mL	
250m	5	2594	Stn CAA-8	4125mL	Sept 24 2345h
200m	8	2597	AN rosette	4150mL	
150m	13	2602	Event 471 - Sept 24	6025mL	
100m	14	2603	1005h-1054h	6150mL	
Tmin	15	2604	74.08.32N	4200mL	Sept 24 1600h
Chlmax	20	2609	108.50.14W	4080mL	
10m	22	2611		3100mL	

continued on the following page

Bottom	4	2617	Stn CAA-9	3075mL	Sept 27 0800h
250m	5	2618	AN rosette	3100mL	(0700h)
200m	8	2621	Event 480	5010mL	
150m	13	2626	Sept 26	5160mL	
120m	14	2627	2213h-2246h	5175mL	Sept 27 0030h
Tmin	17	2630	76.19.93N	5220mL	
Chlmax	20	2633	96.44.69W	3850mL	
Tmax	8	2657	CAA-9; AN; Event 483	2870mL	
Partmax	12	2661	Sept 27 0032h-0116h	2675mL	Sept 27 0800h
10m	19	2668	76.19.956N 96.45.679W	2550mL	(0700h)

Maldonado – **Fe speciation** – *Table 5.1.9.5*

2x500mL clean bottles (rinsed thrice with sample water) were 90% filled by the TM team with gravity-filtered seawater from the TM rosette at each target depth. Samples stored at -20ºC in the chest freezer outside the aft lab.

Table 5.1.9.5. Samples taken for Fe speciation (Maldonado). Event 402 recorded as 202 on labels. Times given are UTC-5, coordinates given are when cast began.

Depth	Goflo	Sample	Station	Event info
Partmax	8	2026		Event 402 - Sept 7 - TM rosette
10m	10	2028	**CB-1**	1652h - 1710h 75.06.80N 120.38.51W
200m	9	2068		Event 406 – Sept 7 - TM rosette 2208h - 2225h - 75.07.04N 120.37.89W
200m	1	2126		Event 416 – Sept 9 - TM rosette
Chlmax	9	2134		2027h - 2056h
10m	10	2135	**CB-2**	75.48.88N 129.13.16W
100m	9	2176		Event 419 – Sept 10 - TM rosette
40m	10	2177		0315h - 0413h - 75.47.91N 129.14.82W
200m	1	2248		Event 431 – Sept 11 - TM rosette
Chlmax	6	2253		1700h - 1719h
10m	10	2257	**CB-3**	76.58.828N 140.02.279W
100m	10	2293		Event 434 – Sept 12 - TM rosette
40m	12	2295		0021h - 0125h - 76.59.477N 140.01.90W
Tmin	1	2344		Event 446 – Sept 14 - TM rosette
Chlmax	6	2349		1647h - 1712h
10m	10	2353	**CB-4**	74.59.81N 150.00.08W
100m	10	2371		Event 448 – Sept 15 - TM rosette
40m	12	2373		0020h - 0406h -74.00.168N 150.00.017W
Chlmax	5	2534		Event 466 – Sept 23 - TM rosette
Partmax	8	2537		2228h - 2248h
10m	10	2539	**CAA-8**	74.08.31N 108.50.39W
200m	9	2580		469 – Sept 24 - TM rosette 0432h - 0506h 74.08.34N 108.50.19W
Chlmax	5	2642		Event 481 – Sept 27 - TM rosette
Partmax	8	2645		0002h - 0016h
10m	10	2647	**CAA-9**	76.20.006N 96.45.206W
150m	8	2675		Event 485 – Sept 27 - TM rosette 0500h - 0523h - 76.19.82N 96.45.40W

Ross – **Ligands** – *Table 5.1.9.6*

4x1L clean bottles (rinsed thrice with sample water) were 90% filled by the TM team with seawater from the TM rosette at each target depth. At least 2L for each depth were gravity-filtered; additional volume was filtered depending on flow rates. Samples stored at -20ºC in the chest freezer outside the aft lab or the -20ºC stand-up freezer in the aft labs.

Table 5.1.9.6. Samples taken for Fe speciation (Maldonado). Event 402 recorded as 202 on labels. Times given are UTC-5, coordinates given are when cast began.

Depth	**Goflo**	**Sample**	**Station**	**Event info**
Chlmax	5	2023	**CB-1**	Event 402 - Sept 7 - TM rosette 1652h - 1710h 75.06.80N 120.38.51W
Chlmax	6	2024		
Partmax	8	2026		
10m	10	2028		
10m	12	2030		
200m	9	2068		Event 406 – Sept 7 - TM rosette 2208h - 2225h - 75.07.04N 120.37.89W
200m	1	2126	**CB-2**	Event 416 – Sept 9 - TM rosette 2027h - 2056h 75.48.88N 129.13.16W
Chlmax	8	2133		
Chlmax	9	2134		
10m	10	2135		
10m	12	2137		
100m	9	2176		Event 419 – Sept 10 - TM rosette 0315h - 0413h - 75.47.91N 129.14.82W
40m	10	2177		
200m	1	2248	**CB-3**	Event 431 – Sept 11 - TM rosette 1700h - 1719h 76.58.828N 140.02.279W
Chlmax	6	2253		
Chlmax	8	2255		
10m	10	2257		
10m	12	2259		
120m	9	2292		Event 434 – Sept 12 - TM rosette 0021h - 0125h 76.59.477N 140.01.90W
100m	10	2293		
40m	12	2295		
3500m	1	2356	**CB-4**	Event 444 – Sept 13 - TM rosette 0433h - 0643h - 76.59.60N 140.04.26W
2000m	6	2361		
Tmin	1	2344		Event 446 – Sept 14 - TM rosette 1647h - 1712h 74.59.81N 150.00.08W
Chlmax	6	2349		
10m	10	2353		
120m	9	2370		Event 448 – Sept 15 - TM rosette 0020h - 0406h 74.00.168N 150.00.017W
100m	10	2371		
40m	12	2373		
Chlmax	5	2534		Event 466 – Sept 23 - TM rosette 2228h - 2248h
Chlmax	6	2535		
Partmax	8	2537		

10m	10	2539	**CAA-8**	74.08.31N 108.50.39W
10m	12	2541		
200m	9	2580		Event 469 – Sept 24 - TM rosette 0432h - 0506h - 74.08.34N 108.50.19W
Chlmax	5	2642	**CAA-9**	Event 481 – Sept 27 TM rosette 0002h - 0016h 76.20.006N 96.45.206W
Chlmax	6	2643		
Partmax	8	2645		
10m	10	2647		
10m	12	2649		
150m	8	2675		Event 485 – Sept 27 - TM rosette 0500h - 0523h - 76.19.82N 96.45.40W

Preliminary results

The purpose of this voyage was strictly sample collection. No analyses were performed.

User Experience

A) 5 – B) 4 – C) 5 – D) 5 – E) 5

General comments: A wholly enjoyable experience, the Amundsen crew and science team were professional and friendly. For the entire duration I felt well-accommodated and safe. The only change I could recommend is to have water budgets fleshed out sooner, although I recognize doing so may present logistical challenges which cannot be overcome. This was my first time aboard a research vessel and I am eager to repeat the experience soon.

Personal comment: The amount of research I was responsible for exceeded reasonable scheduling. I strongly recommend against allotting future scientists this sampling scheme.

5.1.10 Aerosol sampling: Measurement of atmospheric fluxes of trace elements and isotopes in the Canadian Basin and the Canadian Arctic Archipelago during CCGS Amundsen 2015 Leg 3b

Principal Investigators: Bridget Bergquist
Cruise Participants: Priyanka Chandan

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Introduction and Objectives:

Atmospheric aerosol deposition is considered an important pathway for the input of nutrients and trace metal loads to the open ocean waters via dry and wet deposition processes (Macdonald et al. 2005; Mahowald et al. 2005; Morton et al. 2013; Zhan and Gao, 2014). In the atmosphere, the trace elements are associated with aerosol particles such as mineral dust, soot, volcanic ash, organic particles, sea salt crystals, bacteria and microscopic particles, from both natural and anthropogenic sources (Duce et al. 1991;

Duce, 2005; Witt et al. 2006, Landing and Payton, 2010). The wet and dry deposition of these aerosol particles to the open oceans can significantly impact the trace element distributions in the surface oceans, enhance the ocean primary productivity and influence the climate (Macdonald et al. 2005; Gong and Barrie, 2005; Landing and Payton, 2010). As such, quantifying atmospheric trace elements and isotopes (such as Al, Fe, Ti, Zn, Pb and Hg) will help us gain insight into the atmospheric fluxes of key trace metals, their origin of aerosol particle sources and the biogeochemical cycling of atmospheric trace elements over the Canadian Arctic waters.

Arctic GEOTRACES Leg 3b, which ran from September – October, 2015 gave us an incredible opportunity to study and understand the atmospheric aerosol deposition over the Canadian Basin (CB) and the Canadian Arctic Archipelago (CAA) from the CCGS Amundsen. Similarly to Leg 2, the aim of this study was to collect bulk aerosols on Whatman 41 filters to assess (1) chemical characterization of key trace metals and isotopes, (2) quantification of atmospheric inputs of trace elements and isotopes, and (3) understand the biogeochemical cycling of trace elements over the Canadian Arctic Ocean.

Operations conducted during the Leg / Methodology:
The shipboard aerosol sampling during Leg 3b from September – October, 2015 was conducted using a commercially available volumetric flow controlled (VFC) high volume aerosol sampler from TISCH Environmental (TE-5170V-BL). The aerosol sampler consisted of the following components:

1. Aluminum frame and roof
2. Brushless motor
3. Elapsed time indicator (ETI)
4. Flow funnel attached to the motor
5. Filter holder with a PVC adapter that holds 12-47mm filters (Figure 5.1.10.3)

The aerosol sampler was deployed as high and forward as possible on the ship as suggested in Morton et al. (2008) to prevent contamination from the ship smoke stack. The best possible position for deployment of high volume air sampler on the Amundsen was on the bridge deck (Figure 5.1.10.1). The aerosol sampler was connected to an automated sector control comprising of an anemometer and a CR10 data logger. The anemometer was also mounted closer to the aerosol sampler on the bridge deck such that the cups were facing the bow and the vane was facing the stern (Figure 5.1.10.2). The sector control was controlled by Campbell Scientific software with predefined parameters for wind direction and speed. The wind direction and speed was set as $\pm 75^o$ either side of the bow (105^o - 225^o) and > 0.2m/s respectively. When the wind was out of the pre-set parameters, the aerosol sampler automatically shut down. A delay time of 150s was set for the wind direction and wind speed to meet the pre-set parameters for the aerosol sampler to restart again.
The aerosol samples were collected over the Canadian Basin and the Canadian Arctic Archipelago (Figure 5.1.10.4). The bulk aerosol samples were collected on acid cleaned 12 – 47mm Whatman 41 filters (Fisher Scientific 1441-047) for up to 70 hour integrated time period at a flow rate of 1 m^3/min. We followed Bill Landing filter changing protocols (Morton et al. 2008), where the filters were changed in a clean bubble, located

in the moon pool of the Amundsen. Due to large variation in transit times and station time, aerosols were strategically collected throughout Leg 3b. When the transit time and on station time was significant (>20 hours), aerosols were collected separately during *Transit* and *On Station*. For instance, Sample 12 was collected continuously from CB2 – CB3 and CB3 – CB4 over a time period of 117 hours. Based on the Elapsed time indicator installed on the sampler, the bulk aerosols were only collected for ~ 19 hours. The ETI time was significantly shorter than the run time because the ETI shut down when the wind was out of sector, which automatically shut down the aerosol sampler (Table 5.1.10.1). However, when the transit time was minimal (4-8 hours), aerosol sampling continued on the same set of filters during *Transit* and *On Station* as shown in Table 1. For instance, Sample 11 was collected during transit from CB1 → CB2. Due to short *Transit* times, the aerosol sampler also remained ON at CB2 station. The details of the aerosol sampling during *Transit* and *On Station* in given in Table 2. To monitor for potential contamination, blanks were also periodically collected by exposing filters loaded onto PVC filter holder near the aerosol sampler while the wind was in sector (Table 5.1.10.1). At the end of Leg 2 and Leg 3b, a total of 15 samples and 5 blanks were collected and stored in individual acid cleaned and pre-labeled petridishes at -20^{o} C.

Table 5.1.10.1: The table below summarizes the date, location and sampling parameters of aerosol samples and blanks on Leg 3b.

Samples	Latitude Start	Latitude Stop	Longitude Start	Longitude Stop	UTC Start	UTC Stop	Run time (hours)	ETI (hours)
Sample 10A	75.07	75.07	-120.4	-120.5	2015-09-06 23:38	2015-09-08 4:13	28.58	4
Blank 4	75.08		-120.4		2015-09-06 23:50	2015-09-06 23:55	0.08	
Sample 11	75.09	75.54	-121.0	-128.5	2015-09-08 5:02	2015-09-10 22:57	65.92	28
Sample 12A	75.52	76.59	-128.5	-139.5	2015-09-10 0:29	2015-09-11 19:06	42.61	17
Sample 10B	76.59	76.36	-139.5	-141.5	2015-09-11 19:10	2015-09-13 17:50	46.67	4
Sample 12B	76.36	74.51	-141.5	-149.3	2015-09-13 18:02	2015-09-16 20:22	74.33	2
Sample 13	74.51	70.34	-149.3	-99.22	2015-09-16 20:32	2015-09-22 12:21	135.8	74
Sample 14	70.34	75.41	-99.22	-95.02	2015-09-22 0:39	2015-09-26 20:56	116.3	61
Blank 5	70.93		-99.42		2015-09-22 1:30	2015-09-22 1:35	0.08	
Sample 15	75.41	74.59	-95.02	-92.17	2015-09-26 21:10	2015-09-29 19:00	69.83	30

Table 5.1.10.2: A summary of aerosol samples and blanks collected during Transit and On Station on Leg 3b

Samples	Transit Sampling		On Station Sampling	
Sample 10A			X	CB1
Blank 4			X	CB1
Sample 11	X	CB1 - CB2	X	CB2
Sample 12A	X	CB2 - CB3		
Sample 10B			X	CB3
Sample 12B	X	CB3 - CB4	X	CB4
Sample 13	X	CB4 - QMG-2 (AN)	X	QMG-2 (AN)
Sample 14	X	QMG-2 (AN) - CAA9		
Blank 5	X	QMG-2 (AN) - CAA9		
Sample 15	X	CAA9 (Penny Strait)	X	CAA9 (Penny Strait)

Figure 5.1.10.1: The TISCH volume flow controlled (VFC) high volume aerosol sampler deployed on the bridge deck of the CCGS Amundsen during Leg 3b from September – October, 2015.

Figure 5.1.10.2: The anemometer, which is attached to the aerosol sampler through CR10 datalogger.

Figure 5.1.10.3: The PVC adapter plate that holds 12 – 47mm filter holders (courtesy of Bill Landing)

Preliminary Results:

The aerosol filter samples were not analyzed or processed during Leg 3b. The measurement of key trace elements and isotopes on the aerosol filters will be carried out once the samples are returned back to the stable isotope laboratory at University of Toronto after CCGS Amundsen's return to Quebec City in November.

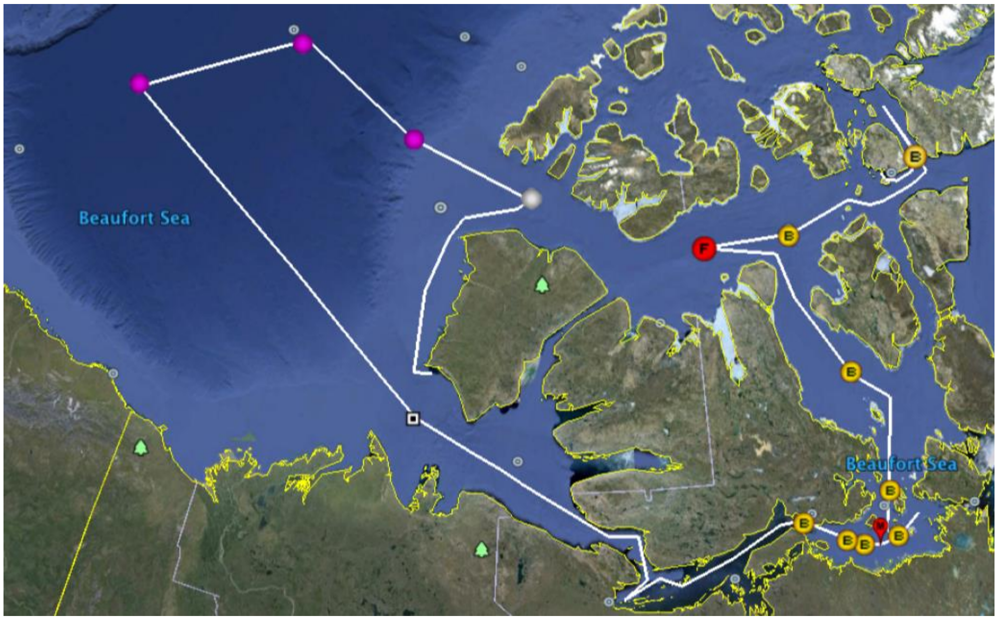

Figure 5.1.10.4: The aerosol sampling locations and route in the Canadian Basin and the Canadian Arctic Archipelago during Leg 3b

Five Questions:

- **a)** The process to gain access to the vessel and request ship times for our team's project was clear and easy to follow. *4. Satisfied*
- **b)** The annual *Amundsen* expedition was effectively planned and organized (e.g., planning meeting, vessel scheduling, dissemination of information, mobilization, etc.). *5. Satisfied*

- **c)** The *Amundsen's* central pool of equipment (e.g., scientific winches, CTD-Rosette system, MVP system, onboard laboratories, sonars, piston corer, Remotely Operated Vehicle, etc.) was properly maintained and operational at sea. *4. Very Satisfied*
- **d)** Safety in the workplace (i.e. were you satisfied with the overall safety of the science operations conducted on and from the *Amundsen*?) *4. Very Satisfied*
- **e)** What is your overall level of satisfaction regarding your experience conducting research on board the *Amundsen* this year? *5. Satisfied*

Comments: My experience in carrying out aerosol sample collection during leg3b was satisfactory. The Captain and the crew were very helpful in the smooth running of the high volume air sampling from September to October, just as in Leg 2. The officers of the ship were very accommodating in changing the position of the ship to allow me to change sample filters with the wind in sector. Just like in Leg 2, I was collecting aerosols both during *Transit* and *On Station*. However, unlike Leg 2, I did face some challenges in collecting aerosols while the ship was on station. Due to the position of the ship during stations (not facing forward wind), my automated sector control was not turned on and as such, the aerosol sampler was shut down throughout majority of the stations during Leg 3b.

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5.1.11 Moving Vessel Profiler and CTD mesoscale and mixing survey: Wellington, Maury, and Perry Channels

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Cruise Participants: Ken Hughes, Hauke Blanke

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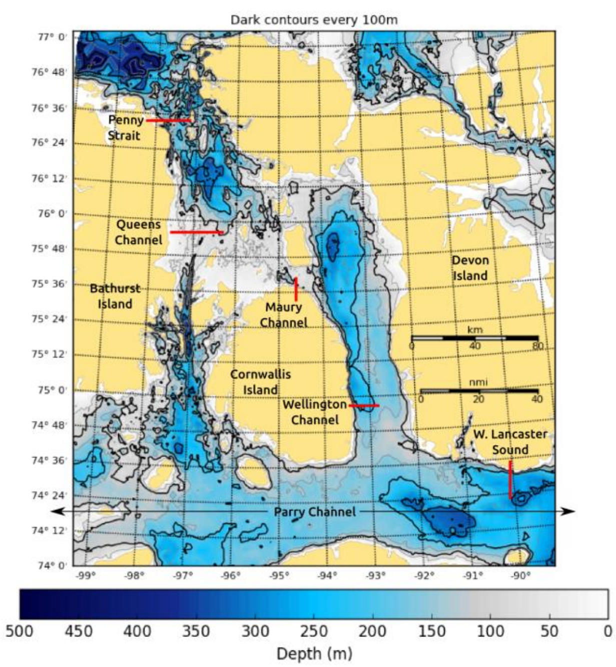
Introduction and objectives
The central sills of the Canadian Arctic Archipelago (i.e., Penny Strait, Byam Martin Channel, Channel, Wellington Channel and the surrounding areas) are believed to be regions of large vertical mixing, the result of strong tidal currents and shallow bathymetry (Figure 1). As Arctic water flowing from the northwest encounters the sills in and south of Penny Strait, water properties from 70–80m depth outcrop at the surface and the water column becomes well-mixed [DeLangeBoom, 1987]. This not only modifies the Arctic water flowing toward the Atlantic, but also alters the baroclinic (density-driven) flow within the Archipelago.

After it leaves Wellington Channel, the water enters western Lancaster Sound, a site where moorings have been maintained for several years [Prinsenberg, 2009] with the intention of estimating and understanding seasonal and interannual changes in heat, freshwater, and volume fluxes of water that is ultimately headed toward Baffin Bay and Labrador Sea. Fluxes through the Archipelago will be heavily influenced water mass modification in the central sills area, i.e., the region up to 300–400km upstream.

Our aim was to map the turbulent structures, determine the locations of strong property fronts, and evaluate vertical mixing rates within Wellington Channel and Penny Strait using the Moving Vessel Profiler (MVP), the shipboard ADCP, and when MVP was impractical, the ship’s CTD. The MVP is an ideal tool to capture the complex flow resulting from the influence of sills and islands. The high-spatial-resolution data we obtain will allow us to develop volume, freshwater, and heat budgets and observe changes in properties over steep topography. Further, because we sample as the ship travels, we can get almost-synoptic two-dimensional pictures of the ocean over scales of tens of kilometers, which is a similar to the length over which topography varies within our sampling region.



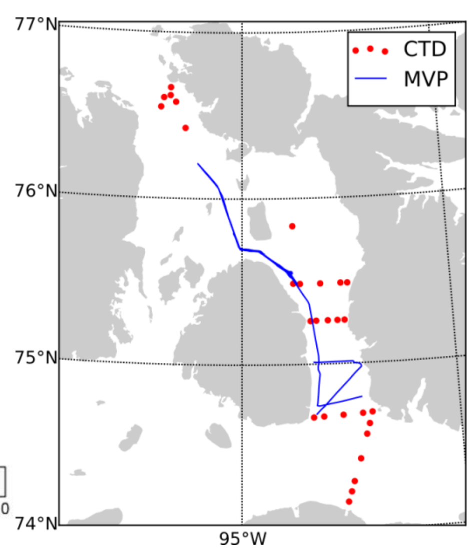


Figure 5.1.11.1: Bathymetry of the region studied with the moving vessel profiler. Right: MVP tracks and CTD stations during intensive sampling.

Methodology

The MVP towfish records a number of different quantities from which the following are derived: temperature, salinity, pressure, depth, sound velocity, dissolved oxygen, transmissivity, and fluorescence. With the boat travelling at approximately 8 knots and the fish freefalling, we obtain two-dimensional transects of the aforementioned properties with horizontal resolution of 1 km or less, and vertical resolution of about 1 m (Figure 2).

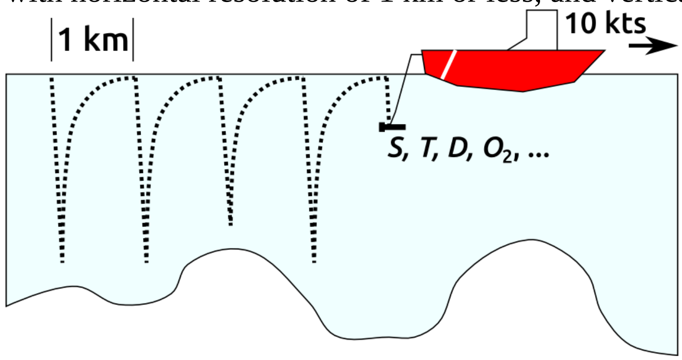


Figure 5.1.11.2: Schematic diagram of the operation of the moving vessel profiler. A 10kt boat speed, which gives approximate spacing of 1km between casts, allows observation of finescale oceanographic processes spanning distances on the order of tens to hundreds of kilometres. Oceanographic data are continuously recorded, with the freefall component being picked out during post-processing.

The timing of our sampling coincides with the approximate time of year when ice conditions within and south of Penny Strait are rapidly changing. Sea ice from the northwest episodically blows south through Penny Strait, and there is also the potential for new ice growth throughout September. Our ideal plan was to take MVP observations through Penny Strait approximately 1–2 days after leaving Resolute on the 27th of September. However, by approximately mid-September, it was evident that this would not happen given that Penny Strait was already becoming blocked by sea ice (it is a danger to the towfish to sample when any ice is present). By considering changes in the ice conditions over several days, we altered our original plan to go through the constrictions north of Cornwallis Island (see Figure 1) and ideally over into the deeper basin south of Penny Strait. The time originally set for sampling through Penny Strait was reallocated to a focused study on changes throughout a tidal cycle in Maury Channel.

Table 5.1.11.: Wellington Channel Survey Timeline

Survey	Time (UTC) and Date (2015)	No. of Casts
Wellington Ch. E to W (1)	08:30 26 Sep –10:30 26 Sep	40
Wellington Ch. to Queens Ch.	10:30 26 Sep – 01:00 27 Sep	290
Penny St. rosette CTDs	11:10 27 Sep – 18:30 27 Sep	6
Maury Ch. W to E (1)	22:00 27 Sep – 06:30 28 Sep	180
Maury Ch. E to W (1)	06:30 28 Sep – 14:20 28 Sep	160
Maury Ch. W to E (2)	14:20 28 Sep – 18:30 28 Sep	125

Maury Ch. E to W (2)	18:30 28 Sep – 23:00 28 Sep	125
Maury Ch. W to E (3)	23:00 28 Sep – 00:40 29 Sep	80
Wellington Ch. rosette CTDs	03:00 29 Sep – 15:00 29 Sep	10
Wellington Ch. W to E	16:40 29 Sep – 19:20 29 Sep	55
Wellington Ch. E to W (2)	19:20 29 Sep – 22:30 29 Sep	45
Wellington Ch. rosette CTDs	00:10 30 Sep – 06:20 30 Sep	5
Lancaster Snd rosette CTDs	06:20 30 Sep – 11:10 30 Sep	7

Despite Penny Strait being blocked, we still planned for our first transect between southern Wellington Channel and Queens Channel to take approximately 15 hours. During this time, we analysed the MVP data in real time, i.e., we maintained up-to-date plots of the observed properties versus depth and distance. This required exisiting Python scripts to be adjusted for Arctic Net's MVP, which is a different model and has a different output format compared to our group's own MVP. This adjusting was undertaken while onboard but before sampling started by using MVP data from the beginning of Leb 3B.

When profiling began, at least two of the four of our group were either monitoring the MVP's software for any unusual signs (for example, slow cable return speed) or watching the profiler from the aft deck with radio contact to the data acquisition room. Shifts began or ended at approximately 3am and 3pm. Continual monitoring from both the acquisition room and the aft deck proved necessary as a number of problems arose, which required coordination between both ends. A summary of the transects undertaken with the MVP is given in the Table.

Preliminary results

Our initial transect down Wellington Channel, through Maury Channel, and ending in Queens Channel showed evidence of internal waves of various scales. From previous studies in the area, we expect that water in these channels flows southeastward, which corresponds to right to left in Figure 3. This is consistent with what appears to be a mode-1 internal wave formed by the steep topography centred at 50km. Much shorter waves are formed by rough topography in the sill regions between 100 and 170km. These are shown zoomed in on the lower panel of Figure 5.1.11.3. It is evident from the plot that the dominant wavelengths of the internal waves in this region are correlated with the roughness scales of the bottom topography as one might expect. Other features of this long section include divergening isopycnals from right to left as water mixes after travelling over the sill and decreasing temperature moving northward. Causes of this temperature structure will be determined after further analysis.

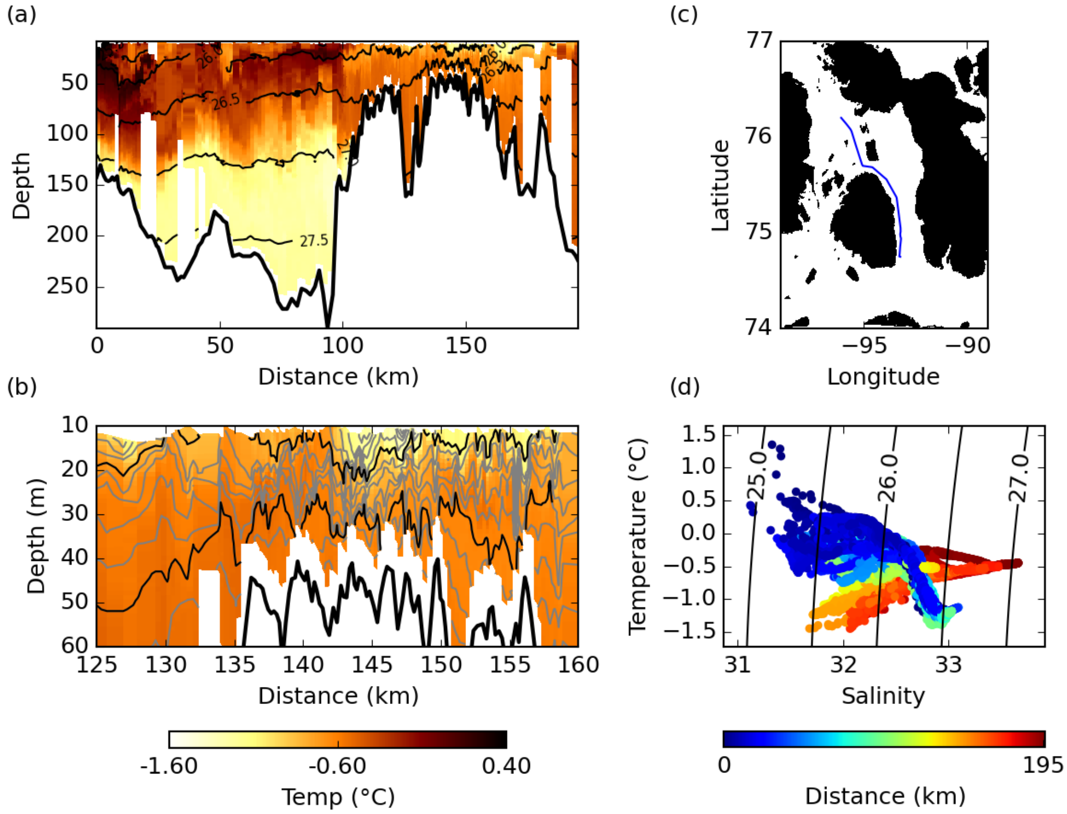


Figure 5.1.11.3: (a) Temperature (colours) and density (contours) from a long-section along Wellington Channel, through Maury Channel, and ending in Queens Channel. Note the longer mode-1 waves at approximately 0–80km. (b) Enlarged version of (a) showing the shallow area of Maury Channel and the presence of shorter internal waves, which result from flow over the rough, shallow seafloor. (c) Transect location. (d) Temperature–salinity diagram, with colours denoting distance as in panels (a) and (b).

Our other initial transect, a cross-section across the southern end of Wellington Channel (Figure 5.1.11.4) shows clear evidence of a buoyant coastal current on the right hand side. Isopycnals sloping downward toward the right form a wedge-like feature like that described by [@Leblond1980]. These coastal currents are ubiquitous in the Canadian Archipelago and often flow in the opposite direction to the overall southeastward flow. We planned to use the MVP to map this coastal current at the end of our study; however, we had to resort to rosette CTD casts at a number of different stations in Wellington Channel.

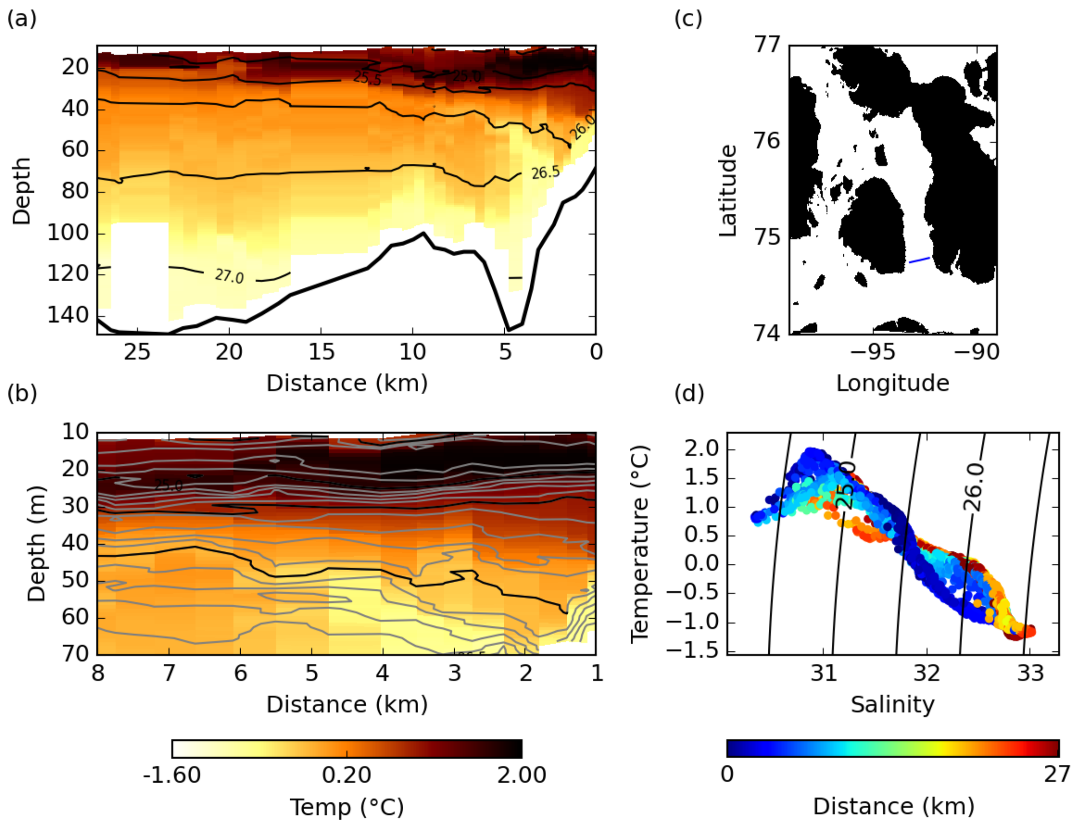


Fig. 5.1.11.4 (a) Temperature (colours) and density (contours) from a cross-section across southern Wellington Channel (into the page is northward). Distances increase from a starting point not far from the eastern boundary of the channel. (b) Enlarged version of (a) showing clearly the wedge-like feature that is a buoyant coastal current enlarged in the bottom panel. (c) Transect location. (d) Temperature–salinity diagram, with colours denoting distance as in panels (a) and (b).

MVP System Suggestions

The MVP was a learning experience for our group, not having worked with the system in cold weather before. Temperatures often dipped below -8 degrees C, and there were problems with ice on the cable and the moving parts. The ice on the cable is a problem because it triggers failsafe switches on the system, so we had many drops terminate prematurely, necessitating a manual recover to the surface. This was particularly challenging when making the transition from shallow topography to deep topography because the drum built up ice sheets on the deeper wraps.

The other ice issues was on the sheaves and the level wind rollers. If these seized up it greatly increased tension on the system. The motor responded appropriately, slowing the pay in speed, but the extra friction may not have been good for the cable.

There was a solution to keeping the outer sheave warm, which was to turn the installed outer-sheave heaters on. This seemed to work quite well in keeping the sheave relatively ice free. In the future, all techs should be made aware of this feature (which is not in the manual), and be sure to turn this on.

There was a solution to terminated downcasts, which was to hold the inner sheave defeat button down during the down cast, and then release it during the upcast. This still held the possibility of aborted drops if ice made it to the outer sheave, but this was much less likely than ice in the inner sheave.

The final mechanical issue was with the brake. Its level of maintenance was very questionable. The turnbuckle adjustment appeared to back off about 6 turns the first few hours of use, causing the brake to not engage. The turnbuckle is supposed to have locking nuts and cotter pins. None were installed. The brake subsequently seized up the next day, perhaps due to ice in the brake. The brake assembly should definitely be fully reconditioned before the system is used again.
It was also surprising to not have a maintenance log readily available.

An overall solution to the winch issues in such cold weather would be to enclose the winch and to heat the enclosure. Something like a tent or polyurethane freezer flaps might work well. If the winch and inner boom assembly had stayed above zero, and the outer sheave heater turned on, there would have been far fewer problems. I don't think this would be too expensive and for sustained MVP work would be helpful. The only caveat about that is that it is good for the person next to the winch to be able to see the water, so something clear at head level would be desirable. Barring that, using the *salt water* from the ship's system seemed the most effective way of clearing ice from the system. The crew found a locking spray nozzle (i.e. it could be locked to stay on so as to not freeze) and that worked very well. Another possibility is to have a compressed air nozzle dry the cable on the way in.

A couple of secondary suggestions: The physical separation of the control room and the winch was almost unmanageable. Both the winch and the control room jobs require some expertise. If there are only a few people trained to operate the MVP, it is preferable that they be in close proximity, not running from one end of the ship and up 4 flights of stairs just to help each other. For more casual MVP work this might be a good arrangement, but if there is a lot of troubleshooting going on, its quite challenging. I appreciate that lab space is tight, but a control station in the aft labs would be more ideal. One could imagine doing this via a remote desktop client to the machine in the acquisition room, the only hang up being one could not turn the deck box on and off.

The second suggestion would be that ArcticNet consider buying a smaller dual-sensor fish. The current fish is very large, and is very hard to get in and out of the water, requiring the bosun and two crew members. A smaller fish could be handled by two people without difficulty. I'm not clear on the design constraints behind the current fish, perhaps it is so large just because of weight, but I think a lot of it is hollow, so I'm not sure thats the case. If the science payload is really deemed desirable there are still smaller multi-sensor fish available.

User Experience

- The process to gain access to the vessel and request ship time for our team’s project was clear and easy to follow

- Satisfaction: N/A
- Comments: Done via GEOTRACES

The annual Amundsen expedition was effectively planned and organized (e.g., planning meeting, vessel scheduling, dissemination of information, mobilization, etc.).

- Satisfaction: 5
- Comments: We were kept up-to-date with regular emails from Keith Lévesque regarding all necessary information: paperwork, boarding times, mobilization dates etc.

The Amundsen’s central pool of equipment (e.g., scientific winches, CTD-Rosette system, MVP system, onboard laboratories, sonars, piston corer, Remotely Operated Vehicle, etc.) was properly maintained and operational at sea.

- Satisfaction: 3
- Comments: See above for comments and suggestions; Summary: Control room unreasonably far from winch. Wasn’t clear MVP brake had been properly serviced. Service records for rest of winch not available. System not prepared to deal with cold conditions. Note, not “Dissatisfied” in any way, but there was a learning experience for all parties.

Safety in the workplace (i.e. were you satisfied with the overall safety of the science operations conducted on and from the Amundsen?)

- Satisfaction: 5
- Comments: The crew were very safety conscious. All operations were performed with clarity and in a way that ensured safety of crew and scientists.

What is your overall level of satisfaction regarding your experience conducting research on board the Amundsen this year?

- Satisfaction: 4
- Comments: Besides the MVP system needing some work to combat the harsh environment we had to deal with, the overall scientific experience was excellent. The officers, crew, and ArcticNet technicians were all very knowledgeable, helpful, and fun to work with.

5.2 ArcticNet

5.2.1 ArcticNet CTD/Rosette

Principal Investigator: ArcticNet
Cruise Participants: Callum Mireault and Olivier Asselin

ArcticNet, Laval University

Objectives

The objective of our shipboard fieldwork is to characterize the water column physical and chemical properties: temperature, salinity, fluorescence, CDOM, dissolved oxygen concentration, nitrate concentration, light penetration and turbidity. We use a SBE 911 CTD with various other sensors (see Table 1) mounted on a cylindrical frame known as a rosette. A 300 kHz Lowered Acoustic Doppler Current Profiler (LADCP) is attached to the frame to provide us with vertical profiles of the velocities on station. The rosette also supplies water samples for biologists and chemists.

