2015 CCGS *Amundsen* Expedition

LEG 2 GEOTRACES/ARCTICNET
July 10 – August 20, 2015
Quebec City - Kugluktuk

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1. Cruise synopsis

Leg 2 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. The project also included extensive biological and trace gases components of direct relevance to the long-term goals of ArcticNet, which facilitated coordination of sampling for both programs.

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
- 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
- underway trace gas analysis with a Membrane Inlet Mass Spectrometer (MIMS) and a Gas Chromatograph (GC)

Additional planned activities included:

- incubations for productivity measurements with different isotopic tracers
- ocean acidification experiments
- sea ice melt pond sampling
- Argo floats deployments
- river sampling
- seafloor mapping with a multibeam sonar and a CHIRP sub-bottom profiler
- mooring deployment in Queen Maud Gulf

The initial plan (Fig. 1.1) was to occupy 15 stations (2 stations in the Labrador Sea, 4 in Baffin Bay, and 9 in the Canadian Arctic Archipelago) which would satisfy the extensive sampling needs of GEOTRACES, while also providing productivity and hydrographic data for ArcticNet. Additional stations were to be occupied for ArcticNet on a section between Greenland and Devon Island, and in Kane Basin, Kennedy Channel and Petermann Fjord. Time was also allocated for additional stations in Queen Maud Gulf as part of The W. Garfield Weston Foundation - Parks Canada - ArcticNet collaborative project.

The CCGS *Amundsen* left Quebec City on July 10th and work in the Labrador Sea was completed on schedule. On July 19th, as we were underway to Baffin Bay, the ship was unexpectedly diverted to Hudson Bay for ice-breaking duties. This unfortunate turn of events resulted in a 2-week hiatus (from July 19th to August 3rd) and a need to dramatically reduce our science plan. To the benefit of the GEOTRACES program, ArcticNet cancelled nearly all its stations and the remaining science plan was reduced to occupying 3 of the 4 GEOTRACES Baffin Bay stations and 7 of the 9 archipelago (CAA) stations (Fig. 1.

2; Table 1.1). GEOTRACES Sampling strategy in the CAA was also adjusted to existing ice conditions and to optimize scientific return within the remaining time. By the end of leg 2, ArcticNet had lost most of its stations not shared with GEOTRACES, while GEOTRACES lost 3 of its 15 stations station BB4 in Baffin Bay and 2 stations in the CAA (Fig. 1.2), the latter two were sampled during the following leg 3B.

At the end of leg 2, 186 operations in the water column had been completed (Daily Log Geotraces LEG 2.xls file):

- 67 hydrocasts with ArcticNet's CTD-rosette (LogBook_AN ROSETTE LEG 2.xls)
- 31 hydrocasts with GEOTRACES' trace metal clean CTD- rosette
- 24 casts with GEOTRACES' six large volume pumps
- 28 deployments with ArcticNet's nets
- 22 deployments of XCTDs
- 10 deployments of ArcticNet's Profiling Natural Fluorometer system
- 3 ArcticNet's ArgoBio float deployments
- 1 GEOTRACES trace metal clean deck pump deployment

This resulted in 1,545 seawater or marine particle samples for multi-element and isotopic analysis (Table 2.1), which will amount to 5,336 measurements, and additional zooplankton, ichtyoplankton and fish samples.

We also conducted 434 incubations for carbon fixation and nutrient uptake measurements:

- 156 twelve-hour ^{14}C incubations
- 88 two-hour ^{14}C incubations
- 60 ^{13}C and ^{15}N incubations
- 60 ^{32}Si incubations
- 60 ^{18}O incubations
- 10 ^{55}Fe incubations

Three CO_2 manipulation experiments and sampling at 15 Arctic rivers draining in the CAA (Fig. 1.3) were also successfully completed.

Finally, seabed mapping and sub-bottom stratigraphy were conducted during transit between stations, using a multibeam sonar and a CHIRP sub-bottom profiler. The deployment of BioArgo floats in Baffin Bay was attempted but failed because of ballasting problems,

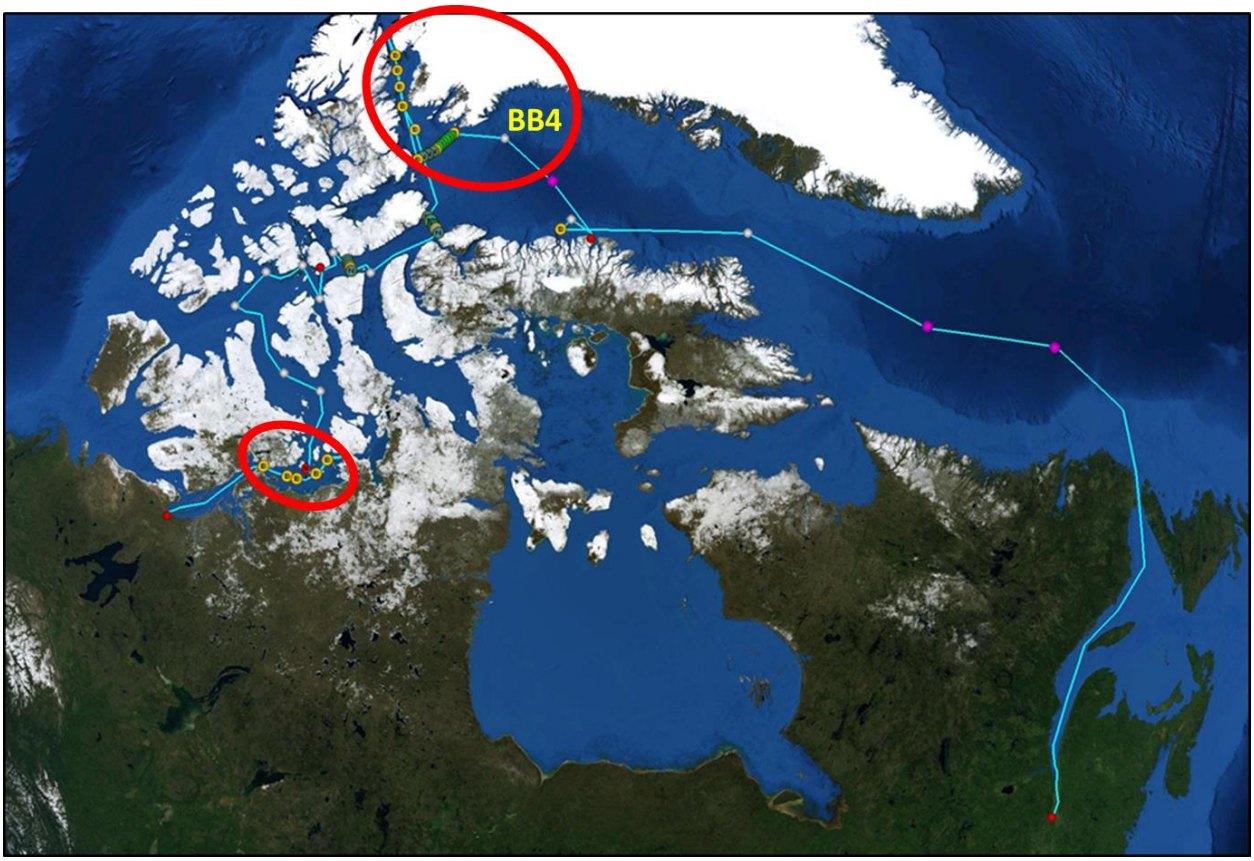

Fig. 1.1: Proposed cruise track for the 2015 CCGS *Amundsen* Expedition - LEG 2. Stations that had to be cancelled as a result of spending two weeks in Hudson Bay for escort duty are circled.

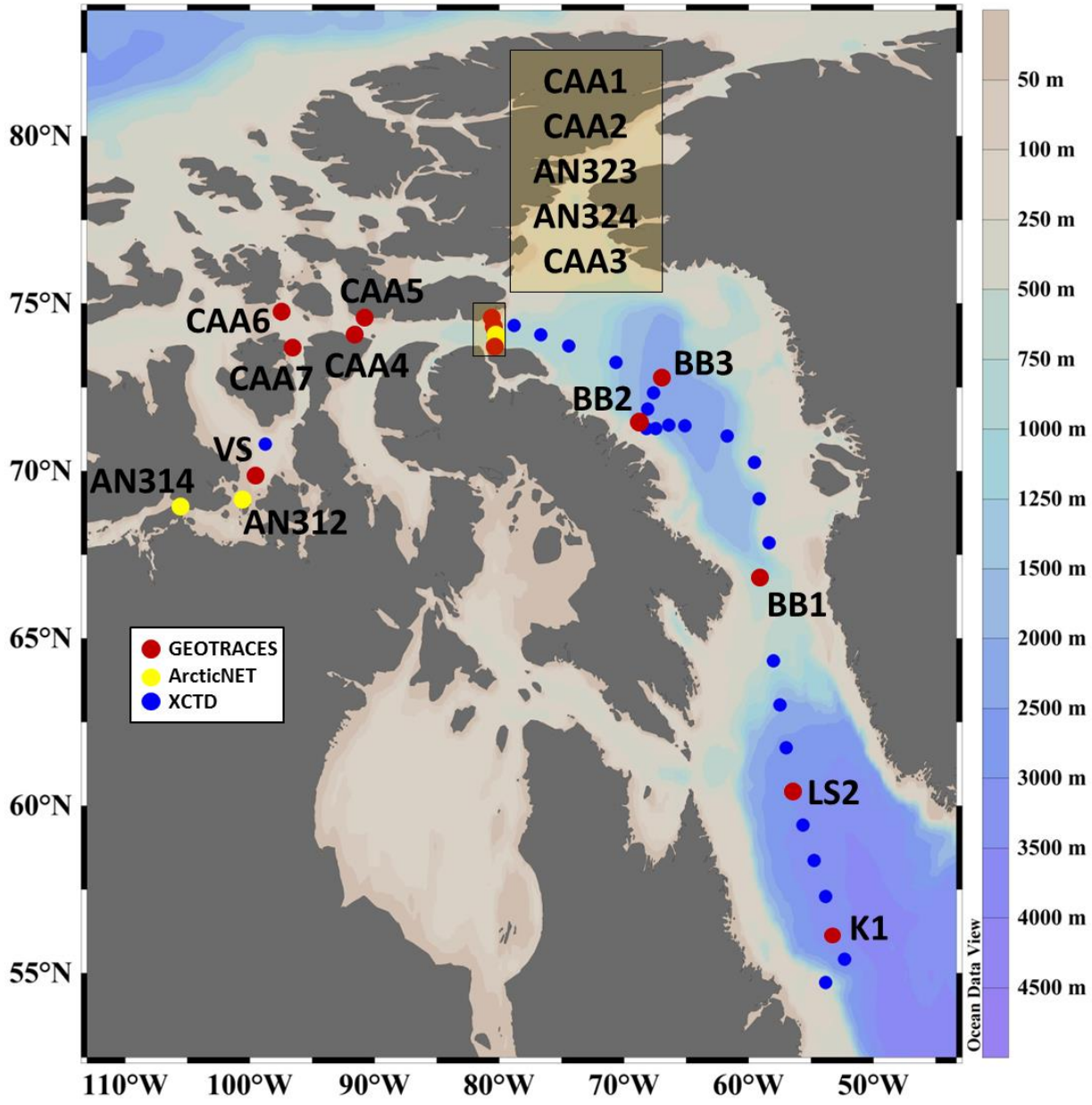

Fig. 1.2: Station location during GEOTRACES/ArcticNet CCGS *Amundsen* 2015 expedition Leg 2 (July 10 – August 20). Red circles = shared GEOTRACES/ArcticNet stations; yellow circles = ArcticNet stations; blue circles = underway XCTD deployments.