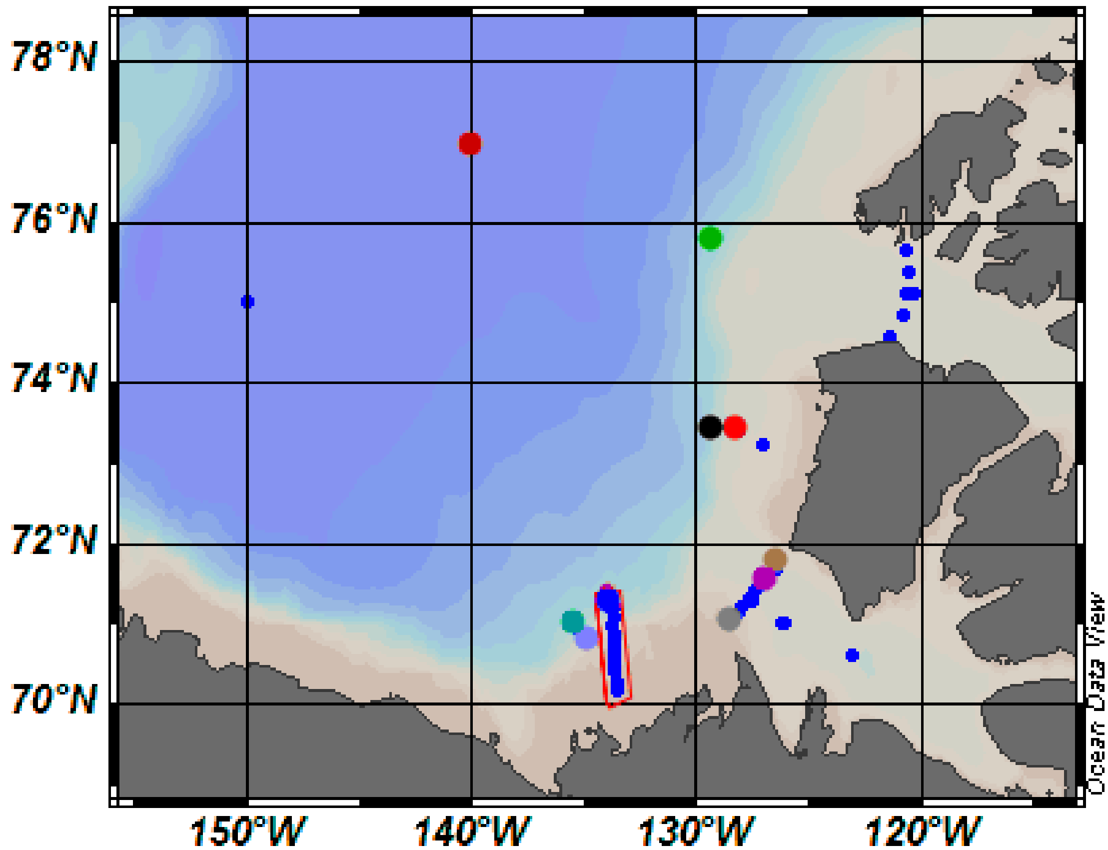
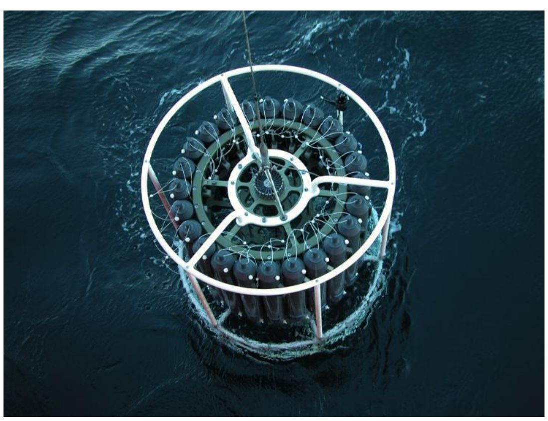


Figure 5.2.1.1 ArcticNet study region in the Western Canadian Arctic, Leg 3A&B.

Methodology
1. CTD-Rosette



The rosette frame is equipped with twenty-four (24) twelve (12) liter bottles and the sensors described in Tables 1 and 2.

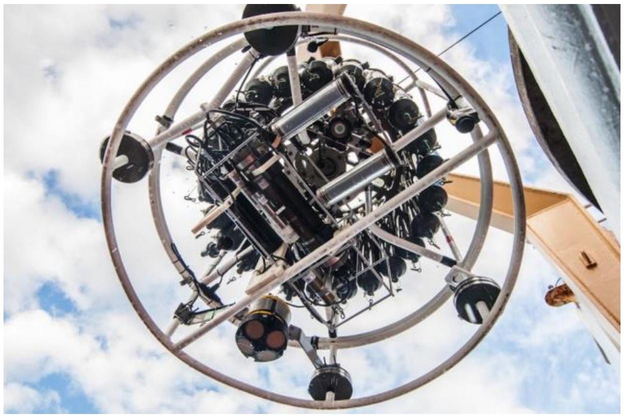


Table 5.2.1.1 Rosette sensors

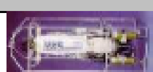
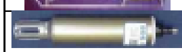
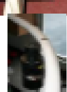
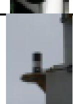
Photo	Instrument	Parameter	Properties	Serial Number	Calibration date
	Sea-Bird SBE 911plus	CTP	Sampling rate : 24 Hz	09P24760-0679	
	SBE 3plus	Temperature	Range: -5°C to + 35°C Accuracy: 0.001	03P4204	02-Dec-2014
	ParoscientificDigiquartz®	Pressure	Accuracy: 0.015% of full range	0679	26-Nov-2014
	SBE 4C	Conductivity	Range: 0 to 7 S/m Accuracy: 0.0003	042876	02-Dec-2014
	SBE 43	Dissolved Oxygen	Range: 120% of saturation Accuracy: 2% of saturation	430427	26-Nov-2014
	MBARI-ISUS Satlantic	Nitrates	Range: 0.5 to 200 µM Accuracy: ± 2 µM	138	12-Feb-2015
	QCP-2300 Biosherical	PAR	PAR Dynamic Range: $1.4x10^{-5}$ to 0.5 µE/(cm^2 sec)	7270	19-Dec-2014
	QCR-2200 Biosherical	Surface PAR	PAR Spectral Response: Equal (better than ±10%) quantum response from 400 to 700nm	20147	19-Dec-2014
	Seapoint	Fluorometer	Minimum Detectable Level 0.02 µg/l Gain Sens, V/(µg/l) Range/(µg/l), 10x 0.33 15	SCT-3120	27-Jan-2015
	WetLabs C-Star	Transmissometer	Path length: 25 cm Sensitivity: 1.25 mV	CST-671DR	17-Dec-2014
	Teledyne PSA-916	Altimeter	Range: 50 m from bottom	1065	Feb 2014
	WetLabs ECO	fluorometer (CDOM)	FL(RT)D Digital output resolution : 14 bit Analog output signal: 0-5V Range: 0.09-500ppb Ex/Em: 370/460nm	FLCDRTD-2344	16-Jun-2015

Table 5.2.1.2: Sensor specifications

Parameter	Sensor		Range	Accuracy	Resolution
	Compagny	Instrument Type			
Attached to the Rosette					
Data Logger	SeaBird	SBE-9plus [1]			
Temperature	SeaBird	SBE-03 [1]	-5°C à +35°C	0.001°C	0.0002°C
Conductivity	SeaBird	SBE-4C [1]	0-7 S/m (0-70mmho/cm)	0.0003 S/m (0.003mmho/cm)	0.00004 S/m (0.0004 mmho/cm)
Pressure	Paroscientific	410K-105	up to 10 500m (15 000psia)[2]	0.015% of full scale	0.001% of full scale
Dissolved oxygen	SeaBird	SBE-43 [3]	120% of surface saturation[4]	2% of saturation	unknown
Nitrates concentration	Satlantic	MBARI-ISUS 5T [6]	0.5 to 2000 µM	±2 µM	±0.5 µM
Light intensity (PAR)	Biospherical	QCP-2300		□	□
sPAR	Biospherical	QCR-2200		□	
Fluorescence	Seapoint	Chlorophyll-fluorometer	0.02-150 µg/l	unknown	30
Transmissiometer	Wetlabs	C-Star	0-5 V	unknown	1.25 mV
Altimeter	Benthos	PSA-916 [7]	0 - 100 m	unknown	0.01 m
CDOM fluorescence	Wet Labs	FL(RT)D [7]	0.09-500ppb	unknown	14 bit

Notes: [1] Maximum depth of 6800m
[2] Depending on the configuration
[3] Maximum depth of 7,000m
[4] In all natural waters, fresh and marine
[5] Maximum depth of 1,200m
[6] Maximum depth of 1,000m
[7] Maximum depth of 6,000m

Probes calibration
a) Salinity:

Seabird CTD

Water samples were taken on every Geotrace ArcticNet cast during section 3B with 200 ml bottles. They were analyzed with a GuildLine, Autosal model 8400B. Its range goes from 0.005 to 42 PSU with an accuracy better than 0.002.

This part was mostly performed by the Geotraces team members, with additional aid from Olivier Asselin and Nathalie Theriault. The comparison was performed by Callum Mireault.
An initial analysis performed on the correlation between the CTD probe and Autosal salinity values is shown in Figure 2. This figure was made using the unfiltered values of the average salinities of the three samples taken from the Autosal samples versus the point value of the equivalent salinity of the bottle it was sampled from. The result was a correlation of 0.9955 (R2 value) and the data had differences (CTD probe minus Autosal)

with a mean of -0.0281 and a median of -0.0062. This suggests that on average the Autosal machine is underestimating the salinity values of the CTD probe. The mean difference value is fairly high considering the accuracy of the Autosal machine (0.002) but the median value of 0.0062 suggests that the machine is still performing accurately.

Figure 5.2.1.2 CTD salinity validations with *in situ* titrations.

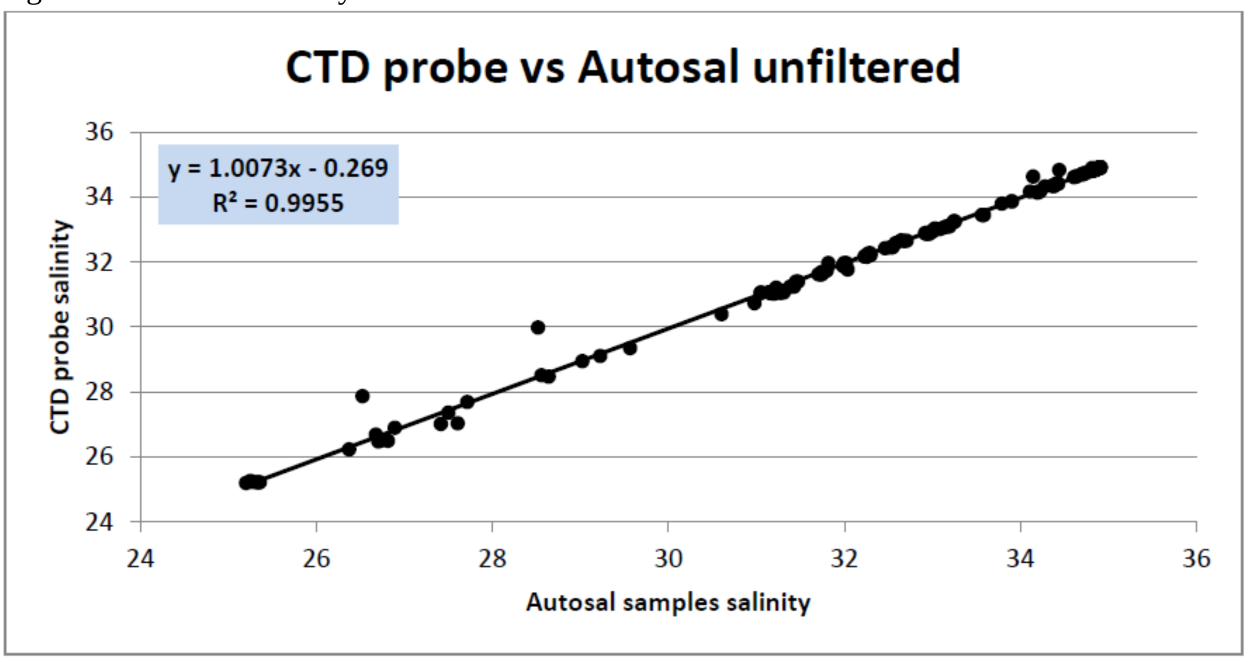


Figure 5.2.1. 2 CTD salinity validations with *in situ* titrations.

The difference of 0.0042 in the calculated accuracy of the Autosal machine with regards to the CTD probe could be a number of different factors. It could be Autosal operator errors, it could be a degradation of accuracy of the Autosal machine or it could be a degradation of the accuracy of the CTD probe. Unfortunately without a further specific analysis of the data it is impossible to determine which of these factors could have led to the differences of accuracy between the actual and calculated Autosal accuracies.

The data could be further filtered to account for human error or unreliable data points (from rapid changes in salinity in the water column) but this would affect the integrity of the analysis and render it a null exercise.

2. Seabird TSG.
Water samples were taken at different times during the transit from the surface thermosalinograph to measure salinity and fluorescence. The probe is located in the engine room. The samples were also analyzed with the GuildLine. As far as the fluorescence is concerned, the samples were analyzed with a fluorometer.

Problem encountered:
A special attention has been made to keep the autosal room at an appropriate temperature (22°C). It is a crucial point to get accurate salinity values.

b) Oxygen:
Oxygen sensor calibration was performed based on dissolved oxygen concentration measured in water samples using Winkler's method and a Mettler Toledo titration machine. This part was mostly performed by the Geotraces team members.

1.2 Water sampling
Water was sampled with the rosette according to each team's requests. To identify each water sample, we used the term "rosette cast" to describe one CTD-rosette operation. A different cast number is associated with each cast. The cast number is incremented every time the rosette is lowered in the water. The cast number is a seven-digit number: **xxyyzzz,** with

xx: the last two digits of the current year;
yy : a sequential (Québec-Océan) cruise number;
zzz : the sequential cast number.

For this cruise, the first cast number is: **1500001.** To identify the twenty-four rosette bottles on this cast we simply append the bottle number: **1501001nn,** where "nn" is the bottle number (01 to 24).

All the information concerning the Rosette casts is summarized in the *CTD Logbook* (one row per cast). The information includes the cast and event number and station id, date and time of sampling in UTC, latitude and longitude, bottom and cast depths, and minimalist comments concerning the casts (Table 5.2.1.3).

Table 5.2.1.3 1502 leg3 log book

Cruise ID 1503
Cruise NAME ArcticNet

Cast	Station	Date début UTC	Heure UTC	Lat. (N)	Long. (W)	Fond (m)	Prof. cast (m)	Commentaires	Type	Init
001	405	22 / 08 / 15	22 : 56	70 ° 36.581	123 ° 2.014	604	594		BASIC	CM
002	405	23 / 08 / 15	01 : 41	70 ° 36.490	123 ° 2.060	610	600		BASIC	OA
003	407	23 / 08 / 15	18 : 45	71 ° 1.150	126 ° 9.170	382	369		FULL	OA
004	CA-08	23 / 08 / 15	21 : 33	71 ° 0.600	126 ° 4.000	392	378		MOORING	OA
005	407	23 / 08 / 15	02 : 11	71 ° 0.609	126 ° 4.853	394	378		FULL	CM
006	437	24 / 08 / 15	11 : 32	71 ° 47.848	126 ° 30.140	298	287		BASIC	CM
007	437	24 / 08 / 15	13 : 40	71 ° 48.000	126 ° 29.000	290	280		BASIC	OA
008	410	24 / 08 / 15	17 : 05	71 ° 41.972	126 ° 29.415	409	392		NUTRIENT	OA
009	CA-05	24 / 08 / 15	22 : 33	71 ° 16.703	127 ° 31.029	206	192		MOORING	OA
010	411	24 / 08 / 15	:	°	°			Incomplete	CTD	OA
011	412	25 / 08 / 15	03 : 10	71 ° 33.852	126 ° 55.328	417	403		NUTRIENT	CM
012	413	25 / 08 / 15	04 : 35	71 ° 29.760	127 ° 7.933	373	361		CTD	CM
013	414	25 / 08 / 15	05 : 41	71 ° 25.041	127 ° 21.452	304	294		NUTRIENT	CM
014	408	25 / 08 / 15	07 : 18	71 ° 18.735	127 ° 34.908	204	195		FULL	CM
015	408	25 / 08 / 15	09 : 25	71 ° 18.534	127 ° 35.892	197	187		FULL	CM
016	417	25 / 08 / 15	13 : 06	71 ° 13.399	127 ° 58.606	85	71		CTD	CM
017	418	25 / 08 / 15	13 : 49	71 ° 9.792	128 ° 10.291	65	55	not sampled	NUTRIENT	OA
018	419	25 / 08 / 15	14 : 40	71 ° 6.388	128 ° 20.593	56	46		CTD	OA
019	418	25 / 08 / 15	15 : 29	71 ° 9.615	128 ° 10.439	65	55	Went back for more samples	NUTRIENT	OA
020	420	25 / 08 / 15	17 : 08	71 ° 3.058	128 ° 30.662	43	31	Bottles 3 and 23 didn't fire	BASIC	OA
021	434	26 / 08 / 15	05 : 25	70 ° 10.614	133 ° 33.233	47	35		BASIC	CM
022	433	26 / 08 / 15	09 : 05	70 ° 17.303	133 ° 34.712	56	44	LADCP not enough data	CTD	CM
023	432	26 / 08 / 15	09 : 55	70 ° 23.666	133 ° 36.130	63	50		NUTRIENT	CM
024	BR-K	26 / 08 / 15	13 : 43	70 ° 51.542	135 ° 1.482	152	137		MOORING	OA
025	BS-1	26 / 08 / 15	15 : 31	70 ° 48.465	134 ° 50.288	81	68		MOORING	OA
026	BS-2	26 / 08 / 15	15 : 35	70 ° 53.038	135 ° 5.809	306	296		MOORING	OA
027	BR-G	26 / 08 / 15	20 : 20	71 ° 0.467	135 ° 30.937	721	708		MOORING	OA
028	423	27 / 08 / 15	02 : 17	71 ° 16.265	133 ° 51.718	794	778		CTD	OA
029	424	27 / 08 / 15	02 : 52	71 ° 10.371	133 ° 49.729	576	564	LADCP processing problem	NUTRIENT	CM
030	435	27 / 08 / 15	05 : 00	71 ° 4.745	133 ° 37.859	299	287		FULL	CM
031	435	27 / 08 / 15	07 : 38	71 ° 4.727	133 ° 37.824	300	287		FULL	CM
032	BR-K	27 / 08 / 15	15 : 10	70 ° 51.403	135 ° 2.349	157	151		MOORING	OA
033	422	28 / 08 / 15	11 : 30	71 ° 22.815	133 ° 52.948	1100	1080	Bottle 2 didn't fire	NUTRIENT	CM
034	BR-G	28 / 08 / 15	17 : 10	71 ° 0.130	135 ° 30.427	708	683		MOORING	OA
035	BS-3	28 / 08 / 15	20 : 41	70 ° 55.474	135 ° 13.503	491	479		MOORING	OA
036	LANDER2	28 / 08 / 15	23 : 31	70 ° 50.145	135 ° 7.824	164	156		LANDER	OA
037	431	29 / 08 / 15	06 : 31	70 ° 29.711	133 ° 37.615	68	56		CTD	CM
038	430	29 / 08 / 15	07 : 22	70 ° 35.906	133 ° 38.706	71	58	Bottle 2 didn't fire	NUTRIENT	CM
039	429	29 / 08 / 15	08 : 20	70 ° 41.685	133 ° 39.930	70	56	Bottle 2 fired successfully	CTD	CM
040	428	29 / 08 / 15	09 : 05	70 ° 47.425	133 ° 41.155	75	63		NUTRIENT	CM
041	427	29 / 08 / 15	10 : 00	70 ° 52.835	133 ° 43.117	80	68		CTD	CM
042	426	29 / 08 / 15	10 : 44	70 ° 59.069	133 ° 44.818	100	88		NUTRIENT	CM
043	BENTHOS	29 / 08 / 15	14 : 16	71 ° 12.533	133 ° 41.537	720	707		BENTHOS	OA
044	421	29 / 08 / 15	23 : 11	71 ° 25.819	133 ° 59.393	1207	1195		BASIC	OA
045	421	30 / 08 / 15	02 : 44	71 ° 25.730	134 ° 0.461	1210	1190		BASIC	CM
046	BR-3	31 / 08 / 15	02 : 11	73 ° 13.355	127 ° 3.077	156	148		BR-3	CM
047	535	31 / 08 / 15	06 : 00	73 ° 24.808	128 ° 10.482	287	272		FULL	CM
048	535	31 / 08 / 15	08 : 35	73 ° 24.939	128 ° 11.799	291	277		FULL	CM
049	BR-3	31 / 08 / 15	14 : 08	73 ° 24.222	129 ° 21.437	692	680		MOORING	OA
050	536	31 / 08 / 15	20 : 50	73 ° 25.138	129 ° 23.350	732	722		BASIC	OA
051	536	31 / 08 / 15	23 : 16	73 ° 25.012	129 ° 21.677	727	717		BASIC	OA
052	518	02 / 09 / 15	03 : 55	74 ° 33.880	121 ° 27.104	186	170		BASIC	CM
053	518	02 / 09 / 15	06 : 05	74 ° 34.331	121 ° 26.338	281	267		BASIC	CM
054	516	02 / 09 / 15	11 : 56	74 ° 49.697	120 ° 50.524	469	454		NUTRIENT	CM
055	514	02 / 09 / 15	14 : 39	75 ° 6.904	120 ° 38.504	468	456		BASIC	OA
056	514	02 / 09 / 15	17 : 42	75 ° 6.183	120 ° 37.704	457	447		BASIC	OA
057	512	02 / 09 / 15	21 : 51	75 ° 22.569	120 ° 33.024	412	402		NUTRIENT	OA
058	510	02 / 09 / 15	23 : 58	75 ° 38.332	120 ° 38.381	374	364		NUTRIENT	OA
059	CB-1	06 / 09 / 15	19 : 53	75 ° 7.563	120 ° 23.740	413	401	Pump cable broken: bad data. No sampling done.	RADS	OA
060	CB-1 / e201	06 / 09 / 15	21 : 18	75 ° 7.350	120 ° 38.466	463	453	Problem fixed. Correct data	RADS	OA
061	CB-1 / e204	07 / 09 / 15	03 : 30	75 ° 6.414	120 ° 31.103	430	418		GEOCHEM-1	CM
062	CB-1 / e207	07 / 09 / 15	06 : 20	75 ° 6.113	120 ° 33.790	437	425		GEOCHEM-2	CM
063	CB-1*	07 / 09 / 15	15 : 37	75 ° 6.886	120 ° 21.474	409	398	4 miles east of CB-1: CB-1*	BENTHOS	OA
064	CB-1	07 / 09 / 15	21 : 23	75 ° 6.856	120 ° 38.680	468	100	Looking at transmission min		OA
065	CB-2	08 / 09 / 15	23 : 03	75 ° 49.252	129 ° 13.415	1374	700		RADS	OA
066	CB-2	09 / 09 / 15	06 : 20	75 ° 48.383	129 ° 14.050	1356	1346	Bottle 3 did not close	GEOCHEM-1	CM
067	CB-2	09 / 09 / 15	09 : 45	75 ° 48.109	129 ° 11.683	1346	1325		GEOCHEM-2	CM
068	CB-2	10 / 09 / 15	07 : 40	75 ° 47.123	129 ° 17.417	1354	1340	Bottle 2 did not close	Box-core	OA
069	CB-3	11 / 09 / 15	19 : 51	76 ° 58.840	140 ° 2.750	3728	1400		RADS	OA
070	CB-3	12 / 09 / 15	03 : 00	76 ° 58.508	140 ° 3.108	3736	1600	Bottle 5 didn't close	GEOCHEM-2	OA
071	CB-3	12 / 09 / 15	08 : 10	76 ° 59.535	140 ° 2.830	3728	1600	Comms error with SBE	GEOCHEM-1	CM
072	CB-3	13 / 09 / 15	13 : 07	76 ° 59.423	140 ° 2.609	3697	1500	Cable fixed	GEOCHEM-1	OA
073	CB-4	14 / 09 / 15	20 : 13	74 ° 59.976	149 ° 59.655	3828	1400		RADS	OA
074	CB-4	15 / 09 / 15	00 : 47	75 ° 0.145	150 ° 0.048	3829	1400		GEOCHEM-2	OA
075	CB-4	15 / 09 / 15	09 : 44	74 ° 59.996	149 ° 59.482	3829	1500		GEOCHEM-1	CM
076	CB-4	16 / 09 / 15	00 : 21	74 ° 59.975	149 ° 59.495	3828	220		RADS-SH	OA/C
077	CB-4	16 / 09 / 15	05 : 48	74 ° 59.929	150 ° 0.135	3828	1000		RADS-DEEP	OA/C
078	407	18 / 09 / 15	13 : 24	71 ° 0.351	126 ° 4.526	390	380		Box-core	OA
079	314	20 / 09 / 15	16 : 37	68 ° 58.191	105 ° 28.889	77	66		BASIC	OA
080	QMG4	21 / 09 / 15	01 : 20	68 ° 28.995	103 ° 25.477	71	60		BASIC	OA
081	QMG3	21 / 09 / 15	07 : 05	68 ° 19.774	102 ° 36.340	64	53		BASIC	CM
082	QMG	21 / 09 / 15	14 : 47	68 ° 14.517	101 ° 47.570	103	91		Mooring	CM
083	QMG	21 / 09 / 15	18 : 40	68 ° 14.796	101 ° 43.014	107	93		BASIC	OA
084	QMG2	21 / 09 / 15	23 : 54	68 ° 18.810	100 ° 48.008	54	42		BASIC	OA
085	QMG1	22 / 09 / 15	04 : 00	68 ° 29.631	099 ° 53.441	34	24		BASIC	CM
086	312	22 / 09 / 15	14 : 03	69 ° 10.337	100 ° 41.577	65	55		BASIC	OA
087	310	23 / 09 / 15	06 : 42	71 ° 27.408	101 ° 16.924	163	153		BASIC	CM

088	308/CAA8	24 / 09 / 15	02 : 26	74 ° 8.325	108 ° 50.079	565	554	Bottle 3 didn't fire	RADS	OA
089	308/CAA8	24 / 09 / 15	08 : 27	74 ° 8.333	108 ° 50.309	562	551		GEOCHEM-1	CM
090	308/CAA8	24 / 09 / 15	15 : 07	74 ° 8.323	108 ° 50.130	566	553		GEOCHEM-2	OA
091	307	25 / 09 / 15	07 : 55	74 ° 6.660	103 ° 7.517	355	345		BASIC	CM
092	342	26 / 09 / 15	01 : 49	74 ° 47.671	092 ° 46.857	137	128		BASIC	OA
093	CAA9	27 / 09 / 15	03 : 14	76 ° 19.930	096 ° 44.688	340	333		BASIC	OA/CI
094	CAA9	27 / 09 / 15	05 : 30	76 ° 19.971	096 ° 45.598	331	319		BASIC	CM
095	J1	27 / 09 / 15	11 : 16	76 ° 25.472	096 ° 26.907	280	265		CTD	CM
096	J2	27 / 09 / 15	12 : 54	76 ° 34.836	096 ° 42.625	217	207		CTD	OA
097	J3	27 / 09 / 15	14 : 53	76 ° 40.042	096 ° 51.156	231	207		CTD	OA
098	J4	27 / 09 / 15	15 : 38	76 ° 37.170	096 ° 51.350	187	176		CTD	OA
099	J5	27 / 09 / 15	17 : 30	76 ° 36.380	097 ° 1.456	148	143		CTD	OA
100	J6	27 / 09 / 15	18 : 29	76 ° 33.004	097 ° 5.564	141	129		CTD	OA
101	WC01	29 / 09 / 15	03 : 44	75 ° 50.013	093 ° 45.750	331	319		CTD	OA
102	WC02	29 / 09 / 15	05 : 54	75 ° 29.249	093 ° 46.155	250	240		CTD	OA
103	WC03	29 / 09 / 15	06 : 35	75 ° 29.113	093 ° 36.438	232	221		CTD	OA
104	WC04	29 / 09 / 15	08 : 42	75 ° 29.107	093 ° 7.276	152	140		CTD	CM
105	WC05	29 / 09 / 15	09 : 38	75 ° 29.170	092 ° 38.021	159	145		CTD	CM
106	WC05.5	29 / 09 / 15	10 : 10	75 ° 29.128	092 ° 28.219	100	88		CTD	CM
107	WC06	29 / 09 / 15	12 : 13	75 ° 15.736	092 ° 34.273	176	166		CTD	CM
108	WC07	29 / 09 / 15	12 : 43	75 ° 15.732	092 ° 44.347	175	164		CTD	OA
109	WC08	29 / 09 / 15	13 : 22	75 ° 15.731	092 ° 58.061	153	142		CTD	OA
110	WC09	29 / 09 / 15	14 : 05	75 ° 15.703	093 ° 14.520	222			CTD	OA
111	WC10	29 / 09 / 15	14 : 46	75 ° 15.610	093 ° 22.550	226	214		CTD	OA
112	WC16	30 / 09 / 15	00 : 03	74 ° 40.765	093 ° 21.369	103	90		CTD	OA
113	WC17	30 / 09 / 15	01 : 08	74 ° 41.012	093 ° 7.481	143	131		CTD	OA
114	WC18	30 / 09 / 15	02 : 24	74 ° 41.414	092 ° 40.949	145	133		CTD	OA
115	WC19	30 / 09 / 15	03 : 37	74 ° 41.833	092 ° 14.120	91	80		CTD	OA
116	WC20	30 / 09 / 15	04 : 23	74 ° 42.175	092 ° 1.045	116	106		CTD	OA
117	BS1	30 / 09 / 15	05 : 24	74 ° 38.017	092 ° 5.448	124	112		CTD	CM
118	BS2	30 / 09 / 15	06 : 18	74 ° 34.227	092 ° 9.803	170	158		CTD	CM
119	BS3	30 / 09 / 15	07 : 48	74 ° 25.426	092 ° 19.583	266	253		CTD	CM
120	BS4	30 / 09 / 15	09 : 21	74 ° 17.323	092 ° 29.442	177	164		CTD	CM
121	BS5	30 / 09 / 15	10 : 12	74 ° 13.649	092 ° 33.657	165	153		CTD	CM
122	BS6	30 / 09 / 15	11 : 06	74 ° 9.996	092 ° 38.166	152	141		CTD	CM

An Excel® *Rosette Sheet* is also created for every single cast. It includes the same information as the CTD Logbook plus a table of what was actually sampled and at what depth. Weather information at the sampling time is included in each Rosette. For every cast, data from three seconds after a bottle is closed to seven seconds later is averaged and recorded in the ascii '*bottle files'* (files with a *btl* extension). The information includes the bottle number, time and date, trip pressure, temperature, salinity, light transmission, fluorescence, dissolved oxygen, irradiance and CDOM measurements. All those files are available in the directory "Data\Rosette" on the 'Shares' folder on the Amundsen server. There are six sub-directories in the rosette folder.

\Rosette\log\: Rosette sheets and CTD logbooks.

\Rosette\plots\: plots of every cast including salinity, temperature, oxygen, light transmission, nitrate, fluorescence and irradiance data.

\Rosette\odv\: Ocean Data Viewer file that include ctd cast files.

\Rosette\svp\: bin average files to help multibeam team to create a salinity velocity profile.

\Rosette\avg\: bin average files of every cast.

\Rosette\LADCP\: LADCP post-process data results.

1.3 Problems encountered with the CTD-Rosette

During cast 1503071 there was a communication error with the SBE 911 CTD unit that caused all data to stop transmitting from the rosette to the deck unit. The rosette was brought back on board and an inspection was done on the deck unit and sea cable. A problem was found in the sea cable splice where water had seeped into both the splice and the sea cable. 85m was cut from the winch in order to mitigate this seepage and the splice and mechanical support were redone to fix the problem. After 15 hours of drying time for the splice resin the rosette was recast for cast number 1503072 and the rosette worked without incident for the remainder of the leg.

2. Lowered Acoustic Doppler Current Profiler (LADCP)

A 300 kHz LADCP (a RD-Instrument Workhorse®) was mounted on the rosette frame. The LADCP gets its power through the rosette cable and the data is uploaded on a portable computer connected to the instrument through a RS-232 interface after each cast. The LADCP is programmed in *individual ping* mode (one every second). The horizontal velocities are averaged over thirty-two, 8 m *bins* for a total (theoretical) range of 100 to 120 m. The settings are 57600 bauds, with no parity and one stop bit. Since the LADCP is lowered with the rosette, there will be several measurements for each depth interval. The processing is done in Matlab® according to Visbek (2002; J. Atmos. Ocean. Tech., 19, 794-807).

Problems encountered with the LADCP
Thanks to new power supply upgrade, the ADCP intensity was sufficient even for deep cast.
Sometimes and probably due to the new power supply, it was difficult to communicate with the LADCP from the BBtalk software. An investigation should be done to fix the problem.

Preliminary Results
All the preliminary results are based on raw data (not processed and not validated). So the figures must not be used.

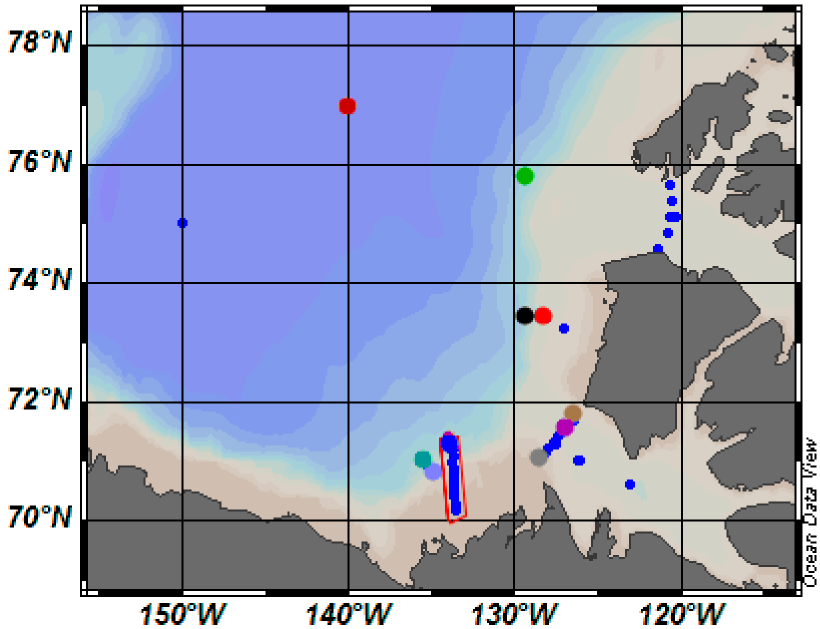


Figure 5.2.1.4 CTD casts location for leg 3A and the beginning of 3B.

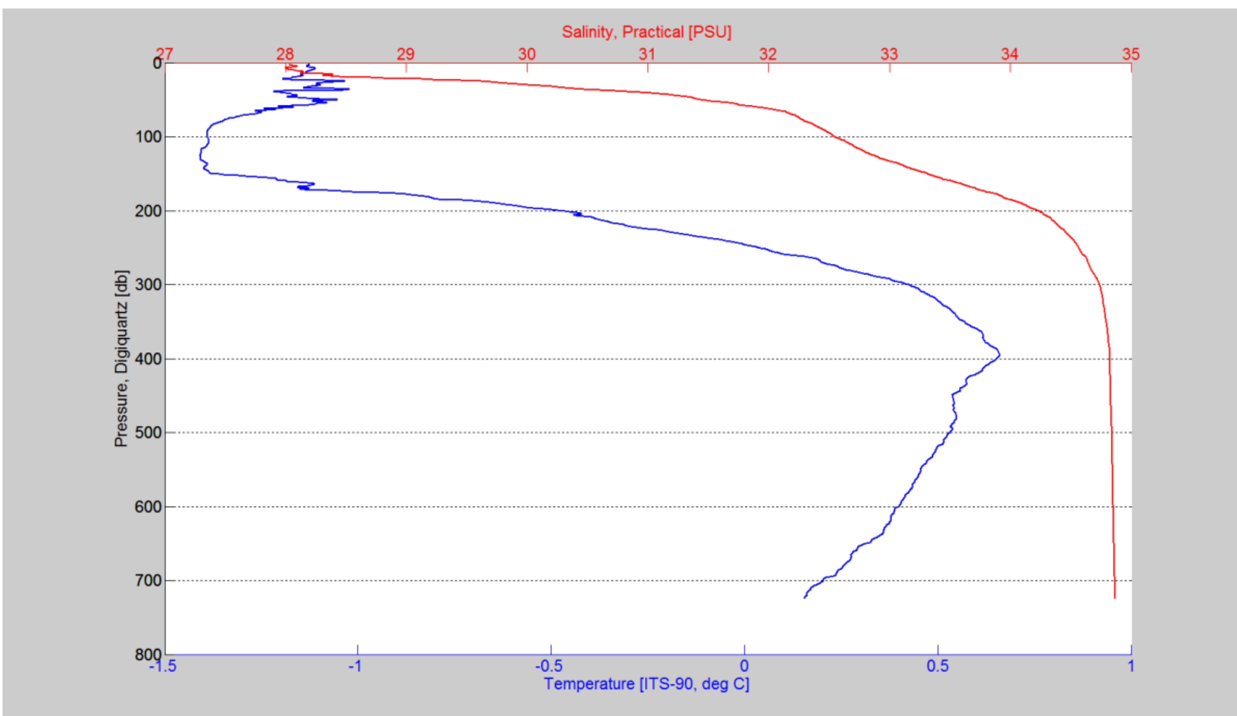


Figure 5.2.1.5 Example of the vertical structure (temperature and salinity) for the cast 051.

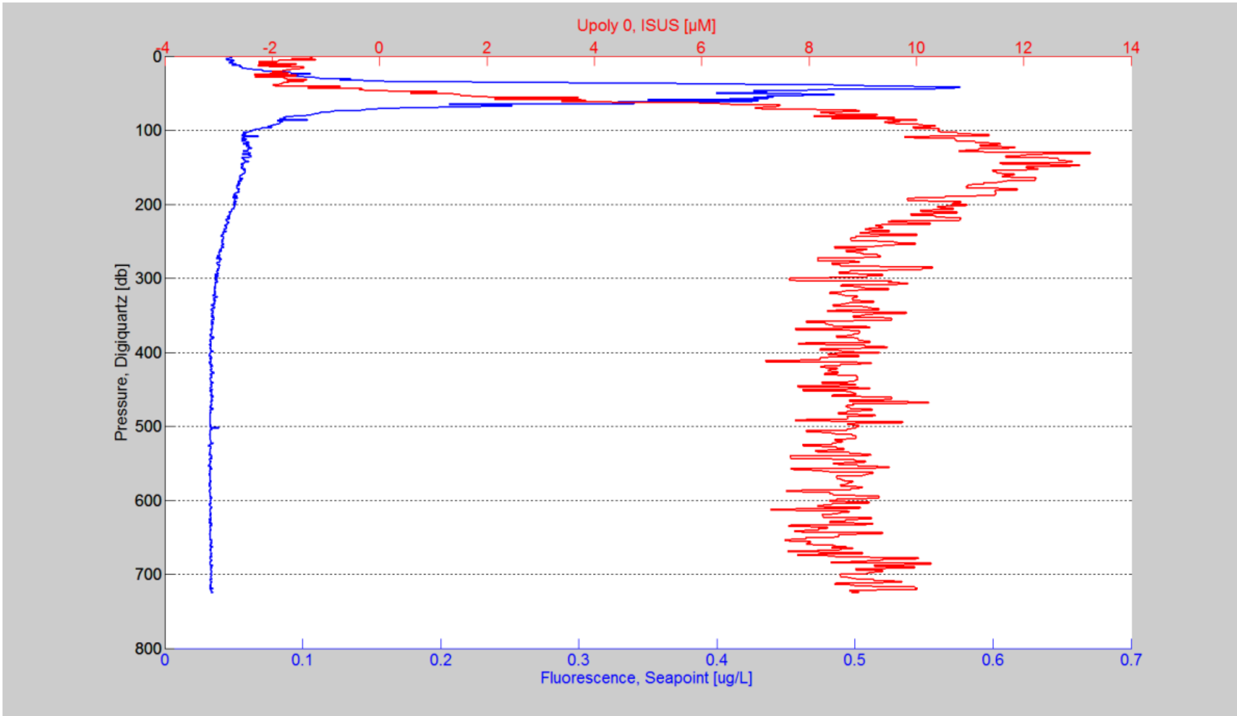


Figure 5.2.1.6 Example of the vertical structure (nitrate and fluorescence) for the cast 051.