Table 1.1: CCGS *Amundsen* 2015 Expedition - LEG 2 Station locations

Date 2015	Station name	Latitude	Longitude	Depth m	Station type
13-Jul	X-CTD1	54°43.4'N	53°49.3'W	305	X-CTD
14-Jul	K1	56°07.2'N	53°22.2'W	3313	GEOTRACES
15-Jul	X-CTD2	55°25.1'N	52°18.3'W	3211	X-CTD
16-Jul	X-CTD3	57°17.7'N	53°49.0'W	3376	X-CTD
16-Jul	X-CTD4	58°22.2'N	54°44.0'W	3377	X-CTD
16-Jul	X-CTD5	59°25.4'N	55°37.9'W	3216	X-CTD
17-Jul	LS2	60°26.7'N	56°33.3'W	3024	GEOTRACES
19-Jul	X-CTD6	61°43.7'N	56°59.7'W	2679	X-CTD
19-Jul	X-CTD7	63°01.0'N	57°29.7'W	2002	X-CTD
19-Jul	X-CTD8	64°19.9'N	58°00.1'W	873	X-CTD
19-Jul - 03 Aug : ice-breaking; Hudson Bay					
03-Aug	BB1	66°51.4'N	59°04.0'W	1037	GEOTRACES
04-Aug	X-CTD9	67°51.4'N	58°21.5'W	331	X-CTD
04-Aug	X-CTD10	69°10.1'N	59°09.6'W	1214	X-CTD
04-Aug	X-CTD11	70°15.5'N	59°31.8'W	458	X-CTD
04-Aug	X-CTD12	71°02.4'N	61°43.1'W	1778	X-CTD
05-Aug	X-CTD13	71°21.2'N	65°07.0'W	2237	X-CTD
05-Aug	X-CTD14	71°22.4'N	66°23.4'W	2165	X-CTD
05-Aug	X-CTD15	71°15.8'N	67°27.3'W	1592	X-CTD
05-Aug	X-CTD16	71°15.8'N	68°12.0'W	813	X-CTD
05-Aug	BB3	71°24.5'N	68°34.6'W	1274	GEOTRACES
06-Aug	X-CTD17	71°51.3'N	68°06.4'W	2226	X-CTD
06-Aug	X-CTD18	72°19.8'N	67°37.8'W	2333	X-CTD
07-Aug	BB2	72°45.3'N	66°59.2'W	2369	GEOTRACES
09-Aug	X-CTD19	73°14.5'N	70°37.7'W	1444	X-CTD
09-Aug	X-CTD20	73°44.1'N	74°25.3'W	895	X-CTD
09-Aug	X-CTD21	74°04.0'N	76°40.2'W	815	X-CTD
09-Aug	X-CTD22	74°20.5'N	78°48.8'W	690	X-CTD
09-Aug	CAA1	74°31.3'N	80°36.2'W	636	GEOTRACES
10-Aug	CAA2	74°19.1'N	80°30.8'W	702	GEOTRACES
11-Aug	AN323	74°09.3'N	80°28.2'W	796	ARCTICNET
11-Aug	AN324	73°58.7'N	80°27.1'W	774	ARCTICNET
11-Aug	CAA3	73°48.9'N	80°27.8'W	677	GEOTRACES
12-Aug	CAA5	74°32.4'N	90°48.4'W	257	GEOTRACES
13-Aug	CAA4	74°07.4'N	91°29.1	185	GEOTRACES
14-Aug	CAA6	74°45.5'N	97°27.2'W	253	GEOTRACES
15-Aug	CAA7	73°39.9'N	96°32.2'W	218	GEOTRACES
17-Aug	X-CTD23	70°48.3'N	98°45.8'W	190	X-CTD
17-Aug	VS	69°52.5'N	99°32.5'W	140	GEOTRACES
17-Aug	AN312	69°09.8'N	100°41.8'W	59	ARCTICNET
18-Aug	AN314	68°58.2'N	105°27.7'W	79	ARCTICNET

Fig. 1.3: River sampling locations along the Geotraces Leg 2 cruise track through the Canadian Arctic Archipelago.

2. Parameters measured or sampled in the water column

Stations K1, LS2, BB1, 2, 3, CAA1, 2, 3, 4, 5, 6, 7 (GEOTRACES/ArcticNet):
Sixty-seven chemical and biological parameters (Table 1.2) were measured on board or sampled for later analysis

Stations AN323 and AN324 (ArcticNet)
Hydrography, nutrients, Dissolved Inorganic Carbon

Station VS (GEOTRACES)
Hydrography, nutrients, CH_4, DMS, DIC, alkalinity, pH, ^{14}C productivity, Nd isotopes, Ra isotopes

Stations AN312
Hydrography, nutrients, CH_4, DMS, DIC, alkalinity, pH, ^{14}C productivity, Nd isotopes, Ra isotopes

Station 314
Hydrography, nutrients, CH_4, DMS, DIC, alkalinity, pH, ^{14}C productivity, genomics, Ra isotopes

Table 2: List of parameters measured in the water column at the GEOTRACES/ArcticNet stations

Hydrography/CTD sensors	**Biological parameters**	**Trace gases**
Pressure	Particulate organic carbon	Biogenic gases
Temperature	Particulate organic nitrogen	CH_4, N_2O
Salinity	Size fractionated chlorophyll a	O_2/Ar, N_2/Ar (K1; LS2; BB1, 2, 3; CAA1, 3, 4, 5, 6, 7)
Oxygen	Pigments	Triple oxygen isotopes (K1; LS2; BB1, 2, 3; CAA1, 3, 4, 5, 6, 7)
Fluorescence	Particulate biogenic silica	Noble gases (K1 and BB2)
Light transmission	Flow cytometry	**Trace elements and isotopes**
Nutrients	Genomics	Dissolved and particulate trace metals
Phosphate	Proteomics	Al, Mn, Fe, Cd, Zn, Cu, Pb, Ga, Ba, Cr, REE, Hg, MeHg
Nitrate/Nitrite	Incubations	Dissolved and particulate radioisotopes
Ammonia	^{14}C uptake (K1; LS2; BB1, 2, 3; CAA1, 2, 3, 4, 5, 6, 7; VS, AN314)	^{230}Th, ^{231}Pa, ^{234}Th, ^{228}Ra, ^{224}Ra, ^{223}Ra
Silicate	^{13}C uptake (K1; LS2; BB1, 2, 3; CAA1, 3, 5, 6, 7)	Dissolved and particulate radiogenic isotopes
Chemical parameters	^{15}NO3 uptake (K1; LS2; BB1, 2, 3; CAA1, 3, 5, 6, 7)	Nd, Pb
Dissolved inorganic carbon	$^{15}NH_4$ uptake (LS2; BB1, 2, 3; CAA1, 3, 5, 6, 7)	Dissolved and particulate stable isotopes
Total alkalinity	^{32}Si uptake (LS2; BB1, 2, 3; CAA1, 3, 5, 6, 7)	δ^{18}O in water
pH	$H_2{}^{18}O$ uptake (K1; LS2; BB1, 2, 3; CAA1, 3, 5, 6, 7)	δ^{13}C in DIC
Dissolved organic carbon	^{55}Fe uptake	δ^{15}N and δ^{18}O in nitrate
Fluorerscent dissolved organic matter	Zooplankton, ichtyoplankton	δ^{30}Si
Coloured dissolved organic matter	Fish	δ^{53}Cr
Thiols		δ^{56}Fe
Organic ligands		Anthropogenic isotopes
		^{129}I, ^{236}U, ^{135}Cs
		Large volume in-situ pumps
		Paticulate ^{230}Th, ^{231}Pa, ^{234}Th
		Paticulate Si, Nd and Cr isotopes

3. Parameters measured or sampled in underway

- Atmospheric Hg concentration (Gaseous Elementary Mercury [GEM], Reactive Gaseous Mercury [RGM] and Particulate Hg [PHg]) with an automated Tekran atmospheric mercury speciation system. Discrete GEM measurements were obtained every 5 minutes. Analysis of PHg and RGM samples occurred after 2-hour collection periods.

- Surface gas measurements were conducted using automated purge and trap gas chromatography (PT-GC; for DMS/P/O), and membrane inlet mass spectrometry (MIMS; for CO_2, ΔO_2/Ar, and DMS) from the ship's seawater intake.

- Photo-physiological measurements (e.g. variable Chl*a* fluorescence, F_v/F_m, and cross sectional absorption area, σ) were measured from the ship's seawater intake using an FRRF equipped with a flow-through measurement cuvette.

4. Participants

The science party consisted of 23 GEOTRACES (from 7 Canadian Universities and 2 partner foreign research institutions) and 17 ArcticNet scientists (Table 4.1).

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 4.1: List of participants

2015 CCGS Amundsen Expedition Participants			
LEG 2: 10 July to 20 August (Quebec to Kugluktuk)			
Name (Family, First)	**Position**	**Affiliation**	
François, Roger	Chief Scientist	University of British Columbia	
Tortell, Philippe	Researcher/Professor	University of British Columbia	
Cullen, Jay	Researcher/Professor	University of Victoria	
Thomas, Helmuth	Researcher/Professor	Dalhousie University	Clyde River - Kugluktuk
Soon, Maureen	Research Staff	University of British Columbia	
Guignard, Constance	Research Staff	McGill University	
Brown, Kristina	Posdoctoral Fellow	WHOI	
Grenier, Mélanie	Posdoctoral Fellow	University of British Columbia	
Semienuk, Dave	Posdoctoral Fellow	University of British Columbia	
Hoppe, Clara	Posdoctoral Fellow	Alfred Wegener Institute	
Janssen, David	PhD Student	University of Victoria	
Colombo, Manuel	PhD Student	University of British Columbia	
Chandan, Priyanka	PhD Student	University of Toronto	
Timmerman, Amanda	PhD Student	University of Victoria	
Schuback, Nina	PhD Student	University of British Columbia	
Jarnikova, Tereza	PhD Student	University of British Columbia	
Giesbrecht, Karina	PhD Student	University of Victoria	
Lehmann, Nadine	PhD Student	Dalhousie University	
Wang, Kang	PhD Student	University of Manitoba	
Li, Jingxuan	MSc Student	University of British Columbia	
Gao, Jeff (Zhiyuan)	MSc Student	Trent University	
Mol, Jacoba	MSc Student	Dalhousie University	
Kuang, Cheng	BSc Student	University of British Columbia	
Linkowski, Thomas	Professional	ArcticNet	
Guillot, Pascal	Professional	Quebec-Ocean	
Seaton, Cris	Professional	ArcticNet	
Toldi, Glenn	Professional	Canadian Hydrographic Service	
Brouard, Étienne	Professional	Université Laval	
Deslongchamps, Gabrièle	Professional	Université Laval	
Lagunas, Jose Luis	Professional	Université Laval	Clyde River - Kugluktuk
Bouchard, Caroline	Research Staff	Université Laval	
Blais, Marjolaine	Research Staff	Université du Quebec - Rimouski	
Lizotte, Martine	Research Staff	Université Laval	
Munson, Kathleen	Posdoctoral Fellow	University of Manitoba	Quebec City - Clyde River
Xu, Wen	MSc Student	University of Manitoba	Clyde River - Kugluktuk
Courchesne, Isabelle	MSc Student	Université Laval	
Leblanc, Mathieu	MSc Student	Université Laval	
Hussherr, Rachel	MSc Student	Université Laval	
Noël, Laura	MSc Student	Université du Quebec - Rimouski	
Hegmans, Alyse	BSc Student	Environment Canada	Quebec City -Inukjuak

5. Cruise reports by group

5.1 GEOTRACES

5.1.1 Trace metal rosette sampling operations

Principal Investigators: Jay T. Cullen[1], Roger Francois[2], Celine Guéguen[3], Chris Holmden[4], Maite Maldonado[2], Kristin Orians[2] and Feiyue Wang[5]
Cruise Participants: Priyanka Chandan[2], Manuel Colombo[2], Jeff Gao[3], David Janssen[1], Jingxuan Li[2], Kathleen Munson[5], David Semeniuk[2], Kang Wang[5], Wen Xu[5]

[1]*School of Earth and Ocean Sciences, University of Victoria*
[2]*Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia*
[3]*Department of Chemistry, Trent University*
[4]*Department of Geological Sciences, University of Saskatchewan*
[5]*Department of Environment and Geography, University of Manitoba*

Introduction and Objectives
The Trace Metal Rosette team was responsible for collecting trace element clean samples to characterize dissolved and particulate trace element and isotope distributions in the Labrador Sea, Baffin Bay and Canadian Arctic Archipelago from the CCGS Amundsen during Leg 2. 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 trace elements and isotopes 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, Cu, Zn, Cd, Pb, Hg, Ag, Ba
- Dissolved ^{129}I, ^{230}Th, ^{231}Pa concentration

- Radiogenic Pb and Nd isotopes
- Particulate trace elements and their isotopes

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 and 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. A stylized video of the operation was posted to the share folder of the CCGS Amundsen intranet in the folder "Movies GEOTRACES". To monitor for potential contamination during sampling operations, dissolved Zn was measured immediately onboard ship using flow injection analysis (FIA) with an established fluorescence based detection method [Nowicki et al. 1994, Janssen et al. 2015]. Other samples were preserved or frozen for analysis in the PI's laboratories on shore.

The rosette was deployed on 31 occasions and travelled almost 62 vertical kilometers during the leg. The absolute number of deployments was increased to access deeper waters for general geochemical measurements in the Labrador Sea and Baffin Bay given that the ships main rosette was limited to sampling waters shallower than 1600 m.

Station locations are indicated on the following map:

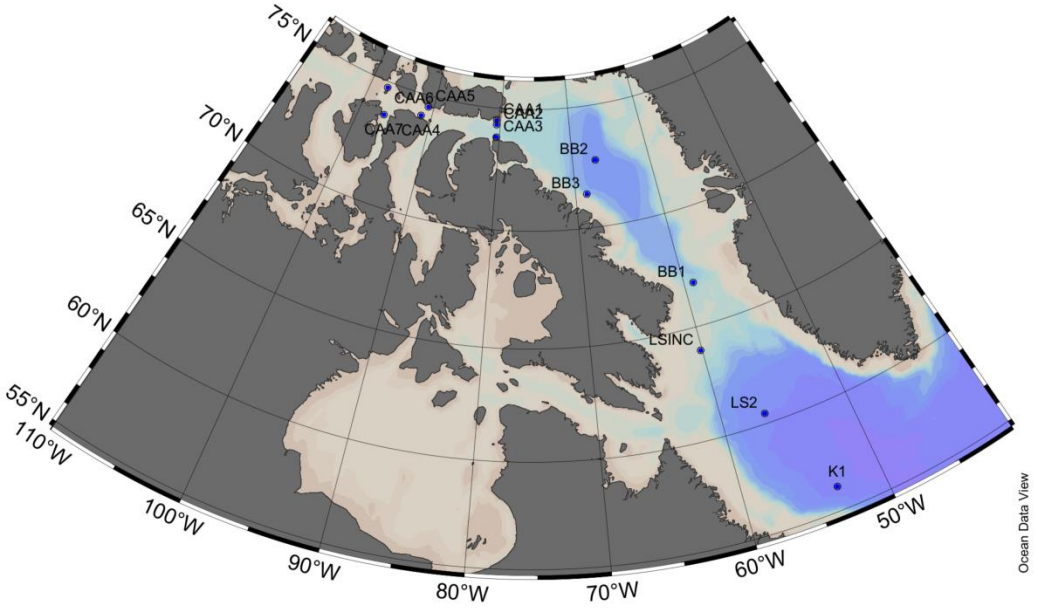

Figure 5.1.1 Location of stations where the Trace Metal Rosette was deployed on Leg 2

Preliminary Results

The table below summarizes the date and location of the TM rosette deployments on Leg 2.

Table 1. Date and location of TM rosette deployments on Leg 2

TMR Cast	TMR Cast at Station	Date	Station	Cruise Event Number	Latitude	Longitude	Bottom Depth (m)	Maximum Rosette Depth (m)
1	1	13/07/2015 11:42PM	K1	1	56.12017	-53.3615	3309	3010
2	2	14/07/2015 03:30AM	K1	3	56.11823	-53.3637	3311	2010
3	3	14/07/2015 08:09AM	K1	5	56.12012	-53.3667	3310	815
4	4	14/07/2015 02:37PM	K1	7	56.12087	-53.3693	3310	3015
5	1	17/07/2015 02:08AM	LS2	14	60.44933	-56.5441	3021	2400
6	2	17/07/2015 05:32AM	LS2	16	60.45237	-56.5635	3031	2800
7	3	17/07/2015 03:25PM	LS2	18	60.4534	-56.5506	3022	1215
8	4	18/07/2015 09:02AM	LS2	25	60.44635	-56.5467	3019	215
9	5	18/07/2015 05:15PM	LS2	28	60.44847	-56.5495	3022	2800
10	1	19/07/2015 10:28PM	LSINC	33	63.94828	-60.1259	481	65
11	2	19/07/2015 11:19PM	LSINC	33	63.94828	-60.1259	481	65
12	1	03/08/2015 03:43AM	BB1	34	66.85768	-59.0632	1040	1010
13	2	03/08/2015 12:40PM	BB1	40	66.85778	-59.0716	1040	210
14	1	05/08/2015 6:43PM	BB3	54	71.40887	-68.5976	1243	1010
15	2	06/08/2015 1:04AM	BB3	57	71.40748	-68.5991	1243	210
16	3	06/08/2015 7:25AM	BB3	60	71.40545	-68.601	1270	60
17	1	07/08/2015 04:40AM	BB2	69	72.7495	-66.9867	2370	810
18	2	07/08/2015 10:08PM	BB2	74	72.74973	-66.9885	2371	1010
19	3	08/08/2015 03:56AM	BB2	76	72.75105	-67	2369	2310
20	4	08/08/2015 09:07AM	BB2	79	72.75098	-66.9986	2369	160
21	5	08/08/2015 12:43PM	BB2	82	72.75037	-66.9872	2368	2337
22	1	09/08/2015 7:20PM	CAA1	92	74.52142	-80.5621	635	110
23	2	10/08/2015 0:44AM	CAA1	95	74.52197	-80.574	645	609
24	1	10/08/2015 7:04PM	CAA2	108	74.31532	-80.4993	700	600
25	1	11/08/2015 09:07AM	CAA3	117	73.80933	-80.4112	679	113
26	2	11/08/2015 7:05PM	CAA3	123	73.81622	-80.4931	676	610
27	1	12/08/2015 6:14PM	CAA5	130	74.53882	-90.8045	253	111
28	2	13/08/2015 1:41AM	CAA5	136	74.5371	-90.8078	260	252
29	1	14/08/2015 01:57AM	CAA4	149	74.1223	-91.5109	181	162
30	1	15/08/2015 04:18AM	CAA6	160	74.75433	-97.4575	260	245
31	1	15/08/2015 10:45PM	CAA7	168	73.67288	-96.5238	219	198

The bulk of our measurements will be made on return of samples to the respective home laboratories after CCGS Amundsen's return to Quebec later this year. We measured dissolved Zn on the ship as an indicator of sample integrity given that Zn is highly prone to contamination during sample collection and handling. These analyses were carried out by Dave Janssen in the aft Clean Lab where a trace element clean bubble was constructed during Leg 2. The onboard dissolved Zn analyses indicate we were broadly successful obtaining trace element clean samples over the course of the Leg although initially a subset of sampling bottles showed signs of some Zn contamination. Our ability to obtain clean samples improved over the course of the Leg. Zinc's vertical distribution in the ocean is similar to the major algal nutrients reflecting its uptake in surface waters by phytoplankton and subsequent remineralization at depth. A characteristic profile is shown in the Figure below.

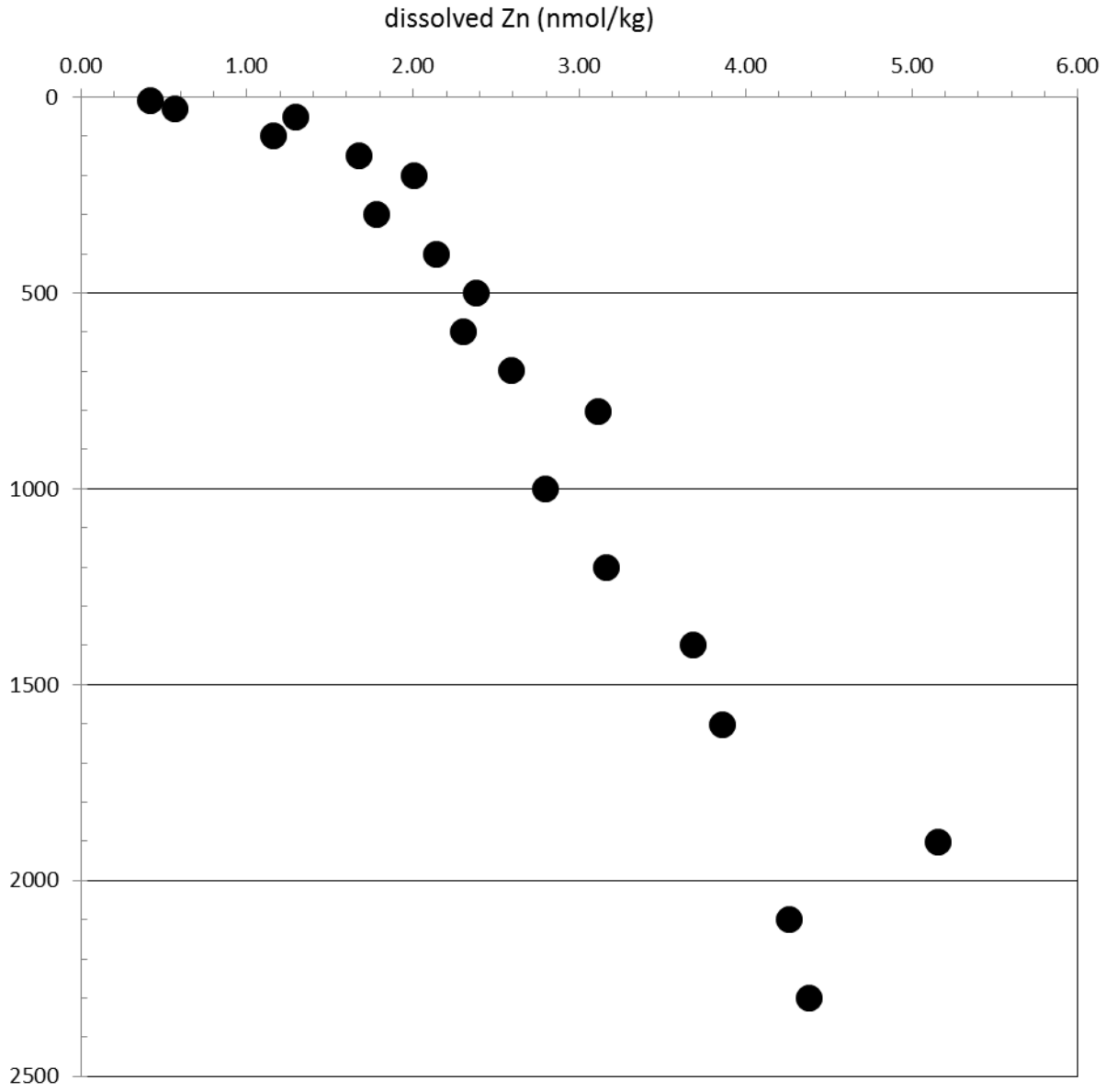

Figure 5.1.2 Depth versus dissolved Zn concentration for station BB3. Preliminary results with some indication of contamination in outlying data points.