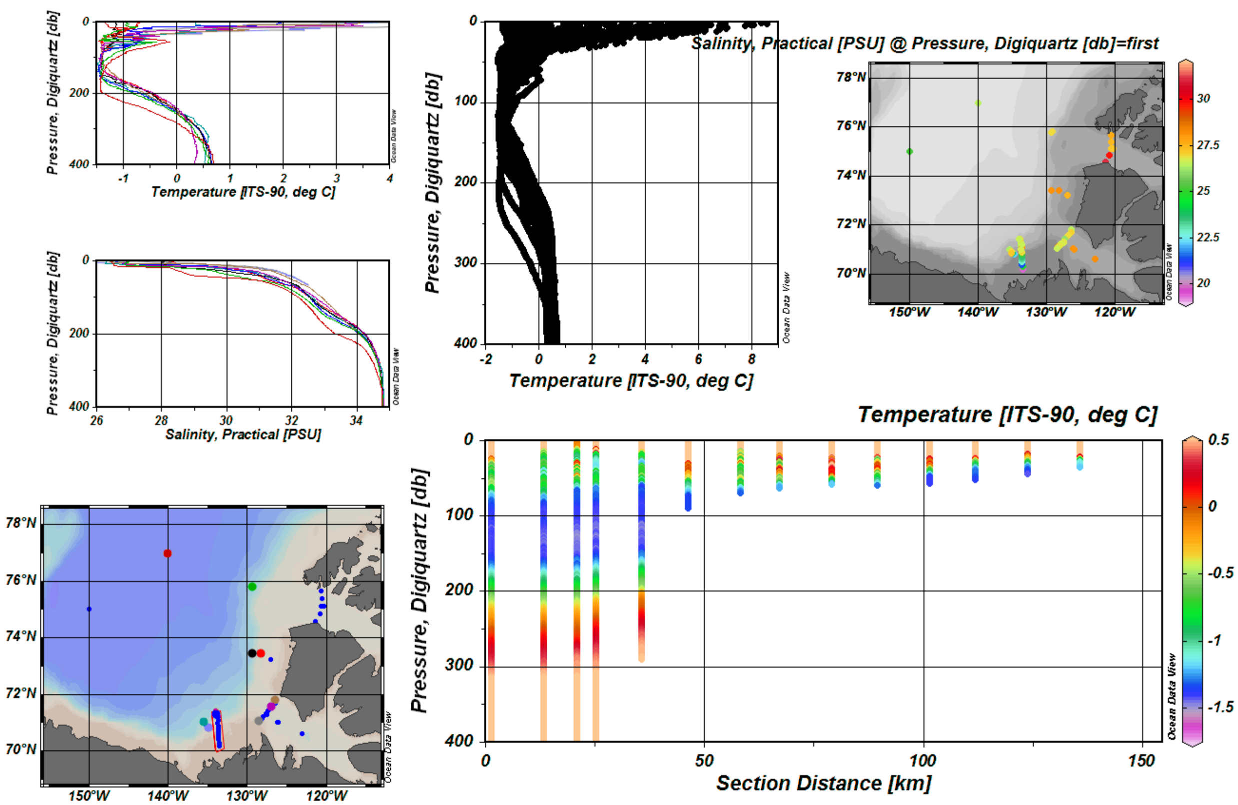


Figure 5.2.1.7 Evolution of the main parameters along the transect “Lancaster Sound’.

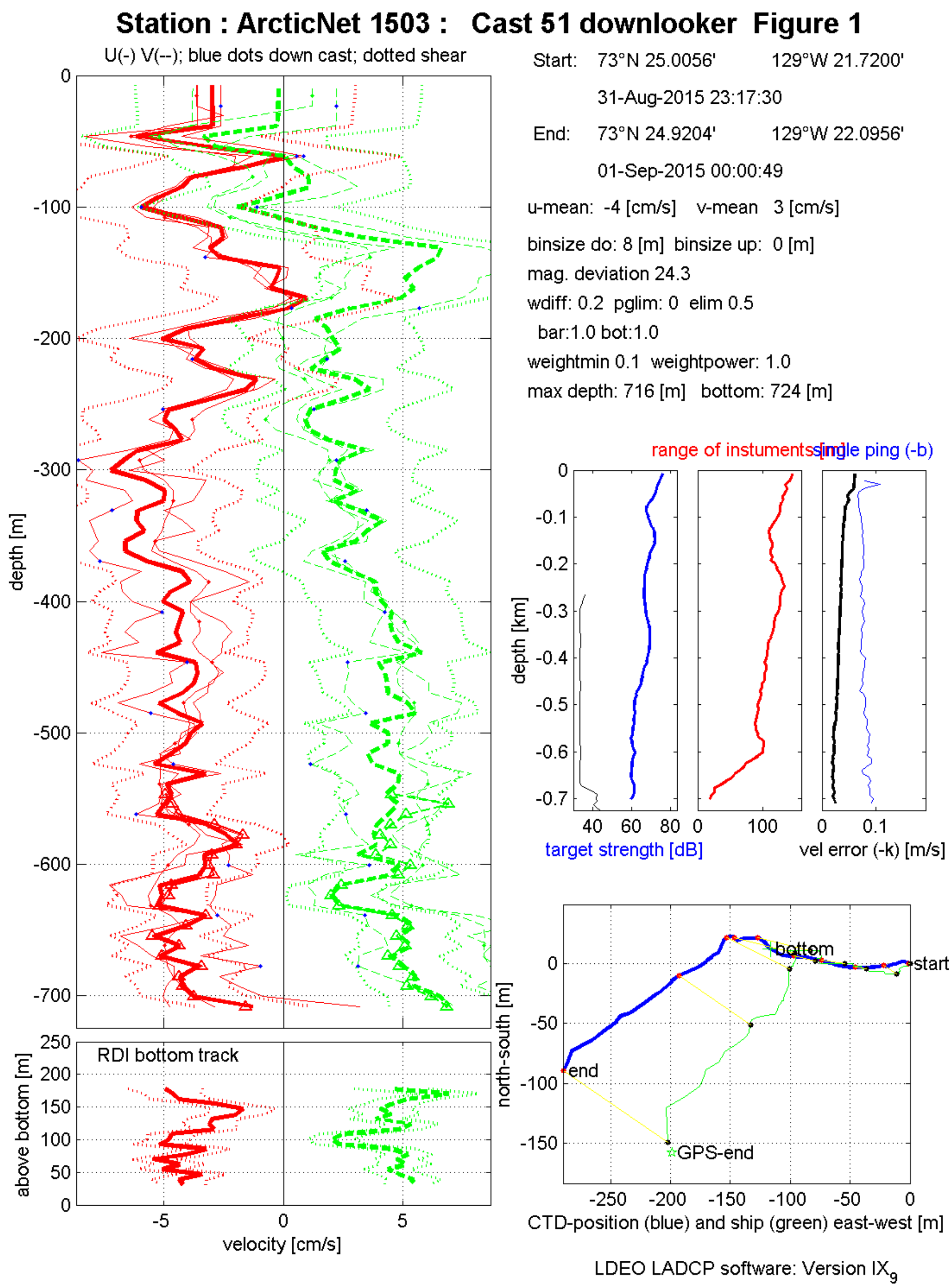


Figure 5.2.1.8 Example of current velocities for the cast 051 recorded by the LADCP.

5.2.2 Carbon and nutrients fluxes

Principal Investigator: Jean-Éric Tremblay
Cruise Participants: Gabrièle Deslongchamps

Department of Biology, Laval University

Introduction.
The Arctic climate displays high inter-annual variability and decadal oscillations that modulate growth conditions for marine primary producers. Much deeper perturbations recently became evident in conjunction with globally rising CO_2 levels and temperatures (IPCC 2007).

Environmental changes already observed include a decline in the volume and extent of the sea-ice cover (Johannessen et al. 1999, Comiso et al. 2008), an advance in the melt period (Overpeck et al. 1997, Comiso 2006), and an increase in river discharge to the Arctic Ocean (Peterson et al. 2002, McClelland et al. 2006) due to increasing precipitation and terrestrial ice melt (Peterson et al. 2006). Consequently a longer ice-free season was observed in both Arctic (Laxon et al. 2003) and subarctic (Stabeno & Overland 2001) environments. These changes entail a longer growth season associated with a greater penetration of light into surface waters, which is expected to favoring phytoplankton production (Rysgaard et al. 1999), food web productivity and CO_2 drawdown by the ocean. However, phytoplankton productivity is likely to be limited by light but also by allochtonous nitrogen availability. The supply of allochtonous nitrogen is influenced by climate-driven processes, mainly the large-scale circulation, river discharge, upwelling and regional mixing processes. In the global change context, it appears crucial to improve the knowledge of the environmental processes (i.e. mainly light and nutrient availability) interacting to control phytoplankton productivity in the Canadian Arctic.

Objectives.
The main goals of our team for leg 3b of ArcticNet 2015 were to establish the horizontal and vertical distributions of phytoplankton nutrients and to measure the primary production located at the surface of the water column using O2/Ar ratios. The secondary objectives were to quantify nitrification and regeneration processes by doing incubations with 15N tracer. In addition, natural abundance of nitrate (N isotopes) and DNA/RNA data were collected at all geotraces stations.

Methods.
Samples for inorganic nutrients (ammonium, nitrite, nitrate, orthophosphate and orthosilicic acid) were taken at all ArcticNet stations (NUTRIENTS/BASIC/FULL) stations and all GeoTraces stations to establish detailed vertical profiles (see Table 1). Nutrients samples collected during Leg 3b were frozen after sampling for later analysis. Additional samples for ammonium determination were taken at all stations and processed immediately after collection using the fluorometric method of Holmes et al. (1999). Water samples for N isotopes (natural abundance of nitrate) were collected at all GeoTraces stations and stored at -20˚C. During leg 3b, 24h incubations with ^{15}N tracer

were accessed at 5 stations to quantify nitrification and regeneration processes. In addition, DNA and RNA data were collected at all stations where incubations were performed. During the entire cruise, quadrupole mass spectrometer (PrismaPlus, Pfeiffer Vacuum) was used to measure the dissolved gases (N_2, O_2, CO_2, Ar) coming for the underway seawater line located in the 610 laboratory. O_2 to Ar ratios will later be analyzed to measure primary production that occurred up to 10 days prior of the ship's passage in all the areas visited.

References.

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Rysgaard et al. (1999) Mar Ecol Prog Ser 179:13–25
Stabeno & Overland (2001) EOS 82:317–321

Preliminary results.

No preliminary result for leg3b.

User Experience.

a) The process to gain access to the vessel and request ship time for our team's project was clear and easy to follow.

Answer: 5

b) The annual *Amundsen* expedition was effectively planned and organized (e.g., planning meeting, vessel scheduling, dissemination of information, mobilization, etc.).

Answer: 3

Comments: More science meetings could have been useful during leg 3b (especially during the ArcticNet stations sampling). The schedules could have been updated more frequently as well.

c) The *Amundsen's* central pool of equipment (e.g., scientific winches, CTD-Rosette system, MVP system, onboard laboratories, sonars, piston corer, Remotely Operated Vehicle, etc.) was properly maintained and operational at sea.

Answer: 5

d) Safety in the workplace (i.e. were you satisfied with the overall safety of the science operations conducted on and from the *Amundsen*?)

Answer: 5

e) What is your overall level of satisfaction regarding your experience conducting research on board the *Amundsen* this year?

Answer: 5

Table 5.2.2.1. List of sampling stations and measurements during leg 3b.

Station	NO3, NO2, Si, PO4	NH4	N Isotope	Incubation	DNA/RNA
CB1	X	X	X	X	
CB2	X	X	X	X	X
CB3	X	X	X	X	X
CB4	X	X	X	X	X
QMG	X	X			
QMG1	X	X			
QMG2	X	X			
QMG3	X	X			
QMG4	X	X			
AN 307	X	X			
AN 310	X	X			
AN 312	X	X			
AN 314	X	X			
AN 342	X	X			
AN 407	X	X	X	X	X
CAA8	X	X	X		
CAA9	X	X	X		

5.2.3 Biogeochemical cycling of methane in Canadian Arctic Seas

Principle Investigator: Huixiang Xie[1]
Cruise participant: Lantao Geng[1, 2]

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Introduction and Objectives
Methane (CH_4) is the second important greenhouse gas (after $CO_{2)}$ in the atmosphere. The ocean has been considered as a minor source of atmospheric CH_4 as compared to anthropogenic inputs and other natural sources. However, climate warming, particularly over the Arctic region, may significantly change the CH_4 budget. The concentration of CH_4 in Arctic seawater is expected to rise substantially due to permafrost thawing, CH_4-enriched freshwater discharge, submarine hydrothermal venting, and potential CH_4 hydrate dissolution.

Currently, few data are available on CH_4 distribution and its biogeochemical cycling in Canadian Arctic seas. The objectives of 2015 Expedition are (1) to assess methane production potentials of DMS (dimethyl sulfide), DMSO (dimethylsulphoxide) and DMSP (dimethylsulphoniopropionate) which have been hypothesized as the precursors of methane, (2) to estimate the net production or consumption rate of methane in water column and (3) to identify potential CH_4 hotspots related to hydrothermal activity or permafrost melting.

Methodology

Dark incubation samples were taken at selected stations (Fig. 1) and depths (surface, 10 m and subsurface chlorophyll maximum) and analyzed immediately after sampling for the first time. For assessing methane production potential of these precursors, those samples must be spiked with associated chemicals first before analysis. Thereafter, all dark incubation samples were stored in incubator or cold room at 4 degree. The second and the third measurements were conducted after 10 days and 20 days, respectively. Additionally, CH_4 profiles were collected at some basic and full stations as well. CH_4 concentration was measured using a PP1 methane analyzer (Peak Laboratories).

Preliminary results

No result of dark incubation is available at this moment because they are not finished yet. Here are two sections showing the distribution of CH_4 concentrations in M'Clure Strait (Fig. 2) and Queen Maud Gulf of the Canadian Archipelago (Fig. 3), respectively.

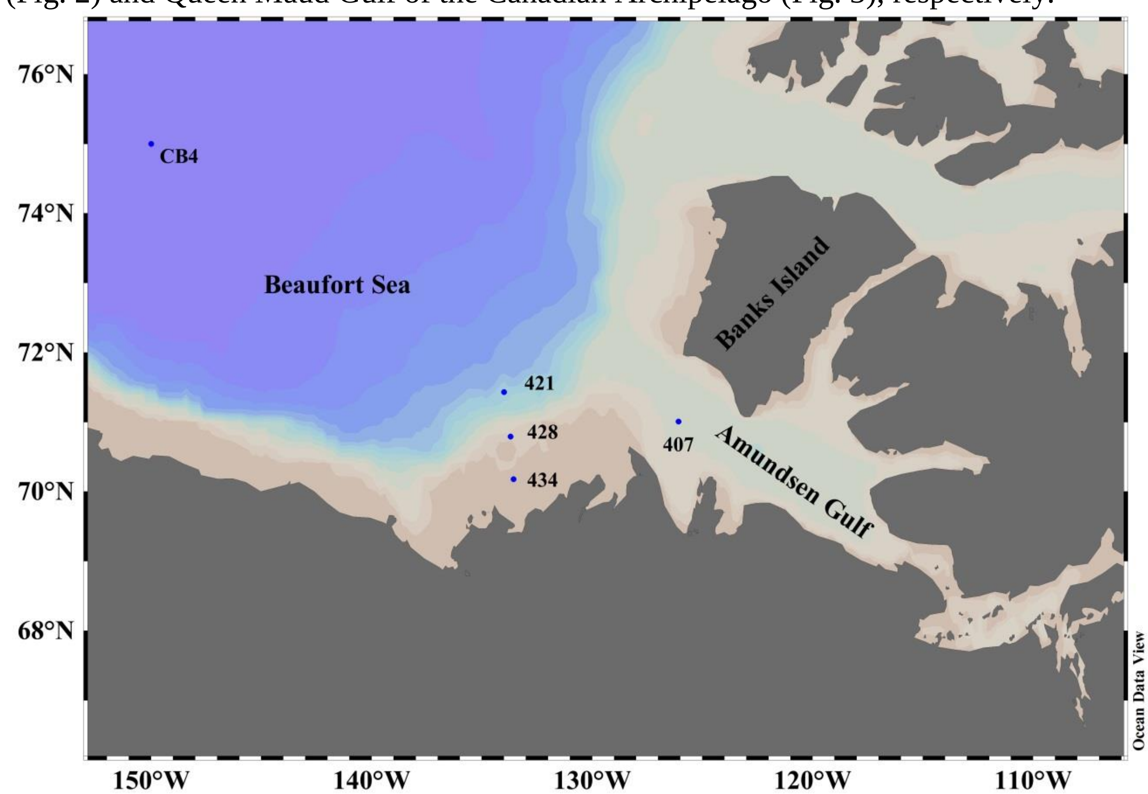

Fig. 5.2.3.1 Locations of the sampling stations for dark incubation in Leg 3 2015

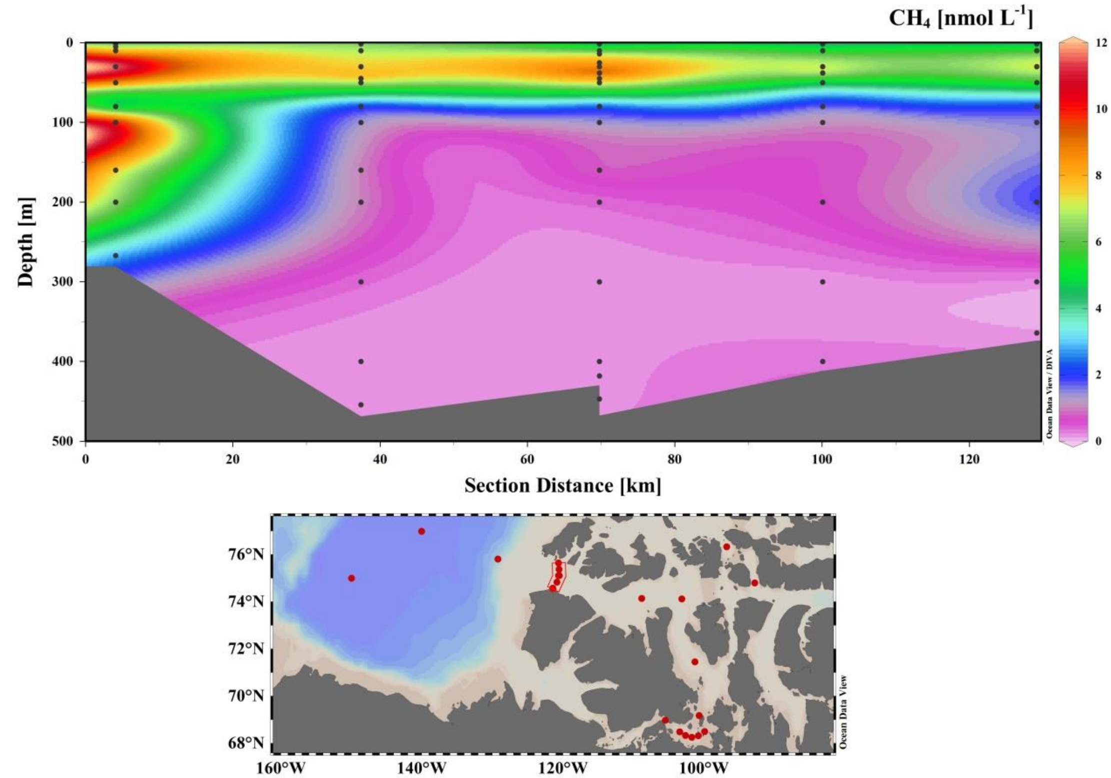

Fig. 5.2.3.2 *in-situ* CH_4 concentration in M’Clure Strait

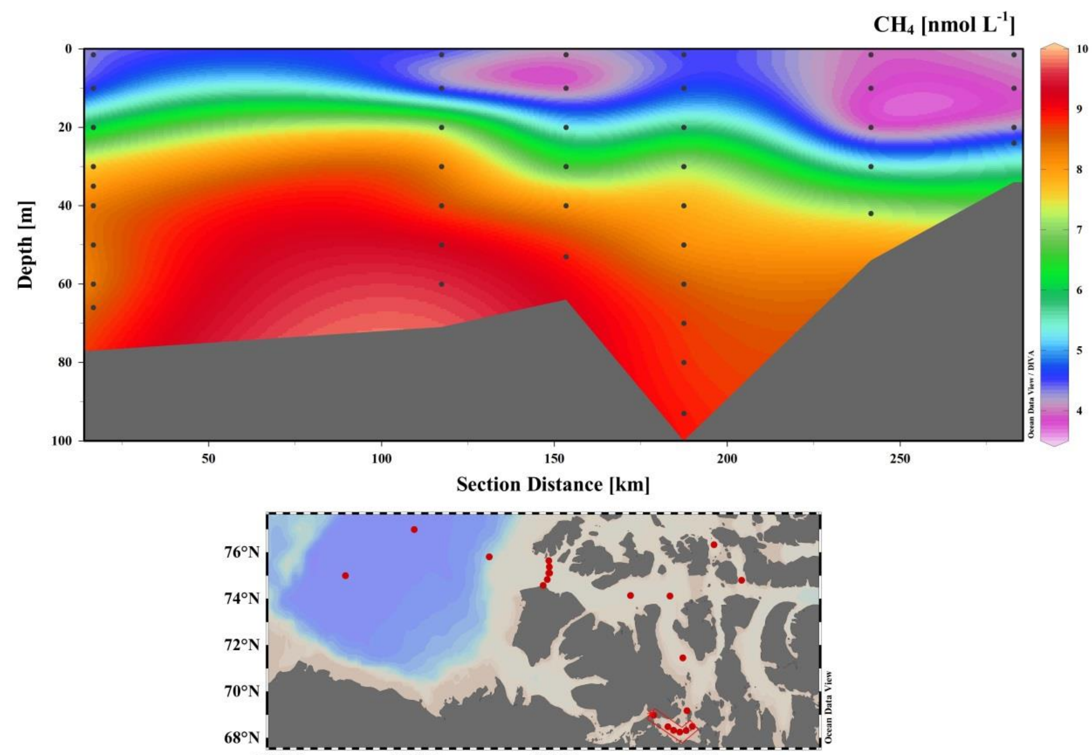

Fig. 5.2.3.2 *in-situ* CH_4 concentration in Queen Maud Gulf of the Canadian Archipelago

User experience
a) The process to gain access to the vessel and request ship time for our team's project was clear and easy to follow
5. Very satisfied
b) The annual *Amundsen* expedition was effectively planned and organized (planning meeting, vessel scheduling, dissimination of information, mobilization, etc).
5. Very satisfied
c) The *Amundsen* central pool of equipment (e.g. scientific winches, CTD-Rosette system, MVP system, onboard labs, sonars, piston corer, ROV, etc.) was properly maintained and operational at sea.
5. Very satisfied
d) Safety in the workplace (i.e. were you satisfied with the overall safety of the science operations conducted on and from the *Amundsen*?)
5. Very satisfied
e) What is your overall level of satisfaction regarding your experience conducting research on board the Amundsen this year?
5. Very satisfied

5.2.4 Microbial hydrocarbon biodegradation and hydrocarbon analysis in marine sediment

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Section 1: Sediment-associated hydrocarbon sampling

Introduction and Objectives:
Oil reserves are currently being studied for extraction in the Beaufort Sea by major oil companies; with some potential reservoirs estimated to contain billions of barrels of oil. Global warming and reduced ice coverage has made these reserves more accessible and the exploration/exploitation of offshore oil in the region more feasible. With declining ice conditions, oil exploration and shipping traffic through the North West Passage will increase; both of these activities have the potential to increase petroleum hydrocarbon concentrations in the Southern Beaufort Sea and Amundsen Gulf. However,

hydrocarbons are also present as a result of natural oil seeps, fossil fuel combustion, and terrestrial run-off. The purpose of this study is to measure baseline concentrations of hydrocarbons in the Southern Beaufort Sea and Amundsen Gulf marine environment in advance of continued oil exploration/exploitation and increased shipping.

Operations conducted during the leg/Methodology:
While on board the *CCGS Amundsen* surface sediment and sediment cores were collected.

Push coring: Samples destined for hydrocarbon analysis were collected using 10cm diameter plastic push cores from the boxcore (Table I). The sediment core was subsequently placed on a manual extruder and sectioned by 0.5cm intervals for the first 10 cm, and then 1.0 cm for the balance of the core (approximately 30cm total). Sediment was stored in Whirl-pac plastic bags, and stored at -20°C. Surface sediment (0-5cm) was collected for this research as well.

Table 5.2.4.1. Sediment and water samples collected during leg 3B of ArcticNet 2015

Leg	**Station**	**Location**	**Date**	**Operation**	**Cast**	**Depth**	**Lat**	**Long**
3B	CB1	McClure Strait	06-Sep-15	CTD Rosette	1	465	75°07.350	-120°38.500
3B	CB1	McClure Strait	07-Sep-15	Box Core	1	409	75°06.750	-120°21.400
3B	CB2	Beaufort Sea	10-Sep-15	CTD Rosette	1	1344	75°47.108	-129°17.443
3B	CB2	Beaufort Sea	10-Sep-15	Box Core	1	1350	75°47.030	-129°17.080
3B	CB3	Beaufort Sea	11-Sep-15	CTD Rosette	1	3735	76°58.510	-140°03.090
3B	CB3	Beaufort Sea	12-Sep-15	TM Rosette	1	3731	76°59.938	-140°05.702
3B	CB3	Beaufort Sea	12-Sep-15	TM Rosette	2	3732	77°01.150	-140°02.710
3B	CB4	Beaufort Sea	14-Sep-15	CTD Rosette	1	3829	75°00.030	-149°59.600
3B	CB4	Beaufort Sea	15-Sep-15	TM Rosette	1	3829	75°00.030	-149°59.600
3B	407	Beaufort Sea	18-Sep-15	CTD Rosette	1	390	71°00.330	-126°04.560
3B	407	Beaufort Sea	18-Sep-15	Box Core	1	398	70°59.600	-126°03.280
3B	314	NW Passage	20-Sep-15	CTD Rosette	1	77	68°58.200	-105°28.890
3B	314	NW Passage	20-Sep-15	Box Core	1	81	68°58.256	-105°28.251
3B	314	NW Passage	20-Sep-15	Box Core	2	80	68°58.193	-105°28.505
3B	314	NW Passage	20-Sep-15	Box Core	3	81	68°58.208	-105°28.348
3B	QMG4	NW Passage	20-Sep-15	CTD Rosette	1	71	68°29.000	-103°25.480
3B	QMG4	NW Passage	20-Sep-15	Box Core	1	67	68°29.060	-103°25.660
3B	QMG3	NW Passage	21-Sep-15	CTD Rosette	1	64	68°19.770	-102°36.398
3B	QMG3	NW Passage	21-Sep-15	Box Core	1	67	---	---
3B	QMG	NW Passage	21-Sep-15	CTD Rosette	1	107	68°14.803	-101°43.057
3B	QMG	NW Passage	21-Sep-15	Box Core	1	100	---	---
3B	QMG2	NW Passage	21-Sep-15	CTD Rosette	1	54	68°18.810	-100°47.990
3B	QMG2	NW Passage	21-Sep-15	Box Core	1	59	68°18.720	-100°47.890
3B	QMG1	NW Passage	21-Sep-15	CTD Rosette	1	35	68°29.630	-99°53.440
3B	QMG1	NW Passage	22-Sep-15	Box Core	1	48	68°29.469	-99°54.091
3B	312	NW Passage	22-Sep-15	CTD Rosette	1	65	69°10.330	-100°41.600

3B	312	NW Passage	22-Sep-15	Box Core	1	64	69°10.220	-100°41.700
3B	310	NW Passage	23-Sep-15	CTD Rosette	1	163	71°27.411	-101°16.734
3B	310	NW Passage	23-Sep-15	Box Core	1	158	71°27.411	-101°16.734
3B	308	NW Passage	24-Sep-15	CTD Rosette	1	565	74°08.320	-108°50.080
3B	308	NW Passage	24-Sep-15	Box Core	1	564	74°08.356	-108°50.193
3B	308	NW Passage	24-Sep-15	Box Core	2	---	---	---
3B	308	NW Passage	24-Sep-15	Box Core	3	---	---	---
3B	307	NW Passage	25-Sep-15	CTD Rosette	1	357	74°06.675	-103°07.454
3B	307	NW Passage	25-Sep-15	Box Core	1	350	74°06.980	-103°06.000
3B	342	NW Passage	25-Sep-15	CTD Rosette	1	137	74°47.670	-92°46.860
3B	342	NW Passage	25-Sep-15	Box Core	1	138	74°47.650	-92°46.880

Preliminary results:
No analyses were performed on the ship.

Section 2: Benthic microbial diversity and hydrocarbon biodegradation

Introduction and Objectives:
Marine sediment environments are high in microbial diversity and abundance with a cubic centimeter of seabed typically containing billions of microbial cells – about a thousand fold more than in overlying seawater. The theme of our research in the Canadian Arctic archipelago is to establish baseline data for the diversity and activity of microorganisms in Arctic sediments, and experimentally investigate how short and long term changes in environmental parameters (e.g. temperature; pulses of organic compounds such as hydrocarbons) may affect the community composition, metabolic rates and cycling of carbon and other nutrients. This work will determine the impact of permanently cold temperatures on the rates of biogeochemical processes such as sulfate reduction, which is responsible for up to half of organic carbon mineralization in coastal sediments.

The occurrence and locations of marine hydrocarbon seeps in Canada’s Arctic are important to assess the ability of microbiota in Arctic seawater and sediments to biodegrade accidentally released crude oil or other pollutants. A rapid natural response may depend on a region’s microbiota being ‘primed’ for such biodegradation by the slow natural release of hydrocarbons from seabed seeps. Given that industrial activity and traffic in the Northwest Passage is poised to increase, the inherent biodegradative capacity of marine microorganisms will be tested experimentally on samples obtained. Sediment associated microbial communities will also be compared to microbial communities in the water column to elucidate possible relationships of hydrocarbon degrading communities between the two environments. Samples collected will also be compared to Gulf of Mexico (GoM) sediment samples to measure any differences in the potential for biodegradation (microbial communities, rates of hydrocarbon oxidation). This data will be used to help develop a predictive measure of how different regions of the Arctic could respond to various pollution scenarios.

Another goal of our work is targeted diversity studies to explore the abundance and function of spore-forming thermophilic sulfate-reducing bacteria in permanently cold sediments, extending biogeography analyses that have been performed in other Arctic sediments. Arctic thermophiles are thought to derive from warm deep sediments and get transported up into the cold ocean via seabed hydrocarbon seepage.

Operations conducted during the Leg/Methodology:
During leg 3B, sediment was collected using the boxcore and water was collected using the CTD Rosette.

Surface sediment sampling:
Samples collected (Table I) for microorganism incubation experiments were scraped from the top 5cm of the boxcore using a plastic spatula, stored in 2L heat sealed plastic bags and then kept at 4°C. An effort was made to eliminate all headspace from the plastic bags. Surface samples destined for microorganism diversity analysis were scraped from the top 5cm of the boxcore using a stainless steel pallet knife into 15mL plastic cryovials, spiked with 5mL of 95% ethanol and stored at -80°C. 2mL headspace was kept for freezing expansion. Triplicate sample vials were collected whenever possible.

Sediment push coring:
Cores for microorganism incubations and diversity were collected using the same equipment the hydrocarbon study. These cores were sectioned by 2.0cm intervals for the first 10cm and then 5.0cm intervals for the balance. At each interval, triplicate subsamples were collected for microorganism diversity using the same 15mL vials and methods described earlier. The bulk of the remaining section was kept in Whirl-pac plastic bags and stored at 4°C.

Sediment push coring for GoM comparison:
Push cores from the boxcore full stations were sectioned at 1cm intervals and stored at -80C for DNA extraction in Whirl-pac plastic bags.

Water sampling:
Water was requested for microbial community analysis to compare to sediment microbial communities (collected as previously described). 4L each of surface and bottom water was requested and sampled from Niskin bottles into rinsed and bleached Nalgene carboys at each of the Full and Basic stations. 2L of water from each depth was successively filtered over 0.8µm, 0.45µm, and 0.2µm Pall membrane filters. Filters were stored in whirlpack bags at -20°C for future DNA extraction and sequencing of the 16s rRNA genes.

Water sampling for GoM comparison:
Water samples were collected at the surface and bottom depths from the CTD Rosette Niskin bottles. For each depth, 1L of the water sample was passed through a 0.22µm filter tower and preserved in -80C freezer for DNA extraction. Approximately 100ml of additional water was filtered through 0.22µm syringe filter for future nutrient analysis.

Diesel biodegradation experiments:
Surface sediment from stations CB1, CB2 and 314 were used to inoculate anaerobic diesel biodegradation incubations. Inoculated bottles used 10mL of sediment, 40mL of artificial seawater with 20mM sulphate, and 50µL of diesel or crude oil and incubated at 4°C. Unamended and sediment-free controls were set up in line. Incubations will be sampled every two months; sulfate reduction, diesel removal, and microbial community composition will be monitored.

GoM crude oil incubations:
2.5mL of surface sediment collected at Full stations was mixed with 7.5 volumes of filtered bottom water from the same station and incubated with 0.1% v/v crude oil. For water incubations, 10mL of seawater was also incubated with 0.1% v/v crude oil. For both types of incubations, additional triplicate enrichments with no oil addition were included as controls. To simulate *in situ* conditions and prevent any photochemical processes, incubations were stored at 4°C and in the dark. No obvious oxygen consumption has been observed yet.

Preliminary results:
No analyses were performed on the ship.

Recommendations/Notes:
We were unable to collect samples at the deep stations (CB3 and CB4) due to insufficient winch cable length for both the CTD Rosette and the boxcore. Sediment samples from these depths could be very interesting to compare to shelf and slope samples in the future; therefore, a longer cable for both could be useful.

Acknowledgements: Thank you to Solveig Bourgeois and Laure de Montety for their time on the deck as part of the boxcore team. Thank you as well to Callum Mireault for helping on deck and Olivier Asselin in the lab when we needed an extra set of hands.

Big thanks to the Rosette operators Olivier Asselin, and Callum Mireault for accommodating our water requests.

Finally, thank you to Commandant Lacerte and crew of the *CCGS Amundsen* for facilitating an excellent scientific expedition. We could never complete our scientific endeavours without you!

5.2.5 Project: Benthic diversity and functioning across the Canadian Arctic

Principal Investigator: Philippe Archambault[1]**,** Christian Nozais[2]**,** Ursula Witte[3]
Cruise participants: Solveig Bourgeois[3], Laure de Montety[1], Christian Nozais[2]

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[2] *UQUAR – Université du Québec à Rimouski*
[3] *Oceanlab, University of Aberdeen*

Introduction & Objectives

It is widely recognized that wide areas of the Arctic are changing from arctic to subarctic conditions. Rapid warming is causing higher water temperatures and reduced ice cover, two factors that will certainly provoke severe ecosystem changes propagating through all trophic levels. Over the past decade, a geographical displacement of marine mammal population distribution has been observed, that coincides with a reduction of benthic prey populations. According to a widely accepted model, the relative importance of sea-ice, pelagic and benthic biota in the overall carbon and energy flux will shift from a sea-ice algae-benthos to a phytoplankton-zooplankton dominance. In the context of the potential benthic community changes, it is essential to establish benchmarks in biodiversity and understand the functioning of the benthic community at key locations in the Canadian Arctic prior to the expected changes in ice cover, ocean chemistry and climate and the future human activities (transport, trawling or dredging, drilling, etc.) that are likely to happen in response to the predicted environmental changes. Unlike Canada's two other oceans, we have the opportunity to document pristine conditions before ocean changes and exploitation occurs.

The main objectives are to

a) describe and compare the biodiversity (using a variety of different diversity indices) in different locations of the Canadian Arctic in relation to environmental variables
b) describe the relative importance of phytoplankton and ice algae as a food source to benthic organisms by looking at compound specific isotopes in faunal tissues, sediments and water column particulate organic matter
c) track pathways of particulate organic carbon processing and uptake by the benthic community during isotope tracing experiment

Methodology

The box core (Figure 5.2.5.1) was deployed to quantitatively sample diversity, abundance and biomass of mega- and macroendobenthic fauna and to obtain sediment cores for sediment analyses and incubations. From 28 box cores, sediments of usually a surface area of 0.125 m^2 and 10-15 cm in depth were collected and passed through a 0.5 mm mesh sieve and preserved in a 4 % formaldehyde solution for further identification in the laboratory (Table 5.2.5.1). Sub-cores of sediments were collected for sediment pigment content (with 10 mL truncated syringes of an area of 1.5 cm^2 each), organic carbon content, sediment grain size and compound specific isotopes (with 60 mL truncated syringes of an area of 5 cm^2 each); for sediment pigments, organic carbon content and compound specific isotopes, the top 1 cm was collected, although for sediment grain size, the top 5 cm was collected. Sediment pigment and compound specific isotope samples were frozen at -80°C, and organic carbon samples, porosity and sediment grain size samples were frozen at -20°C. All samples will be transported off the ship for analyses in the lab at the Université du Québec à Rimouski and University of Aberdeen (for compound specific isotope analysis).


Figure 5.2.5.1. Box core deployment and sediment cores sampling.

For the isotope tracing experiment (Figure 5.2.5.2), incubations of 15 sediment cores were performed at 2 stations (Table 1) in a dark and temperature controlled room (ca 4°C). Five cores acted as controls; ^{13}C, ^{15}N labelled ice algae or phytoplankton was added to five cores each. The oxygen concentrations in the water column overlying the sediment (bottom water collected from rosette water samples obtained at the same station) in the incubation cores were measured periodically (about 24h intervals) over 4 days to examine sediment community oxygen consumption. To examine carbon remineralization rates, water samples for $DI^{13}C$ analysis were collected at 24 hour intervals. Additional water samples for nutrient and $DO^{13}C$ (bacterial breakdown of organic matter) analysis were taken at days 0, 2 and 4. At the end of the incubations, the top 10 centimeters of sediment in the cores was sliced. Half of each slice was frozen in -80°C for phospholipid fatty acid analysis whereas the other half was sieved on a 0.5 mm mesh sieve to obtain macrofauna that were preserved in a 4% seawater-formalin solution for later isotope tracer uptake analysis.

At 20 stations, the Agassiz trawl (Figure 5.2.5.3) was deployed to collect mega- and macroepibenthic fauna (Table 5.2.5.2). Catches were passed through a 2 mm mesh sieve. When possible, specimens were identified to the lowest taxonomic level, then count and weigh. The unidentified specimens were preserved in a 4% seawater-formalin solution or frozen at -20°C for later identification. At 11 stations, some specimens were frozen at -80°C for compound specific isotope analysis.

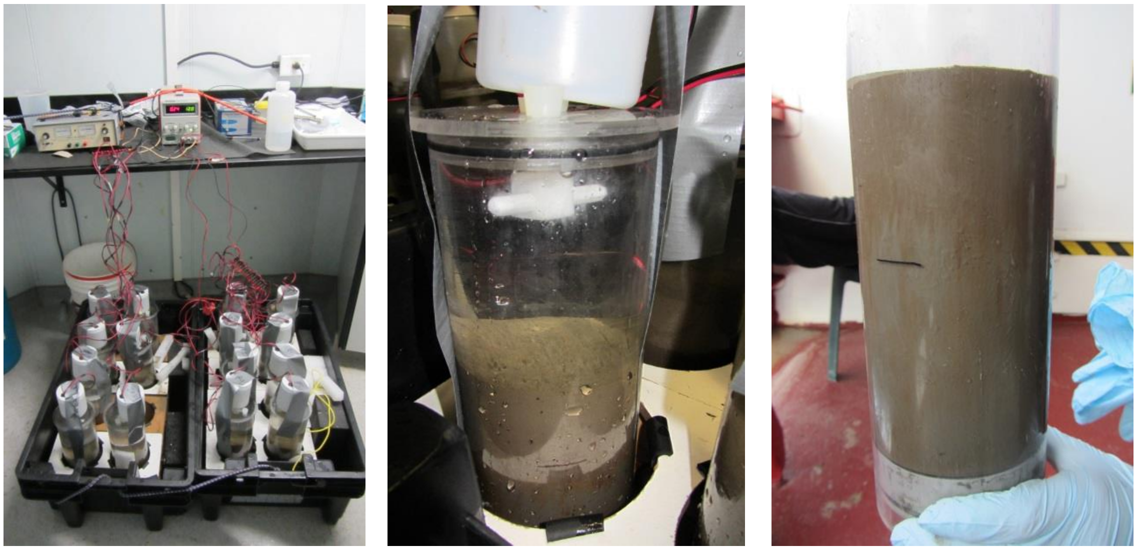

Figure 5.2.5.2. Isotope tracing experiment set-up in the temperature controlled room and slicing of sediment cores after finishing the experiment.

Figure 5.2.5.3. Agassiz trawl deployment and identification of the specimens.

At the stations where the megafauna was kept for further analysis, water samples (10 m above bottom and chlorophyll maximum) were taken from the CTD Rosette, filtered on GF/F filters and kept at -80°C for particulate organic matter compound specific isotope analysis.