User Experience

Overall we were very satisfied with ship operations as we were on our last expedition in 2009. This level of satisfaction does not factor in the delays in the scientific program owing to Coast Guard operations in Hudson Bay which was an unfortunate and frustrating turn of affairs outside of the ships control.

The Captain and Crew of CCGS Amundsen were outstanding and demonstrated considerable skill and coordination to deploy the Trace Metal Rosette. Over the course of the leg the

procedure for deploying and retrieving the TMR was refined and improved with the help of the ships officers and deckhands. Given demands on the ships A-frames for other gear deployment (ArcticNet Rosette and Plankton Nets) the TMR must be deployed using the starboard foredeck crane. This requires close coordination of the crew operating the crane and the winch as the rosette must be lifted high above the gunwale from the deck before being lowered into the water. The crane must lift the block into place, the rosette cable placed in the block, the block raised above the deck, crane extends its arm, rotates out over the water and then the rosette lowered into the sea. During all of these crane manipulations the winch must manage the cable to keep tension to the block and to keep the rosette from contacting the gunwale or the side of the ship. Even in calm conditions this a complicated procedure. This mode of deployment also puts considerable strain on our sea cable and requires the cable to bend past its specified bend radius under load. On return to the deck these operations are reversed and the cable removed from the block, the block disconnected from the crane and secured on deck. On three occasions the rosette made significant contact with the ship and sustained minor and mostly cosmetic damage. In our opinion there is some undue risk to equipment and personnel with the current mode of deployment. A recommendation for future work (some work with the rosette is likely to occur during the Green Edges program) would be to dedicate an existing A-frame on the ship for the TMR or to consider installing a J- or A-frame on the starboard foredeck for rosette operations.

On two occasions the strain on our sea cable led to breaches of the cable sheath and electrical shorts in the cable requiring retermination. This was expertly and efficiently done by the ArcticNet technicians onboard. Without their efforts our sampling program would have not been nearly as successful.

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.
- **c)** Everything the TMR team required was available to us and found to be in working order. Our requests for modification of the Aft Clean Lab (removal of cupboards and wood framing for a clean enclosure) and construction of a clean enclosure in the moon pool were completed before departure from Quebec City. Our experience with the ships technicians found them to world class in skill and easy and agreeable to work with.
- **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.
- **e)** The TMR team is satisfied with operations this year. Despite delays in the scientific program and 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. On many other ships that I have sailed on the nature and length and of the delay we experienced, away from scientific operations for 11 days, the morale on the ship would have likely deteriorated rapidly. The leadership of the Captain and the quality of the crew was made evident during this period of time.

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]

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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.

Goal 1: 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.

Goal 2: During the first cruise in the CAA, we also conducted with pCO_2 / pH manipulation experiments at 2 stations (in collaboration with Tortell). We aimed to investigate how changes in pH affect Fe bioavailability to polar plankton communities, using short-term Fe uptake assays. These data will also be combined with the dissolved and speciation trace metal data.

Goal 3: We also aimed to establish what controls Fe transport in indigenous Arctic plankton communities. To do so, we determined Fe transport kinetic parameters (using short-term Fe uptake) for 2 plankton size fractions at 5 stations in the first cruise along the CAA. These data will be examined along the particulate trace metal data, the dissolved metals and the Fe speciation data.

Operations conducted during the Leg / Methodology

To achieve our goals we determined (a) phytoplankton biomass (size-fractionated chlorophyll *a*) and species composition [by microscopic examination / HPLC analysis of accessory pigments (Maldonado/Tortell) and flow cytometry (Varela/Maldonado)]; (b) trace metal quotas of size-fractionated particles (using HR-ICPMS, as well as radiotracers); (c) phytoplankton photosynthetic efficiency and photosynthesis-irradiance curves using active fluorescence; (d) size-fractionated rates of trace metal uptake at saturating and sub-saturating concentrations, as well as micronutrient uptake kinetics using radiotracers. These physiological and ecological data will be complemented with differential proteomic analyses of samples collected from regions with distinct trace metal characteristics, and will enable us to elucidate how trace elements control protein expression. Various shipboard incubations will be set up to test whether phytoplankton communities are limited by one or various trace elements, or co-limited by trace metals/light/macronutrients.

pMe operation: 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 cubitainor. 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.

Fe speciation operation: 2x500mL 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.

Table 5.1.2.1: List of particulate trace metal samples

Depth	Goflo	Sample	Station	Event info (UTC)	Depth	Goflo	Sample	Station	Event info (UTC)
3000m	2	2		1 – July 13	40	5	712		92 – Aug 9
2750m	4	4		TM rosette	LL=0.2	6	713		TM rosette
2600m	6	6		2342h	LL=1	7	714		1920h
2450m	8	8		56.12017N	Chlmax	9	716		74.52142N
2450m	9	9		53.3615W	LL=30	10	717		80.5621W
2300m	10	10			LL=50	11	718		
2300m	11	11			600m	1	750		95 – Aug 10
2150m	12	12	**K1**		400m	3	752	**CAA1**	TM rosette
200m	6	18		3 – July 14	300m	5	754		0044h
				TM rosette	200m	7	756		74.52197N
				0330h					80.574W
				56.11823N					
				53.3637W					
800m	1	49		5 – July 14	150m	9	758		
600m	3	51		TM rosette	100m	12	761		
				0809h					
				56.12012N					
				53.3667W					
2400m	4	148		14 – July 17	40m	4	985		117 – Aug 11
2000m	6	150		TM rosette	Chlmax	7	988		TM rosette
2000m	7	151		0208h	20m	9	990		0907h
2000m	9	153		60.44933N	10m	11	992		73.80933N

				56.5441W
1800m	10	154		
1600m	11	155		
2700m	3	182	**LS2**	16 – July 17
2600m	4	183		TM rosette
2200m	8	187		0532h
1600m	11	190		60.45237N
				56.5635W
700m	6	203		18 – July 13
				TM rosette
				1525h
				60.4534N
				56.5506W
2000m	12	308		28 – July 18
				TM rosette
				1715h
				60.44847N
				56.5495W
1000m	2	312		34 – Aug 3
700m	4	314		TM rosette
500m	7	317		0343h
				66.85768N
				59.0632W
300m	10	320		
150m	2	378	**BB1**	40 – Aug 3
LL=0.2	5	381		TM rosette
				1240h
				66.85778N
				59.0716W
LL=1	7	383		
Chlmax	9	384		
LL=30	10	386		
LL=50	12	388		
1000m	1	603		74 – Aug 7
600m	5	607		TM rosette
300m	7	609		2208h
				72.74973N
				66.9885W
2250m	1	657		79 – Aug 8
2100m	5	661		TM rosette
1600m	6	662		0907h
150m	7	663	**BB2**	72.75098N
LL=0.2	9	665		66.9986W
LL=1	11	667		
Chlmax	2	689		82 – Aug 8
LL=30	4	691		TM rosette
LL=10	9	696		1243h
				72.750378N
				66.9872W
1000m	2	444		54 – Aug 5
700m	4	446		TM rosette
500m	7	449		1843h
300m	12	454		71.40887N
				68.5976W
150m	2	486	**BB3**	57 – Aug 6
LL=0.2	5	489		TM rosette

				80.4112W
600m	2	1026	**CAA3**	123 – Aug 11
400m	4	1028		TM rosette
300m	6	1030		1905h
200m	7	1031		73.81622N
150m	10	1034		80.4931W
100m	12	1036		
150m	1	1240		149 – Aug 14
				TM rosette
				0157h
			CAA4	74.1223N
				91.5109W
40m	7	1246		
Chlmax	10	1249		
10m	11	1250		
220m	3	1074		130 – Aug 12
100m	12	1082		TM rosette
				1814h
				74.53882N
				90.8045W
LL=1	7	1143		136 – Aug 13
Chlmax	9	1145		TM rosette
LL=50	11	1147	**CAA 5**	0141h
				74.5371N
				90.8078W
240	1	1339		160 – Aug 15
190	3	1341		TM rosette
150	5	1343		0418h
75	7	1345	**CAA6**	74.75433N
Chlmax	10	1348		97.4575W
10	11	1349		
190m	1	1409		168 – Aug 15
				TM rosette
				2245h
160m	3	1411		73.67288N
120m	4	1412	**CAA7**	96.5238W
75m	7	1415		
Chlmax	10	1418		
10m	11	1419		

LL=1	7	491		0104h	
Chlmax	9	493		71.40748N	
15m	10	494		68.5991W	
10m	12	496			

Table 5.1.2.2 List of samples for speciation

Depth	Goflo	Sample	Station	Event info (UTC)
1000m	2	199	**LS2**	18 – July 13 TM rosette, 1525h 60.4534N, 56.5506W
500m	8	318	**BB1**	34 – Aug 3 TM rosette, 0343h 66.85768N, 59.0632W
50m	6	382		40 – Aug 3 TM rosette, 1240h 66.85778N, 59.0716W
10m	11	387		
50m	10	546	**BB2**	69 – Aug 7 TM rosette, 0440h 72.7495N, 66.9867W
10m	12	548		
1000m	3	605		74 – Aug 7 TM rosette, 2208h 72.74973N, 66.9885W
50m	6	490	**BB3**	57 – Aug 6 TM rosette, 0104h 71.40748N, 68.5991W
10m	11	495		
43m	4	711	**CAA1**	92 – Aug 9 TM rosette, 1920h 74.52142N, 80.5621W
10m	12	719		
40m	10	877	**CAA2**	108 – Aug 10 TM rosette, 1904h 74.31532N, 80.4993W
10m	12	879		
40m	5	986	**CAA3**	117 – Aug 11 TM rosette, 0907h 73.80933N, 80.4112W
15m (4)	10	991		
10m	12	993		
40m	8	1247	**CAA4**	149 – Aug 14 TM rosette, 0157h 74.1223N, 91.5109W
Chlmax	9	1248		
10m	12	1251		
40m	4	1142	**CAA5**	136 – Aug 13 TM rosette, 0141h 74.5371N, 90.8078W
10m	12	1148		
75m	8	1346	**CAA6**	160 – Aug 15 TM rosette, 0418h 74.75433N, 97.4575W
Chlmax	9	1347		
10m	12	1350		
75m	6	1414	**CAA7**	168 – Aug 15 TM rosette, 2245h

Chlmax	9	1417		73.67288N, 96.5238W
Chlmax	10	1418		
10m	12	1420		

5.1.3 Sampling operations for mercury

Principal Investigator: Feiyue Wang
Cruise Participants: Kathleen Munson, Kang Wang[5], Wen Xu

[5]*Department of Environment and Geography, University of Manitoba*

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) remineralization.

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 (except LS2) along the route of Amundsen during Leg2 (Table 5.1.3.1). 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 the Station of K1 and BB2. In Station of BB2, extra samples of Hg_T and MeHg are collected for inter-calibration.

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 2.

Station	**Location**	**Coordinates**	**Bottom Depth**	**Samples Collected**
K1	Labrador Sea			Hg_T, Hg_P, MeHg
BB1	Baffin Bay			Hg_T, MeHg
BB3	Baffin Bay			Hg_T, MeHg
BB2	Baffin Bay			Hg_T, Hg_P, MeHg inter-calibration
CAA1	NorthWest Passage			Hg_T, MeHg
CAA2	NorthWest Passage			Hg_T, MeHg
CAA3	NorthWest Passage			Hg_T, MeHg
CAA5	NorthWest Passage			Hg_T, MeHg
CAA4	NorthWest Passage			Hg_T, MeHg
CAA6	NorthWest Passage			Hg_T, MeHg
CAA7	NorthWest Passage			Hg_T, MeHg

Preliminary results.
With most of Hg_T and MeHg data in process, the distribution of Hg_T in Station K1 is presented in Figure 5.1.3.1. The average Hg_T concentration in this station is 0.67 ± 0.14 pM, comparable with the recent published data in North Atlantic Ocean (Bowman, et al., 2014). The low Hg_T in surface water might be resulted from particle scavenging, while the increasing concentrations in deep water are probably reflecting the release of Hg during remineralization.

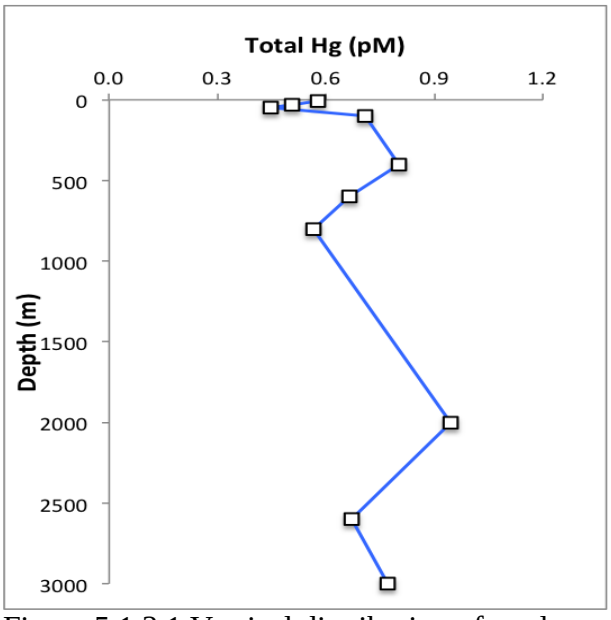

Figure 5.1.3.1 Vertical distribution of total mercury in Station K1.

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 2 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.

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 1.2 ng m^{-3} during Leg 2.

Concentrations of RGM and HgP are much lower.

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.).
2. Dissatisfied ✓
Comments: Although we appreciate the effort of the chief scientist and ship captain to maximize our scientific operations given the assignment of icebreaking duties, we were dissatisfied with the diversion from our planned scientific plan in order to escort commercial vessels.

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 and electrical departments to help install the stand needed for our sampling unit as well as help repairing water damage to our outdoor sampling units.

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?

3. Neutral ✓
Comments: Because the atmospheric sampling was continuous throughout the cruise, we were able to collect atmospheric data during the diversion in the Hudson Bay. As a result, the atmospheric sampling was not hindered to the extent that our seawater sampling was during the icebreaking diversion.

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

Principal Investigators: Roger Francois[1], Chris Holmden[2]
Cruise participants: Mélanie Grenier[1]

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Introduction and objectives
Climate-driven alterations of the Arctic Ocean (sea ice cover, hydrography, circulation) strongly influence biological productivity, ecosystem structure, air-sea exchange of climate-active gases, and the distribution of contaminants. At present, our ability to evaluate the full impact of these 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 scientific expedition, Leg 2, and the upcoming Leg 3b), US, Germany and France to generate a quasi-synoptic database of biogeochemical tracers of circulation, ecosystem structure and productivity, and sea ice state.

Fully integrated in the Canadian program, M. Grenier's research project focuses on measuring trace elements (Rare Earth Elements; REE) and isotopes (ε_{Nd}, ^{230}Th and ^{231}Pa) in seawater, powerful tracers of processes impacted by climate change in the Arctic: the ocean circulation and land/ocean chemical exchanges. These trace elements and isotopes (TEIs) are core parameters defined in the GEOTRACES science plan. Seawater acquires its Nd isotopic composition from continental sources, resulting in distinct isotopic signatures in the North Pacific and North Atlantic. The dominance of old cratons in surrounding land masses imparts a very negative ("non-radiogenic") ε_{Nd} to the seawater of Baffin Bay and the Labrador Sea[1,2,3]. Contrastingly, Pacific water has a less negative ("more radiogenic") ε_{Nd}, acquired from the young volcanic rock formations surrounding this ocean. "Boundary Exchange" (BE), i.e. the exchange of chemical elements between margin sediments and seawater, was first identified with Nd isotopes[4]. The apparent ubiquity of BE suggests that it might add to seawater more essential bioactive metals (e.g. Mo, Fe, Cu, Zn) than what has been estimated so far[5,6,7,8]. Lacan and Jeandel demonstrated

[1] Stordal, M.C., and G.J. Wasserburg, *Earth and Planetary Science Letters*, **77**, 259 (Jan, 1986).
[2] Lacan, F., and C. Jeandel, *Geophysical Research Letters* **31**, L14306 (Jul, 2004).
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[5] Radic, A., F. Lacan, and J. W. Murray, *Earth and Planetary Science Letters* **306**, 1 (Apr, 2011).
[6] Slemons, L., B. Paul, J. Resing, and J.W. Murray, *Marine Chemistry* **142-144**, 54 (Sep, 2012).
[7] Grenier, M., et al., *Journal of Geophysical Research* **118**(2), 592 (Jan, 2013).

that Nd isotopes are particularly effective in tracing this process. In the Arctic, this approach will be particularly powerful because "radiogenic" water from the Pacific is coming into contact with margins that are very "unradiogenic", providing an ideal setting to evaluate the extent of this process. ε_{Nd} will also help identify Pacific Water as it transits through the Arctic, particularly through the CAA[9].

There are 14 naturally occurring REEs that fractionate slightly from each other in physical and chemical transformations due to small differences in ionic radius. The resulting changes in REE "patterns" provide a powerful tool for investigating environmental processes[10,11]. While ε_{Nd} reveals the source of water masses and exchanges in the water column, the REE patterns provide complementary constraints on the processes (e.g., scavenging, lithogenic sources) that govern isotope exchanges. Thus, a likely outcome of this project will be the quantification of exchange of trace elements between waters and shelf sediments, with implications for biological productivity and contaminant dispersion.

The main purpose of ^{230}Th and ^{231}Pa measurements is to further develop these naturally occurring long-lived radioisotopes as tracers of deep and intermediate water circulation in Canada Basin, Baffin Bay and the Labrador Sea[12,13]. After formation in seawater by α-decay of uranium, they are rapidly removed by adsorption on the surface of settling particles, a process called "scavenging"[14,15,16]. ^{230}Th is more particle-reactive and has a mean residence time shorter (ca. 40 yr) than ^{231}Pa (ca. 200 yr). Consequently, ^{231}Pa is transported by ocean circulation over longer distance than ^{230}Th, which results in systematic variations in the ^{231}Pa/^{230}Th activity ratio in seawater in relation to water mass movement or mixing[17,18]. In the water column, large changes in ^{230}Th profiles were found in the Canada Basin between 1995 and 2009[19,20], consistent with evidence for a recent circulation reversal of Atlantic Water in Canada Basin[21]. In the Labrador Sea, a significant increase in dissolved ^{230}Th concentration between 1993 and 1999 was attributed to a reduction in deep winter convection[22]. In the present study, ^{230}Th and ^{231}Pa will be combined with hydrographic data and complementary tracers of circulation (^{129}I, ^{236}U) and water masses (ε_{Nd}, N*, Cr isotopes), in combination with numerical modelling, to further constrain changes in Atlantic Water circulation in the Canada Basin.

Operations conducted during the Leg / Methodology

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During the Leg 2, seawater samples were collected at all stations for the measurement of the REE concentration and ε_{Nd}, while for ^{230}Th and ^{231}Pa measurement, seawater samples were only collected at the deep stations in the Labrador Sea and Baffin Bay. Aliquots (~3-4 L) from samples dedicated to ε_{Nd} measurements were also taken for the analysis of Cr isotopes, conducted by Isabelle Baconnais, PhD student at the University of Saskatchewan. She will be in charge of the operations related to these trace elements and isotopes (REE, ε_{Nd}, ^{230}Th, ^{231}Pa, and Cr isotopes) during the Leg 3b.

The Canadian section done during this Leg is connected to the French GEOVIDE section by a common cross-over intercalibration station in the Labrador Sea (station K1). Depth replicates were also collected at several stations for intercalibration of the measurement of ^{230}Th and ^{231}Pa with Prof. Gideon Henderson (Department of Earth Sciences, University of Oxford, Oxford, United Kingdom) and of the measurement of ε_{Nd} and REE concentration with Dr. Catherine Jeandel (LEGOS, Toulouse, France).

Seawater samples were collected from the Amundsen rosette (see casts labelled AN# or AM# in Table 5.1.4.1), except the deepest ones that required a longer cable and were collected from the trace metal (TM) rosette provided by the University of Victoria (PI: Jay Cullen; see casts labelled TM# in Table 5.1.4.1). Each seawater sample comes from 2 different Niskin bottles (or Go-Flo bottles when collected from the TM rosette) closed simultaneously at targeted depths.

The samples were collected in acid-cleaned 20 L jerricans (preconditioned with 3 sample rinses) and brought back to the on-board lab. Each sample was filtered through a unique filter cartridge AquaPrep® mounted on an acid-cleaned tubing system connected to a peristaltic pump. Filtered seawater was first collected into a 1 L acid-cleaned Nalgene® bottle for REE concentration measurement, then into a 20 L acid-cleaned cubitainer. At the end of the filtration, an aliquot of 3-4 L of filtered seawater was transferred from the 20 L cubitainer into a 5 L acid-cleaned cubitainer dedicated to the measurement of Cr isotopes, acidified with ~4-5 mL of concentrated HCl seastar and stored into Isabelle's coolers. The 1 L Nalgene® bottle samples were acidified with 2.5-3.5 mL of 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) and stored into R. Francois's team (UBC Vancouver) coolers. All the containers (cubitainers and 1 L Nalgene® bottle) were preconditioned with 3 sample rinses.