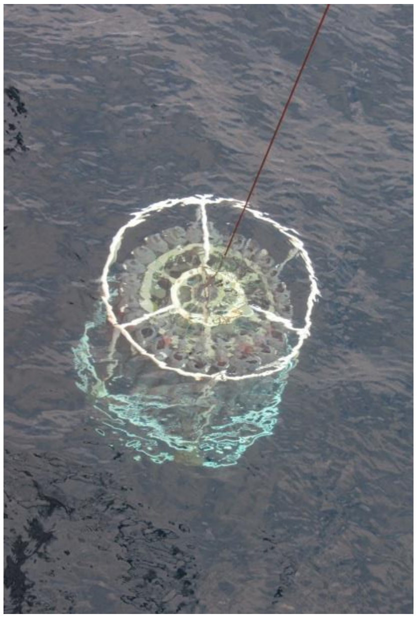
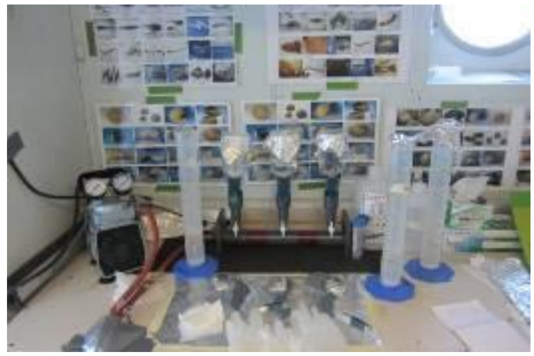

Figure 5.2.5.4. CTDRosette deployment and filters.

Preliminary results

At this point, we do not know exactly if spatial and temporal variability of benthic diversity is governed by sediment type, food availability or other environmental variables. Samples collected for compound specific isotope analysis and during the incubation experiments also require further analysis. For detailed results, identification of organisms and sediment analyses will be carried on in home labs.

Here are some striking comments that we can make at this point:

- Stations CB-2 and 308 exhibited very lower benthic diversity, abundance and biomass than all the other stations sampled.

Notes:

We did not deploy the box core and the agassiz trawl at stations 420 and 342 respectively because the bottom was too rocky; using a benthic camera might be a good alternative to get data at those stations.

We did not deploy the box core at the deepest stations CB-3 and CB-4 because the cable was not long enough to reach the seafloor.

We did not deploy the Agassiz trawl at the stations 310, 307 and CAA9 because of ice or weather conditions.

Acknowledgement

We gratefully thanks the chief scientists Keith Levesque and Roger Francois and the Captain of the Amundsen Alain Lacerte. We also thank the day and night deck crew for their help with the gear deployment. Thanks to Amy Noel, Oscar Montoya and Xiaoxu Sun for their help with the boxcore sampling and cleaning. Finally, thank you to the ArcticNet team, Olivier Asselin and Callum Mireault (rosette operator) and Simon Morisset for their time.

Table 5.2.5.1. Box coring stations during leg 3.

Station ID	Local Date	Latitude (N)	Longitude (W)	Depth (m)	Diversity	Grain size	Pigments	Organic content	Isotopes Sediments	Incubation	Comments
405	Aug 22 2015	70°36.5006	123°01.7862	628	X	X	X	X	X		
407	Aug 23 2015	71°00.6511	126°06.0055	393	X	X	X	X			
437	Aug 24 2015	71°48.273	126°29.796	274	X	X	X	X			
408	Aug 25 2015	71°18.784	127°35.677	202	X	X	X	X			
434	Aug 26 2015	70°10	133°33	47	X	X	X	X	X		
435	Aug 27 2015	71°04.77	133°38.15	302	X	X	X	X	X		
435	Aug 27 2015	71°04.74	133°37.96	307						X	
435	Aug 27 2015	71°04.75	133°37.79	302						X	
421	Aug 29 2015	71°25.589	134°00.038	1203	X	X	X	X			
535	Aug 31 2015	73°25.01	128°11.76	291	X	X	X	X			
518	Sep 02 2015	74°34.341	121°26.567	269	X	X	X	X	X		
514	Sep 02 2015	75°06.226	120°37.679	457	X	X	X	X			
CB1/4 Miles East	Sep 07 2015	75°06.73	120°21.34	409	X	X	X	X			
CB2	Sep 10 2015	75°47.13	129°17.45	1355	X	X	X	X	X		
407	Sep 18 2015	70°59.62	126°03.39	395						X	
407	Sep 18 2015	70°59.68	126°03.77	398						X	
314	Sep 20 2015	68°58.291	105°28.415	78	X	X	X	X			
QMG4	Sep 20 2015	68°29.06	103°25.71	69	X	X	X	X			
QMG3	Sep 21 2015	68°19.801	102°36.545	67	X	X	X	X			

QMG-Mooring	**Sep 21 2015**	**68°14.654**	**101°43.039**	**100**	**X**	**X**	**X**	**X**			
QMG-2	**Sep 21 2015**	**68°18.72**	**100°47.91**	**59**	**X**	**X**	**X**	**X**			
QMG-1	**Sep 22 2015**	**68°29.497**	**99°54.276**	**45**	**X**	**X**	**X**	**X**			
312	**Sep 22 2015**	**69°10.23**	**100°41.59**	**63**	**X**	**X**	**X**	**X**			
310	**Sep 23 2015**	**71°26.98**	**101°17.54**	**158**	**X**	**X**	**X**	**X**			**gravels**
308	**Sep 24 2015**	**74°08.356**	**108°50.193**	**564**	**X**	**X**	**X**	**X**			
307	**Sep 27 2015**	**74°07.10**	**103°05.54**	**349**	**X**	**X**	**X**	**X**			
342	**Sep 25 2015**	**74°47.63**	**092°47.01**	**138**	**X**		**X**	**X**			**sediment with rocks**
CAA9	**Sep 27 2015**	**76°19.81**	**096°45.35**	**336**	**X**	**X**	**X**	**X**	**X**		**sediment with rocks**

Table5.2.5.2. Agassiz trawl stations during leg 3.

		Start			**End**				
Station ID	**Local Date**	**Latitude (N)**	**Longitude (W)**	**Depth (m)**	**Latitude (N)**	**Longitude (W)**	**Depth (m)**	**Duration (min)**	**Comments**
405	**Aug 22 2015**	**70°36.670**	**123°01.840**	**628**	**70°36.645**	**123°02.756**	**602**	**3**	
407	**Aug 23 2015**	**71°00.840**	**126°06.930**	**393**	**71°00**	**126°08**	**393**	**3**	
437	**Aug 24 2015**	**71°48.167**	**126°30.477**	**293**	**71°47.741**	**126°29.897**	**298**	**3**	**rocks**
408	**Aug 25 2015**	**71°18.794**	**127°35.816**	**202**	**71°18.514**	**127°35.968**	**200**	**3**	
420	**Aug 25 2015**	**71°03**	**128°31**	**40**	**71°02**	**128°31**	**43**	**5**	**hard bottom**
434	**Aug 26 2015**	**70°10.99**	**133°34**	**46**	**70°11**	**133°34**	**47**	**5**	**1st trawl at 2 knots, didn't work**
435	**Aug 27 2015**	**71°04.73**	**133°38.05**	**298**	**71°04.50**	**133°40.32**	**300**	**5**	
435	**Aug 29 2015**	**71°12.490**	**133°41.840**	**716**	**71°11.290**	**133°44.407**	**648**	**8**	
535	**Aug 31 2015**	**73°25.01**	**128°11.84**	**291**	**73°24.22**	**128°14.00**	**304**		**net empty**
518	**Sep 02 2015**	**74°34.372**	**121°25.955**	**308**	**74°34.2**	**121°28.7**	**227**	**5**	

514	**Sep 02 2015**	**75°06.098**	**120°37.186**	**451**	**75°06.110**	**120°35.427**	**440**	**5**	
CB1/ 4 miles east	**Sep 07 2015**	**75°06.810**	**120°21.446**	**408**	**75°07.693**	**120°20.910**	**408**	**3**	
314	**Sep 20 2015**	**68°58.154**	**105°28.634**	**75**	**68°58.366**	**105°28.886**	**74**	**3**	
QMG4	**Sep 20 2015**	**68°29.08**	**103°25.67**	**68**	**68°28.66**	**103°26.39**	**76**	**3**	
QMG3	**Sep 21 2015**	**68°19.75**	**102°36.47**	**63**	**68°19.46**	**102°36.47**	**62**	**3**	
QMG-Mooring	**Sep 21 2015**	**68°14.583**	**101°43.347**	**105**	**68°14.176**	**101°42.732**	**98**	**3**	
QMG-2	**Sep 21 2015**	**68°18.77**	**100°47.88**	**59**	**68°18.56**	**100°47.90**	**74**	**3**	
312	**Sep 22 2015**	**69°10.11**	**100°42.25**	**64**	**69°09.94**	**100°41.78**	**60**	**03:15**	
310	**Sep 23 2015**	**71°27.53**	**101°16.20**	**166**	**71°26.75**	**101°17.64**	**158**		**cancelled, strong wind, boat speed more than 2 knots**
308	**Sep 24 2015**	**74°08.242**	**108°49.705**	**563**	**74°08.89**	**108°52.48**	**561**		**gravel**

User Experience

b) The annual *Amundsen* expedition was effectively planned and organized (e.g., planning meeting, vessel scheduling, dissemination of information, mobilization, etc.).

Comments: We really appreciated that our special station requests onboard were accepted.

c) The *Amundsen's* central pool of equipment (e.g., scientific winches, CTDRosette system, MVP system, onboard laboratories, sonars, piston corer, Remotely Operated Vehicle, etc.) was properly maintained and operational at sea.

10. Very satisfied

Comments: It could be interesting to have a longer cable in order to sample at deep stations (under 2500m) and also a benthic camera when it is not possible to deploy the Agassiz (e.g. rocky bottom).

d) Safety in the workplace (i.e. were you satisfied with the overall safety of the science operations conducted on and from the *Amundsen*?)

5. Very satisfied

e) What is your overall level of satisfaction regarding your experience conducting research on board the *Amundsen* this year?

5. Very satisfied

5.2.6 Zooplankton and Fish Ecology / Acoustic

Principal Investigator: Louis Fortier

Cruise Participants: Cyril Aubry, Marie Parenteau, Thibaud Dezutter and Maxime Geoffroy (

Biology Department, Université Laval

Introduction and objectives

The main objective of our team during this leg was the monitoring of zooplankton and fish key parameters (abundance, diversity, biomass and distribution) using various sampling nets, the echosounder, and a fisheries sonar. Additionally, specific field objectives for leg 3b were to collect zooplankton and fish samples, acoustic data and marine mammals' observation to:

1- Provide new and key information on the biodiversity and ecosystem function in the marine waters of the Kitikmeot region, considered a *mare incognita* for which information on marine ecosystems is acutely wanting (C. Bouchard, U. Laval)
2- Study the population genetics of the dominant species (J. Nelson, U. Victoria)

Before going further into this report, we would like to express our sincere gratitude to the commanding officer, the officers and crew of the CCGS *Amundsen*, whose precious help was essential for making this mission a success.

Operations conducted during leg 3b

- 5 Nets Vertical Sampler (5NVS) (2 × 200µm, 1 × 500µm, 1 × 50µm, LOKI). Zooplankton sampler. Four 1-m^2 metal frames attached together and rigged with three 4-m long, conical-square plankton nets, an external 10-cm diameter, 50-µm mesh net, and a LOKI (Lightframe Onsight Keyspecies Investigation system). Deployed vertically from 10 meters off the bottom to the surface, or less at deep station as the maximum depth recommended for the LOKI is 1000 m. The 5NVS was equipped with three TSK® flowmeters. After removal of fish larvae/juveniles (kept separately in 95% ethanol + 1% glycerol), zooplankton samples from one 200-µm, one 500-µm mesh, and the LOKI nets were preserved in 4% formaldehyde solution for abundance measurements while samples from the other 200-µm mesh net were frozen at -20°C for dry weight measurements.

- Double Square Net (DSN) (1 × 500µm, 1 × 750µm, 1 × 50µm). Ichthyoplankton Net. Rectangular frame carrying two 4,5-m long, 1-m^2 mouth aperture, square-conical nets and an external 10-cm diameter, 50-µm mesh net (to collect microzooplanktonic prey of the fish larvae). The sampler was towed obliquely from the side of the ship at a speed of ca. 2-3 knots to a maximum depth of 90 m (depth estimated during deployment from cable length and angle; real depth obtained afterward from a Star-Oddi® mini-CTD attached to the frame). The DSN was equipped with three KC® flowmeters. Fish larvae collected with the DSN were measured and preserved individually in 95% ethanol. + 1% glycerol Zooplankton samples from the 500-µm mesh net were preserved in 4% formaldehyde solution for further taxonomic identification while those from the 750-µm mesh net were preserved in 95% ethanol for genetic analyses.
- Isaac-Kidd Midwater Trawl (IKMT). Pelagic juvenile and adult fish sampler. Rectangular net with a 9-m^2 mouth aperture and mesh size of 11 mm in the first section, 5 mm in the last section. The net was lowered to a depth where a fish aggregation has been detected by the echosounder and towed at that depth for 20 minutes at a speed of 2-3 knots (depth estimated during deployment from cable length and angle; real depth obtained afterward from a Star-Oddi® mini-CTD attached to the frame). Fish collected with this sampler were measured and stored at -80°C.
- Benthic Beam Trawl. Demersal fish sampler. Rectangular net with a 3-m^2 mouth aperture, 32-mm mesh size in the first section, 16 mm in the last section, and a 10-mm mesh liner. The net was lowered to the bottom and towed for 20 minutes at a speed of 3 knots. Fish collected with this sampler were measured and stored at -80°C.
- Acoustic monitoring. The Simrad® EK60 echosounder of the *Amundsen* allows our group to continuously monitor the spatial and vertical distribution of zooplankton and fish, the later mostly represented by Arctic cod (*Boreogadus saida*). The hull-mounted transducers are in operation 24h a day thus providing an extensive mapping of where the fishes are along the ship track.
- Sonar observation. The Kongsberg® SX90 fish sonar let us observed the presence of marine mammals and possible near surface schools of fish. Marine mammal observations were validated by a wildlife observer working at the bridge from 08:00 to 20:00 (local time).

Preliminary results

Forty-four net deployments were conducted during leg 3b (Table 5.2.6.1) in which a total of 577 fish were caught. Two hundred and eighty-two individuals were young-of-the-year (61% Arctic cod) and 295 were adults (33.9% Arctic cod). Mean standard length (SL) and mean weight (W) of the young Arctic cod were 2.9 cm and 0.247 g (n=85) (Table 2), and 15.9 cm and 40.44 g (n=100) for the adults (Table 3). SL of the fish was measured onboard, while mean weight was estimated using a W to SL model ($W(g)=0.0055*SL(cm)^{3.19}$) from Geoffroy *et al*. (in review).

Eight and a half hours of SX90 survey were completed in the Mc'Lintock Channel from 17h (UTC) on September 22 to 1h30 on September 23. The marine wildlife observer identified 20 seals, 1 polar bear and many different bird species from September 20-30.

Table 5.2.6.1. Summary of operations conducted and samples collected during leg 2

Station	Date	5NVS	DSN	Hydrobios	IKMT	Beam Trawl
CB1	07 09 15	X	X	X		X
CB2	10 09 15	X	X	X		
CB3	12 09 15	X	X	X		
CB4	14 09 15	X	X	X		
314	20 09 15	X	X			X
QMG4	21 09 15	X	X			X
QMG3	21 09 15	X	X			X
QMG-mooring	21 09 15	X	X		X	X
QMG2	21 09 15	X	X			X
QMG1	22 09 15	X				
312	22 09 15	X	X			X
310	23 09 15	X	X			
308	24 09 15	X	X	X		X
307	25 09 15	X				
342	26 09 15	X	X			X
CAA9	27 09 15	X				

Table 5.2.6.2. Mean standard length and weight of young-of-the year Arctic cod at each station

Station	Mean SL (cm)	Mean W (g)	n	Total arctic cod sampled	% of Arctic cod
CB1	2.43	0.120	7	7	87.5%
CB2	1.39	0.016	1	1	100%
CB3			0	0	
CB4			0	0	
314	2.8	0.147	1	1	33.3%
QMG4	3.11	0.258	4	4	30.77%
QMG3	3.2	0.225	1	1	6.66%
QMG-mooring	4.15	0.528	2	2	22.22%
QMG2	3.7	0.358	2	2	8%
QMG1				Not sampled	
312	2.16	0.075	20	20	69%
310	1.88	0.046	14	14	93.33%
308	2.34	0.084	6	6	85.71%

307				Not sampled	
342	4.07	0.494	27	114	72.61%
CAA9				Not sampled	
All	2.90	0.247	85	172	61%

Table 5.2.6.3. Mean standard length and weight of adult Arctic cod at each station

Station	**Mean SL (cm)**	**Mean W (g)**	**n**	**Total fish sampled**	**% of Arctic cod**
CB1	15.05	36.26	11	35	31.4 %
CB2				Not sampled	
CB3				Not sampled	
CB4				Not sampled	
314			0	2	0%
QMG4			0	0	
QMG3	6.4	2.05	1	6	16.66%
QMG-mooring			0	2	0%
QMG2			0	5	0%
QMG1				Not sampled	
312			0	3	0%
310				Not sampled	
308	16.33	42.71	84	92	91.3%
307				Not sampled	
342	11.55	13.89	4	150	2.66%
CAA9				Not sampled	
All	15.9	40.44	100	295	33.9%

References

Geoffroy M, Majewski A, LeBlanc M, Gauthier S, Walkusz W, Reist J, Fortier L (in review) Vertical segregation of age-0 and age-1+ polar cod (*Boreogadus saida*) over the annual cycle in the Canadian Beaufort Sea.

User experience

a) The process to gain access to the vessel and request ship time for our team's project was clear and easy to follow

Not applicable

b) The annual *Amundsen* expedition was effectively planned and organized (planning meeting, vessel scheduling, dissimination of information, mobilization, etc).

5. Very satisfied

c) The *Amundsen* central pool of equipment (e.g. scientific winches, CTD-Rosette system, MVP **system, onboard labs, sonars, piston corer, ROV, etc.) was properly maintained and operational at sea.**

5. Very satisfied

d) Safety in the workplace (i.e. were you satisfied with the overall safety of the science operations conducted on and from the *Amundsen*?)

5. Very satisfied

e) What is your overall level of satisfaction regarding your experience conducting research on board the Amundsen this year?

5. Very satisfied

5.2.7 Dynamics and thermodynamics of the ocean-sea ice-atmosphere coupling

Principle Investigator: David
Cruise participants: Lauren Candlish, and Nathalie Thériault

Centre for Earth Observation Science, University of Manitoba, Winnipeg

Introduction and objectives

The University of Manitoba with collaboration from Exxon, Imperial Oil, and Environment Canada will do an in depth study on the interactions between the ocean-sea ice-atmosphere with respect to dynamics interactions. During leg 3 a network of autonomous equipment will be deployed on multiyear sea ice floes in the Beaufort Sea and left to drift with the icepack. The equipment will utilize the iridium satellite communications network and transmit in situ data back to the University of Manitoba. The network of equipment consists of:

19 ice beacons will be deployed on multiyear ice floes and be used to track ice drift.

4 weather stations will be deployed on multiyear ice floes and will collect in situ observations of surface winds, air temperature, humidity and air pressure.

1 POPs buoy will be deployed in the open ocean and will measure temperature, humidity, and pressure at the surface of the ocean, with a CTD that measures from 5 to 600m deep.

The network will provide spatially and temporally coincident observations on ice drift and the oceanic and atmospheric forcing mechanisms that govern ice drift. The duration of the equipment is subject to the stability of the ice floe, therefore equipment will be preferentially deployed on large, thick, multiyear ice floes that are more likely to last through the end of the melt season and freeze into the ice pack during winter. The objective is to monitor how ice drift and the ice packs respond to external forcing mechanisms. The in situ observations will be supplemented with remotely sensed data from Radarsat that will be used to calculate local ice concentrations and floe size distributions. A similar study was carried out in 2012 during the spring season as part of the Beaufort Regional Environmental Assessment (BREA), and in 2014 during leg 2. The analysis will focus on the seasonal change in the scaling factor and turning angle between surface winds and ice drift, the scaling factor between ocean currents and ice drift, and ice drift at inertial frequencies. A key objective is to define the point at which ice drift changes from summer conditions to winter conditions and to define the ice state that dictates when this transition occurs. A schematic of the operations is shown in figure 1.

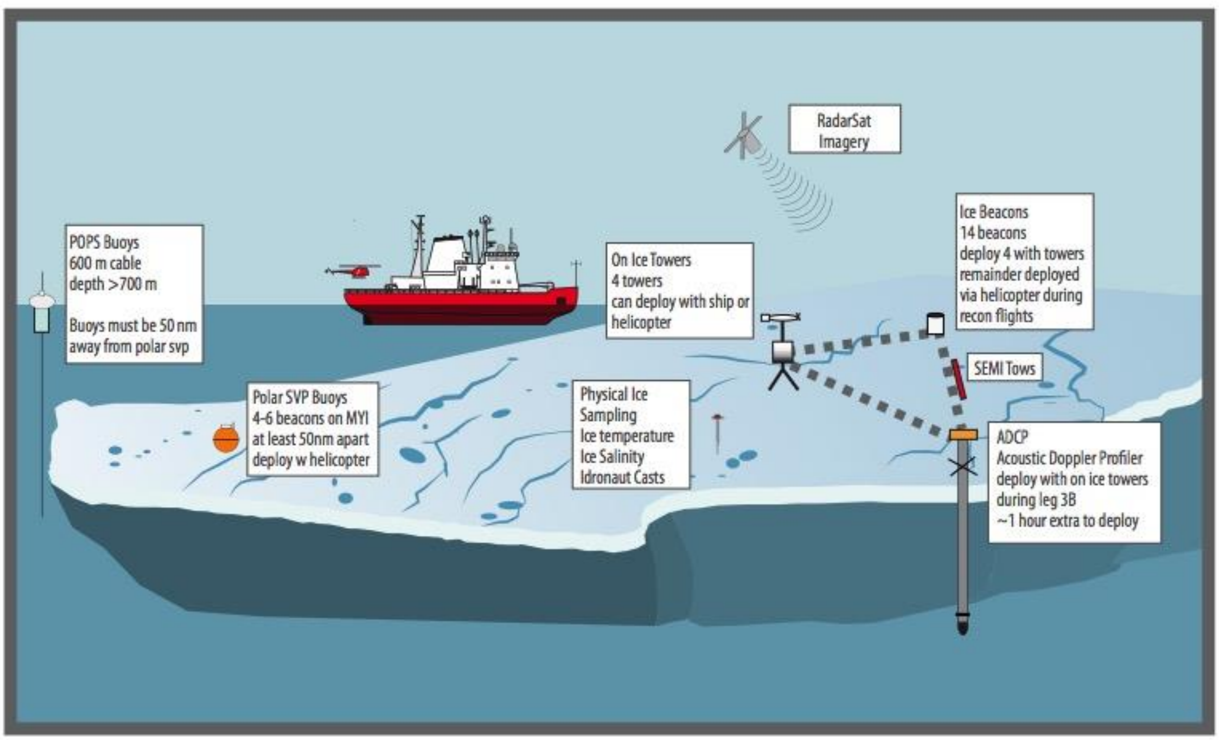

Figure 5.2.7.1. A schematic showing the Ocean- Sea Ice-Atmosphere sampling methods.

An additional study on the validation of winds over the marine environment will be performed during this leg. Previous studies have shown that intense storms with strong winds will break-up the ice pack (Screen et al., 2011; Long and Perrie, 2012; Asplin et al., 2012), while accounts of the record minimum in the September 2012 sea ice extent attribute the loss to mechanical weakening and melting of an already thin sea ice cover due to strong winds (NSIDC, 2012b, Simmonds and Rudeva, 2012). In order to accurately predict the movement of sea ice and ice break-up accurate estimates of surface winds are needed. During late August and September, 4 on ice met towers will be deployed in the Beaufort Sea collecting near surface winds. The met towers will collect data on ice for ideally 6 – 12 months. The in-situ data will be compared to different forecasted winds and re-analysis datasets to evaluate the current understanding and ability to correctly forecast or model winds in the high Arctic.

Methodology

Atmosphere Measurements

The upper atmosphere program is designed to monitor the atmospheric variables that can affect the Arctic atmosphere-ocean interactions. The instrumentation used will provide high temporal measurements of temperature, humidity, pressure and wind for the surface up to approximately 20 km. The boundary layer is of particular importance and will be monitored using a Microwave Profiling Radiometer (MWRP) at a frequency of approximately 1s.

Microwave Profiling Radiometer Instrumentation

A Radiometrics temperature and water vapour 3000A profiling radiometer (TP/WVP3000A) is used to measure the temperature and water vapour within the atmosphere up to 10km using passive microwave radiometry at 22 – 29GHz, and 51 – 59GHz. The TP/WVP3000A is installed on a mount attached to the white container laboratory (the 'Met-Ocean Container') located directly behind the ship's wheelhouse, approximately 19m above sea level. The instrument is suspended away from the roof of the shed to ensure that the field-of-view (approximately 15° above the horizon to the left and right to the zenith) is clear of any obstruction.

The instrument generates a vertical profile of upper-level air variables including temperature, water vapour density, relative humidity, and liquid water from the surface to an altitude of 10km. The resolution of the measurements varies with height. The resolution of the instrument is 50 m from the surface to an altitude of 500 m, then increases to 100 m from 500 m to 2 km altitude, and is 250 m for measurements from 2 km to 10 km. Note: the height given for 50m is actually 69m as the instrument assumes it's at sea level when it's mounted 19m above sea level. In addition, the instrument also measures concurrent basic surface meteorology variables, including pressure, relative humidity, and ambient temperature. A skyward-looking infrared sensor measures the temperature of the sky. A rain-sensor detects the presence of any precipitation. It should be noted that the fog registered as precipitation during much of the field season. The instrument also calculates integrated column water vapour, and liquid water content. The sampling frequency for all data is approximately one complete profile per minute.

The calibration of the water vapour profiling process is continuously maintained by hourly tip curves. An external liquid-nitrogen-cooled blackbody was used to intermittently calibrate the temperature profiling process. All channels also viewed an internal black body target every 5 minutes for relative calibration. Temperature and humidity values were derived from microwave brightness temperatures using the manufacturer's neutral network retrievals that had been trained using historical radiosonde measurements, and a radiative transfer model (Solheim et al., 1998). Historical radiosonde data from Inuvik N.W.T. was used to develop neural network coefficients for the Southern Beaufort Sea Region.

Vaisala CT25K Ceilometer

The Vaisala CT25K laser ceilometer measures cloud heights and vertical visibilities using pulsed diode laser LIDAR (Light Detection And Ranging) technology, where short powerful laser pulses are sent out in a vertical or near-vertical direction. The laser operates at a centre wavelength of 905 ± 5 nm, a pulse width of 100 ns, beamwidth of ±0.53 mrad edge, ±0.75 mrad diagonal and a peak power of 16 W. The manufacturer suggested measurement range is 0 – 25,000ft (0 – 7.5 km), however, it has been found that high, very visible cirrostratus cloud (~18-20 kft) are consistently undetected by the unit (Hanesiak, 1998). The vertical resolution of the measurements is 50 ft, but decreases to 100 ft after ASCII data file conversion. The reflection of light backscatter caused by haze, fog, mist, virga, precipitation, and clouds is measured as the laser pulses traverse the sky. The resulting backscatter profile (i.e., signal strength versus height) is stored, processed and the cloud bases are detected. Knowing the speed of light, the time delay between the launch of the laser pulse and the backscatter signal indicates the cloud base height. The CT25K is designed to detect three cloud layers simultaneously, given suitable conditions. Besides cloud layers, it detects whether there is precipitation or other obstruction to vision. No adjustments in the field are needed. Output files were created hourly by the system and are in ASCII format.

All-Sky Camera

The all-sky camera system takes images of the sky and cloud cover. The system consists of a Nikon D-90 camera outfitted with fish-eye lenses with a viewing angle of 160 degrees, mounted in a heated weather-proof enclosure. The camera is programmed to take pictures using an external intervalometer set at 10-minute intervals, or 144 images per day. The system is to be mounted in a small ‘crow’s nest’ immediately above the ship’s wheelhouse.

Manual Meteorological Observations

Manual meteorological observations were conducted 3-hourly throughout daytime (7am-10pm) during the entire leg. Observations included current weather and sea conditions with relation to precipitation type and intensity, visibility, cloud cover (octets), and sea ice coverage (tenths). Basic meteorological values were read and recorded from the onboard weather station, which is owned and operated by the Meteorological Service of Canada. Visibility, cloud octets, sea ice concentration, precipitation type and intensity, and wave swell and state (Beaufort scale) observations are subjective based on the observer. If the cloud coverage was not 100% it was not recorded at 8/8, similarly if the coverage has even 1% of clouds the cloud fraction was not recorded as 0/8.

The CCGS Amundsen is equipped with an AXYS Automated Voluntary Observation Ship (AVOS), with all sensors located on the roof of the wheelhouse. The AVOS is an interactive environmental reporting system that allows for the hourly transmission of current meteorological conditions to a central land station via Iridium satellite telemetry. Temperatures (air and sea surface), pressure, relative humidity (RH), and current GPS location are updated every ten minutes and displayed on a computer monitor located in the wheelhouse of the ship. The AVOS deploys a Rotronics MP 101A sensor for temperature and RH, with a resolution of 0.1ºC and an accuracy of ± 0.3ºC, and a 1% ± 1% accuracy for temperature and RH, respectively. Atmospheric pressure was obtained from a Vaisala PTB210 sensor with a 0.01mb resolution and an accuracy of ±0.15 mb. Wind speed and wind direction were obtained from the navigation’s anemometer (higher and more reliable than the AVOS anemometer) collected from an RM Young 05103 anemometer, accurate to ±3º in direction and ±0.3 m/s.

Table 5.2.7.2. Parameters recorded by the observer.

Parameter	Units
Date	UTC
Time	UTC
Latitude	decimal degrees
Longitude	decimal degrees
Temperature	ºC
Relative Humidity	%
Wind Speed	Kts
Wind Direction	º
Precipitation Type	snow, rain etc
Precipitation Intensity	Heavy, moderate, light etc.
Visibility	Km
Cloud Fraction	Octets
Wave Height	M
Beaufort Sea State	0-10
Sea Ice Concentration	Tenths
Sea Ice Type	MYI, FYI, rotten, icebergs

3.2 Ocean – Sea Ice

A total of 3 on ice met towers were deployed and 10 ice tracking beacons.

On Ice Meteorological Towers

During leg 3 our goal was to deploy 4 on ice towers. Due to time constraints, transmission issue with the met tower#6 (that we replaced with tower#7), and being unable to fly the helicopter (broken during 2 weeks, and some bad weather) we were able to deploy only 3 of these towers. The deployment of each tower required finding the correct type of ice. Typically the ice floes in the area were rotting first year ice, making finding a suitable thick piece of ice difficult. The goal was to find a piece of ice that would survive through the melt and into the fall freeze up, and possibly through to the next summer. The helicopter was used to access the correct location on the ice floe and determine how suitable and safe the ice conditions were.

Each tower has a marine grade wind anemometer and compass, a temperature and relative humidity sensor and pressure sensor. The tower has 2 deep cycle batteries connected to 3 solar panels to ensure that the batteries are fully charged going into the Arctic winter. The battery box was mounted on wooden blocks to prevent ice melt with the possible warming of the box. This will possibly increase the longevity of the on ice towers. Deployment from the ship took approximately 2-4 hours depending on the amount of physical samplings.

An Idronaut cast was also used with a CTD probe that could reach 50 m from the surface of the ice.

Figure 5.2.7.2. The deployment of the first on ice tower via the ship.

Table 5.2.7.2. The details of the on ice met tower deployments.

Ice Station	7 (initially 6)	8	9
date deployed	Sept 10 11:00 UTC	Sept 9 19:00 UTC	Sept 10 5:57 UTC
date lost			
Latitude	76°02.58	76°07.42	76°21.271
Longitude	128°42.03	129°18.58	129°03.733
Beacon IMEI	300234060655960	300234060652970	300234060534480
Ice Thickness (m)	3.41m	2.83m	>6m

Physical sampling

Physical samplings were done at 2 locations, one next to an on ice weather station in the Beaufort Sea, and the second in Penny Strait. Temperature profiles were taken immediately after drilling the ice. Salinity samples were brought back, melted, and analysed on the ship. One ice core will be kept in the freezer and will be scanned with the MRI of the University of Manitoba (structure analysis). All cores were taken with a 6" core barrel. Some other samples were brought back for analysis by other teams on the ship (for contamination analysis).

Ice beacons

The beacon is deployed while at an ice station and it also can be deployed from the helicopter while doing surveys. While on the ice floe, an 8" hole was augured into the ice for the installation of the beacon. At hourly intervals, the instrument records its location and transmits this information to an email server. The beacons transmit data via an iridium satellite in the form of an email attachment. From the 5 Canatec beacons that were deployed in Beaufort Sea, 3 were at a weather station. The Oceanetics beacon was deployed in Penny Strait.

As part of the 2015 agreement with Environment Canada, CEOS deployed 4 Polar SVP beacon in Beaufort Sea. Each beacon was positioned as far away from each other as possible, however some are less than 50nm apart.

POPs Buoys

We deployed 1 POPs buoy from the Amundsen, for Environment Canada, in the SE Beaufort Sea in open water conditions, somewhere off the continental shelf. The assembly of each buoy is not all that "quick." It involved attaching the individual ocean sensors along the pre-marked cable, and then attaching the cable to the floating hull in the proper way. There is a user's manual, which includes deployment instructions.

The surface unit is 397 lbs and 83" x 31" x 36 with a 600 meters long cable with a NOVA profiling unit on it. The deployment of the buoy took about 2 hours. The buoy had to be deployed weight first, unreel most of the cable into the water, attach the profiler and lower the profiler into the water, then attach and lower the surface unit in. The unit then had to be turned on using the zodiac as the buoy must first be in the water before the unit can be activated. The location was chosen according to the depth of the ocean, far from the coast, and also far from big ice floe that would damage the instrument.

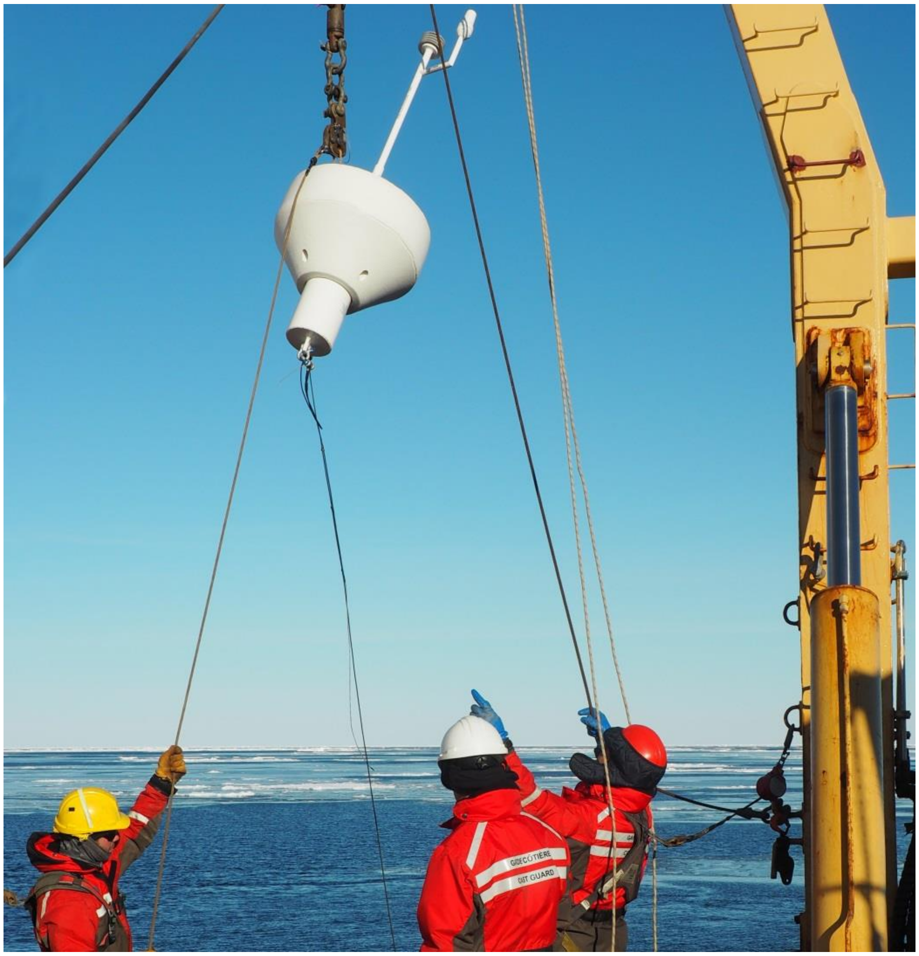

Figure 5.2.7.3. Deployment of the POPS buoys

Preliminary results

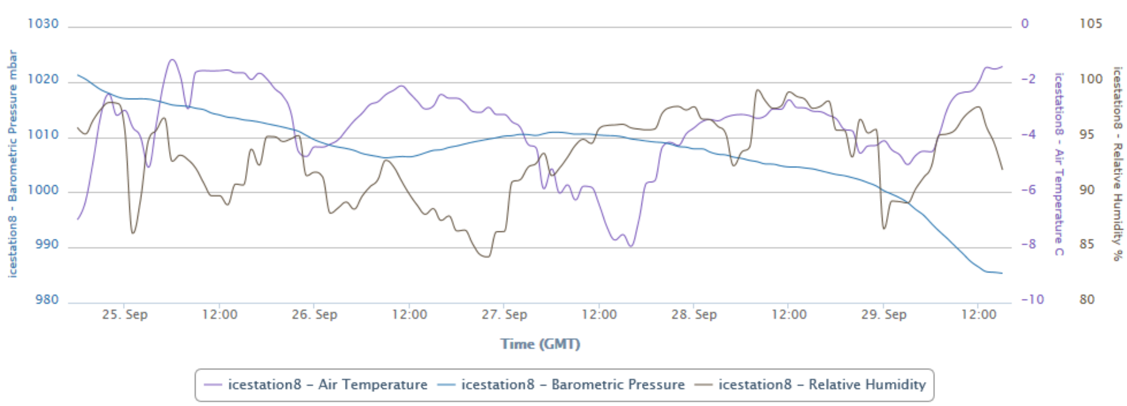

Figure 5.2.7.4. The air temperature, pressure and relative humidity data from the on ice met tower #8 deployed on September 9th, 2015.

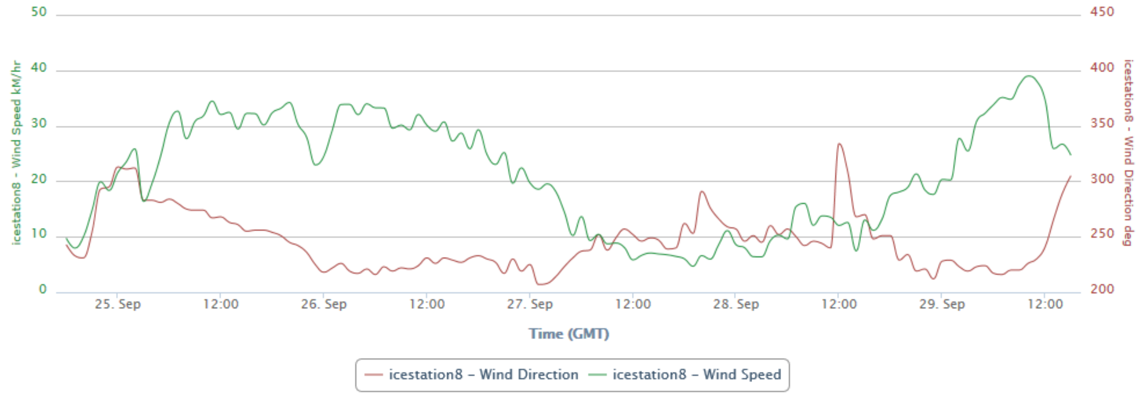

Figure 5.2.7.5. Wind direction (red) and wind speed (green) from station #8 deployed on September 9th, 2015.