The measurement of ^{230}Th and ^{231}Pa concentrations is done by isotopic dilution method. Thus, for the samples dedicated to the measurement of REE, Pa and Th, the 20 L cubitainers were accurately weighed before the adding of the spike solution. This solution is a mixture of 0.5 mL of ^{233}Pa at ~ 0.4788 pmol g^{-1}, 0.2 mL of ^{229}Th at ~ 1.5 dpm, and 2 mL of $Fecl_3$ at ~ 50 mg mL^{-1}. This mixture was prepared in 70 15 mL test tubes just before the cruise. To facilitate the transport of this solution and avoid to lose some of it, as isotopic dilution requires to be quantitative, few mL of concentrated NH_4OH were added to the mixture to co-precipitate iron; the co-precipitate was centrifuged and the NH_4OH supernatant discarded. On-board, the precipitate was redissolved with ~ 10 mL of 6N HCl EG. Once the redissolved solution poured into the sample, the 15 mL test tube was rinsed 3 times with ~ 10 mL of 6N HCl EG to ensure a complete transfer of the spikes into the sample. Thus, in total ~ 40 mL of 6N HCl EG were

added to the sample to acidify it to pH ~ 2. Samples were then stored during ~ 24 h to allow homogenisation of the spikes and Fe. Then, the pH was raised to 8 with ~ 25 mL of concentrated NH_4OH to engage the co-precipitation. After 36 to 48 h of settling, a maximum of the supernatant was drained and the remaining "seawater + co-precipitate" was poured into a 1 L acid-cleaned transparent bottle (Figure 5.1.4.1). The cubitainer was rinsed once at least with milli-Q® water coming from the on-board Arctic Net system and the 1 L bottle was stored for settling (Figure 5.1.4.2). After 10 to 24 h, similarly, a maximum of the supernatant was drained and the remaining "seawater + co-precipitate" was poured into a 50 mL acid-cleaned graduated test tube. The 1 L bottle was rinsed with milli-Q® water and the sample was eventually centrifuged and, after removal of the supernatant, stored.

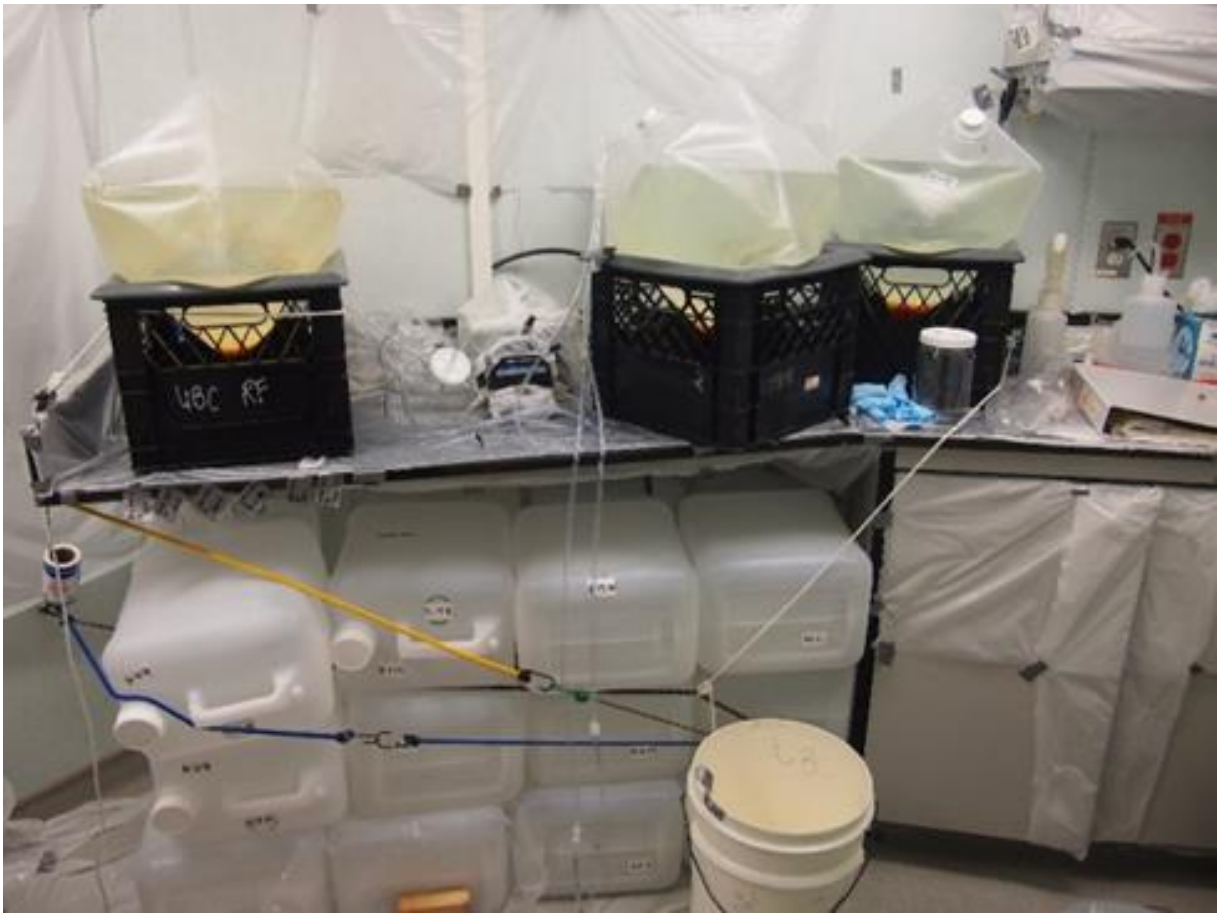

Figure 5.1.4.1: Arrangement of the on-board lab bench area. Ropes hold the 20 L jerricans below the bench. On the bench, 3 samples stand in milkcrates for settling of the iron co-precipitate, in the 20 L cubitainers;

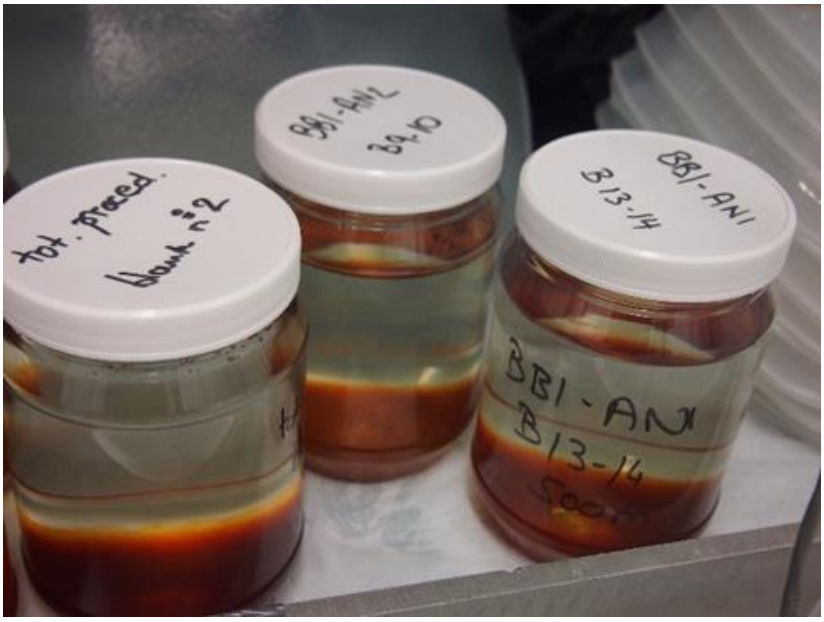

Fig. 1.5.4.2 Second settling, after transfer of the remaining "seawater + co-precipitate" from the 20 L cubitainers in the 1 L bottles.

A similar methodology was followed for samples collected for the REE concentration and ε_{Nd} measurement only, except that samples were not weighed accurately and that only $FeCl_3$ (2 mL for a 20 L sample) was added after the acidification of the sample at pH = 2.

Samples collected for intercalibration of ^{230}Th and ^{231}Pa measurements (with G. Henderson, UK) were filtered into a 10 L jerrican, following the method described above, acidified with 25 mL of 6 N HCl EG, and stored into G. Henderson's plastic boxes. Samples collected for intercalibration of ε_{Nd} measurements (with C. Jeandel, France; ~ 10 L) were filtered into the 20 L cubitainers, following the method described above and acidified with 25 mL of 6 N HCl EG to pH = 2 while waiting for pre-concentration. Before the pre-concentration procedure on C18 SepPak cartridges loaded with a REE complexant (HDEHP/H2MEHP)[23], pH was raised to 3.7 with ~ 12 mL of concentrated NH_4OH. Then, each of the 5 samples collected for this intercalibration were pre-concentrated on 2 C18 cartridges using 2 tubing systems and the peristaltic pump at a flow rate of 20 mL min^{-1}. The 2 cartridges were then disconnected, wrapped into parafilm, labelled and stored into small plastic bags, ready to be sent back to LEGOS (Toulouse, France). 3 total procedural blanks were realised, at the beginning, in the middle and at the end of Leg 2b. They were processed exactly as a sample, except that they did not "see" the rosette. For each total procedural blank, a 20 L jerrican was 3 times rinsed and filled with the on-board milli-Q® water, then filtered following the methodology described above. The first 2 blanks were processed as samples dedicated to the measurement of REE, Pa and Th. Thus, a "spike + iron" solution was added after the filtration and weighing. The 3rd and last total procedural blank realised during this Leg was processed as a sample dedicated to the REE concentration and □$_{Nd}$ measurement only, so 2 mL of $FeCl_3$ only were added after acidification.

[23] Shabani et al., *Analytical Chemistry* **64**, 7 (Apr, 1992).