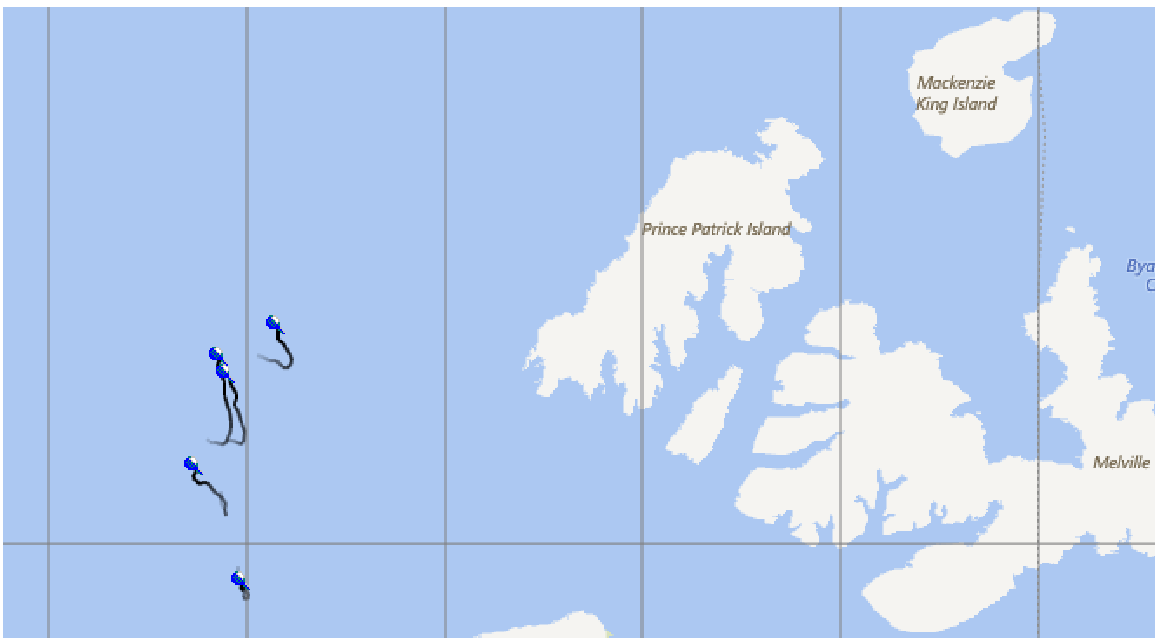

Figure 5.2.7.6. The trajectory from September 22nd to September 29th of 5 beacons deployed in the Beaufort Sea.

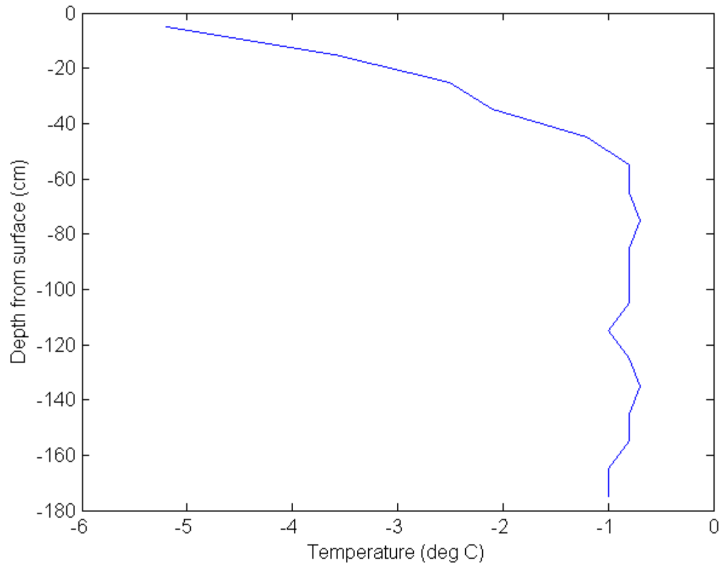

Figure 5.2.7.7. Temperature profile of the ice core taken in Penny Strait.

User Experience
a) The process to gain access to the vessel and request ship time for our team's project was clear and easy to follow.
1. Very dissatisfied
Comments: Please send out the dates for the Montreal planning meeting to the PI's as well as their coordinators as soon as possible!
b) The annual *Amundsen* expedition was effectively planned and organized (e.g., planning meeting, vessel scheduling, dissemination of information, mobilization, etc.).
4. Satisfied
Comments: Both Leg were well organized. Leg 3a had daily meeting always at the same time, Leg3b had meetings only when necessary. Communication between teams, the captain and the chief scientist seemed easier with everyday meetings. Also, it could be interesting to have a consistent way to name 'station ID', 'station types', and 'station activity' through different legs. It would help scientist to easily track down the information they need.
c) The *Amundsen's* central pool of equipment (e.g., scientific winches, CTD-Rosette system, MVP system, onboard laboratories, sonars, piston corer, Remotely Operated Vehicle, etc.) was properly maintained and operational at sea.
5. Very satisfied
Comments: Crew members were taken good care of all equipment, and were very helpful.
d) Safety in the workplace (i.e. were you satisfied with the overall safety of the science operations conducted on and from the *Amundsen*?)
5. Very satisfied
Comments: The familiarization and some safety meetings with the crew assured the safety of everyone.
e) What is your overall level of satisfaction regarding your experience conducting research on board the *Amundsen* this year?

5. Very satisfied
Comments: Everyone onboard was devoted to do their task as well as they could.

5.2.8 Seabed mapping

Principal Investigator: Patrick Lajeunesse[1]
Cruise Participants: Etienne Brouard[1], Glenn Toldi[2]

[1]*Département de géographie, Université Laval.*
[2] *Canadian Hydrographic Service (Central & Arctic Region), Department of Fisheries & Oceans Canada, Burlington Ontario*

5.2.9 Mooring Program

Principal Investigator: Louis Fortier[1]
Cruise Participants: Shawn Meredyk[1](Lead), Luc Michaud[1], Alexandre Forest[2]

[1]*ArcticNet, Université Laval*
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Executive Summary

The 2015 Mooring Operations in the Amundsen Gulf, Beaufort Sea and Queen Maud Gulf were successful and performed safely. The mission saw 100% equipment recovery and 94% preliminary raw data recovery for the final year of the BREA program. Three moorings BRK, BRG, and BR3, were redeployed for the new iBO project. Two LTOO moorings (CA05 and CA08) were deployed in the Amundsen Gulf to complete the 10 year LTOO mooring program \ dataset. The Weston foundation – ArcticNet – Parks Canada moorings (WF1 and WF2) were deployed near the site of the shipwreck *Erebus*. WF2 was a benthic tripod very near the ship, deployed by Parks Canada divers (from the CCGS *Marty Bergman*) in 20m of water and WF1 was deployed in the Queen Maud Gulf via the CCGS *Amundsen*.

Table of Contents

Executive Summary .... **Error! Bookmark not defined.**
Table of Figures 111
Table of Tables 111
1 Introduction and Regional Setting 113
1.1 Mooring Program Objectives 113
1.1.1 Areas of Focus 113
1.1.2 Mooring Arrays 114
1.2 Regional Setting 115
1.3 Individual Mooring Objectives (2015) 115
1.4 Mooring Instrumentation 117
1.4.1 2015 Field Compass Calibrations 121
1.4.2 Aanderaa RCM (Recording Current Meter) Calibration Procedure (ArcticNet) 122
1.4.1 Current Meter Compass Calibration Summary 126
1.5 Health and Safety 128
1.5.1 Mooring Operations Safety Documents 130
2 Mooring Operations 132
2.1 2015 Mooring Recovery Summary 132
2.1.1 Mooring Dragging Operations 132
2.2 Mooring Data Recovery Summary 133
2.2.2 Preliminary Data Results 135
2.3 2015 Mooring Deployment Summary 136
2.3.1 Re-Deployment Summary 136
2.3.2 Deployment Summary 137
2.3.3 Mooring Re/Deployment Procedure 137
2.3.4 Mooring Deployment Instrumentation Setup/Programming 141
2.3.5 Mooring Deployment Lessons Learned 152
3 Lessons Learned Summary 152
3.1 Amundsen Leb 3a 152
3.1.1 OCEANO Acoustic Releases 152
3.1.2 Battery Canister problems 152
3.1.3 Stainless Steel Shackles 153

Acknowledgements....154
Appendix 1 (Oceanographic Equipment on 2015 Moorings) 155
Appendix 2 – BREA / ArcticNet Mooring Designs / Field Operations Sheets 158
Appendix 3 : Job Safety Assessment for Mooring Operations – 2015 179

Table of Figures

Figure 1. 2015 ArcticNet Leg 3a/3b Cruise Plans....115
Figure 2. Mooring Locations 2014-2015-2016: BREA-iBO-ArcticNet Mooring Arrays 116
Figure 3. Tilt and rotate calibration jig / table as utilized in Inuvik, NWT 122
Figure 4. Indicating arrow inside an RCM11 points to the unit's zero heading (beside serial number) (2010)....123
Figure 5. Anderaa RCM Deck Unit 3127 for communicating to the RCM7/11 in real-time (2010)....124
Figure 6. Aanderaa RCM current simulator transducers cover for instrument sensor testing purposes (2010) 124
Figure 7. Survitec Group Immersion Suits used for Personnel Transfers to / from the CCGS Amundsen 129
Figure 8. Mooring Pre-Deployment 'Toolbox' Meeting (Alexis Burt, 2015) 130
Figure 9. ArcticNet Dragging Anchor for BS1-14 133
Figure 10. Triangulation Plot from BS1-14 using Art's Acoustic Survey Matlab Script....139
Figure 11. Multibeam imagery identifying orientation and instrument depths (screenshot courtesy of ArcticNet multibeam processing team)....140
Figure 12. Rosette Temperature - Salinity Profile example plot (BS2-14)....140

Table of Tables

Table 1. Oceanographic Equipment that required Compass Calibration, including calibration Procedures 126
Table 2. 2015 Short Mooring Re-Deployment Summary 133
Table 3. 2015 Short Mooring Re-Deployment Summary 136
Table 4. Mooring Deployment Summary 2015....137
Table 5. 2015 Equipment Programming / Sampling Parameters 141
Table 6. Summary table of Lessons Learned throughout the mission 153
Table 7. Summary of Compass Error after Hard and Soft Iron Calibration in Inuvik,NWT, 2015....178
Table 8. 2015 Nortek Compass Verifications \ Post-Calibration (Inuvik, 2015) 178

1 Introduction and Regional Setting

1.1 Mooring Program Objectives

Sampling year 2015, was part of a summer-fall expedition, studying the air-sea interactions, underwater sound ecology, ocean circulation variability and basin-shelf sediment interactions of the southern Beaufort Sea and Amundsen Gulf.

Mooring operations during Leg 3a (August 20 – September 4) were part of the ArcticNet Long-Term Ocean Observatory (LTOO) project / and Integrated Beaufort Observatory (iBO; a new program partly supported by the Environmental Study Research Fund). The iBO mooring sites are based on key locations targeted by the Southern and Northeastern Beaufort Sea Marine Observatories project funded under the former Beaufort Regional Environmental Assessment (BREA) initiative from 2011 to 2014.

Mooring operations during Leg 3b (September 18 – October 1) were part of the ArcticNet – Parks Canada – Weston Foundation innovative to investigate the oceanographic conditions near and surrounding the shipwreck *Erubus* in the Queen Maud Gulf.

In total, during leg 3 onboard the Amundsen, seven moorings were recovered and seven moorings were deployed over the slope of the southeastern Beaufort Sea, Amundsen Gulf and in the Queen Maud Gulf.

1.1.1 Areas of Focus

The Amundsen Gulf is an area where the air-sea interactions occurring in the ice-free sections of the southern Beaufort Sea and Amundsen Gulf were investigated.This productivity hotspot is of interest, to monitor the intermittent upwelling of cold-saline water on the eastern shelf, despite the fact that the origin of the upwelling is much closer to Cape Bathurst (e.g. CA06). In fact, ocean circulation is highly variable here, but the along-shelf flow of Pacific-derived water entering the Amundsen Gulf can be potentially monitored at depth. Mooring CA08-15 is the center of the 'Cape Bathurst polynya' as defined in Barber and Hanesiak (2004). This location is a very good candidate for the long-term monitoring of particle flux, as it has all the advantages of catching adequately both the seasonal signal and the inter-annual variability of marine productivity in the Amundsen Gulf, without having too much of the terrigenous inputs that characterize the moorings close to the Mackenzie Shelf.

The Mackenzie Trough, a cross-shelf canyon in the Beaufort Sea shelf, has been observed to be a site of enhanced shelf-break exchange via upwelling (caused by wind- and ice-driven ocean surface stresses). The canyon provides a conduit for bringing deeper, nutrient rich water to the shelf. Shelf waters in the area are seasonally influenced by freshwater output from the Mackenzie River, both in terms of temperature-salinity properties and suspended sediments / turbidity.

Capturing the Beaufort gyre's anti-cyclonic (west) movement relative to a long-shore counter-current (east) plays an important role in understanding deep and shallow water movements relative to nutrient and particle fluxes.

Ice cover, examined by moored ice profilers and satellite imagery, plays a significant role in terms of affecting momentum transfer from wind to water, constrained (in the case of landfast ice) and enhanced (in the case of drift ice) by wind.

Hydrophone recordings on the shelf-slope area will monitor bioacoustics vocalizations throughout the year to better understand the potential impact that future operations in the Beaufort Sea could have on the marine mammals.

1.1.2 Mooring Arrays

Over 2014-2015, the legacy BREA moorings (BRG, BR1, BR2, BRK, BR3 and BR4) accompanied by three ArcticNet moorings (BS1, BS2, BS3), formed three shelf –slope arrays that examined the spatial variability in shelf-slope processes in the southeastern Beaufort Sea. These moorings continued a long-term integrated observation of ice, water circulation and particle fluxes established in the southern Beaufort Sea since 2002. Moorings BRG, BR3 and BRK were re-deployed during leg 3a as part of the iBO program while mooring BS1, BS2, BS3 and BR04 were recovered and not redeployed. Moorings BR1 and BR2 are planned for recovery from the CCGS *Laurier* in October 2015 and only BR1 will be redeployed.

LTOO moorings CA08 and CA05 were deployed in the Amundsen Gulf to extend the annual time-series collected in the area from 2002 to 2009. This region, also known as the "Cape Bathurst Polynya", was previously identified as an area of increased biological activity due to an earlier retreat of sea ice in spring and frequent upwelling of nutrient-rich waters that develops along Cape Bathurst and near the eastern edge of the Mackenzie Shelf.

New moorings WF1 and WF2 are moorings that are part of a combined effort by the Weston Foundation, ArcticNet and Parks Canada deployed to study the oceanographic conditions near the *Erebus* and in the Queen Maud Gulf near the location of the wreck site. The Weston Foundation provided sufficient funding for oceanographic equipment and ArcticNet and Parks Canada provided technical and operations support with the vessel support from the CCGS *Amundsen / Marty Bergman*. Mooring WF1 was in 100m of water in the Queen Maud Gulf and WF2 was a benthic tripod (placed near the *Erebus* at 20m depth) with an upward looking ADCP (RDI Sentinel V) combined with an RBR CTD-Tu sensor (Appendix 2).

1.2 Regional Setting

i. Figure 1 outlines the expedition plan for the 2015 Leg 3a\b operations. Leg 3a/3b activities started in Kugluktuk, NWT, Canada, August 20th, 2015 and ended in Resolute Oct.1st, 2015).

Figure 1. 2015 ArcticNet Leg 3a/3b Cruise Plans

1.3 Individual Mooring Objectives (2015)

i. New \ continued LTOO Moorings CA08 (400m) and CA05 (200m) were deployed, in an effort to collect data in the center and NW extent of the Amundsen Gulf. The moorings were deployed with a similar design (more instruments were added to get a more complete water column dataset) as previously deployed in 2009 and earlier.

ii. Moorings BS1(80m), BRK (156m), BS2(300m), BS3(500m), BRG (701m), BR1 (757m) and BR2 (159m) were located across the shelf-slope boundary over the central shelf (off Kugmallit Valley). BRK-15 (170 m), BRG-15 (700 m) and BR3-

15 (690m) (BR1-15 being re-deployed from the CCGS *Sir Wilfred-Laurier*) were re-deployed as part of the ongoing effort to assess ocean circulation (the southern extent of the Beaufort gyre current near the Mackenzie Shelf), biogeochemical fluxes and sea ice motion and thickness distribution in key areas of the Mackenzie shelf-slope system (Fig. 2).

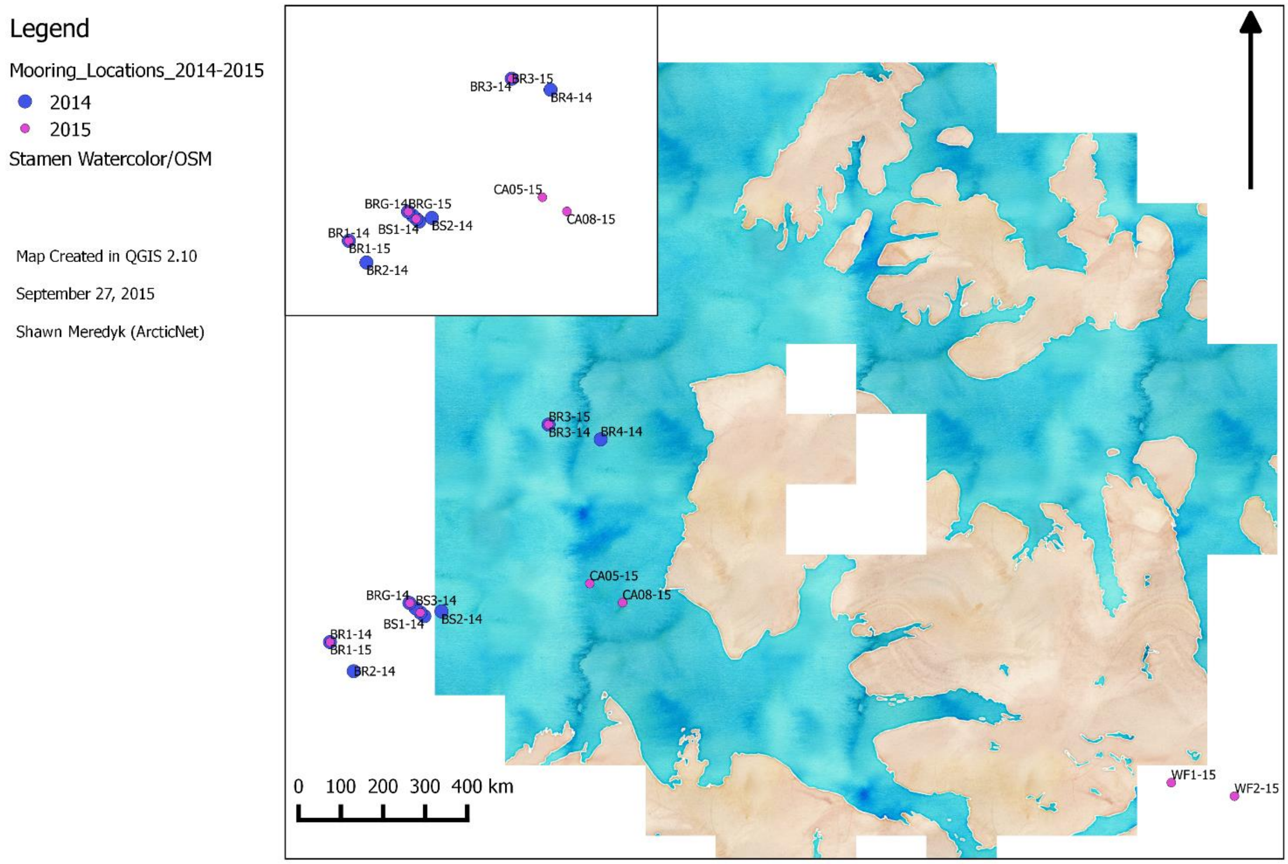


Figure 2. Mooring Locations 2014-2015-2016: BREA-iBO-ArcticNet Mooring Arrays

1.4 Mooring Instrumentation

A list of oceanographic equipment deployed on the moorings can be found in Appendix 1.

i. The ArcticNet moorings were generally designed to be of taut-line configuration consisting of a top float (50-60m depth),
    a. an ALEC CTW - Conductivity, Temperature (CT) probes to record water characteristics, ALEC CLW – Chlorophyll – Turbidity probes , ALEC ALW – Photosynthetic Active Radiation (PAR),
    b. two current profilers (Continental 470 kHz) with 2m vertical resolution, to record the water velocities within the water column,
    c. hydrophone (Aural M2) with a 16 kHz, 90min sampling rate to listen to bioacoustics signatures within the water column,
    d. in-line floatation (30" ORE steel float) to balance the weight/ float/ tension throughout the mooring line,
    e. sediment trap (Technicap PPS 3/3 with 24 sample cups – semi-monthly sampling rate) to trap descending sediment for particle flux analysis and accumulation rates,
    f. two 1000 kHz Nortek Aquadopp current meters (or a single-point RCM11 current meter\CTD) measuring near-bottom current speeds with associated oceanographic sensors,
    g. Tandem mooring releases (Benthos or Oceano) and
    h. An anchor (one to three train wheels).

    *A detailed deployment plan of the deployed BREA-ArcticNet moorings can be found in appendix 2.

ii. The iBO-ArcticNet moorings were designed to be of a taut-line configuration.
    a. The longer moorings (BRG, BR3,BR1) consisted of the following key components:
        i. ASL Ice Profiling Sonar (IPS) were used at approximately 50-60 m depth to measure ice draft. IPS were mounted in 30-inch spherical Mooring Systems International (MSI) syntactic foam floats.

ii. 150 kHz Teledyne RDI (TRDI) Quarter Master Acoustic Doppler Current Profiler (QM ADCP) were used at approximately 180 m water depth to profile currents with a vertical resolution of 8 m, as well as to measure ice velocity using the Bottom-Track feature. The QM ADCPs were mounted up-looking in 40-inch syntactic foam floats manufactured by Flotation Technologies.

iii. 75 kHz TRDI Long Ranger ADCP (LR ADCP) were used at approximately 460 m water depth to measure water velocity profile at a coarser 16 m resolution (redundancy for QM). The LR ADCPs were mounted up-looking in 40-inch syntactic foam floats manufactured by Flotation Technologies.

iv. In water depths greater than 500 m, high frequency short-range (<1m) Nortek Aquadopp DW (AQD) point current meters were used approximately every 100 m to measure water velocity.

v. Two Technicap PPS 3/3-24S 24 cup sequential sediment traps were deployed between the IPS and LR ADCP to record the annual cycle in vertical carbon flux.

vi. RBR Conductivity and Temperature (CT) loggers were installed at various depths (relative to equipment that benefits from more precise CT data) to measure water temperature and salinity and to compute sound speed (used to improve IPS and ADCP processing). In some cases Conductivity, Temperature, and Depth (CTD) loggers were used on the moorings.

vii. Various smaller syntactic foam floats were distributed along the mooring as required.

viii. Tandem EdgeTech acoustic releases were used as the primary recovery device.

ix. One to three train wheels were used as an anchor

b. The shallow moorings (BRK, BR4,BR2) consisted of the following key components:

i. IPS were used at approximately 50-60 m depth to measure ice draft. The IPS were mounted on an ASL dual cage with 8 Viny 12B3 floats.

ii. 300 kHz TRDI Workhorse Sentinel Acoustic Doppler Current Profiler (WHS ADCP) were used at approximately 130 to 140 m water depth to profile currents with a vertical resolution of 8 m, as well as to measure ice velocity using the Bottom-Track feature. The WHS ADCPs were mounted upward looking in 33-inch syntactic foam ellipsoid floats manufactured by MSI.

iii. RBR CT loggers were installed at various depths near instruments to measure water temperature and salinity and to compute sound speed (used to improve IPS and ADCP processing). In some cases CTD loggers were used on the moorings. Additionally, a few RBR loggers also had additional sensors to measure turbidity, dissolved oxygen, fluorometry-chlorophyll.

iv. Sequoia LISST 100X laser diffraction systems were located 18 m above the seafloor to provide measurements of particle size distributions and associated volume concentrations in the lower water column. The LISST measurements will help to better quantify the seasonal and annual variability of vertical and horizontal fluxes of organic and inorganic solids.

v. 1000 kHz Nortek Aquadopp profiling current meters (AQP) were mounted down-looking below the LISST instrument to provide details of the flow and acoustic backscatter structure near the seafloor on the continental shelf edge. The AQP's measure three-dimensional current velocities and provide a measure of acoustic backscatter intensity in 2 m range bins from the bottom to about 16 m above seabed. Combined with the velocity profile information from upward looking ADCP's the profilers provide a detailed and complete view of the water column vertical structure.

vi. An additional syntactic foam ellipsoid float was located above the LISST cage to provide floatation for the lower portion of the mooring.

vii. Tandem EdgeTech acoustic releases were used as the primary recovery device.

viii. One to three train wheels were used as an anchor

On 2014-2015 moorings in the cross-shelf-slope array (BRG and BRK) additional Seabird Electronics SBE37 CTD loggers were mounted at approximately 60 m for consistency with the BS1, BS2, and BS3 mooring datasets (recovered in 2015). RBR CTDs were mounted at 100 m on BRK and at 100 m and 150 m on BRG to maintain consistency with the ArcticNet moorings' recovered datasets (2015).

Semi-permeable membrane devices (SPMDs) were re-deployed on moorings BRK-15 (60m), BRG-15 (60, and 260m and 460m), BR3-15 (60 m). The SPMDs are small passive water samplers that clamp directly to the mooring line or instrument cage (Appendix 1). The goal of the SPMDs was to monitor concentrations of persistent organic pollutants (POPs) in the mixed surface layer (Pacific water mass and the deep Atlantic waters) by Gary Stern at CEOS in Winnipeg, Manitoba (for further reference to SPMD analysis and results contact Gary Stern).

The only mooring that had a unique configuration was the benthic tripod mooring that only consisted of a 50cm tall tripod with lead weight on the tripod legs to keep the unit on the seafloor. The tripod's objective was to carry an ADCP (RDI Sentinel V) with a CTD sensor with turbidity capabilities. This new ADCP from RDI was purchased and programmed with the idea to extract wave, ice and water column velocities for an entire year near the shipwreck.

*Detailed deployment plans of the deployed moorings, along with their field deployment sheets, can be found in appendix 2.

1.4.1 2015 Field Compass Calibrations

Compass accuracy is essential for current meters deployed near or above the Arctic Circle, due to the reduced magnitude of the horizontal component of the earth's magnetic field. Therefore, it was important to calibrate internal compasses near the approximate latitude where they were deployed and care was taken to eliminate all ferrous material in the mooring cages and in the calibration environment. A list of oceanographic equipment that contains internal compasses can be found in Table 1.

Calibration of the all of the RDI LR/QM/Sentinel ADCPs used for the entire 2015 mooring operations (Amundsen and Laurier) were performed in 2015 in Inuvik, NT by Golder and the post-verifications of the Nortek ADCPs was also performed in 2015 in Inuvik, NWT by Golder and ArcticNet Appendix 3. The calibration was conducted with a tilt and rotate jig (Fig 4). The calibration procedures followed standard manufacturer protocols for each instrument (see below). Table 5 contains the results from the 2015 compass calibrations performed in Inuvik, NT and Table 6 contains the Nortek compass verifications performed in Inuvik, NT.

1.4.1.1 RDI ADCP Field Calibration Procedure

ADCP calibrations were conducted with a leveled tilt and rotate jig / table. The calibration procedures followed standard manufacturer protocols for each instrument (See Table 1). The general calibration procedure is briefly described below:

a. Communication was established with the instrument using the manufacturer's (RDI BBtalk) calibration software over a RS-232 serial communication line.
b. Power was provided to the instrument by an external adapter powered by a portable battery pack / battery charger with a 120 VAC outlet.
c. The current meters were oriented in the configuration in which they would be deployed (facing Up).
d. The calibration table was rotated in 10° increments, through 360 degrees, having recorded the varying degrees

of pitch, roll and heading relative to true north, until a successful (< 5° compass error) calibration was achieved.

Figure 3. Tilt and rotate calibration jig / table as utilized in Inuvik, NWT

ii. A handheld Garmin GPSMap 76S was used to determine true North and the calibration table zero indicator \ mark was aligned with the table and a marker 50m away, along the same longitude. Compass calibrations and verifications were verified by rotating the current meter through 360 degrees and measuring the headings corrected for magnetic declination at each 10 degree increments and comparing these against the true north measurements from the GPS unit.

1.4.2 Aanderaa RCM (Recording Current Meter) Calibration Procedure (ArcticNet)

The CTD sensors on the RCM units used in the ArcticNet LTOO moorings were calibrated by ArcticNet (ULaval) in 2011. The CTD sensor compass calibration procedure was performed by the 2015 Golder mooring assistant (Alex Forest).

The RCM11 unit was opened to verify the internal zero heading indicator, to connect the battery pack and to turn the unit onto continuous sampling (1 sensor per second) for all 8 channels (sensors connected)(Fig. 4). Deck Unit Aanderaa A-3127 was connected to the port on top of the RCM11 (Fig. 5) and to the laptop-PC, and the Hyperterm terminal program was used to look at (and during actual compass calibrations, to capture to file) the ascii output from it.

The water-current simulation Test Unit (Aanderaa A-3731) was placed over the Doppler current sensors (type DCS-3900), with transducer surfaces moistened for best acoustic contact (Fig. 6). The RCM11 was rotated 90 degrees to verify that the acoustic sensors functioned properly and changed the simulated "direction" by about that amount (channel 3 is the compass sensor's heading data channel). The instrument was inclined to check the built-in tilt sensor functionality.

By rotating the calibration table in 10° increments and recording the values on channel 3 (takes at least two readings before compass stabilizes), then converting the raw values (channel 3 value * 0.352) into actual headings and plotting the 6^{th} order slope of the fitted line, compass calibration coefficients and the compass error can be calculated / recorded for post-processing of the unit's data.

Figure 4. Indicating arrow inside an RCM11 points to the unit's zero heading (beside serial number) (2010)

Figure 5. Anderaa RCM Deck Unit 3127 for communicating to the RCM7/11 in real-time (2010)

Figure 6. Aanderaa RCM current simulator transducers cover for instrument sensor testing purposes (2010)

1.4.2.1 ADCP Calibration Problems / Concerns

All Nortek equipment was repaired and calibrated at the Nortek factory two weeks prior to the CCGS Amundsen's Québec city departure in 2014, due to a discovery of compass calibration errors within the Nortek equipment and a deficiency* within Nortek's calibration subroutine (June-July, 2014).

In 2015, all of the RDI and Anderaa RCM11 units were calibrated in Inuvik at the BBE calibration field (June, 2015: 68.308266° N Lat, 133.4872833° W Long, IGRF Mag. Decl. 22° 52.86' E) (Appendix 3: Table 7).

Post-deployment verification of the Nortek ADCP compasses (deployed in 2014) was required to develop a corrective algorithm (post-processing QA\QC necessity) to account for any heading bias issues that the Nortek devices are not able to correct internally \ real-time (Appendix 3: Table 8)(Sept 5-6, 2015: 68.308266° N Lat, 133.4872833° W Long, IGRF Mag. Decl. 22° 52.86' E).

The results from the Nortek Compass Verifications shows that the instruments didn't have any broken pitch\ roll sensors and that the compasses had reasonably functioned throughout the year. With that being said there were some concerns.

The primary concern was that the calibration table used could be more precise when determining the heading in relation to true north. The concern is a multi-faceted problem that starts with a calibration table that despite a flat base, the inner ring of the calibration table moves slightly (< 2 deg X \ Y axis). This pitch an roll variance does affect the measured heading, though the quantitative affects to the heading are unknown, though assumed to be negligible as long as the pitch and roll don't exceed ±2 degrees. The next concern is that the calibration table might not be exactly set to true north due to a 1 degree vs. 0.1 degree variance between handheld GPS (Garmin 76S Map) and dual antenna (ComNav G1) GPS units. Setting the calibration table to true north is not difficult as the table's 0 zero marker needs to be aligned with the same longitude as the distance marker (if using a handheld GPS unit), where as a dual antenna GPS is placed underneath the calibration table and aligned using the read-out from the antenna's NMEA stream. Both of these methods work well but are all subject to error as the table is aligned using string. The next stage of error is when the instrument is inserted into the jig apparatus. The head of the unit has a north arrow but this arrow is aligned visually and further error can also be added at this stage. Efforts to use the GPS – Compass capabilities of a handheld smartphone greatly reduce this error but again, the north arrow of the phone and of the instrument are visually aligned. Another time when heading error can present itself, is well the instrument is turning and \ or tilted, as the instrument collars are tight but do move slightly as the unit is rotated. The other factor that can also affect the heading readings is the weak vertical component of the magnetic field, due to its proximity to the pole. The matter is further complicated when the magnetic field moves, as it can and will move to give an error of several degrees, from one hour to the next. Lastly, the heading indicators marked on the outer ring of the calibration table are aligned with the best precision possible, but the table is turned by hand and the possibility that the heading isn't exactly 0,10 ,20, etc. could also add error to the final heading reading.

The results from the verification indicate that the majority of the instruments performed within their ±5 degrees of, acceptable polar location error (set forth by RDI). Though units AQD 8418, CNL 6107, 6112 and 6116 showed a max heading variance \ error over the acceptable recommendation of 5 degrees. Unit CNL 6107 had the greatest variance in heading and this unit will need to be inspected and repaired before re-deployment.

The good news from the verifications showed that even with all the potential true direction heading errors, that the unit was consistently approximately 10 degrees W of the true heading. This equipment offset was slightly different for each instrument but after the equipment offset and magnetic declination corrections were applied, the instrument data was plotted and a correction equation \ polynomial curve was created, reducing the heading error to 1-2 degrees.

There was also a uniform North-South bias (soft-iron). This bias was evident in the oval shape of the verification spin \ curve observed in the Nortek Calibration routine (Appendix 3: Fig 13).

Calibration efforts for 2016 are recommended to build \ refurbish a calibration table that integrates a dual GPS antenna to align the table to true north and the instrument head as well, throughout the calibration \ verification turn.

**A complete account of the 2014 Nortek calibration problems experienced by ArcticNet/ IMG-Golder mooring teams can be found in 2014 ArcticNet Mooring Report.*

1.4.1 Current Meter Compass Calibration Summary

The pre-deployment compass calibrations of the RDI and Anderaa current meters was successfully completed in Inuvik, 2015. The instruments were returned to ArcticNet (Québec) and two RDI ADCPs (QM and LR) were also shipped to IOS to be loaded on-board the CCGS *Laurier* before its respective summer expeditions (Table 7).

The results from the verification session identify that there is still good reason to perform these verifications. As the device heading offset and error was quite large in some Nortek devices and users of the data need to be aware of this and they also need to have the polynomial fit that corrects these equipment's' compass variations (Table 8).

The results show that with the verification data and a polynomial fit equation we can greatly reduce the heading error and effectively correct the heading measured by the device. Unit CNL 6107 displayed a large offset and large North – South heading bias and will need to be inspected by Nortek before re-deployment. Other units AQD 8418, CNL 6112 and CNL 6116 verification data indicate that these units are less precise \ more sensitive than the other devices. Their recorded heading data is still good but the variation in these units was higher than other units, but with the verification \ calibration data, the heading data in these units is easily corrected to within less than 2 degrees of heading error (Table 8).

Table 3. Oceanographic Equipment that required Compass Calibration, including calibration Procedures

Equipment	Location	Purpose	Equipment Used	Calibration Procedure
Nortek Aquadopp	Nortek Factory, Norway (2014)	Single-Point water	None	Nortek software does not correct compass bias for soft iron effects. The hard

	*post-verification, Inuvik (2015)	velocity profiler		iron effects are negligible for the LTOO and BREA projects due to non-magnetic frame designs and lithium batteries ~50cm away from the transducer heads; thereby, negating hard-iron effects and removing the need to perform hard-iron calibrations on these devices.
Nortek Continental 190 / 470 kHz ADCP 	Nortek Factory, Norway (2014) *post-verification, Inuvik (2015)	3 beam - 3D water velocity profiler	None	Nortek software does not correct compass bias for soft iron effects. The hard iron effects are negligible for the LTOO and BREA projects due to non-magnetic frame designs and lithium batteries ~50cm away from the transducer heads; thereby, negating hard-iron effects and removing the need to perform hard-iron calibrations on these devices.
RDI 75 /150 kHz Long ranger / Quarter Master ADCP	Inuvik, NT (2015)	4 beam 3D water velocity profiler, with	Calibration Table / Jig, Laptop with WinSC installed,	Install into calibration table, point to 0 heading and open WinSC software, 'test' unit to verify all tests pass, set

		bottom tracking	USB to Serial adapter	unit to zero pressure, set unit to UTC, verify compass, calibrate compass using af command, record the heading deviation by using pc2 to view the heading of the ADCP relative to the calibration table heading, measured at 10° intervals.
RDI 300 kHz Work Horse Sentinel ADCP 	Kugluktuk, NWT (2015)	4 beam 3D water velocity profiler, with bottom tracking	Calibration Table / Jig, Laptop with WinSC installed, USB to Serial adapter	Install into calibration table, point to 0 heading and open WinSC software, 'test' unit to verify all tests pass, set unit to zero pressure, set unit to UTC, verify compass, calibrate compass using af command, record the heading deviation by using pc2 to view the heading of the ADCP relative to the calibration table heading, measured at 10° intervals.
Aanderaa RCM11 1MHz 	Sensors: Université Laval (2011) Compass: Inuvik, 2015 (pre-deploy)	4-beam 2D current meter and CTD-Tu-FL-DO sensors	5059 Data Reading Program	Install into calibration table, point to 0 heading and read the data values for channel 3 and convert to real heading by multiplying the raw value by 0.352. Record headings and raw values in a table and plot the values to extract the polynomial fit.

1.5 Health and Safety

All scientific personnel used Survitec Group immersion suits for transfers to and from the CCGS *Amundsen* (Fig. 5). ArcticNet provided Survitec Group immersion suits for personnel transfers and advised that all mission participants needing to complete a helicopter ditching survival course provided by Survival systems (Dartmouth, NS, Canada). A safety briefing was conducted prior to boarding the helicopter in Kugluktuk, NWT and again onboard the *Amundsen* prior to transfer from the ship. The mooring team also attended the *Amundsen* safety briefing and familiarization onboard the ship and participated in the individual leg fire drill.

Figure 7. Survitec Group Immersion Suits used for Personnel Transfers to / from the CCGS Amundsen

1.5.1 Mooring Operations Safety Documents

A Job Safety Assessment (JSA) / ÉPST (French version of JSA) concerning mooring operations was completed and made available to all crew members (Appendix 5). The JSA identified potential risks and hazards involved in mooring operations. The JSA was approved by the ArcticNet Scientific operations supervisor (Keith Levesque). The ÉPST (French version of the JSA) was also completed following the Canadian Coast Guard template and was made available to all crew members; however, it contains the same information as the JSA.

In addition to completing a JSA \ EPST, a mooring operations familiarization presentation was presented (by the Mooring Team Leader – Shawn Meredyk) to all of the relevant crew members (Captain, Boatswain, Chief Officer, deckhands) several days before mooring operations commenced.

In addition to the JSA\EPST and presentation, a'Toolbox' meeting (mini meeting) was held 5min before mooring operations began. The 'toolbox' meeting identified the equipment, lifting points, risks, roles and responsibilities required during mooring deployment operations. The 'toolbox' is an essential step within mooring operations and creates a safe working environment for all involved (Fig. 5).

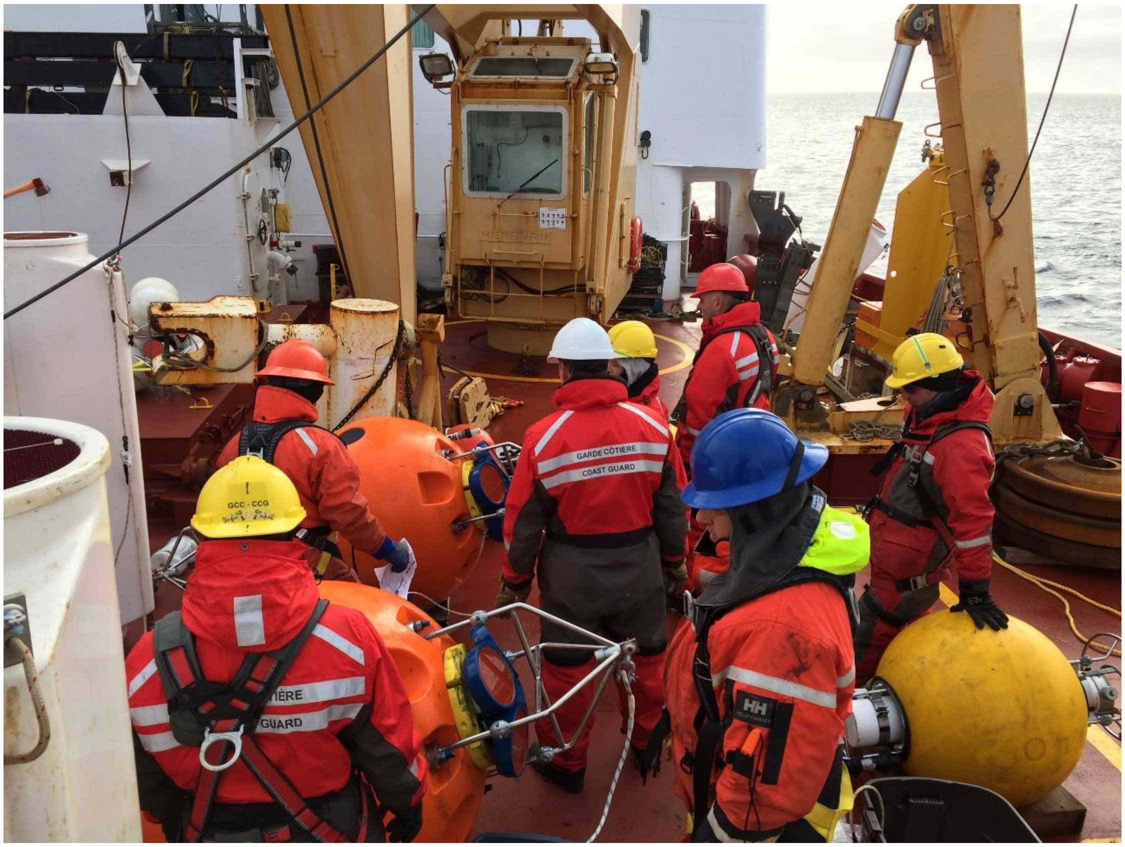


Figure 8. Mooring Pre-Deployment 'Toolbox' Meeting (Alexis Burt, 2015)

2 Mooring Operations

2.1 2015 Mooring Recovery Summary

All seven moorings from the Beaufort Sea (BS1, BS2, BS3, BR3, BR4, BRK and BRG) were successfully recovered using the CCGS *Amundsen* and CCGS *Laurier (BR1 and BR2)*. For a full record of the recovered moorings see Appendix 2.

Mooring BS1-14 was the only mooring that had given the mooring team any problem. The acoustic releases were interrogated (as with all of the other moorings) and returned acknowledgement; however, the mooring didn't surface. Both releases were released and the multibeam imagery showed that the mooring was still there and upright. The decision was made to retrieve BRK-14 and BS2-14 that same day, in-place of the BS1-14 and BS2-14 and BRK-14 original plan. The following day the releases gave the same response, "released", but it didn't come to the surface, and still the multibeam showed that it was there and vertical.
The decision to 'drag' for the mooring was then the only remaining operation to attempt to recover the mooring. A design for a dragging device was made (Luc Michaud) and fabricated by the chief mechanic (Eric Dubée). The forward section of the drag anchor was three 2m sections of mooring anchor chain (in an effort to weight the leading section of the cable).

2.1.1 Mooring Dragging Operations

The dragging anchor was connected to the 500Hp winch and approximately 250m of cable was deployed with the dragging anchor (Fig. 9).

The captain then dragged the dragging anchor in diagonal passes over the mooring in an effort to dislodge the mooring. Several attempts were made and eventually the mooring was dislodged and raised to the surface. Unfortunately, it rose directly under the vessel and the propeller blades made contact with the surface float and under-lying ADCP frame, cutting the top buoy into two pieces and damaging the ADCP frame and breaking 3 out of 6 buoys off of the frame.

The recovery operation took a long time as there was a great deal of debris from the ship's damage to the mooring equipment and the operations teams were confused by the float type and colours. The covering of the floats were yellow but the interior was white and this created confusion amongst the mooring team as to whether or not the mooring was in-deed BS1-14. Eventually, by visiting several debris pieces and seeing that the covers of buoys had mislead us into thinking that the items at the surface where from a different mooring, they pieces were in fact debris from the damage inflicted by the vessel propellers. The damage to the equipment was not observed or heard, so it wasn't until the equipment was recovered onboard that it could be determined that the damage was in fact from the vessel propellers, which hindered or expedient recovery process. None-the-less, the mooring was recovered and all data was recovered with no equipment damage apart from the top buoy (cut in half) and the Nortek ADCP frame (completely twisted).

Figure 9. ArcticNet Dragging Anchor for BS1-14

2.2 *Mooring Data Recovery Summary*

The seven moorings planned for recovery aboard the CCGS Amundsen between August-October 2015 were 100% successfully recovered from their original deployment locations. Table 2 presents a summary of the raw data recovery success, which cumulates overall at 94%.

Table 4. 2015 Short Mooring Re-Deployment Summary

Mooring	Instrument	Serial number	Raw data recovery success
BR-G-14	ASL Ice Profiler	51104	100%
	Nortek Aquadopp DW	9743	100%
	Nortek Aquadopp DW	9847	100%
	RBR XR420 CT	15266	100%
	RBR XR420 CT	15272	100%
	RBR XR420 CT	15273	100%
	RBR XR420 CT	15280	100%
	RBR XR420 CTD	17352	100%
	SBE 37SM Microcat	12235	100%

	Technicap Trap PPS3	11_17	100%
	Technicap Trap PPS3	12_18	100%
	TRDI Long Ranger ADCP	13079	100%
	TRDI Quarter Master ADCP	8784	100%
BR-K-14	ASL Ice Profiler	51108	100%
	Nortek Aquadopp Profiler	11147	100%
	RBR XR420 CT-Fl-Tu-DO	22044	6% (failed battery)
	RBR XR420 CT-Fl-Tu-DO	10419	100%
	SBE 37SM Microcat	12236	100%
	Sequoia LISST 100X	1473	100%
	TRDI WH Sentinel ADCP	2646	100%
BR-03-14	ASL Ice Profiler	51109	100%
	Nortek Aquadopp DW	2756	100%
	Nortek Aquadopp DW	8418	100%
	RBR XR420 CT	15263	100%
	RBR XR420 CT	15264	100%
	RBR XR420 CT	15275	100%
	RBR XR420 CT	15281	100%
	Technicap Trap PPS3	09_345	100%
	Technicap Trap PPS3	12_25	100%
	TRDI Long Ranger ADCP	18785	100%
	TRDI Quarter Master ADCP	12823	8% (leaking connector)
BR-04-14	ASL Ice Profiler	51103	100%
	Nortek Aquadopp DW	9752	100%
	RBR XR420 CT	15274	100%
	RBR XR420 CT-Fl-Tu-DO	17114	100%
	Sequoia LISST 100X	1319	100%
	TRDI WH Sentinel ADCP	6320	67% (failed battery)
BS-1-14	Nortek Continental	6070	100%
	RBR XR420 CT-Fl-Tu-DO	17113	100%
	SBE 37SM Microcat	10851	100%
BS-2-14	AURAL hydrophone	22	To be determined
	Nortek Continental	6063	100%
	Nortek Continental	6107	100%
	RBR XR420 CT	15258	100%
	RBR XR420 CT	15270	100%
	SBE 37SM Microcat	10849	100%
	SBE 37SM Microcat	10852	100%
	Technicap Trap PPS3	05_319	100%
BS-3-14	AURAL hydrophone	37	To be determined
	Nortek Continental	6112	100%
	Nortek Continental	6116	100%

Nortek Continental	6064	0% (misprogrammation)
RBR XR420 CT	15269	100%
RBR XR420 CT	15271	100%
RBR XR420 CT	15268	100%
SBE 37SM Microcat	10196	100%
SBE 37SM Microcat	10850	100%
Technicap Trap PPS3	03_225	100%

2.2.1.1 Data Recovery Problems

The instruments that provided less data than expected were investigated to identify the cause of failure. The following causes were identified:

- RBR XR420 CT-Fl-Tu-DO #22044: the instrument stopped recording data on September 8, 2014. One of the four CR123 3V Lithium batteries failed due to a possible short-circuiting. This battery was rated at 0V at recovery (3V at deployment), when compared to ~2.6V for other batteries. Further inspection of the instrument is needed to identify the cause of the possible short-circuiting. No water was found in the instrument.
- TRDI Quarter Master ADCP #12823: the connector on the dummy plug side of the external battery housing leaked, which caused a failure in the instrument recording which stopped on September 14, 2014.
- TRDI WH Sentinel ADCP #6320: a short-circuit in one the two 45V battery packs of the external housing of this instrument resulted in the over-heating and failure of this battery pack. The instrument stopped recording data on April 14, 2015. No water was found in the instrument.
- Nortek Continental #6064: no data was recovered in this instrument (battery canister had a full charge upon recovery) due to a potential programming mix-up (the recording never started, but it was also observed that #6063 was programmed twice).

2.2.2 Preliminary Data Results

The preliminary look at the CTD data from the recovered moorings show a variety of benthic and pelagic currents that arrive at different times of the year. The most interesting event from a design perspective occurred on the 2nd of March, 2014 at locations BS2 and BS3. A large ice berg with an ice keel large enough to lay over the BS2-14 mooring down to at least 205m which is where the sediment trap was moored. Unfortunately, The CT on the Sediment trap didn't have pressure sensing capabilities which could identified if the traps had been pulled-down as well. Though in all the instruments that recorded the ice berg push-down a depression of 50m was only recorded. On BS3-14 CT sensors on the Nortek ADCP and deeper sediment trap recorded a reduction by 0.5°C at the time of the lay-over, which doesn't mean that the trap or ADCP was pushed down but when the ADCP data is processed it will be evident as to whether or not the ice keel depth reached down to 300m or not.

Regardless, this was a very large piece of ice that depressed bot BS2-14 and BS3-14 for 4 days, with the largest lay-over period lasting only 12 hours (Fig. 10).

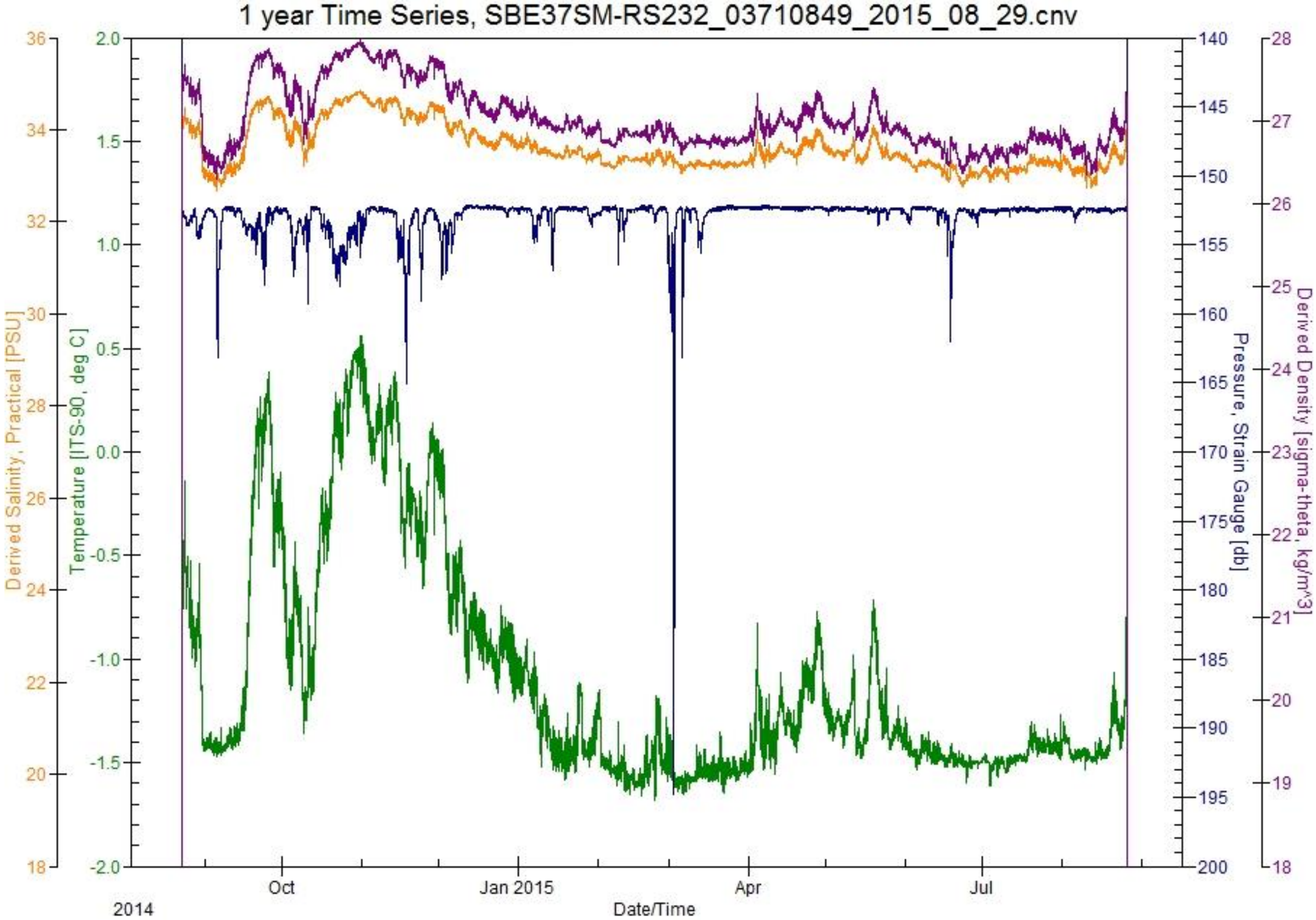


Figure 10. BS2-14 CTD plot from the SBE37 moored at 152 db (162m) showing the large lay-over event on March 2, 2014 (ice berg keel)

2.3 2015 Mooring Deployment Summary

2.3.1 Re-Deployment Summary

All three moorings (BR3, BRK, BRG) were successfully re-deployed very near their targeted locations and very near their target depths (Table 2 and Fig. 3). For a full record of the moorings deployed see Appendix 2.

Table 5. 2015 Short Mooring Re-Deployment Summary

Leg	Mooring ID	Latitude	Longitude	Latitude (DD)	Longitude (DD)	Depth (m)
3a	BRK-15	70° 51.763' N	135° 1.706' W	70.8627	-135.0284	170

3a	BRG-15	71° 0.122' N	135° 29.612' W	71.0020	-135.4935	700
3a	BR3-15	73° 24.566' N	129° 21.224' W	73.4094	-129.3537	690
?	BR1-15	70 25.909 N	139 1.37 W	70.4318	-139.0228	754

**Re-deployed via the CCGS Laurier (H. Melling)*

2.3.2 Deployment Summary

Four moorings were deployed during Leg 3a\3b. Two LTOO moorings CA08-15 and CA05-15 during Leg 3a and two Weston Foundation – ArcticNet – Parks Canada moorings (WF1-15 and WF2-15) were deployed during Leg 3b (Table 4 and Fig. 3). Benthic Tripod Mooring WF2-15 was deployed from the CCGS *Marty Bergman* by Parks Canada submarine archeological dive team, led by Marc-Andre Bernier. The benthic tripod ADCP and CTD-Tu sensor were pre-programmed by the ArcticNet Mooring Team (Shawn Meredyk) and the tripod was assembled and equipment attached to the frame by the dive team.

Table 6. Mooring Deployment Summary 2015

Leg	Mooring ID	Latitude	Longitude	Latitude (DD)	Longitude (DD)	Depth (m)
3a	CA05-15	71° 16.768' N	127° 32.002' W	71.2795	-127.5334	200
3a	CA08-15	71° 0.445' N	126° 4.719' W	71.0074	-126.0787	391
3b	WF1-15	68° 14.4866 N	101° 48.4376' W	68.2414	-101.8073	97
3b	WF2-15	68° 1.13046' N	99° 0.78183' W	68.0188	-99.0130	20

2.3.3 Mooring Re/Deployment Procedure

1) Instruments programmed and mounted into respective frames / floats
2) Verify Mooring releases function properly
3) Assemble the mooring Top-down on the fore-deck as per mooring design
4) Mooring Equipment attachments confirmed / double checked
5) Toolbox meeting with Mooring and Ship's mooring crew to identify roles and safety considerations (Zodiac® deployed if ice pack present)
6) Launch Zodiac® (if required)
7) Date and Time are recorded for the start of mooring operations by an observing mooring team member, stationed on the bridge.
8) Lower the first instrument buoy with the 500Hp winch, released at surface by SeaCatch®.
9) Have the zodiac attach the a tow-line to the bow horn / tack from the top instrument buoy
10) The mooring line is then tacked / secured and the zodiac is then instructed to maintain a taught-line (**not** tight), unless otherwise instructed by the lead mooring professional / chief officer.

11) Raise the next instrument off of the deck and extend the A-frame, undoing the mooring line tack before the instrument reaches the deck edge.

12) Descend the instrument and release the safety pin of the SeaCatch®, at deck level, then subsequently releasing the SeaCatch® and top float at the water surface. **Depending on wave conditions, timing of SeaCatch® release may need to be timed with a high in wave period.*

13) The SeaCatch® is then brought back to the deck level (A-frame brought back in at the same time) and attached to the next solid structure (i.e. cage), pearl link / d-ring (added to the top-side of next device to be lifted).

14) Pay-out the mooring line until there is 5-10m remaining (10m is advisable for rough seas). Then put the mooring line on-tack.

15) The next instrument is then raised by the 500hp winch wire as the mooring line in-tack is released

16) The same procedure of lowering the device to the water then putting the mooring line on tack, then attaching the SeaCatch® to the top-side of the next device follows until each device is in the water. Meanwhile, the zodiac continues to maintain a taught-line , so as to not allow for the deployed / in-water equipment to get entangled

17) The final release of the anchor is preceded by the zodiac releasing its tow-line of the top float (if zodiac is in the water) and the chief officer confirms the tagline release from the zodiac and confirmation that the vessel is at the desired depth / position.

18) The SeaCatch® on the Anchor chain shackle (located in the middle of the 2m anchor chain , just above the protective chain cylinder) was released (proceeding permission from the bridge) and the mooring free-falls into position at depth.

19) The Zodiac® and 4th team member on the bridge then marks the time and mooring / target location of the last seen vertical position of the top float on-descent (if zodiac is in the water).

20) The Zodiac® returns to the vessel and the A-frame and 500hp winch are stopped and secured (if zodiac is deployed).

21) The vessel then proceeds to 3 triangulation points around the target location (distance of mooring depth away from drop location) and verification of acoustic release communications through ranging / ‘pinging’ allow for the anchor position to be calculated. These data were then input into a MatLab® triangulation script to determine the

triangulated position of the mooring and kept within the field deployment sheets (Appendix 2) (example image Fig. 11).

22) Multibeam survey was performed to confirm the orientation and triangulated position of the mooring. Depending on the vessel's proximity to the mooring line, equipment and top-float depths might be visible if the vessel travels directly over-top the mooring. The multibeam images for each mooring deployment were kept within the field deployment workbook (EXCEL) and also archived at ArcticNet (Example image Fig. 12).

23) A post-deployment CTD cast / profile was taken, though pre-deployment cast is sufficient if the CTD-Rosette is programmed to take several water samples at the same time while profiling the water column. The CTD profile plots for each mooring were kept within the field deployment workbook (EXCEL) and also archived at ArcticNet (Example image Fig. 13).

24) The fore deck is cleaned of debris and remaining mooring equipment / cages are secured on the foredeck.

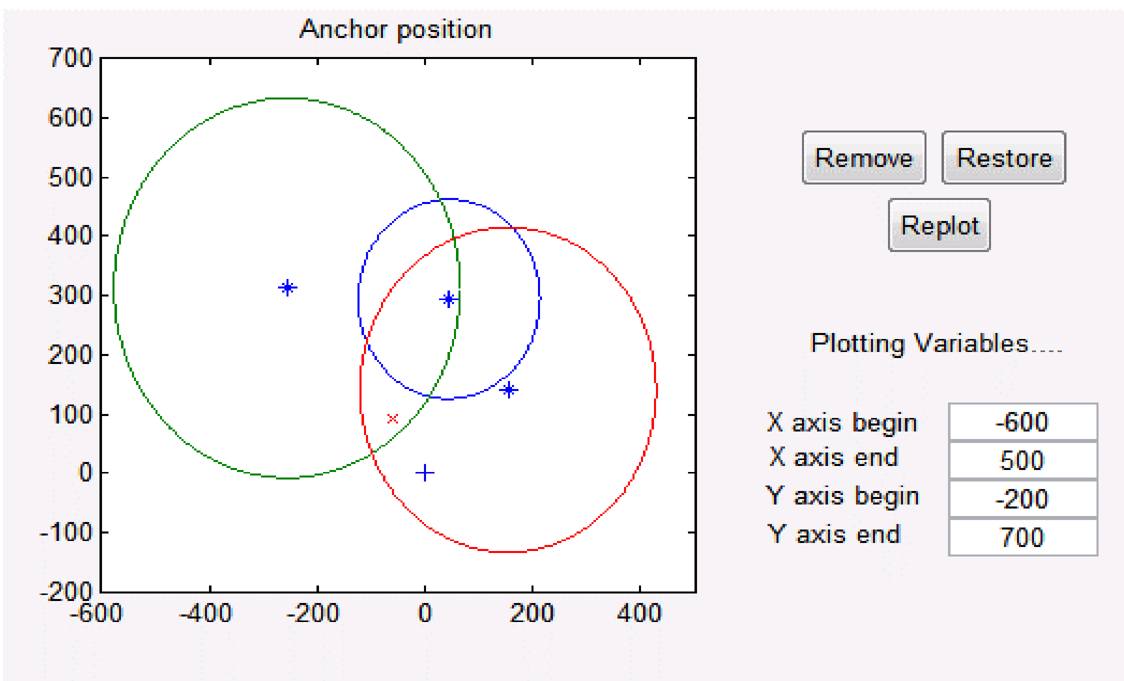


Figure 11. Triangulation Plot from BS1-14 using Art's Acoustic Survey Matlab Script

Figure 12. Multibeam imagery identifying orientation and instrument depths (screenshot courtesy of ArcticNet multibeam processing team)

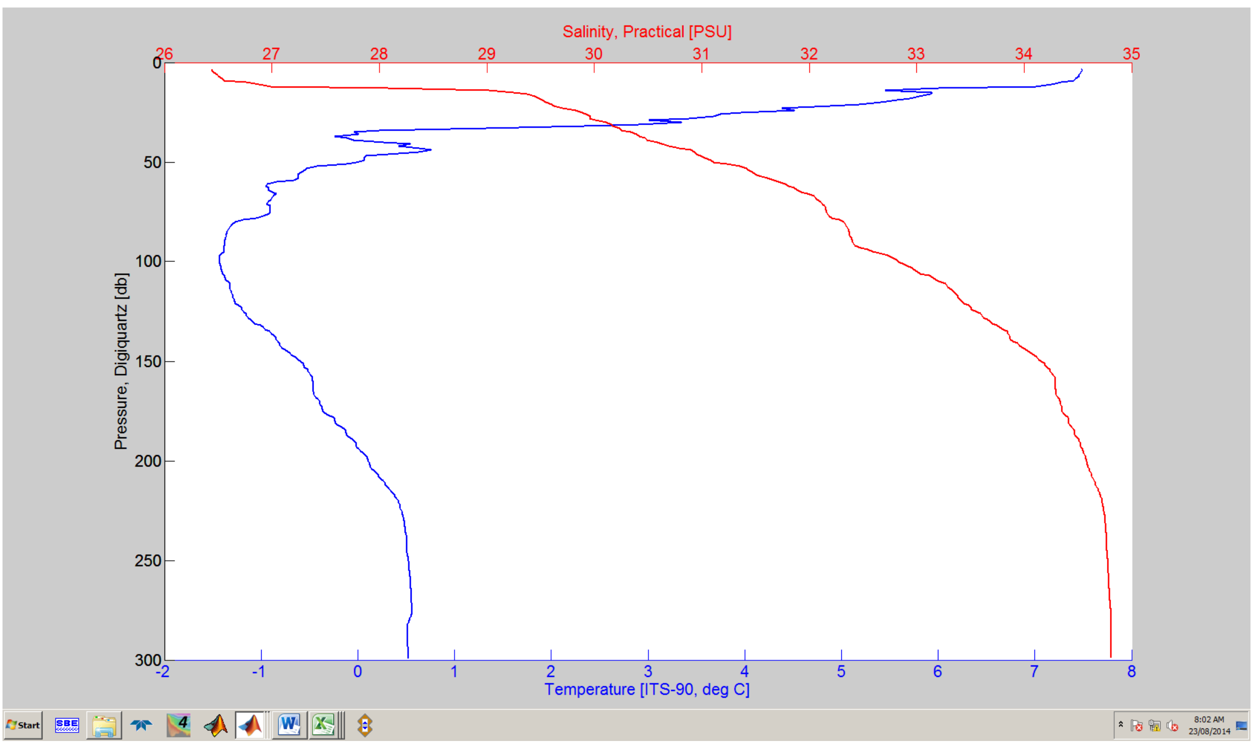


Figure 13. Rosette Temperature - Salinity Profile example plot (BS2-14)

2.3.4 Mooring Deployment Instrumentation Setup/Programming

i. See Table 3 (below) for a summary of the Instrumentation Programming Parameters.

Table 7. 2015 Equipment Programming / Sampling Parameters

Equipment Type	**Sampling Parameters**
Nortek_1MHz_Aquadopp	AQD_1MHz single point current meter
_DeepWater	---
	Measurement interval (s) : 1800
CA08, CA05, WF1	Average interval (s) : 240
	Blanking distance (m) : 0.50
BR-1: 2 units	Measurement load (%) : 4
BR-G: 2 units	Power level : HIGH
BR-3: 2 units	Diagnostics interval(min) : 720:00
BR-K: -	Diagnostics samples : 20
	Compass upd. rate (s) : 5
	Coordinate System : ENU
	Speed of sound (m/s) : MEASURED
	Salinity (ppt) : 34
	Baud rate : 115200

	Assumed duration (days) : 365.0
	Battery utilization (%) : 95.0
	Battery level (V) : 11.3
	Recorder size (MB) : 9
	Recorder free space (MB) : 8.973
	Memory required (MB) : 1.3
	Vertical vel. prec (cm/s) : 0.7
	Horizon. vel. prec (cm/s) : 0.5
Nortek_1MHz_Aquadopp	AquaPro_1MHz_ADCP
_Profiler	---
	Profile interval (s) : 3600
BR-1: -	Number of cells : 20
BR-G: -	Cell size (m) : 1.00
BR-3: -	Blanking distance (m) : 0.40
BR-K: 1 unit	Measurement load (%) : 13
	Average interval (s) : 240
	Power level : HIGH
	Wave data collection : DISABLED
	Compass upd. rate (s) : 2
	Coordinate System : ENU
	Speed of sound (m/s) : MEASURED
	Salinity (ppt) : 34
	Baud rate : 115200

	--
	Assumed duration (days) : 365.0
	Battery utilization (%) : 86.0
	Battery level (V) : 11.4
	Recorder size (MB) : 9
	Recorder free space (MB) : 8.973
	Memory required (MB) : 1.8
	Vertical vel. prec (cm/s) : 0.6
	Horizon. vel. prec (cm/s) : 1.9
Nortek_470kHz_ADCP	CNA_Continental 470 kHz
	--
CA08, CA05, WF1	Profile interval (s): 360
	Number of cells : 30
	Cell size (m): 4.00
	Average interval (s) : 60
	Blanking distance (m) : 1.00
	Measurement load (%) : 33
	Power level : HIGH
	Compass upd. rate (s) : 2
	Coordinate System : ENU
	Speed of sound (m/s) : MEASURED
	Salinity (ppt) : 33
	Baud rate : 115200
	--
	Assumed duration (days) : 370.0
	Battery utilization :max 660 (%) : 657.0
	Battery level (V) : 17.5
	Recorder size (MB) : 154
	Recorder free space (MB) : 153.973
	Memory required (MB) : 30.8
	Vertical vel. prec (cm/s) : 0.4
	Horizon. vel. prec (cm/s) : 1.3
RDI_Sentinel_ADCP	Instrument = Workhorse Sentinel
	Frequency = 307200
BR-1: -	Water Profile = YES
BR-G: -	Bottom Track = YES
BR-3: -	High Res. Modes = NO
BR-K: 1 unit	High Rate Pinging = NO
	Shallow Bottom Mode= NO
	Wave Gauge = NO
	Lowered ADCP = NO
	Ice Track = NO
	Surface Track = NO
	Beam angle = 20
	Temperature = -1.00

Deployment hours = 8760.00
Battery packs = 2
Automatic TP = YES
BT range [m] = 185.00
Memory size [MB] = 100
Saved Screen = 2
Bandwidth: Narrowband

Deployment Duration: 365 days
Ensemble Interval: 30 minutes
Pings Per Ensemble: 38
Depth Cell Size: 8 m
Bottom Track Pings Per Ensemble: 6

Consequences generated by PlanADCP version 2.06:
First cell range = 10.02 m
Last cell range = 186.02 m
Max range = 155.83 m
Standard deviation = 0.60 cm/s
Ensemble size = 701 bytes
Storage required = 11.71 MB (12281520 bytes)
Power usage = 817.64 Wh
Battery usage = 1.8

RDI_LongRanger_ADCP _on_BR1 (Low Power) BR-1: 1 unit BR-G: - BR-3: - BR-K: -	Instrument = Workhorse Long Ranger Frequency = 76800 Water Profile = YES Bottom Track = NO High Res. Modes = NO High Rate Pinging = NO Shallow Bottom Mode= NO Wave Gauge = NO Lowered ADCP = NO Ice Track = NO Surface Track = NO Beam angle = 20 Temperature = 0.00 Deployment hours = 8760.00 Battery packs = 4 Automatic TP = YES Memory size [MB] = 256 Saved Screen = 2 Power: Low Bandwidth: Narrowband Deployment Duration: 365 days

Ensemble Interval: 30 minutes
Pings Per Ensemble: 50
Depth Cell Size: 16 m

Consequences generated by PlanADCP version 2.06:
First cell range = 22.86 m
Last cell range = 566.86 m
Max range = 519.47 m
Standard deviation = 1.07 cm/s
Ensemble size = 854 bytes
Storage required = 14.27 MB (14962080 bytes)
Power usage = 1136.23 Wh
Battery usage = 2.5

RDI_LongRanger_ADCP
_on_BR3_&_BRG
(High Power)

BR-1: -
BR-G: 1 unit
BR-3: 1 unit
BR-K: -

Instrument = Workhorse Long Ranger
Frequency = 76800
Water Profile = YES
Bottom Track = NO
High Res. Modes = NO
High Rate Pinging = NO
Shallow Bottom Mode= NO
Wave Gauge = NO
Lowered ADCP = NO
Ice Track = NO
Surface Track = NO
Beam angle = 20
Temperature = 0.00
Deployment hours = 8760.00
Battery packs = 4
Automatic TP = YES
Memory size [MB] = 256
Saved Screen = 2
Power: High
Bandwidth: Narrowband

Deployment Duration: 365 days
Ensemble Interval: 30 minutes
Pings Per Ensemble: 11
Depth Cell Size: 16 m

Consequences generated by PlanADCP version 2.06:
First cell range = 24.45 m
Last cell range = 568.45 m
Max range = 730.26 m
Standard deviation = 2.28 cm/s
Ensemble size = 854 bytes

	Storage required = 14.27 MB (14962080 bytes) Power usage = 1629.37 Wh Battery usage = 3.6
RDI_QuarterMaster_ADCP BR-1: 1 unit BR-G: 1 unit BR-3: 1 unit BR-K: -	Instrument = Workhorse Sentinel Frequency = 153600 Water Profile = YES Bottom Track = YES High Res. Modes = NO High Rate Pinging = NO Shallow Bottom Mode= NO Wave Gauge = NO Lowered ADCP = NO Ice Track = NO Surface Track = NO Beam angle = 20 Temperature = -1.00 Deployment hours = 8760.00 Battery packs = 4 Automatic TP = YES BT range [m] = 210.00 Memory size [MB] = 256 Saved Screen = 2 Bandwidth: Narrowband Deployment Duration: 365 days Ensemble Interval: 30 minutes Pings Per Ensemble: 50 Depth Cell Size: 4 m Bottom Track Pings Per Ensemble: 3 Consequences generated by PlanADCP version 2.06: First cell range = 8.30 m Last cell range = 212.30 m Max range = 326.58 m Standard deviation = 1.96 cm/s Ensemble size = 1281 bytes Storage required = 42.81 MB (44886240 bytes) Power usage = 1634.58 Wh Battery usage = 3.6
Sequoia_LISST BR-1: - BR-G: - BR-3: - BR-K: 1 unit	Burst Interval: 3600 s Samples Per Burst: 20 Sample Interval 10 s Measurement to Average: 10

RBR XR-420 CT BR-1:4 units BR-G: 4 units BR-3: 4 units BR-K: -	Sampling period: 600 s Averaging period: 4 s
RBR XR-420 CTD BR-1:1 unit (titanium) BR-G: 1 unit (below trap) BR-3: 1 unit (below trap) BR-K: -	Sampling period: 1200 s Averaging period: 5 s
RBR XR-420 CT-DO-Tu-Fl BR-1: - BR-G: - BR-3: - BR-K: 1 unit	Sampling period: 3600 s Averaging period: 5 s
Seabird_SBE37	Sample Interval: 600 s Sample Duration: 1.8 s
Satlantic_ISUS-V3 CA08, CA05, WF1	Sample Interval : 3600s Sample Duration : 5s
JFE_ALEC_CTW CA08, CA05, WF1	Sample Interval : 5400s Sample Duration: 2s Number of Samples: 10 Mode: Burst
JFE_ALEC_CLW CA08, CA05, WF1	Sample Interval : 1800s Sample Duration: 1s Number of Samples: 10 Mode: Burst
JFE_ALEC_ALW CA08, CA05, WF1	Sample Interval : 1800s Sample Duration: 1s Number of Samples: 10 Mode: Burst

Aanderaa_RCM11 CA05	Sample Interval: 3600s Sample Duration: 1s per channel Channels: All Battery duration : 635 days Battery Capacity : 35 Ah \ 2.3 mA

Technicap Sediment Traps (PPS3)

BR-1: 2 units
BR-G: 2 units
BR-3: 2 units
CA08, CA05, WF1: 1 unit

Sample	Days	Date
Start		1-Sep-15 (or 1-Oct-15 for BR1)
1	15	1-Sep-15
2	15	16-Sep-15
3	15	1-Oct-15
4	16	16-Oct-15
5	15	1-Nov-15
6	15	16-Nov-15
7	15	1-Dec-15
8	16	16-Dec-15
9	15	1-Jan-16
10	16	16-Jan-16
11	15	1-Feb-16
12	14	16-Feb-16
13	15	1-Mar-16
14	16	16-Mar-16
15	15	1-Apr-16
16	15	16-Apr-16
17	15	1-May-16
18	16	16-May-16
19	15	1-Jun-16
20	15	16-Jun-16
21	15	1-Jul-16
22	16	16-Jul-16
23	15	1-Aug-16
24	16	16-Aug-16
End	---	1-Sep-16

ASL_IPS

BR-1: 1 unit
BR-G: 1 unit
BR-3: 1 unit
CA05: 1 unit

Parameter Version 3
Configuration Version 1
File name format YYMMDDHH
OperatingMode Target Detection
DataOutput FLASH
SoundSpeed 1450.500000
Acquisition Start: Sep 01, 2016 00:00:00 (or adjust)
Number of phases 8

Date span: Sep 01, 2015 00:00:00 - Sep 30, 2016 23:59:59

Phase 1
Acquisition Period: Sep 01, 2015 00:00:00 - Oct 15, 2015 23:59:59
Duration 45.0000 days
Phase Type 'WAVE'
Pulse Length 68 uS
Dig. Rate 64 kHz (0.0113 m/smpl)
Ping Period 2.0 sec
Sensor Period 60.0 sec [30 Pings]
Burst Period 3600.0 sec [60 sensors]
Burst Length 1024.0 sec [2048 pings]
Range 95.00 meters [8383 samples]
Gain '1'
Maximum Targets 3
Range Lockout 22.00 meters [1941 samples]
Start Amplitude 35000
Stop Amplitude 25000
Min. Persist 46 us [3 samp.]
Burst Save Format Save burst as profile
Target Algorithm Max Persistence
****

Phase 2
Acquisition Period: Oct 16, 2015 00:00:00 - Nov 15, 2015 23:59:59
Duration 31.0000 days
Phase Type 'ICE'
Pulse Length 68 uS
Dig. Rate 64 kHz (0.0113 m/smpl)
Ping Period 1.0 sec
Sensor Period 60.0 sec [60 Pings]
Burst Period 180.0 sec [3 sensors]
Burst Length 1.0 sec [1 pings]
Range 95.00 meters [8383 samples]
Gain '1'
Maximum Targets 4
Range Lockout 22.00 meters [1941 samples]
Start Amplitude 20000
Stop Amplitude 15000
Min. Persist 46 us [3 samp.]
Burst Save Format Save burst as profile
Target Algorithm Max Persistence
****

Phase 3
Acquisition Period: Nov 16, 2015 00:00:00 - Mar 15, 2016 23:59:59
Duration 121.0000 days
Phase Type 'ICE'
Pulse Length 68 uS
Dig. Rate 64 kHz (0.0113 m/smpl)
Ping Period 2.0 sec
Sensor Period 60.0 sec [30 Pings]
Burst Period 240.0 sec [4 sensors]
Burst Length 1.0 sec [1 pings]
Range 95.00 meters [8383 samples]
Gain '1'
Maximum Targets 5
Range Lockout 22.00 meters [1941 samples]
Start Amplitude 10000
Stop Amplitude 9000
Min. Persist 46 us [3 samp.]
Burst Save Format Save burst as profile
Target Algorithm Max Persistence
****

Phase 4
Acquisition Period: Mar 16, 2016 00:00:00 - May 15, 2016 23:59:59
Duration 61.0000 days
Phase Type 'ICE'
Pulse Length 68 uS
Dig. Rate 64 kHz (0.0113 m/smpl)
Ping Period 1.0 sec
Sensor Period 60.0 sec [60 Pings]
Burst Period 240.0 sec [4 sensors]
Burst Length 1.0 sec [1 pings]
Range 95.00 meters [8383 samples]
Gain '1'
Maximum Targets 5
Range Lockout 22.00 meters [1941 samples]
Start Amplitude 10000
Stop Amplitude 9000
Min. Persist 46 us [3 samp.]
Burst Save Format Save burst as profile
Target Algorithm Max Persistence
****

Phase 5
Acquisition Period: May 16, 2016 00:00:00 - Jun 15, 2016 23:59:59
Duration 31.0000 days
Phase Type 'ICE'
Pulse Length 68 uS
Dig. Rate 64 kHz (0.0113 m/smpl)
Ping Period 1.0 sec
Sensor Period 60.0 sec [60 Pings]
Burst Period 240.0 sec [4 sensors]
Burst Length 1.0 sec [1 pings]
Range 95.00 meters [8383 samples]
Gain '1'
Maximum Targets 5
Range Lockout 22.00 meters [1941 samples]
Start Amplitude 10000
Stop Amplitude 9000
Min. Persist 46 us [3 samp.]
Burst Save Format Save burst as profile
Target Algorithm Max Persistence
****

Phase 6
Acquisition Period: Jun 16, 2016 00:00:00 - Jul 31, 2016 23:59:59
Duration 31.0000 days
Phase Type 'ICE'
Pulse Length 68 uS
Dig. Rate 64 kHz (0.0113 m/smpl)
Ping Period 1.0 sec
Sensor Period 60.0 sec [60 Pings]
Burst Period 240.0 sec [4 sensors]
Burst Length 1.0 sec [1 pings]
Range 95.00 meters [8383 samples]
Gain '1'
Maximum Targets 5
Range Lockout 22.00 meters [1941 samples]
Start Amplitude 10000
Stop Amplitude 9000
Min. Persist 46 us [3 samp.]
Burst Save Format Save burst as profile
Target Algorithm Max Persistence
****

Phase 7

Acquisition Period: Aug 01, 2016 00:00:00 - Aug 31, 2016 23:59:59
Duration 24.0000 days
Phase Type 'ICE'
Pulse Length 68 uS
Dig. Rate 64 kHz (0.0113 m/smpl)
Ping Period 1.0 sec
Sensor Period 60.0 sec [60 Pings]
Burst Period 1800.0 sec [30 sensors]
Burst Length 1.0 sec [1 pings]
Range 95.00 meters [8383 samples]
Gain '1'
Maximum Targets 3
Range Lockout 22.00 meters [1941 samples]
Start Amplitude 20000
Stop Amplitude 15000
Min. Persist 46 us [3 samp.]
Burst Save Format Save burst as profile
Target Algorithm Max Persistence
****

Phase 8
Acquisition Period: Sep 01, 2016 00:00:00 - Continuous
Duration 30.0000 days
Phase Type 'WAVE'
Pulse Length 68 uS
Dig. Rate 64 kHz (0.0113 m/smpl)
Ping Period 2.0 sec
Sensor Period 60.0 sec [30 Pings]
Burst Period 3600.0 sec [60 sensors]
Burst Length 1024.0 sec [2048 pings]
Range 95.00 meters [8383 samples]
Gain '1'
Maximum Targets 3
Range Lockout 22.00 meters [1941 samples]
Start Amplitude 35000
Stop Amplitude 25000
Min. Persist 46 us [3 samp.]
Burst Save Format Save burst as profile
Target Algorithm Max Persistence
****

2.3.5 Mooring Deployment Lessons Learned

i. See Table 6 (below) for a summary of Mooring Deployment notes

3 Lessons Learned Summary

3.1 Amundsen Leb 3a

3.1.1 OCEANO Acoustic Releases

The mooring chain that is connected by tear-drop links that are shackled to the release chain could be improved to possibly reduce the chance of the release chain from getting caught on the releases or on the stretch-section ring. The needs to be a discussion with OCEANO about this and get their recommendations, as the present recommendations from the ArcticNet mooring team are to reduce the chain length and to increase the ring size and to use slim-type shackles.