Concentration of ^{233}Pa spike:				0.47877 pmol/g						Check			
Concentration of ^{229}Th spike:				~ 1.5 dpm						Warning			
Volume of FeCl3 at ~50 mg/mL (made on Apr 28, 2015				2 mL (only 1 mL added for river						Lost/Problem			
				samples #7 to #14, because smaller									
				volumes -less than 10 L- and also to									
Date of sampling (mm/dd/yy) UTC	Longitude (°E)	Latitude (°N)	Station-cast	Sample ID	Filtered?	REE aliquot (1L)	Spike test tube #	wt of the sample	wt of ^{233}Pa (in g)	wt of ^{229}Th (in g)	Cr aliquot (~3-4L		Remarks
LEG 2b (July 10, 2015 - August 20, 2015)													
July 10, 2015	-	-	-	Total procedural blank 1	YES	YES	1	18670	0.5661	0.2005	NO		
July 13, 2015	-53.5422	56.1750	K1-TM4	B1-2 m	YES	YES	2	11530	0.5671	0.1947	YES		
July 13, 2015	-53.5422	56.1750	K1-TM4	B4-5 m	YES	YES	3	16690	0.5667	0.195	YES		
July 13, 2015	-53.5422	56.1750	K1-TM4	B6-7 m	YES	YES	4	11120	0.5677	0.1987	YES		
July 13, 2015	-53.5422	56.1750	K1-TM4	B8-9 m	YES	YES	5	16910	0.5674	0.1955	YES		
July 13, 2015	-53.5422	56.1750	K1-TM4	B10-11 m	YES	YES	6	8320	0.5667	0.1969	YES but LOST		
July 14, 2015	-53.5786	56.1428	K1-TM3	B1-2 2000 m	YES	YES	7	11770	0.5661	0.1991	YES		
July 14, 2015	-53.4181	56.2964	K1-AN1	B17-18 150 m	YES	YES	8	18940	0.5634	0.1965	YES		
July 14, 2015	-53.4181	56.2964	K1-AN1	B23-24 10 m +/-	YES	YES	9	14920	0.5654	0.1961	YES		
July 14, 2015	-53.6208	56.1183	K1-AN2	B1-2 1500 m	YES	YES	10	17320	0.567	0.1955	YES		
July 14, 2015	-53.6208	56.1183	K1-AN2	B3-4 1500 m Intercalib	YES	YES		4600			NO		Intercalib Nd-C18 C Jeandel and PaTh G Henderson
July 14, 2015	-53.6208	56.1183	K1-AN2	B5-6 1000 m	YES	YES	11	17600	0.5686	0.1943	YES		
July 14, 2015	-53.6208	56.1183	K1-AN2	B7-8 1000 m Intercalib	YES	YES		8700			NO		Intercalib Nd-C18 C Jeandel and PaTh G Henderson
July 14, 2015	-53.6208	56.1183	K1-AN2	B9-10 700 m	YES	YES	12	17460	0.5667	0.1973	YES		
July 14, 2015	-53.6208	56.1183	K1-AN2	B12-13 500 m	YES	YES	13	18010	0.5675	0.1954	YES		
July 14, 2015	-53.6208	56.1183	K1-AN2	B14-15 500 m Intercalib	YES	YES		6670			NO		Intercalib Nd-C18 C Jeandel and PaTh G Henderson
July 14, 2015	-53.6208	56.1183	K1-AN2	B16-17 300 m	YES	YES	14	17910	0.5688	0.1975	YES		
July 14, 2015	-53.6208	56.1183	K1-AN2	B20-21 50 m	YES	YES	15	18060	0.5688	0.1965	YES		
July 14, 2015	-53.4500	56.1919	K1-AN3	B13-14 200 m	YES	YES		18880			YES	13510	Nd only
July 14, 2015	-53.4500	56.1919	K1-AN3	B15-16 100 m	YES	YES		18730			YES	5370	Nd only
July 17, 2015	-56.7119	60.7000	LS2-TM4	B2-3 2400 m	YES	YES	16	13150	0.5669	0.1953	YES		
July 17, 2015	-56.7119	60.7000	LS2-TM4	B6-7 2000 m	YES	YES	17	12450	0.5668	0.1974	YES		
July 17, 2015	-56.7119	60.7000	LS2-TM4	B8 2000 m Intercalib	YES	NO		-			NO		Intercalib PaTh G Henderson
July 17, 2015	-56.5747	60.4894	LS2-TM3	B1 2800 m Cr	YES	NO		-			YES		Cr only
July 17, 2015	-56.5747	60.4894	LS2-TM3	B4 2600 m Cr	YES	NO		-			YES		Cr only
July 17, 2015	-56.5747	60.4894	LS2-TM3	B7 2400 m Cr	YES	NO		-			YES		Cr only
July 17, 2015	-56.5747	60.4894	LS2-TM3	B10 2000 m Cr	YES	NO		-			YES		Cr only
July 17, 2015	-56.5747	60.4894	LS2-TM3	B12 1400 m Cr	YES	NO		-			YES		Cr only
July 17, 2015	-56.5892	60.5931	LS2-AN1	B1-2 1500 m	YES	YES	18	14520	0.5674	0.1966	YES		
July 17, 2015	-56.5892	60.5931	LS2-AN1	B8-9 1000 m	YES	YES	19	13900	0.5679	0.1955	YES		
July 18, 2015	-56.5842	60.5194	LS2-AN2	B1-2 700 m	YES	YES	20	14610	0.5671	0.1958	YES		
July 18, 2015	-56.5842	60.5194	LS2-AN2	B5-6 500 m	YES	YES	21	14960	0.5697	0.1965	YES		
July 18, 2015	-56.5842	60.5194	LS2-AN2	B9-10 300 m	YES	YES	22	14960	0.58	0.1966	YES		
July 18, 2015	-56.5842	60.5194	LS2-AN2	B11-12 100 m	YES	YES	23	14430	0.5667	0.1835	YES		
July 18, 2015	-56.5842	60.5194	LS2-AN2	B14-15 50m	YES	YES	24	14500	0.6778	0.1949	YES		
July 18, 2015	-56.5842	60.5194	LS2-AN2	B21-22 10 m +/-	YES	YES	25	13850	0.5659	0.1973	YES		
July 18, 2015	-56.8025	60.6856	LS2-TM5	B2-3 2800 m	YES	YES	26	15160	0.5679	0.1966	YES		
July 18, 2015	-56.8025	60.6856	LS2-TM5	B4 2800 m Intercalib	YES	NO					NO		Intercalib PaTh G Henderson
July 18, 2015	-56.8025	60.6856	LS2-TM5	B6-7 2600 m	YES	YES	27	15190	0.5684	0.1969	YES		
July 18, 2015	-56.8025	60.6856	LS2-TM5	B8 2600 m Intercalib	YES	NO					NO		Intercalib PaTh G Henderson
August 2, 2015			-	Total procedural blank #2	YES	YES	28	17390	0.5692	0.1965	YES		
August 3, 2015	-59.0666	66.8576	BB1-AN1	B2-3 1000 m	YES	YES	29	17250	0.5693	0.1962	YES		
August 3, 2015	-59.0666	66.8576	BB1-AN1	B6-7 800 m	YES	YES	30	16910	0.5679	0.1972	YES		
August 3, 2015	-59.0666	66.8576	BB1-AN1	B9-10 700 m	YES	YES	31	16470	0.5678	0.1962	YES		
August 3, 2015	-59.0666	66.8576	BB1-AN1	B13-14 500 m	YES	YES	32	16190	0.5906	0.1968	YES		
August 3, 2015	-59.0666	66.8576	BB1-AN1	B17-18 300 m	YES	YES	33	17700	0.567	0.1958	YES		
August 3, 2015	-59.0573	66.8555	BB1-AN2	B9-10 100 m	YES	YES	36	17290	0.5679	0.1965	YES		
August 3, 2015	-59.0573	66.8555	BB1-AN2	B14-15 50 m	YES	YES	35	17590	0.5664	0.1971	YES		
August 3, 2015	-59.0573	66.8555	BB1-AN2	B18-19 10 m	YES	YES	34	16710	0.5675	0.1961	YES		
August 5, 2015	-68.596	71.4091	BB3-AM1	B2-3 1000 m	YES	YES	37	14910	0.5676	0.196	YES		
August 5, 2015	-68.596	71.4091	BB3-AM1	B6-7 800 m	YES	YES	38	12940	0.5673	0.1955	YES		
August 5, 2015	-68.596	71.4091	BB3-AM1	B9-10 700 m	YES	YES	39	14570	0.5682	0.1956	YES		
August 5, 2015	-68.596	71.4091	BB3-AM1	B13-14 500 m	YES	YES	40	16730	0.5685	0.1963	YES		
August 5, 2015	-68.596	71.4091	BB3-AM1	B17-18 300 m - a	YES	YES	41	17360	0.5663	0.1965	YES		
August 5, 2015	-68.6034	71.4109	BB3-AM2	B9-10 100 m	YES	YES	42	17680	0.5677	0.1981	YES		
August 5, 2015	-68.6034	71.4109	BB3-AM2	B14-15 50 m	YES	YES	43	17730	0.5663	0.1869	YES		
August 5, 2015	-68.6034	71.4109	BB3-AM2	B18-19 10 m	YES	YES	44	18520	0.568	0.1954	YES		
August 7, 2015	-66.9933	72.7537	BB2-AM1	B1-2 1500 m	YES	YES	45	16490	0.5678	0.1968	YES		
August 7, 2015	-66.9933	72.7537	BB2-AM1	B7-8 1000 m	YES	YES	46	15700	0.568	0.1965	YES		
August 7, 2015	-66.9933	72.7537	BB2-AM1	B16-17 200 m - a	YES	YES	47	16270	0.5657	0.1965	YES		
August 7, 2015	-67.0218	72.7494	BB2-AM2	B2-3 600 m	YES	YES	49	16930	0.5702	0.1998	YES		
August 7, 2015	-67.0218	72.7494	BB2-AM2	B5-6 400 m	YES	YES	48	16310	0.5803	0.1964	YES		
August 8, 2015	-67.0218	72.7494	BB2-AM2	B7-8 300 m	YES	YES	50	16480	0.5687	0.2009	YES		
August 8, 2015	-67.0218	72.7494	BB2-AM2	B11-12 100 m - a	YES	YES	51	15800	0.5702	0.201	YES		
August 8, 2015			BB2-TM5	B2 2250 m	YES	YES	52	8390	0.5684	0.2	NO		
August 8, 2015			BB2-TM5	B5-6 2100 m	YES	YES	53	17160	0.5678	0.2009	YES		
August 8, 2015			BB2-TM5	B8-9 1900 m	YES	YES	54	15790	0.5666	0.2009	YES		
August 8, 2015	-66.9998	72.7507	BB2-AM4	B1-2 300 m - b	YES	YES	55	16440	0.5669	0.2006	YES		
August 8, 2015	-66.9998	72.7507	BB2-AM4	B3-4 200 m - b	YES	YES	56	16050	0.5664	0.2001	YES		
August 8, 2015	-66.9998	72.7507	BB2-AM4	B5-6 100 m - b	YES	YES	57	14950	0.5665	0.2006	YES		
August 8, 2015	-66.9998	72.7507	BB2-AM4	B7-8 50 m Intercalib	YES	YES		14730			YES		Intercalib Nd-C18 C Jeandel
August 8, 2015	-66.9998	72.7507	BB2-AM4	B9-10 50 m	YES	YES		17020			YES		Nd only
August 8, 2015	-66.9998	72.7507	BB2-AM4	B11-12 10 m Intercalib	YES	YES		15490			YES		Intercalib Nd-C18 C Jeandel
August 8, 2015	-66.9998	72.7507	BB2-AM4	B13-14 10 m	YES	YES		15990			YES		Nd only
August 10, 2015	-80.564	74.5222	CAA1-AM1	B1-2 600 m	YES	YES		17480			YES		
August 10, 2015	-80.564	74.5222	CAA1-AM1	B5-6 400 m	YES	YES		15200			YES		
August 10, 2015	-80.564	74.5222	CAA1-AM1	B11-12 200 m	YES	YES		16200			YES		
August 10, 2015	-80.5679	74.5210	CAA1-AM2	B4-5 100 m	YES	YES		17500			YES		
August 10, 2015	-80.5679	74.5210	CAA1-AM2	B15-16 scm (max chloro	YES	YES		17400			YES		
August 10, 2015	-80.5679	74.5210	CAA1-AM2	B22-23 10 m +/-	YES	YES		17900			YES		
August 10, 2015	-80.4973	74.3159	CAA2-AM2	B4-5 100 m	YES	YES		16500			YES		
August 10, 2015	-80.4973	74.3159	CAA2-AM2	B15-16 scm (max chloro	YES	YES		16400			YES		
August 10, 2015	-80.4973	74.3159	CAA2-AM2	B22-23 10 m +/-	YES	YES		17700			YES		
August 10, 2015	-80.5199	74.3143	CAA2-AM1	B1-2 600 m	YES	YES		17300			YES		
August 10, 2015	-80.5199	74.3143	CAA2-AM1	B5-6 400 m	YES	YES		17800			YES		
August 10, 2015	-80.5199	74.3143	CAA2-AM1	B11-12 200 m	YES	YES		17800			YES		
August 11, 2015	-80.4923	73.8186	CAA3-AM2	B4-5 100 m	YES	YES		16300			YES		
August 11, 2015	-80.4923	73.8186	CAA3-AM2	B13-14 scm (max chloro	YES	YES		16800			YES		
August 11, 2015	-80.4923	73.8186	CAA3-AM2	B20-21 10 m +/-	YES	YES		15200			YES		
August 11, 2015	-80.4894	73.8187	CAA3-AM1	B1-2 600 m	YES	YES		17100			YES		
August 11, 2015	-80.4894	73.8187	CAA3-AM1	B5-6 400 m	YES	YES		16400			YES		
August 11, 2015	-80.4894	73.8187	CAA3-AM1	B11-12 200 m	YES	YES		16500			YES		
			River sample	#1	YES	YES		5100			YES		
			River sample	#2	YES	YES		6700			YES		
			River sample	#4	YES	YES		7900			YES		
			River sample	#5	YES	YES		6600			YES		
			River sample	#6	YES	YES		7900			YES		
August 12, 2015	-90.8018	74.5375	CAA5-AM1	B1-2 250 m	YES	YES		16600			YES		