3.1.2 Battery Canister problems

On Leg 3a one of the TRDI Titanium external battery canisters (from the QM ADCP at BR-03-14) had leaked through the dummy plug connector of the bottom end cap. This issue is different than the impulse connector corrosion problem identified from 2009 and 2010. This latter problem lead to the replacement of all impulse connectors (the ones connecting the ADCP to the external housing) over 2011-2012. Silicon grease was also used to cover these impulse connector as a supplementary mitigation procedure. However, it appears that the connectors on the dummy plus side of the housings were not replaced. Silicon grease was also not applied over this connector because no signal/electricity is directed to this connector during deployment. The amount of water entering the housing was done in small doses and since the O-rings were in good condition and no signs of o-ring associated problems were seen, the problem was isolated to the connector. The energy surges caused internal connector wiring to burn-through and batteries to short-circuit and overheat. The battery canister continued to gass-off even when on deck. Following this incident, it is clear that all connectors on the dummy plug side of the TRDI titanium battery canisters need to be inspected/changed before further use and covering the dummy connector end with silicon grease would be advisable.

One of the battery packs in the plastic canister of the Workhorse Sentinel 300-kHz at BR-04-14 had experienced short-circuiting and failure. No water was found in the instrument (humidity card was OK) and the O-ring were in good condition and properly installed. It was noted that escaping gas was heard when the instrument was on-deck while additional devices such as the Novatech flashers and Benthos Pingers were being removed. Further inspection of the wiring in this battery canister is needed to identify if an incorrect wiring could be the cause of the short-circuiting.

There was one Benthos Pinger canister that had been flooded by corrosion on the conductivity screws (to activate the pinger once in water) or failing o-ring, whereby water entered the canister and caused pressure build-up, which resulted in a bystander to be hit by the top popping off. These instruments were isolated by rubber to the instrument frame and no metal contact was made. So, the reason behind the corrosion of the stainless steel screws on the pingers falls into the same oceanographic conditions problem such as the other stainless steel shackles experienced. Again, moving to using titanium screws instead of stainless steel could solve this problem, along with abandoning the acoustic pingers for XEOS satellite locator beacons.

3.1.3 Stainless Steel Shackles

2011 Mooring Report Exert:

"Extra care needs to be taken when deploying sediment traps with stainless steel shackles to replace anodes in the sediment trap. In 2011 it was decided that a safety line should be employed in combination with stainless shackles in the event that shackle corrosion results in mooring line separation. Evaluate the use of stainless shackles on sediment traps and other parts of moorings; incorporate "safety" lines between mooring line components in case of shackle failure to prevent total loss."

The idea since 2010-2011 was that the Chinese Stainless Steel shackles were defective and not to be trusted. However, the 2014 ArcticNet moorings had used Chinese Stainless Steel shackles by accident and the BREA moorings had used shackles made in France (Wichard). During recovery of the equipment it was observed that the French Stainless Steel shackles had corroded slightly on the Stainless Steel traps, whereas the Chinese shackles showed no sign of corrosion at all, which were installed on the Titanium traps. Knowing now that stainless steel from any country could have good and bad batches of shackles and have only shown corrosion on the Stainless Steel traps, the reasons behind stainless steel corrosion on sediment traps are a combination of local oceanographic conditions and trap construction (stainless steel vs. titanium).

In terms of corrosion remediation with Stainless Steel shackles, it has been observed that Chinese shackles from batch E23 (sometimes looks like 123 on the shackle) has shown signs of corrosion and should be selected over other batches already in-stock. Another way to remedy this problem would be to purchase Titanium shackles for the stainless steel traps.

Table 8. Summary table of Lessons Learned throughout the mission

Problem	Solution	Operation
Some cages and swivels have special shackle and insert sizes	Order more 3\8" and 7\16" shackles and inserts for ISUS and Nortek Cages	Deployment
Stainless Steel Shackle Corrosion	Buy Titanium Shackles	Deployment
1TB hard drive upgrade in Aural M2 could possibly need more energy than older 320 GB drives, dead batteries and no data as a result	Figure out if new battery packs or different hard drives are needed for the 1TB hard drive upgrade for the AURAL M2s ; also don't use the 1TB upgrade	Recovery

	adapters	
RDI battery case flooding through bulkhead connector	Have all RDI battery cases inspected and repaired by RDI	Recovery
Benthos Pinger SW contact corrosion	Ask Benthos recommendations	Recovery
Oceano Release chain can get caught-up on itself and prevent mooring release	Change shackles to slim model and shorten ring chain or increase the chain ring size	Recovery
Broken equipment (buoys primarily) can confuse recovery operations , by chasing false leads	Mooring design schematic images need to show exact model types with color of interior material identified	Recovery
Stainless shackles attached to stainless traps are more susceptible to corrosion than when attached to titanium traps.	Buy Titanium Shackles/traps	Recovery

Acknowledgements

I would like to acknowledge the teamwork and co-operation between the Coast Guard crew of the CCGS *Amundsen* and the Mooring Team (Shawn Meredyk, Luc Michaud and Alexandre Forest (Golder)). Working together as a team and having the fortune of good weather, all the moorings were successfully deployed, recovered and re-deployed efficiently and safely as possible.

I would also like to acknowledge the teamwork and co-operation of Dr. Humfrey Melling (IOS) and the CCGS *Sir-Wilfred Laurier* for their hard work and attention to detail that successfully recovered moorings BS1-14 and BS2-14 and re-deployment of BS1-15.

Appendix 1 (Oceanographic Equipment on 2015 Moorings)

The SBE 37 was used to record the conductivity, temperature and depth (CTD)

Depth 50m intervals on ArcticNet moorings

The AURAL M2 hydrophone from Multi-électronique was deployed to record underwater sounds at a sampling rate of 16 kHz.

Depth 100-150m, on ArcticNet moorings only

The Nortek 190/ 470 kHz Continental model of Acoustic Doppler Current Profiler (ADCP) was housed in stainless steel cage and six panther floats were attached to each side of the ADCP cage. The upward and downward looking profilers were designed to record 100 to 200m of water column velocity data (binning of 4m).

Depth 100 and / or 300m, depending on proposed mooring depth of ArcticNet moorings only

Semi-Permeable Membrane Devices (SPMDs) were designed to be installed on the ADCP cages and mooring line as well, in an effort to trap persistent organic pollutants (POPs) within a gel matrix within the traps.

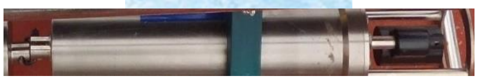
Deployed Depths: 50, 60, 100, 200 and 300m

Satlantic *In situ* ulrtaviolet spectrophotometric (ISUS) V3 Nitrate Sensor.

Deployed Depths: 60m

JFE_ALEC CLW Turbidity and Chlourometer to measure the concentration of chlourophyll and gain a measure of suspended particle concentration

JFE_ALEC Compact ALW Photosynthetic Active Radiation (PAR) to measure photosynthesis activity



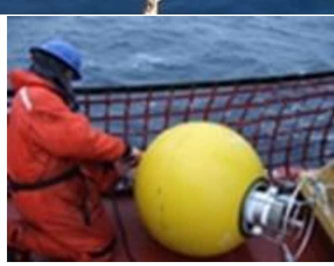
JFE_ALEC CTW device is used to measure conductivity and temperature (CT)

RBR XR420 CT device is used to measure conductivity and temperature (CT) , along with Dissolved Oxygen (DO), Turbidity (TU) and Fluorimetry (FL)

Depths: 100, 200, 300 and 400m

LISST-100x particle analyzer identifies the size of particulate matter in the water column at its designated deployment depth.

Depth 130-150m , BR-K, BR-2, BR-4 shallow moorings



The ASL Environmental Sciences IPS (model 5) was used to measure size and thickness of ice keels and ice velocities.

Deployment depth ~60m with syntactic buoy.

Technicap PPS 3/3-24S 24 cup sequential sediment trap was deployed to record the annual cycle in vertical carbon flux.

Depth 100 and / or 200m and / or 300m, depending on proposed mooring depth

Tandem Benthos, OCEANO, CART or 8242XS acoustic releases were used as the primary recovery / release devices.

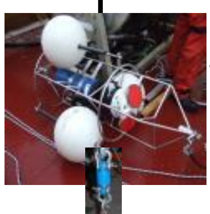
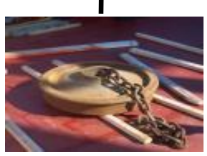
Depth : 5-8m (Oceano) or 12m (CART / 8242XS) above target mooring bottom depth

Appendix 2 – BREA / ArcticNet Mooring Designs / Field Operations Sheets

Recoveries

BS1-14 **Southern Beaufort Sea - Mackenzie Trough**

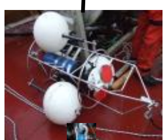
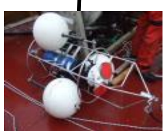
	Longitude	Latitude
Proposed Position		
Decimal degrees (WGS84)	-135.50173	70.65616
Triangulated Position	-134.85061	70.81078667
Target Depth (m):	80	

~ Instr. Depth (m)		Instrument	Water	Other Equipment	Net weight (kg)
45m		ORE 30¨Buoy			
		Buoyancy 168kg	168.0		
				SBE 37 #10851 and SPMD (50m)	
		15m Kevlar line 5/16¨			
60m		Nortek Currentmeter #6070			
		Continental 470kHz			
		Weight in water 15kg	-15.0		
		Cage (Weight in water)	-18.0		
		6 Panther buoys			
		Buoyancy 17.6kg	105.6		
		Galv shackles, swivel			
		15m Kevlar line 5/16¨			
				RBR XR420 CT 17113 (75m)	
75m		OCEANO acoustic releases			
		Tandem assembly			
		Weight in water 22kg	-44.0		
					196.6
		~3m polyrope line			
		shackle			
		~2 m chain			
80m		Anchor (800 lbs train wheel)			
		2 train wheels	-1600.0		

BS2-14 **Southern Beaufort Sea - Mackenzie Trough**

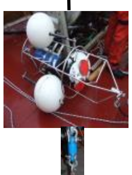
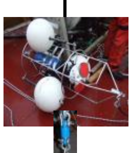
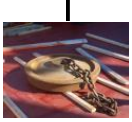
Proposed Position:	Longitude	Latitude
Decimal degrees (WGS84)	-135.69183	70.68495
Triangulated Position:	-134.09446	70.88123667

Target Depth (m) : **300**

Instrument Depth (m)		Instrument	Water Weight (kg)	Other Equipment	Net weight (kg)
41m		ORE 30¨Buoy Buoyancy 168kg	 168.0		
		50m Kevlar line 5/16¨		SBE 37 #10852 and SPMD (50m)	
91m	 	Nortek Currentmeter #6063 Continental 470kHz (UL) Weight in water 14kg Cage (Weight in water 18kg) 6 Panther buoys Buoyancy 17.6kg Galv shackles, swivel 2m Kevlar line 5/16¨	 -14.0 -18.0 105.6	RBR XR420 CT #15270 (100m) and SPMD	
94.5m	 	Nortek Currentmeter #6107 Continental 190kHz (DL) Weight in water 14kg Cage (Weight in water 18kg) 6 Panther buoys Buoyancy 17.6kg Galv shackles, swivel 50m Kevlar line 5/16¨	 -14.0 -18.0 105.6		
146m		Aural M2 hydrophone #31 (8 kHz , 120min cycle/ 10min	-19.0	SBE 37 #10849(150m)	
		50m Kevlar line 5/16¨			
199m		Sediment trap Technicap PPS 3/3-24s Weight in water 18kg	 -18.0	RBR XR420 CT #15258 and SPMD (200m) Sediment trap #30	
		75m Kevlar line 5/16¨			
274m		4 Benthos Buoy 17¨ Buoyancy 25kg	 100.0		
		5 m Kevalr Line 5/16"			
295m		OCEANO acoustic releases Tandem assembly Weight in water 22kg	 -44.0		334.2
		~3m polyrope line shackle ~2 m chain			
300m		Anchor (800 lbs train wheel) 3 train wheels	 -2400.0		

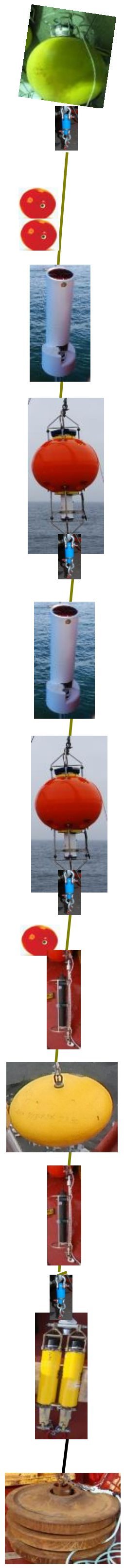
BS3-14 **Southern Beaufort Sea - Mackenzie Trough**

	Longitude	Latitude
Proposed Position :		
Decimal degrees (WGS84)	-135.83698	70.72443
Triangulated Postion:	-135.2357867	70.92594
Target Depth (m) :	500	

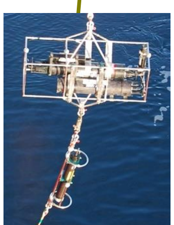
Instrument Depth (m)		Instrument	Water Weight (kg)	Other Equipment	Net weight (kg)
51m		ORE 30¨Buoy Buoyancy 168kg	168.0		
				SBE 37 #10850 and SPMD (50m)	
		45m Kevlar line 5/16¨			
96m		Nortek Currentmeter #6064 Continental 470kHz (UL)	-14.0		
		Cage	-18.0		
		6 Panther buoys Buoyancy 17.6kg each	105.6		
		Galv shackles, swivel 2m Kevlar line 5/16¨			
98m		Nortek Currentmeter #6116 Continental 190kHz (DL)	-14.0	RBR CT #15278 and SPMD (100m)	
		Cage (Weight in water 18kg)	-18.0		
		6 Panther buoys Buoyancy 17.6kg	105.6		
		Galv shackles, swivel 50m Kevlar line 5/16¨			315.2
148m		ORE 30¨Buoy Buoyancy 168kg	168.0		
		2m Kevlar line 5/16¨			
150m		Aural M2 hydrophone (8 kHz , 120min cycle/ 10min sample)	-19.0	SBE 37 #10196 (150m)	
		50m Kevlar line 5/16¨			
198m		Sediment trap Technicap PPS 3/3-24s	-18.0	RBR XR420 CT #15269	
		100m Kevlar line 5/16¨			
298m		Nortek Currentmeter #6112 Continental 190kHz (DL)	-14.0	SPMD on cage (300m) and RBR XR 420 #15271	
		Cage (Weight in water 18kg)	-18.0		
		6 Panther buoys Buoyancy 17.6kg each	105.6		
		Galv shackles, swivel 180m Kevlar line 5/16¨			
		4 Benthos Buoy 17¨ Buoyancy 25kg	100.0		
		~~10m Kevlar line 5/16¨~~			
495m		OCEANO acoustic releases Tandem assembly Weight in water 22kg each	-44.0		
		~3m polyrope line shackle ~2 m chain			220.4
500m		Anchor (800 lbs train wheel) 4 train wheels	-3200.0		

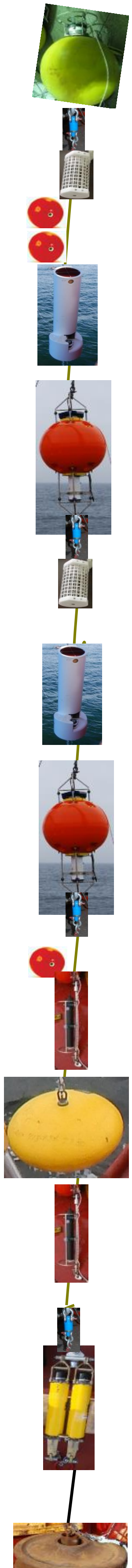
Site BR-K-14	Shelf edge in Ajurak Area	
Target Instrument Depth (m)		Instrument
60		Ice Profiling Sonar IPS5 #51108
		ASL Dual cage
		4 12B3 floats
		4 12B3 floats
		Novatech RF/Flasher #X06-061
		Benthos 27kHz UAT #47745
		1/2" galv shackle, swivel, 3 x 7/16" galv shackles
		SBE37 #12235 (clamped to mooring line below cage)
		5/16" Amsteel 2 rope; 74m
100		RBR CTD +Tu + DO titanium #10419
		1/2" shackle
136		
		300 kHz WH ADCP #2646
		Ext BC for ADCP #3835
		MSI Ellipsoid float
		MSI steel cage
		Benthos 27kHz UAT #47873
		Swivel, galv shackles
		300 m ellipsoid float
		5/16" Amsteel 2 rope; 2 m
		galv shackle
		XR420CTm+Tu+Fl+DO #22044
		LISST-100x particle analyzer #1473
		instrument frame
		galv shackles, swivel
		1 MHz Nortek Aquadopp Current Profiler AQD #11147
142		instrument cage with vane
		5/16" Amsteel 2 rope; 2 m
		Swivel, galv shackles
		dual CART releases #33738 & 33737
		Tandem assembly
		D-ring 3/4-inch shackle
		10m 3/4" polysteel drop line
		~2 m chain + 7/8" shackle
156		
		2 train wheels

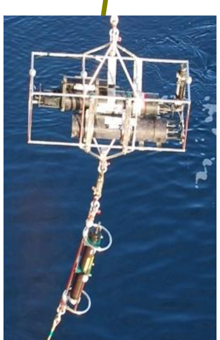
BR-G-14		Slope in Pokak
Target Instrument Depth (m)		Instrument
60		Ice Profiling Sonar IPS5 #51104
		MSI cage
		30" MSI syntactic spherical buoy
		Benthos UAT 27kHz 47748
		Swivel, galv shackles
		SBE37 #12236 (clamped to mooring line below cage)
100		RBR CTD #17352 clamped to line
		5/16" Amsteel 2 rope, 63 m
		2 12B3 floats with prusek hitch
		Stainless shackle
		Technicap PPS 3/3 24 S sediment trap #48
125		
		Stainless shackle
		5/16" Amsteel 2 rope; 75 m
150		RBRXR420 CTD logger #15273 clamped to mooring line
		Stainless shackle
		150 kHz QM ADCP DR #8784
203		Ext batt case (4 BP) #34333
		Flotec M40 1500m extended frame
		Benthos 364A/EL acoustic pinger 27 kHz #47753
		RBRXR420 CT logger #15280
		Novatech RF/Flasher: X06-054
		Swivel, galv shackles
		5/16" Amsteel 2 rope, 100 m
		Stainless shackle
		Technicap PPS 3/3-24S sediment trap #45
306		Stainless shackle
		5/16" Amsteel 2 rope; 150 m
		Galv shackles
		Novatech RF/Flasher: X06-066
458		75 kHz ADCP DR #13079
		External battery case (4 BP) #2031
		Flotec M40 1500m extended frame
		Benthos 364A/EL acoustic pinger 27 kHz #47751
		RBRXR420 CT logger #15266
		Galv shackles, swivel
		5/16" Amsteel 2 rope; 125 m
		galv shackle; prusek
		16" Flotec Hard Ball (3000m)
		shackles
586		Nortek Aquadopp Current Meter #9473
		Aquafin instrument cage
		5/16" Amsteel 2 rope; 100 m
		shackles
		1000 m ellipsoid float
		shackles
687		Nortek Aquadopp Current Meter #9847
		MSI instrument cage with welded vane
		RBR CT #15272
		galv shackles
		5/16" Amsteel 2 rope; 2m
		Swivel, galv shackles
		dual 8242 releases #33697 &33698
		Tandem assembly
690		
		chain, D-ring 5/8-inch shackle
		10m 3/4" polysteel drop line
		~2 m chain, 7/8" shackle
		3 train wheels
703		



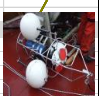
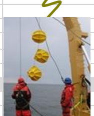
BR-1-14	Slope in Mackenzie Trough
Target Instrument Depth (m)	Instrument
60	Ice Profiling Sonar IPS5 #51105
	MSI cage
	30" MSI syntactic spherical buoy
	Benthos UAT 27kHz 47752
	RBRXR420 CT logger #15262
	Swivel, galv shackles
	2 12B3 floats with prusek hitch
	5/16" Amsteel 2 rope, 63 m
	Stainless shackle
	Technicap PPS 3/3-24S sediment trap #28 motor #07341
125	
	Stainless shackle
	5/16" Amsteel 2 rope; 75 m
	Stainless shackle
	150 kHz QM ADCP DR #12699
203	Ext batt case (4 BP) # 2032
	Flotec M40 1500m extended frame
	Benthos 364A/EL acoustic pinger 27 kHz #47747
	RBRXR420 CT logger #15279
	Novatech RF/Flasher: X06-065
	Swivel, galv shackles
	5/16" Amsteel 2 rope, 125 m
	Stainless shackle
	Technicap PPS 3/3-24S sediment trap #29 motor #1116
331	Stainless shackle
	5/16" Amsteel 2 rope; 125 m
	Stainless shackle
	Novatech RF/Flasher: X06-067
458	75 kHz ADCP DR #12943
	External battery case (4 BP) #2039
	Flotec M40 1500m extended frame
	Benthos 364A/EL acoustic pinger 27 kHz #47292
	RBRXR420 CT logger #15267
	Galv shackles, swivel
	5/16" Amsteel 2 rope; 125 m
	galv shackle; prusek
	16" Flotec Hard Ball (3000m)
	shackles
586	Nortek Aquadopp Current Meter #6270
	Aquafin instrument cage
	RBRXR420 CT logger #15268
	5/16" Amsteel 2 rope; 150 m
	shackles
	1000 m ellipsoid float
	shackles
737	Nortek Aquadopp Current Meter #8414
	Aquafin instrument cage
	shackles
	5/16" Amsteel 2 rope; 2m
	Swivel, galv shackles
	dual CART releases #35661 & 35660
	Tandem assembly
741	
	chain, D-ring 5/8-inch shackle
	10m 3/4" polysteel drop line
	~2 m chain, 7/8" shackle
755	3 train wheels

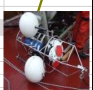
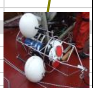
BR-2-14	Shelf edge near Mackenzie Trough	
Target Instrument Depth, m	159	Instrument
60		Ice Profiling Sonar IPS5 #51106
		ASL Dual cage
		4 12B3 floats
		4 12B3 floats
		Benthos 364A/EL acoustic pinger 27 kHz #47151
		RBRduo CT logger #61551
		Novatech RF/Flasher: X06-065
		Swivel, galv shackles
		3/8" Amsteel 2 rope; 74 m
		Stainless shackle
136		Benthos 364A/EL acoustic pinger 27 kHz #47749
		300 kHz WH ADCP w/ BT #7844
		External battery case for ADCP #40037
		MSI ellipsoid float and ADCP cage
		Swivel, galv shackles
		300 m ellipsoid float
		5/16" Amsteel 2 rope; 2 m
		galv shackles
141		XR420CTm+Tu+Fl+DO #17112
		LISST-100x particle analyzer #1447
		instrument frame (estimate)
		galv shackles, swivel
142		1 MHz Nortek Aquadopp Current Profiler #9715
		instrument cage with vane
		3/8" Amsteel 2 rope; 2 m
		Swivel, galv shackles
		dual CART releases #33743 & 33740
		Tandem assembly
		D-ring 3/4-inch shackle
		10m 3/4" polysteel drop line
		
159		~2 m chain + shackles
		2 train wheels

BR-3-14		**Slope near Banks Island**
Target Instrument Depth (m)		Instrument
60		Ice Profiling Sonar IPS5 #51109
		30" MSI syntactic spherical buoy
		MSI cage
		Benthos 364A/EL acoustic pinger 27 kHz
		RBRXR420 CT logger #15264
		Stainless shackle, Swivel, galv shackles
62		SPMD (clamped to mooring line)
		2 12B3 floats with prusek hitch
		5/16" Amsteel 2 rope, 63 m
		Stainless shackle
		Technicap PPS 3/3-24S sediment trap #39
125		motor # 09-845
		Stainless shackle
		5/16" Amsteel 2 rope; 70 m
		Stainless shackle
		150 kHz QM ADCP DR #12823
198		Ext batt case (4 BP) #2034
		Flotec M40 1500m extended frame
		Benthos 364A/EL acoustic pinger 27 kHz
		RBRXR420 CT logger #15263
		Novatech RF/Flasher:
		Swivel, galv shackles
201		SPMD (clamped to mooring line)
		5/16" Amsteel 2 rope, 125 m
		Stainless shackle
		Technicap PPS 3/3-24S sediment trap #47
		motor # 12-25
326		Stainless shackle
		5/16" Amsteel 2 rope; 125 m
		Stainless shackle
		Novatech RF/Flasher:
453		75 kHz ADCP DR #18785
		External battery case (4 BP) #2029
		Flotec M40 1500m extended frame
		Benthos 364A/EL acoustic pinger 27 kHz #47744
		RBRXR420 CT logger #15281
		Galv shackles, swivel
		5/16" Amsteel 2 rope; 125 m
		galv shackle; prusek
		16" Flotec Hard Ball (3000m)
		shackles
581		Nortek Aquadopp Current Meter AQD8418
		Aquafin instrument cage
		5/16" Amsteel 2 rope; 100 m
		Swivel, galv shackles
		1000 m ellipsoid float
		Swivel, galv shackles
682		Nortek Aquadopp Current Meter AQD2756
		Aquafin instrument cage
		shackles
		5/16" Amsteel 2 rope; 2m
		RBRXR420 CT logger #15275
		Swivel, galv shackles
		dual CART releases #33749 & 33748
		Tandem assembly
686		
		chain, D-ring 5/8-inch shackle
		10m 3/4" polysteel drop line
		~2 m chain, 7/8" shackle
700		3 train wheels

BR-4-14		Shelf edge near Banks Island
Target Instrument Depth (m)		Instrument
60		Ice Profiling Sonar IPS5 #51103
		8 12B3 floats
		ASL Dual cage
		Novatech RF/Flasher
		XR420CT #15274
		Benthos 27kHz UAT #45783
		1/2" galv shackle, Swivel, 7/16" galv shackles
		
		SPMD (on cage)
		5/16" Amsteel 2 rope; 70m
		1/2" shackle
132		
		300 kHz WH ADCP #6320 (high pressure housing)
		Ext BC for ADCP #222
		MSI ellipsoid float
		MSI steel cage
		Benthos 27kHz UAT
		
		Swivel, galv shackles
		
		300 m ellipsoid float
		5/16" Amsteel 2 rope; 2 m
		165 inches between LISST pressure and ADCP head
		
		galv shackle
		XR420CTm+Tu+Fl+DO #17114
		LISST-100x particle analyzer #1319
		instrument frame
		Benthos 27 kHz pinger
		galv shackles, swivel
		1 MHz Nortek Aquadopp Current Profiler #9752
138		instrument cage with vane
		
		5/16" Amsteel 2 rope; 2 m
		Swivel, galv shackles
		dual CART releases #33745 & 33744
		Tandem assembly
		D-ring 3/4-inch shackle
		10m 3/4" polysteel drop line
		~2 m chain + 7/8" shackle
155		

Deployments

CA05-15	Mouth of Amundsen Gulf					Target depth	200	Mooring Length	145
Target Instrument Depth (m)		Instrument	Water (kg)	Net (kg)	Net unit (Kg)	Component Length (m)	Instrument Depth (m)	Height above bed (m)	Surplus
							55	144.7	144.65
55		30" MSI syntactic spherical buoy	150.00	150.00					
		Ice Profiling Sonar IPS4/5 #	39.00	111.00		1.5			
		2 x 1/2" galv shackle, swivel, 2 x 1/2" galv shackles	2.00	109.00		0.25			
		5/16" Amsteel 2 rope; 10m	1.00	108.00		10			
		2 x 1/2" galv shackle, swivel, 2 x 1/2" galv shackles	2.00	106.00		0.25			
67		ISUS#: , CLW: , ALW: , CT:	10.00	96.00			67	132.7	
		ISUS frame (estimate)	12.00	84.00		0.6			
		2 x 1/2" galv shackle, swivel, 2 x 1/2" galv shackles	2.00	82.00	59.00	0.25			
		5/16" Amsteel 2 rope; 10 m	1.00	81.00		10			
		2 x 1/2" galv shackle	1.00	80.00		0.15			
78		Aural Hydrophone	19.00	61.00			78	121.7	
		32 kHz 25% duty cycle				1.6			
		2 x 1/2" galv shackle and pear link	1.00	60.00		0.15			
		5/16" Amsteel 2 rope;10 m	1.00	59.00		10			
		2 x 1/2" galv shackle, swivel, 2 x 1/2" galv shackles	2.00	57.00		0.25			
90		Nortek 470kHz ADCP (UL)#	14.0	43.00			90	109.7	
		Continetal frame	18.0	25.00					
		Continetal frame panther buoys (6)	105.60	130.60		1.6			
		RBR-XR420 CT	2.00	128.60					
						0.25			
		2 x 1/2" galv shackle, D-Ring, 2 x 1/2" galv shackles	2.00	126.60					
91.85		Nortek 470kHz ADCP (DL)#	14.0	112.60		1.6	91.85	107.8	
		Continetal frame	18.0	94.60					
		Continetal frame panther buoys (6)	105.60	200.20					
			2.00	198.20					
		2 x 1/2" galv shackle, swivel, 2 x 1/2" galv shackles	2.00	196.20	115.20				
		5/16" Amsteel 2 rope; 30m	1.00	195.20		30			
		2 x 1/2" galv shackle and Pearl Link	1.00	194.20		0.15			
123.6		Technicap PPS 3/3 24 S sediment trap #	18.00	176.20		2	123.6	76.1	
		2 x 1/2" galv shackle	1.00	175.20		0.15			
		5/16" Amsteel 2 rope; 20m	1.00	174.20		20			
		2 x 1/2" galv shackle	1.00	173.20		0.15			
145.9		MSI 30" Syntactic Foam Buoy	168.00	341.20		1	145.9	53.8	
		2 x 1/2" galv shackle and pear link	1.00	340.20		0.15			
		5/16" Amsteel 2 rope; 30m	1.00	339.20		30			
		2 x 1/2" galv shackle	1.00	338.20	137.00	0.15			
177.2		RCM / Seaguard #	25.00	313.20		0.6	177.2	22.5	
		2 x 1/2" galv shackle , swivel and pear link	1.00	312.20		0.15			
		5/16" Amsteel 2 rope; 5m	1.00	311.20		5			
		2 x 1/2" galv shackle and pear link	1.00	310.20		0.15			
183.1		17" Vitrovex Glass Floats (4x with Eddy Grip)	100.00	410.20		3	183.1	16.6	
		2x 1/2" galv shackle	1.00	409.20		0.15			
		5/16" Amsteel 2 rope; 5m	1.00	408.20		5			
		2x 1/2" galv shackle	1.00	407.20		0.15			
		1 x 5/8" galv shackle and pear link	1.00	407.20	44.00	0.15			
192.15		865A Tandem#1: , #2	44.00	363.20		0.6	192.15	7.5	
		Tandem assembly (2x chain SS)	7.00	356.20		1			
		3 x 7/8" shackle, pear link							
		5-8m 3/4" polysteel drop line w/ large Ring	2.00	354.20		5			
		1.5 m chain	10.00	344.20	692.00	1.5			
199.65		2 train wheels	680.00	335.80			199.7	0.00	BOTTOM DEPTH

CA08-15	Mouth of Amundsen Gulf					Target depth	400	Mooring Length	335
Target Instrument Depth (m)		Instrument	Water (kg)	Net (kg)	Net unit (Kg)	Component Length (m)	Instrument Depth (m)	Height above bed (m)	
							65.0	334.60	TOP DEPTH
65		ORE 30" Steel Buoy	168.00	168.00					
		Argos Beacon#:	1.00	167.00					
		Novatech RF/Flasher #	2.00	165.00		1			
				165.00					
		2 x 1/2" galv shackle, swivel, 2 x 1/2" galv shackles	2.00	163.00		0.25			
		5/16" Amsteel 2 rope; 10m	1.00	162.00		10			
		2 x 1/2" galv shackle, swivel, 2 x 1/2" galv shackles	2.00	160.00	135.00	0.25			
76.5		ISUS#: , CLW: , ALW: , CT:	10.00	150.00			76.5	323.10	
		ISUS frame (estimate)	12.00	138.00		0.6			
		2 x 1/2" galv shackle, swivel, 2 x 1/2" galv shackles	2.00	136.00		0.25			
		5/16" Amsteel 2 rope; 10 m	1.00	135.00		10			
		2 x 1/2" galv shackle	1.00	134.00		0.15			
87.5		Aural Hydrophone #	19.00	115.00			87.5	312.10	
		32 kHz 25% duty cycle							
						1.6			
					22.00				
		2 x 1/2" galv shackle and pear link	1.00	114.00		0.15			
		5/16" Amsteel 2 rope; 10 m	1.00	113.00		10			
		2 x 1/2" galv shackle, swivel, 2 x 1/2" galv shackles	2.00	111.00		0.25			
99.5		Nortek 470kHz ADCP (UL)#	14.0	97.00			99.5	300.10	
		Continetal frame	18.0	79.00	69.60				
		Continetal frame panther buoys (6)	105.60	184.60		1.6			
		RBR-XR420 CT	2.00	182.60					
		2 x 1/2" galv shackle, D-Ring, 2 x 1/2" galv shackles	2.00	180.60		0.25			
101.4		Nortek 470kHz ADCP (DL)#	14.0	166.60		1.6	101	298.25	
		Continetal frame	18.0	148.60					
		Continetal frame panther buoys (6)	105.60	254.20					
				254.20					
		2 x 1/2" galv shackle, swivel, 2 x 1/2" galv shackles	2.00	252.20					
		5/16" Amsteel 2 rope; 40m	1.00	179.60		40			
		2 x 1/2" galv shackle and Pearl Link	1.00	178.60		0.15			
						2			
143.1		Technicap PPS 3/3 24 S sediment trap #48	18.00	160.60			143.1	256.50	
		2 x 1/2" galv shackle	1.00	159.60		0.15			
		5/16" Amsteel 2 rope; 40m	1.00	158.60		40			
		2 x 1/2" galv shackle	1.00	157.60		0.15			
					190.15				
185.4		ORE 30" Steel Buoy	168.00	325.60		1	185.4	214.20	
		2 x 1/2" galv shackle	1.00	324.60		0.15			
		5/16" Amsteel 2 rope; 100m	1.00	323.60		100			
		2 x 1/2" galv shackle	1.00	322.60		0.15			
		Swivel, 2 x 1\2"galv shackles	0.91	321.69					
286.7		Nortek Aquadopp Current Meter AQD	2.27	319.42		0.6	286.7	112.90	
		Aquafin instrument cage	5.00	314.42					
		5/16" Amsteel 2 rope; 50m	1.00	313.42		50			
		2 x 1/2" galv shackle	1.00	312.42					
		1 x D-ring	1.00	311.42					
		2 x 1\2"galv shackles	1.00	311.42					
337.3		Nortek Aquadopp Current Meter AQD	2.27	309.15			337.3	62.30	
		Aquafin instrument cage	5.00	304.15		0.6			
		2 x 1/2" galv shackle, swivel and pear link	1.00	303.15		0.15			
		5/16" Amsteel 2 rope; 50m	1.00	302.15		50			
		2 x 1/2" galv shackle	1.00	301.15		0.15			
388.2		17" Vitrovex Glass Floats (4x with Eddy Grip)	100.00	401.15		3	388.2	11.40	
		1 x 1/2" galv shackle and pear ink	1.00	400.15		0.15			
		1 x 5/8" galv shackle	1.00	399.15		0.15			
					46.00				
						0.6			
392.1		865A Tandem#1: , #2	44.00	355.15			392.1	7.50	
		Tandem assembly (2x chain SS)	7.00	348.15					
						1			
		3 x 7/8" shackle and pear link							
		5-8m 3/4" polysteel drop line w/ large Ring	2.00	346.15		5			
		1.5 m chain	10.00	336.15	1032.00				
						1.5			
399.6		3 train wheels	1020.00	683.85			399.6	0.00	BOTTOM DEPTH

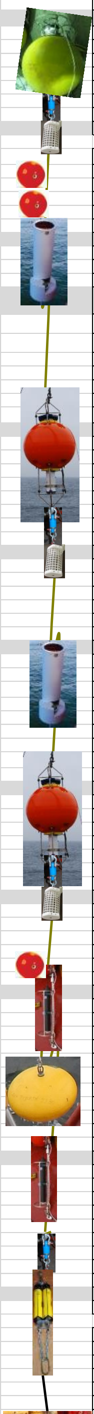
Site BR-K -15	Shelf edge between Ajurak/Pokak Area			LAST REVISION:
Date and Time (UTC)	8/27/2015 14:29			Alexandre Forest, 3 September 2015
Target Position		70° 52.008'N	135° 01.782'W	
Triangulation	Range (1450 m/s), m	Latitude	Longitude	
Anchor drop position	-	70° 51.756' N	135° 01.693' W	Range as read (1500 m/s)
Mark 1	265	70° 51.814' N	135° 02.033' W	274
Mark 2	230	70° 51.672' N	135° 01.616' W	238
Mark 3	302	70° 51.851' N	135° 01.368' W	312
Triangulated position	-	70° 51.763' N	135° 1.706' W	
Triangulated depth (m)	168.9			
Multibeam position	-	70° 51.771' N	135° 01.736' W	
Multibeam depth (m)	170			
Release Codes	Enable	Disable	Release/Arm	
CART #31037	407172	407210	427016	
CART #31091	415107	415124	431334	

**Depths below are planned depths. Actual dept

Site BR-K-15	Shelf edge between Ajurak and Pokak Area		Weight (lb)			Target depth	170	Mooring Length	25
Target Instrument Depth (m)		Instrument	Water	Net	Net unit (lb)	Component Length (m)	Depth (m)	Height above bed (m)	Notes
							145.0	24.70	TOP DEPTH
145.0		300 kHz WH ADCP #102	10.00	10.00					
		Ext BC for ADCP #3835	20.00	30.00					
		MSI Ellipsoid float	200.00	170.00	143.00	1.5	145.0	24.70	
		MSI steel cage	25.00	145.00					
		Benthos 27kHz UAT	2.00	143.00					
146.0		SPMD (attached on cage)					146.0		
		Swivel, galv shackles	5.00	138.00	5.00	0.25	146.5	23.20	
146.8		300 m ellipsoid float	240.00	378.00	239.00	0.5	146.8	22.95	
		5/16" Amsteel 2 rope; 5m	1.00	377.00		5	147.3	22.45	
		galv shackle	1.00	376.00					
		XR420CTm+Tu+Fl+DO #22043	2.00	374.00	41.00	1.15	152.3	17.45	
152.3		LISST-100x particle analyzer #1445	8.00	366.00					
		instrument frame	30.00	336.00					
		SPMD							
		galv shackles, swivel	5.00	331.00	5.00	0.25	153.4	16.30	
153.7		1 MHz Nortek Aquadopp Current Profiler AQD #9711	0.45	330.55	5.45	0.8	153.7	16.05	
		instrument cage with vane	5.00	325.55					
		5/16" Amsteel 2 rope; 2 m	1.00	324.55	6.00	2	154.5	15.25	
		Swivel, galv shackles	5.00	319.55		0.25	156.5	13.25	
156.7		dual CART releases #31037 & #31091	16.00	303.55	23.00	1	156.7	13.00	
		Tandem assembly	7.00	296.55					
		D-ring 3/4-inch shackle	2.00	294.55					
		10m 3/4" polysteel drop line	1.00	293.55		10		169.70	
		~2 m chain + 7/8" shackle	10.00	283.55		2		169.70	
169.70		1 train wheel	700.00	416.45			169.70	0	

BR-G-15	Slope in Pokak Area				LAST REVISION:
Date and Time (UTC)	8/28/2015 18:53				Alexandre Forest, 3 September 2015
Target Position		71° 00.128'N	135° 30.565'W		
Triangulation	Range (1450 m/s), m	Latitude	Longitude		
Anchor drop position	-	71° 00.190' N	135° 29.530' W	Range as read (1500 m/s)	
Mark 1	1143	70° 59.766' N	135° 28.591' W	1182	
Mark 2	1136	71° 00.080' N	135° 31.088' W	1175	
Mark 3	1363	71° 00.726' N	135° 29.071' W	1410	
Triangulated position	-	71° 0.122' N	135° 29.612' W		
Triangulated depth (m)	700.3				
Multibeam position	-	71° 00.127' N	135° 29.614' W		
Multibeam depth (m)	700				
Release Codes	Enable	Disable	Release/Arm		
CART #31904	540074	540105	544176		
CART #33736	203433	203456	224463		

**Depths below are planned depths. Actual depths

BR-G-15	Slope in Pokak		Weight (lb)			Target depth	703	Mooring Length	643
Target Instrument Depth (m)		Instrument	Water	Net	Net unit (lb)	Component Length (m)	Depth (m)	Height above bed (m)	Mobil Notes
							60.0	642.70	TOP DEPTH
60		Ice Profiling Sonar IPS5 #51108	39.00	39.00					
		MSI cage	25.00	64.00	232.00	1.5	60.0	642.7	
		30" MSI syntactic spherical buoy	300.00	236.00					
		Benthos Pinger	2.00	234.00					
		RBRXR420 CT logger #15273	2.00	232.00					
		Swivel, galv shackles	5.00	227.00	5.00	0.25			
61.0		SPMD (clamped to mooring line)					61.0		
		5/16" Amsteel 2 rope, 63 m	1.00	226.00		63			
		2 12B3 floats with prusek hitch	80.00	306.00					
		Stainless shackle	1.00	305.00		0.15			
124.9		Technicap PPS 3/3-24S sediment trap #45 motor #12_27	53.00	252.00		1.8	125	577.80	
		Stainless shackle	1.00	251.00	19.00	0.15			
127.9		RBRXR420 CTD-Tu-DO clamped to mooring line 1 m below trap #10419	2.00	249.00			127.9		
		5/16" Amsteel 2 rope; 40 m	1.00	248.00		40			
		Galv schackle	1.00	247.00		0.15			
		5/16" Amsteel 2 rope; 15 m	1.00	246.00		15			
		Stainless shackle	1.00	245.00		0.15			
182.2		150 kHz QM ADCP DR #12841	79.00	166.00			182	520.55	
		Ext batt case (4 BP) #2038	34.00	132.00					
		Flotec M40 1500m extended frame	417.00	549.00	296.00	2.3			
		NovaTech flasher	0.00	549.00					
		RBRXR420 CT logger #15258	2.00	547.00					
		Benthos Pinger							
		Swivel, galv shackles	5.00	542.00		0.25			
185		SPMD (clamped to mooring line)					185		
		5/16" Amsteel 2 rope, 75 m	1.00	541.00		75			
		Galv shackle	1.00	540.00		0.15			
		5/16" Amsteel 2 rope, 50 m	1.00	539.00	57.00	50			
		Stainless shackle	1.00	538.00		0.15			
310.0		Technicap PPS 3/3-24S sediment trap #45 motor #12_21	53.00	485.00		1.8	310.0	392.70	
		Stainless shackle	3.00	482.00	3.00	0.15			
		5/16" Amsteel 2 rope; 150 m	6.00	476.00	6.00	150			
		Galv shackles	1.00	475.00		0.15			
			79.00	396.00					
464.4		75 kHz ADCP DR #12892	79.00	317.00			464	238.30	
		External battery case (4 BP) #2028	35.00	282.00	217.00	2.3			
		Flotec M40 1500m extended frame	417.00	699.00					
		SPMD							
		RBRXR420 CT logger #15266	1.00	698.00					
		Galv shackles, swivel	5.00	693.00		0.25			
		NovaTech flasher and Benthos Pinger							
467		SPMD (clamped to mooring line)					467		
		5/16" Amsteel 2 rope; 125 m	2.00	691.00	2.00	125			
		galv shackle; prusek							
		16" Flotec Hard Ball (3000m)	29.10	720.10					
		shackles	2.00	718.10					
589.7		Nortek Aquadopp Current Meter #9846	0.00	718.10	20.10	1	590	113.05	
		Aquafin instrument cage	5.00	713.10					
		5/16" Amsteel 2 rope; 100 m	2.00	711.10		100			
		shackles	2.00	709.10		0.15			
		1000 m ellipsoid float	195.00	904.10	191.00	0.5			
		shackles	2.00	902.10		0.15			
691.5		Nortek Aquadopp Current Meter #8434	0.00	902.10			691	11.25	
		MSI instrument cage with welded vane	5.00	897.10	6.00	1			
		RBR CT #15280	1	896.10					
		galv shackles							
		5/16" Amsteel 2 rope; 2m	0.10	896.00	0.10	2			
		Swivel, galv shackles	5	891.00	5	0.25			
694.7		dual CART releases #31904 & #33736	16	875.00	23	1	695	8.00	
		Tandem assembly	7	868.00					
		chain, D-ring 5/8-inch shackle							
		5m 3/4" polysteel drop line	1	867.00	1	5		702.70	

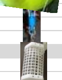
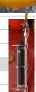
LAST REVISION:

Alexandre Forest, 3 September 2015

BR-3-15	**Slope near Banks Island**			
Date and Time (UTC)	8/31/2015 21:15			
Target Position		73° 24.516'N	129° 21.390'W	
Triangulation	Range (1450 m/s), m	Latitude	Longitude	
Anchor drop position	-	73° 24.535' N	129° 21.428' W	Range as read (1500 m/s)
Mark 1	781	73° 24.768' N	129° 20.999' W	808
Mark 2	698	73° 24.604' N	129° 21.539' W	722
Mark 3	823	73° 24.590' N	129° 20.340' W	851
Triangulated position	-	73° 24.566' N	129° 21.224' W	
Triangulated depth (m)	689.4			
Multibeam position	-	73° 24.566' N	129° 21.207' W	
Multibeam depth (m)	690			
Release Codes	Enable	Disable	Release/Arm	
8242 #33697	201503	201520	223532	
8242 #33698	201545	201566	223557	

*mooring equipment programmed for 2 year deployment

****Depths below are planned depths. Actual depths w**

BR-03-15		**Slope near Banks Island**	Weight (Kg)			Target depth **698**		Mooring Length **638**	
Target Instrument Depth (m)		Instrument	Water	Net	Net unit (Kg)	Component Length (m)	Depth (m)	Height above bed (m)	**Mobil Notes**
							60.0	638.05	TOP DEPTH
60		Ice Profiling Sonar IPS5 #51104	17.69	17.69					
		30" MSI syntactic spherical buoy	136.05	118.36		1.5	60.0	638.05	
		MSI cage	11.34	107.03					
		RBRXR420 CT logger clamped to mooring line #15270	0.91	106.119					
		Stainless shackle, Swivel, galv shackles	2.27	103.85		0.25			
					103.85				
61.0		SPMD (clamped to mooring line)					61.0		
		2x12B3 floats with prusek hitch	36.28	140.13					
		5/16" Amsteel 2 rope, 63 m	0.45	139.68		63			
		Stainless shackle	0.91	138.77		0.15			
124.9		Technicap PPS 3/3-24S sediment trap #39 motor #11_17	24.04	114.74		1.8	124.9	573.15	
			0.00	114.74					
		Stainless shackle	0.45	114.28	8.93	0.15			
127.9		RBRXR420 CTD clamped to mooring line 1 m below trap #17351	1.00	113.28			127.9		
		5/16" Amsteel 2 rope; 40 m	0.25	113.03		40			
		5/16" Amsteel 2 rope; 15 m	0.25	112.78		15			
		Stainless shackle	0.45	112.33		0.15			
182.0		150 kHz QM ADCP DR #12824	35.83	76.50			182.0	516.05	
		Ext batt case (4 BP) #2031	15.42	61.08					
		Flotec M40 1500m extended frame	189.11	250.19		2.3			
		NovaTech Flasher							
		RBRXR420 CT logger #15269	0.91	249.29					
		Benthos Pinger							
		Swivel, galv shackles	2.27	247.02	134.24	0.25			
185		SPMD (clamped to mooring line)					184.6	513.5	
		5/16" Amsteel 2 rope, 125 m	0.91	246.11	27.67	125			
		Stainless shackle	0.45	245.65		0.15			
309.7		Technicap PPS 3/3-24S sediment trap #47 motor #12_18	24.04	221.62		1.8	309.7	388.35	
		Stainless shackle	1.36	220.26		0.15			
		5/16" Amsteel 2 rope; 100 m	0.91	219.35		100			
		Galv schackle	0.45	218.90		0.15			
		5/16" Amsteel 2 rope; 45 m	0.91	217.99		45			
		Stainless shackle	0.45	217.54		0.15			
							457.0	241.1	
457		75 kHz ADCP DR #12942	35.83	181.71					
		External battery case (4 BP) #33578	15.87	165.84					
		Flotec M40 1500m extended frame	189.11	354.95		2.3			
		NovaTech flasher							
		Benthos Pinger							
		RBRXR420 CT logger #15272	0.91	354.04					
		Galv shackles, swivel	2.27	351.77	133.78	0.25			
		5/16" Amsteel 2 rope; 125 m	0.91	350.86		125			
		galv shackle; prusek							
		16" Flotec Hard Ball (3000m)	13.20	364.06					
		shackles	0.91	363.15	11.38				
585		Nortek Aquadopp Current Meter AQD #6109	1.00	362.15		1	584.5	113.55	
		Aquafin instrument cage	2.27	359.89					
		5/16" Amsteel 2 rope; 100 m	0.91	358.98		100			
		shackles	0.91	358.07		0.15			
					82.44				
		1000 m ellipsoid float	88.43	446.50		0.5			
		shackles	0.91	445.60		0.15			
686		Nortek Aquadopp Current Meter AQD #8541	0.00	445.60		1	686.3	11.75	
		Aquafin instrument cage	2.27	443.33					
		shackles							
		5/16" Amsteel 2 rope; 2m	0.05	443.29		2			
		RBRXR420 CT logger #15278							
		Swivel, galv shackles	2.2675	441.02	4.58	0.25			
689.6		dual 8242 releases #33697 & #33698	56.2464	384.77		1.5	689.6	8.5	
		Tandem assembly	6.804	377.97	63.0504				
		chain, D-ring 5/8-inch shackle							
		5 m 3/4" polysteel drop line	0.4535	377.51	0.4535	5			

BR-1-15	Slope in Mackenzie Trough			LAST REVISION:
Date and Time (UTC)				Alexandre Forest, 3 September 2015
Target Position		70° 25.909'N	139° 01.370'W	
Triangulation	Range (1450 m/s), m	Latitude	Longitude	
Anchor drop position	-			Range as read (1500 m/s)
Mark 1	0			
Mark 2	0			
Mark 3	0			
Triangulated position	-			
Triangulated depth (m)				
Multibeam position	-			
Multibeam depth (m)				
Release Codes	Enable	Disable	Release/Arm	
CART #33741	203666	203717	224615	
CART #33742	203734	203751	224636	

change

**Depths below are planned depths. Actual depths will b

BR-1-15		Slope in Mackenzie Trough	Weight (lb)			Target depth	752	Mooring Length	689
Target Instrument Depth (m)		Instrument	Water	Net	Net unit (lb)	Component Length (m)	Depth (m)	Height above bed (m)	**Mobil Notes**
							63.0	689.40	TOP DEPTH
63		Ice Profiling Sonar IPS5 #51105	39.00	39.00					AN-Stock
		MSI cage	25.00	64.00		1.5			Re-Use
		30" MSI syntactic spherical buoy	300.00	236.00					Re-Use
		Benthos 364\EL 27kHz 47752	1.00	235.00					Re-Use
		RBRXR420 CT logger #15262	2.00	233.00	308.00	0			Re-Use
		Swivel, galv shackles	5.00	228.00		0.25			AN-Stock Swivel
		2 12B3 floats with prusek hitch	80.00	308.00					Re-Use
		5/16" Amsteel 2 rope, 63 m	1.00	307.00		63			Re-Use
		Stainless shackle	2.00	305.00		0.15			
127.9		Technicap PPS 3/3-24S sediment trap #28 motor #07341	53.00	252.00		1.8	127.9	624.50	Re-Use
				252.00	60.00				
		Stainless shackle	1.00	251.00		0.15			
130.85		RBRXR420 CT logger #? clamped to mooring line 1 m below trap	2.00	249.00			130.85		Re-Use From BR2-14
		5/16" Amsteel 2 rope; 52 m (1 x 40m, 1 x 12m)	1.00	250.00		52			AN-Stock
		Stainless shackle	1.00	249.00		0.15			
182		150 kHz QM ADCP DR #	79.00	170.00			182.0	570.40	AN-Stock
		Ext batt case (4 BP) # 2032	34.00	136.00					Re-Use
		Flotec M40 1500m extended frame	417.00	553.00		2.3			Re-Use
		Benthos 364A/EL acoustic pinger 27 kHz #47747	1.00	552.00	167.00				Re-Use
		RBRXR420 CT logger #15279	2.00	550.00					Re-Use
		Novatech RF/Flasher: X06-065	2.00	548.00					Re-use
		Swivel, galv shackles	5.00	543.00		0.25			AN-Stock Swivel
		5/16" Amsteel 2 rope, 125 m	1.00	542.00		125			AN-Stock
		Stainless shackle	1.00	541.00		0.15			
309.7		Technicap PPS 3/3-24S sediment trap #29 motor #11_16	53.00	488.00		1.8	309.7	442.70	Re-Use
		Stainless shackle	3.00	485.00		0.15			
		5/16" Amsteel 2 rope; 125 m	6.00	479.00		125			AN-Stock
		5/16" Amsteel 2 rope; 25 m	1.00	478.00		25			AN-Stock
		Stainless shackle	1.00	477.00		0.15			
		Novatech RF/Flasher: X06-067	2.00	475.00			461.8	290.60	Re-Use
462		75 kHz ADCP DR #	79.00	396.00					AN-Stock
		External battery case (4 BP) #2039	35.00	361.00					Re-Use
		Flotec M40 1500m extended frame	417.00	778.00	242.10	2.3			Re-Use
		Benthos 364A/EL acoustic pinger 27 kHz #47292	2.00	776.00					Re-Use
		RBRXR420 CT logger #15267	2.00	774.00					Re-Use
		Galv shackles, swivel	5.00	769.00		0.25			AN-Stock Swivel
		5/16" Amsteel 2 rope; 125 m	2.00	767.00		125			AN-Stock
		galv shackle; prusek							
		16" Flotec Hard Ball (3000m)	29.10	796.10					Re-Use
		shackles	2.00	794.10					
					16.10				
589		Nortek Aquadopp Current Meter #	0.00	794.10		1	589.4	163.05	AN-Stock
		Aquafin instrument cage	5.00	789.10					Re-Use
		RBRXR420 CT logger #15268	2.00	787.10					Re-Use
		5/16" Amsteel 2 rope; 150 m	2.00	785.10		150			AN-Stock
		shackles	2.00	783.10		0.15			
		1000 m ellipsoid float	195.00	978.10	191.00	0.5			Re-Use
		shackles	2.00	976.10					
						0.15			
		shackles	2.00	974.10					
		RBRXR420 CTD Titanium logger #	2.00	972.10					Re-Use
741		Nortek Aquadopp Current Meter #	0.00	974.10		1	741.2	11.25	From AN stock
		Aquafin instrument cage	5.00	969.10	14.10				Re-Use
		shackles							
		5/16" Amsteel 2 rope; 2m	0.10	969.00		2			AN-Stock
		Swivel, galv shackles	5	964.00		0.25			AN-Stock Swivel
744.4		dual CART releases # & #	16	948.00		1	744.4	8.00	From AN stock
		Tandem assembly	7	941.00					From AN stock
					24				
		chain, D-ring 5/8-inch shackle							From AN stock
		5m 3/4" polysteel drop line	1	940.00		5			Team IOS to make

Site WF1-15	Queen Maud Gulf				
Date and Time (UTC)	21 - Sept - 2015 : 14:06 UTC ; HDG 205 ; WindHDG 080 - 20 Km\h , Air 1.7c, water surface 2.73c ; water 70-100m -1.5c ; pres 1009 ; SOS 1400 m\s ; 29 PSU			Last Revision	
Target Position	100m	68° 11' 16.51 N	101° 50' 35.46 W	Shawn Meredyk, Sept 21, 2015	
Triangulation	Range (1400 m/s), m	Latitude	Longitude		
Anchor drop position	14:15 UTC at 97m	68° 14.46 N	101° 48.35 W	Range as read (1500 m/s)	1-way travel time
Mark 1	230	68° 14.388 N	101° 48.586 W	246	0.164
Mark 2	222	68° 14.369 N	101° 48.569 W	238	0.158667
Mark 3	251	68° 14.435 N	101° 48.099 W	269	0.179333
Triangulated position	97m	68° 14.4866 N	101° 48.4376 W		
Triangulated depth (m)					
Multibeam position	-	68° 14.xxx N	101° 48.xxx W		
Multibeam depth (m)					
Release Codes	Enable	Rx/Tx	Release/Arm		
Benthos: 41442	e	11.5 \ 12	D		
Benthos: 41456	e	13.5 \ 12	H		

**Depths below are planned dept

WF1-15	Near Victoria Island					Target depth	100	
Target Instrument Depth (m)		Instrument	Water (kg)	Net (Kg	Net unit (Kg)	Component Length (m)	Depth (m)	Height above bed (m)
							66	
66								
		Nortek 470kHz ADCP (UL)#6088	14.0	14.00				
		Continental frame	18.0	32.00				
		Continental frame panther buoys (6)	105.60	73.60	67.10	0.55		31.00
		ALEC ALW #73, CLW #8, CTW #145	3.00	70.60				
		XEOS beacon# 300234062790570	1.00	69.60				
			0.00	69.60				
		Swivel, 4x SS shackles	2.50	67.10		0.25		
		5/16" Amsteel 2 rope; 10m	1.00	66.10		10		
		1 x 1/2" SS shackle and Rope Loop	1.00	65.10		0.15		
78		Technicap PPS 3/3 24 S sediment trap # motor # 12-23 ; Disc# 132	18.00	47.10		1.6	78.55	20.05
				47.10		0.15		
		5/16" Amsteel 2 rope; 10m	1.00	46.10		10		
		1 x 1/2" SS shackle	1.00	45.10				
		1 x 1/2" galv shackle	1.00	44.10		0.15		
							88.85	8.15
		SF-30-300m elliptical MSI buoy	149.00	193.10		0.55		
		1 x 1/2" , 1 x 7/16" galv shackles, swivel	2.50	190.60		0.25		
		2 x 1/2" SS shackle	1.00	189.60		0.15		
		1 x 5/8" SS shackle						7.2
90		dual 865-A Benthos releases # 41442, 41456	44.00	145.60		1	90	
		Tandem assembly	7.00	138.60				
		D-ring 3/4-inch shackle	1.00	137.60		0.2		6.2
		3m 3/4" polysteel drop line	1.00	136.60		3		
		~2 m chain + 7/8" shackle + Pear Link	20.00	116.60				
97		1 train wheels	340.00	223.40		3	97	0
					Total_m:	31		

Site WF2-15	**Wilmot and Crampton Bay**							
Date:	August 25th, 2015							
Time (UTC):								
Position		68° 11' 56.83 N	99° 4' 42.95 W					
Actual Water Depth, m								
WF2-15	**Wilmot Bay**					Target depth	**20**	
Target Instrument Depth (m)		Instrument	Water (kg)	Net (Kg)	Net unit (Kg)	Component Length (m)	Depth (m)	Height above bed (m)
							19.5	0.5
19.5		MSI Benthic Tripod w\ 16 Kg lead ballast	25.00	25.00				
		Sentinel V ADCP w\ ext. batt pack # ; #	6.00	31.00		0.5		
		RBR ConcertoDuo CTD+Tu #	0.60	31.60	31.60			

Appendix 3. Compass Calibration and Verification Results from Inuvik, 2015

Table 9. Summary of Compass Error after Hard and Soft Iron Calibration in Inuvik, NWT, 2015

Equipment_ID	HDG Err Calibrated
RDI_WHS_102	1.4
RDI_WHS_3778	0.8
RDI_QM_12698	1.7
RDI_QM_12824	1.8
RDI_QM_12841	0.3
RDI_QM_12942	1.3
RDI_QM_12884	1.5
RDI_QM_12892	1.7

Table 10. 2015 Nortek Compass Verifications \ Post-Calibration (Inuvik, NWT, 2015)

Unique_ID	Calib. Equip HDG Offset	Magnectic HDG Error	HDG Err Corrected	HDG Correction Equation
Nortek_AQD_2756	-14.218	1.8	1.051	y = 7.41417326567250E-12x5 - 1.01933577975957E-08x4 + 4.20338793172270E-06x3 - 5.37987767103232E-04x2 + 9.96117385147954E-01x + 3.19730620394694E-01
Nortek_AQD_8418	-11.918	7.8	1.293	y = -5.03171020897996E-11x5 + 3.96837434623112E-08x4 - 7.91123437515751E-06x3 - 1.07673318638035E-04x2 + 1.06732884027952E+00x - 3.67821426421870E-01
Nortek_AQD_9473	-9.118	4.3	1.898	y = 2.92767175994325E-12x5 - 5.46667345158874E-09x4 + 3.15661012151303E-06x3 - 6.46840494027856E-04x2 + 1.03222150400870E+00x + 2.58690973918419E-01
Nortek_AQD_9752	-8.818	3.7	0.717	y = 1.53801552716138E-11x^5 - 6.39802187358401E-09x^4 - 1.05805115757640E-06x^3 + 5.41889163486076E-04x^2 + 9.82478187479501E-01x + 5.19090647372650E-01
Nortek_AQD_9847	-11.818	3.4	0.897	y = -4.19058564552036E-11x5 + 2.52556868031786E-08x4 - 2.10058731275886E-06x3 - 8.77573658215169E-04x2 + 1.11418364472229E+00x - 6.53590961286682E-01
Nortek_AQP_11147	-6.918	3.6	1.174	y = 1.03642313771163E-11x^5 - 1.13929978862518E-08x^4 + 3.74747914499984E-06x^3 - 3.92639757450297E-04x^2 + 1.01211472771138E+00x - 3.33746270334814E-02
Nortek_CNA_6063	-10.118	1.6	0.698	y = -7.45233291055684E-12x5 + 6.66409121115319E-09x4 - 1.86272068991578E-06x3 + 1.22383904539447E-04x2 + 1.01062396772249E+00x + 1.91457478125812E-01
Nortek_CNA_6070	-12.318	2.3	2.256	y = 2.76772884692710E-11x5 - 2.65112679101454E-08x4 + 9.47810989848641E-06x3 - 1.54993470337672E-03x2 + 1.10671607852964E+00x - 4.62225355629926E-01
Nortek_CNL_6107	-9.718	16.7	1.74	y = 1.52960505369557E-11x5 - 5.06770906445395E-08x4 + 2.93787048193384E-05x3 - 4.86346705167762E-03x2 + 1.04569691171127E+00x - 7.53958351197070E-01
Nortek_CNL_6112	-12.818	7.9	0.851	y = -3.11317029453976E-11x5 + 1.84798105507325E-08x4 - 9.65259612462077E-07x3 -

				7.46937441505224E-04x2 + 1.05477649533168E+00x + 8.95290802873205E-03
Nortek_CNL_6116	-10.918	6.5	1.382	y = 4.90830045479971E-11x5 - 5.34214610135170E-08x4 + 1.78897618892115E-05x3 - 1.77019442412529E-03x2 + 9.84594249241127E-01x - 3.48547599642188E-01

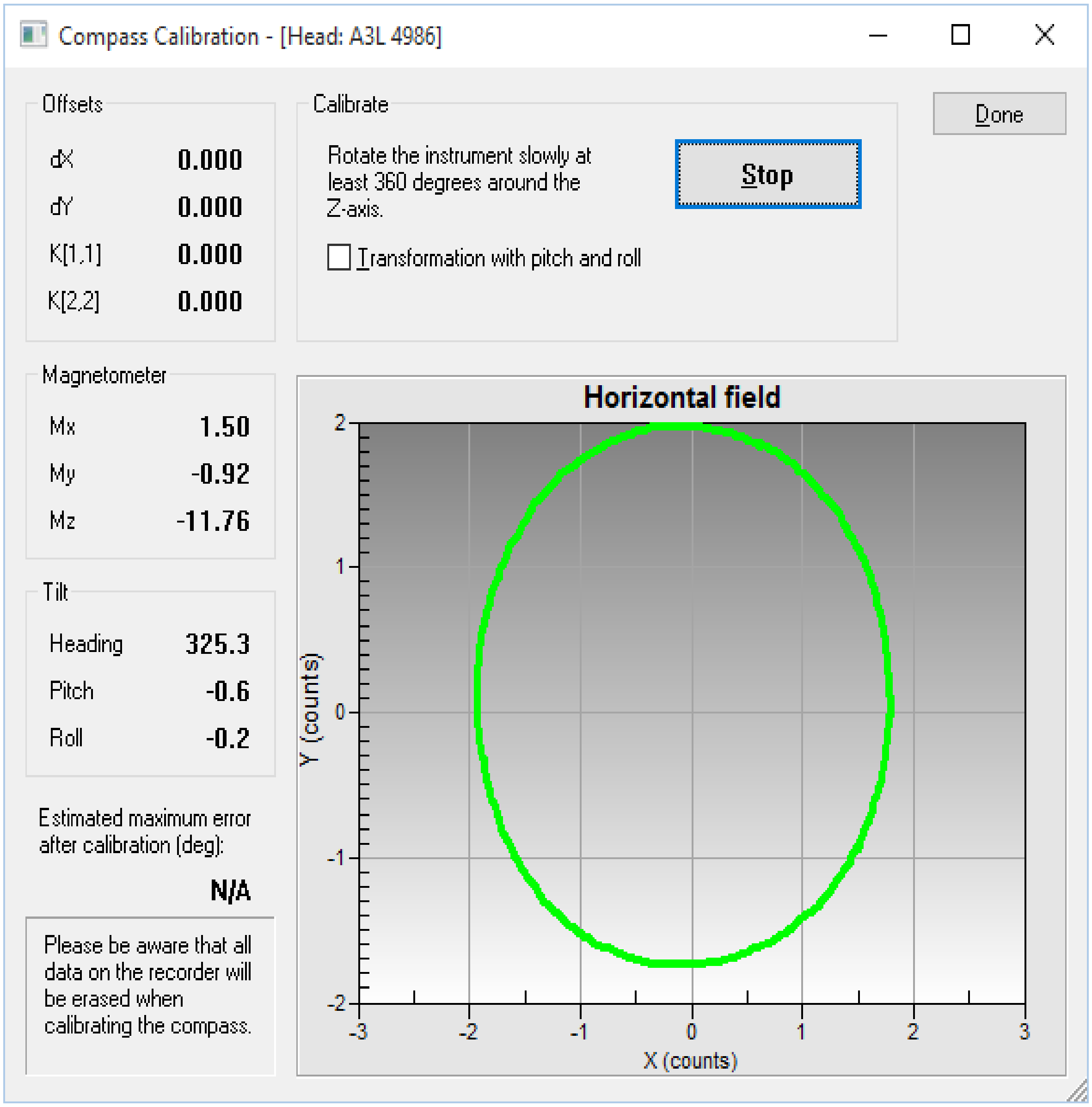


Figure 14. Nortek ADCP Compass Verification Curve (Inuvik, Sept, 2015)

Appendix 4 : Job Safety Assessment for Mooring Operations – 2015

ACTIVITY:	Mooring Operations	ORIGINAL DOCUMENT DATE:	August 20, 2015
IN-CHARGE:	Mooring Professionals	LOCATION OF ACTIVITY:	CCGS *Amundsen* foredeck
JSA SUBMISSION:	Shawn Meredyk (Mooring Professional)	OPERATIONS SUPERVISOR:	Keith Levesque

Attention: All hazards are important. Make notice of all possible hazards. Detailed safe job procedures are necessary. Awareness, teamwork, communications, and alertness apply to every situation. Use complete recommendations to eliminate or reduce hazards. *Safety First!*

SAFETY EQUIPMENT REQUIRED TO DO THIS JOB:

☒	Hard Hat	☐	Fire Extinguisher	☐	Life jacket
☒	Safety Footwear	☐	Safety Glasses w/ Side Shields	☒	2- Life Rings w/ 90' Floating Line
☐	Hearing Protection	☒	Safety Glasses or Sunglasses	☒	Tag Lines
☒	Protective Gloves	☐	Face Shield	☐	Work Permit Required
☐	Leather Gloves	☐	Back Belts	☐	Lockout/Tagout
☐	Rubber Gloves	☒	Safety Harness	☐	Barricades
☐	Welder Gloves	☒	Floor Mat	☒	Flotation suit
☐	Welder Helmet	☐	Dust Mask	☐	

COMMENTS:

A fall arrest safety harness, hard hat, personal floatation gear (life jacket / floatation suit), safety footwear and gloves must be worn at all times by technician and crew members working over water, when deploying/retrieving a mooring.

A Rubber floor mat is to be used to prevent equipment sliding and prevent damage to equipment while on the foredeck.

SEQUENCE OF BASIC JOB STEPS	POTENTIAL HAZARDS	SAFETY CONTROLS TO REDUCE OR ELIMINATE HAZARD
1. Programming of instruments • *lifting of equipment from hold onto aluminum 'Hold' cover plates for programming and maintenance*	• Slip and fall • Lifting strain • Rolling, sliding equipment • Swinging load (winch) • Dropped load • Failure of cable	• No manual lifting >20kg, use of proper lifting technique • Proper footwear, PPE, non-skid surface, caution • Keep equipment close to computer set-up area • Secure equipment from rolling or sliding • Trained operator, proper equipment maintenance, regular survey of gear, belaying lines, sea state limits, good communication between winch operator and person in hold area
2. Transfer equipment from 'Hold' to Foredeck	• Swinging load (crane) • Dropped load • Failure of cable	• Go / no-go decision depending on sea state, weather • Good communication with bridge, crane operator • Trained operator, proper equipment maintenance, regular survey of gear, belaying lines, sea state limits, good communication between personnel, bridge and crane operator

SEQUENCE OF BASIC JOB STEPS	POTENTIAL HAZARDS	SAFETY CONTROLS TO REDUCE OR ELIMINATE HAZARD
3. Assemble mooring on foredeck • *Connect all of the items as identified in the mooring deployment sheet*	• Slip and fall • Lifting strain • Rolling, sliding equipment	• No manual lifting >20kg, use of proper lifting technique • Proper footwear, PPE, non-skid surface, caution • Coordinate with other activities on foredeck • Secure equipment from rolling or sliding
SEQUENCE OF BASIC JOB STEPS	**POTENTIAL HAZARDS**	**SAFETY CONTROLS TO REDUCE OR ELIMINATE HAZARD**
4. Deploy mooring • *top-to-bottom / anchor last*	• Vessel movement • Damaged or leaking hydraulic lines • In sea equipment entangled in prop (Zodiac) • Zodiac capsize • Equipment or rigging failure • Wet and slippery deck • Crew member or technician falls overboard while deploying/retrieving equipment • Miscommunication between vessel, Zodiac and technical crews • Equipment and mooring line entanglement	• Go / no-go decision depending on sea state, weather • Adjust vessel heading to minimize lateral motion of equipment during deploy or recovery • Strict adherence to deployment procedure • Establish deck exclusion zone, required personnel only • Define and use of proper PPE, including harness, safety glasses, etc. • Experienced technical and vessel crew • Risk analysis in-place • Proper footwear, non-skid surface and caution • Good communication between deck, bridge and Zodiac. Be absolutely certain that Zodiac has let go of mooring before the anchors are released • Permission imperative from bridge before commencing deployment • Good visibility of main deck area from bridge • Safety toolbox meetings before work and after each shift change • Proper equipment maintenance • Crane, winch and wire cable has current stress test certification • Decking in good condition, non-slip paint • MOB procedures in place • Tag lines and belay points
SEQUENCE OF BASIC JOB STEPS	**POTENTIAL HAZARDS**	**SAFETY CONTROLS TO REDUCE OR ELIMINATE HAZARD**
5. Recover mooring • *Top-to-Bottom recovery is ideal (top float easy to attach lifting hook and sediment trap needs to be kept upright for effective sedimentation analysis)*	• Vessel movement • Damaged or leaking hydraulic lines • In sea equipment entangled in prop (Zodiac) • Zodiac capsize • Equipment or rigging failure • Wet and slippery deck • Crew member or technician falls overboard while deploying/retrieving equipment • Miscommunication between vessel, Zodiac	• Go / no-go decision depending on sea state, weather • Adjust vessel heading to minimize lateral motion of equipment during deploy or recovery • Strict adherence to deployment procedure • Establish deck exclusion zone, required personnel only • Define and use of proper PPE, including harness, safety glasses, etc. • Experienced technical and vessel crew

	and technical crews • Equipment and mooring line entanglement	• Risk analysis in place • Maintain communication between deck, bridge and Zodiac • Proper footwear, non-skid surface and caution • Permission imperative from bridge before commencing recovery • Good visibility of main deck area from bridge • Safety toolbox meetings before work and after each shift change • Proper equipment maintenance • Crane, winch and wire cable has current stress test certification • Decking in good condition, non-slip paint • MOB procedures in place • Tag lines and belay points • Make Zodiac and deck crew aware of increased risk of entanglement and equipment damage

ACTIVITÉ :	Operations de Mouillage	DATE DE DOCUMENT ORIGINAL :	20 Août 2015
EN CHARGE :	Professionnels de mouillage	LIEU D'ACTIVITÉ :	Pont avant de la NGCC *Amundsen*
PRÉSENTATION DE LA JSA :	Shawn Meredyk (professionnel de mouillage)	SUPERVISEUR DES OPÉRATIONS :	Keith Levesque

ATTENTION : Tous les risques sont importants. Faire des avis de tous les dangers possibles. Procédures de travaux sécuritaires détaillés sont nécessaires. Prise de conscience, travail d'équipe, communication et vivacité d'esprit s'applique à toutes les situations. Recommandations complètes permet d'éliminer ou de réduire les risques. *Sécurité premier!*

ÉQUIPEMENT DE SÉCURITÉ REQUIS POUR FAIRE CE TRAVAIL :

☒	Casque	☐	Extincteur d'incendie	☐	Gilet de sauvetage
☒	Chaussures de sécurité	☐	Lunettes de sécurité avec écrans latéraux	☒	2 - vie sonne w / 90' ligne flottante
☐	Protection auditive	☒	Lunettes de protection ou des lunettes de soleil	☒	Tag Lines / Fil de guidage
☒	Gants de protection	☐	Écran facial	☐	Permis de travail requis
☐	Gants en cuir	☐	Ceintures arrière	☐	Lockout/Tagout
☐	Gants en caoutchouc	☒	Harnais de sécurité	☐	Barricades
☐	Gants de soudeur	☒	Tapis de sol	☒	Costume de flottaison
☐	Casque de soudeur	☐	Masque à poussière	☐	

COMMENTAIRES :

A l'automne harnais de sécurité antichute, casque, équipement personnel de flottaison (gilet de sauvetage / costume de flottaison), chaussures de sécurité et des gants doivent être portés en tout temps par technicien et équipage membres travaillant sur l'eau, lorsque vous déployer/récupérez un mouillage.

Un tapis de sol en caoutchouc doit être utilisé pour prévenir des équipements coulissants et prévenir les dommages aux équipements tandis que sur le pont avant.

SÉQUENCE D'ÉTAPES DE TRAVAIL DE BASE	DANGERS POTENTIELS	CONTRÔLES DE SÉCURITÉ POUR RÉDUIRE OU ÉLIMINER LE RISQUE
1. Programmation d'instruments *levage de l'équipement de cale sur plaques de recouvrement pour la cale, en aluminium, pour la programmation et l'entretien*	Glisser et tomber Blessure au dos Matériel roulant, coulissant Balancement de charge (treuil) Perte de charge Défaillance du câble	Aucun levage manuel > 20kg, l'utilisation de la technique appropriée de levage Surface, attention de chaussures adéquates, EPI, antidérapant Garder l'équipement à proximité de la zone de Configuration ordinateur Équipement sûr de rouler ou glisser Opérateur qualifié, entretien de l'équipement approprié, des enquêtes régulières d'engins, assurage lignes, limites de l'Etat, une bonne communication entre le treuilliste et personne dans la zone d'attente
2. Équipement de cale pour pont avant de transférer	Balancement de charge (grue) Perte de charge Défaillance du câble	Go / No-Go décision selon l'état de la mer, météo Une bonne communication avec pont, grutier Opérateur qualifié, entretien de l'équipement approprié, des enquêtes régulières d'engins, assurage lignes, limites de l'Etat, une bonne communication entre l'opérateur personnel, pont et grue

SÉQUENCE D'ÉTAPES DE TRAVAIL DE BASE	DANGERS POTENTIELS	CONTRÔLES DE SÉCURITÉ POUR RÉDUIRE OU ÉLIMINER LE RISQUE
3. Assemblage d'mouillage sur le pont avant *Connectez tous les éléments, tels qu'identifiés dans le feuille de déploiement de mouillage*	Glisser et tomber Blessure au dos Matériel roulant, coulissant	Aucun levage manuel > 20kg, l'utilisation de la technique appropriée de levage Surface, attention de chaussures adéquates, EPI, antidérapant Coordonner avec d'autres activités sur pont avant Équipement sûr de rouler ou glisser

SÉQUENCE D'ÉTAPES DE TRAVAIL DE BASE	DANGERS POTENTIELS	CONTRÔLES DE SÉCURITÉ POUR RÉDUIRE OU ÉLIMINER LE RISQUE
4. Déploiement de mouillage *haut-bas / dernière d'ancrage*	Mouvement du navire Endommagées ou qui fuient les conduites hydrauliques Dans les équipements de mer empêtré dans prop (Zodiac) Zodiac chavirer Équipement ou échec de gréement Pont humide et glissant Membre de l'équipage ou technicien tombe par-dessus bord lors du déploiement/récupération des équipements Mauvaise communication entre le navire, de Zodiac et d'équipes techniques Enchevêtrement de ligne matériel et mouillage	Go / No-Go décision selon l'état de la mer, météo Ajuster le cap du bateau pour minimiser le mouvement latéral du matériel au cours de déploiement ou de récupération Le respect strict de la procédure de déploiement Établir de zone d'exclusion de pont, personnel requis uniquement Définir et utiliser des EPI approprié, notamment des harnais, des lunettes de sécurité, etc.. Équipage de navire et techniques expérimenté Analyse risque en place Chaussures adéquates, surface antidérapante et prudence Une bonne communication entre le pont, pont et Zodiac. Être absolument certain que le zodiaque a lâché d'mouillage avant que les ancres sont libérés Impératif de permission du pont avant

		de commencer le déploiement Bonne visibilité de la zone du pont principal du pont Réunions de boîte à outils de sécurité travail avant et après chaque quart de travail changer Entretien de l'équipement approprié Grue, treuil et câble de câble a certification actuelle de stress test Platelage en bon état, peinture antidérapante Procédures MOB en place Marquer les lignes et les points d'assurage
SÉQUENCE D'ÉTAPES DE TRAVAIL DE BASE	**DANGERS POTENTIELS**	**CONTRÔLES DE SÉCURITÉ POUR RÉDUIRE OU ÉLIMINER LE RISQUE**
5. Récupération de mouillage *Récupération de haut en bas est idéale* *(top flotteur permettant de fixer le levage crochet et la piège de sédiment besoins à tenir debout pour une analyse efficace de sédimentation)*	Mouvement du navire Endommagées ou qui fuient les conduites hydrauliques Dans les équipements de mer empêtré dans prop (Zodiac) Zodiac chavirer Équipement ou échec de gréement Pont humide et glissant Membre de l'équipage ou technicien tombe par-dessus bord lors du déploiement/récupération des équipements Mauvaise communication entre le navire, de Zodiac et d'équipes techniques Enchevêtrement de ligne matériel et mouillage	Go / No-Go décision selon l'état de la mer, météo Ajuster le cap du bateau pour minimiser le mouvement latéral du matériel au cours de déploiement ou de récupération Le respect strict de la procédure de déploiement Établir de zone d'exclusion de pont, personnel requis uniquement Définir et utiliser des EPI approprié, notamment des harnais, des lunettes de sécurité, etc.. Équipage de navire et techniques expérimenté Analyse des risques en place Maintenir une communication entre le pont, le pont et Zodiac Chaussures adéquates, surface antidérapante et prudence Impératif de permission du pont avant de commencer la récupération Bonne visibilité de la zone du pont principal du pont Réunions de boîte à outils de sécurité travail avant et après chaque quart de travail changer Entretien de l'équipement approprié Grue, treuil et câble de câble a certification actuelle de stress test Platelage en bon état, peinture anti-dérapante Procédures MOB en place Marquer les lignes et les points d'assurage Faire Zodiac et équipage au courant du risque accru d'intrication et dommages à l'équipement de pont

5.2.9 Seabed Mapping

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See attached pdf