August 10, 2015	-80.564	74.5222	CAA1-AM1	B1-2 600 m	YES	YES	17480			YES		
August 10, 2015	-80.564	74.5222	CAA1-AM1	B5-6 400 m	YES	YES	15200			YES		
August 10, 2015	-80.564	74.5222	CAA1-AM1	B11-12 200 m	YES	YES	16200			YES		
August 10, 2015	-80.5679	74.5210	CAA1-AM2	B4-5 100 m	YES	YES	17500			YES		
August 10, 2015	-80.5679	74.5210	CAA1-AM2	B15-16 scm (max chloro	YES	YES	17400			YES		
August 10, 2015	-80.5679	74.5210	CAA1-AM2	B22-23 10 m +/-	YES	YES	17900			YES		
August 10, 2015	-80.4973	74.3159	CAA2-AM2	B4-5 100 m	YES	YES	16500			YES		
August 10, 2015	-80.4973	74.3159	CAA2-AM2	B15-16 scm (max chloro	YES	YES	16400			YES		
August 10, 2015	-80.4973	74.3159	CAA2-AM2	B22-23 10 m +/-	YES	YES	17700			YES		
August 10, 2015	-80.5199	74.3143	CAA2-AM1	B1-2 600 m	YES	YES	17300			YES		
August 10, 2015	-80.5199	74.3143	CAA2-AM1	B5-6 400 m	YES	YES	17800			YES		
August 10, 2015	-80.5199	74.3143	CAA2-AM1	B11-12 200 m	YES	YES	17800			YES		
August 11, 2015	-80.4923	73.8186	CAA3-AM2	B4-5 100 m	YES	YES	16300			YES		
August 11, 2015	-80.4923	73.8186	CAA3-AM2	B13-14 scm (max chloro	YES	YES	16800			YES		
August 11, 2015	-80.4923	73.8186	CAA3-AM2	B20-21 10 m +/-	YES	YES	15200			YES		
August 11, 2015	-80.4894	73.8187	CAA3-AM1	B1-2 600 m	YES	YES	17100			YES		
August 11, 2015	-80.4894	73.8187	CAA3-AM1	B5-6 400 m	YES	YES	16400			YES		
August 11, 2015	-80.4894	73.8187	CAA3-AM1	B11-12 200 m	YES	YES	16500			YES		
			River sample	#1	YES	YES	5100			YES		
			River sample	#2	YES	YES	6700			YES		
			River sample	#4	YES	YES	7900			YES		
			River sample	#5	YES	YES	6600			YES		
			River sample	#6	YES	YES	7900			YES		
August 12, 2015	-90.8018	74.5375	CAA5-AM1	B1-2 250 m	YES	YES	16600			YES		
August 12, 2015	-90.8018	74.5375	CAA5-AM1	B5-6 220 m	YES	YES	15600			YES		
August 12, 2015	-90.8018	74.5375	CAA5-AM1	B11-12 160 m	YES	YES	15700			YES		
August 13, 2015	-90.8064	74.5387	CAA5-AM2	B4-5 100 m	YES	YES	15300			YES		
August 13, 2015	-90.8064	74.5387	CAA5-AM2	B14-15 scm (max chloro	YES	YES	15200			YES		
August 13, 2015	-90.8064	74.5387	CAA5-AM2	B21-22 10 m +/-	YES	YES	15100			YES		CAA stations, river samples and total procedural blank #3 dedicated to the measurement of REE & ε_{Nd} only (and Cr isotopes, but not for Pa/Th)
			River sample	#7	YES	YES	8000			YES		
			River sample	#8	YES	YES	8200			YES		
August 14, 2015	-91.5118	74.1210	CAA4-AM1	B1-2 150 m	YES	YES	5600			YES		
August 14, 2015	-91.5118	74.1210	CAA4-AM1	B7-8 120 m	YES	YES	16900			YES		
August 14, 2015	-91.5118	74.1210	CAA4-AM1	B15-16 60 m	YES	YES	17400			YES		
August 14, 2015	-91.4933	74.1250	CAA4-AM2	B6-7 80 m	YES	YES	16000			YES		
August 14, 2015	-91.4933	74.1250	CAA4-AM2	B14-15 30 m	YES	YES	16600			YES		
August 14, 2015	-91.4933	74.1250	CAA4-AM2	B21-22 10 m	YES	YES	15800			YES		
			River sample	#9	YES	YES	6800			YES		
August 15, 2015	-97.4522	74.7596	CAA6-AM1	B1-2 250 m	YES	YES	17000			YES		
August 15, 2015	-97.4522	74.7596	CAA6-AM1	B5-6 220 m	YES	YES	16600			YES		
August 15, 2015	-97.4522	74.7596	CAA6-AM1	B11-12 160 m	YES	YES	17000			YES		
August 15, 2015	-97.4575	74.7543	CAA6-AM2	B4-5 100 m	YES	YES	15800			YES		
August 15, 2015	-97.4575	74.7543	CAA6-AM2	B14-15 scm (max chloro	YES	YES	17000			YES		
August 15, 2015	-97.4575	74.7543	CAA6-AM2	B21-22 10 m +/-	YES	YES	15300			YES		
August 15, 2015	-96.5238	73.6729	CAA7-AM1	B3-4 190 m	YES	YES	16100			YES		
August 15, 2015	-96.5238	73.6729	CAA7-AM1	B7-8 160 m	YES	YES	17100			YES		
August 15, 2015	-96.5238	73.6729	CAA7-AM1	B19-20 60 m	YES	YES	16000			YES		
August 16, 2015	-96.5362	73.6639	CAA7-AM2	B4-5 100 m	YES	YES	16300			YES		
August 16, 2015	-96.5362	73.6639	CAA7-AM2	B14-15 scm (max chloro	YES	YES	16500			YES		
August 16, 2015	-96.5362	73.6639	CAA7-AM2	B21-22 10 m +/-	YES	YES	14000			YES		
			-	Total procedural blank #3	YES	YES	15600			YES		
			River sample	#10	YES	YES	7700			YES		
			River sample	#11	YES	YES	7700			YES		
			River sample	#12	YES	YES	7100			YES		
August 17, 2015	-100.697	69.1662	AN312-AM1	B1-3 49 m	YES	YES	12100			YES		
August 17, 2015	-100.697	69.1662	AN312-AM1	B8-9 20 m	YES	YES	17800			YES		
August 17, 2015	-100.697	69.1662	AN312-AM1	B14-15 10 m	YES	YES	18400			YES		
			River sample	#13	YES	YES	7900			YES		
			River sample	#14	YES	YES	7300			YES		
				Spike solution blank #1			58		0.5662	0.2003		Spike solutions #58 to #64 dedicated to spike blanks
				Spike solution blank #2			59		0.5667	0.2001		
				Spike solution blank #3			60		0.5663	0.2002		
				Spike solution blank #4			61		0.5659	0.2004		
				Spike solution blank #5			62		0.5661	0.2002		
				Spike solution blank #6			63		0.5641	0.2004		
				Spike solution blank #7			64		0.5669	0.2002		

Table 5.1.4.1: Description of the samples collected during Leg 2. The date, coordinates, station-cast, and sample ID are given. It is also reported whether the sample was filtered, whether an aliquot was taken for REE measurement, what test tube was used for the Pa and Th isotopic dilution and the associated weight of the 2 spikes (^{233}Pa and ^{229}Th), whether an aliquot was taken for Cr isotope measurement and any remark about the sample.

Preliminary results

Samples have not been entirely processed on-board. The last part of the analytical procedure (chromatographic columns) and the measurements will be done in the on-land lab, at UBC (Vancouver, Canada). Therefore, we do not have any preliminary results to present 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, even if the ship time allocated to the science program was drastically reduced (2 weeks) due to independent events (rescue of boats stuck in the ice in the Hudson Bay).

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. A special thank for the remarkable work of the captain and his crew, and for their kindness and devotion.

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, Cheng Kuang

[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)

Geotraces 2015 LEG 2 Large Volume In-Situ Pumps

STN	EVENT #	Target Depth	NiSkin # (LVP #)	Samp #	Nd-Pa-Th-Cr	Th234	Si isotopes	Comments	STN	EVENT #	Target Depth	NiSkin # (LVP #)	Samp #	Nd-Pa-Th-Cr	Th235	Si isotopes	Comments
LS2	17	700	1	192	x				BB2	72	400	1	573	x			
LS2	17	500	2	193	x				BB2	72	300	2	574	x			
LS2	17	300	3	194	x				BB2	72	200	3	575	x			
LS2	17	100	4	195	x	x			BB2	72	100	4	576	x	x		
LS2	17	50	5	196				filter missing	BB2	72	50	5	577	x			
LS2	17	10	6	197	x				BB2	72	10	6	578	x			
LS2	24	2800	1	263	x				BB2	75	2300	1	615	x			
LS2	24	2600	2	264	x				BB2	75	2100	2	616	x			
LS2	24	2400	3	265	x				BB2	75	1900	3	617	x			
LS2	24	2000	4	266				dead board	BB2	75	1500	4	618	x			
LS2	24	1500	5	267	x				BB2	75	1000	5	619	x			
LS2	24	1000	6	268	x				BB2	75	600	6	620	x			
LS2	27	2800	1	291				no sample	BB2	84	2300	1	700			x	
LS2	27	2500	2	292			x		BB2	84	1600	2	701			x	
LS2	27	1000	3	293			x		BB2	84	500	3	702			x	
LS2	27	300	4	294			x		BB2	84	200	4	703			x	
LS2	27	30	5	295			x		BB2	84	30	5	704			x	
LS2	27	10	6	296			x		BB2	84	10	6	705			x	
BB1	37	700	1	347	x				CAA1	93	10	1	720	x			
BB1	37	500	2	348	x				CAA1	93	30	2	721	x			
BB1	37	300	3	349	x				CAA1	93	100	3	722	x	x		
BB1	37	100	4	350	x	x			CAA1	93	200	4	723	x			
BB1	37	50	5	351	x				CAA1	93	400	5	724	x			
BB1	37	10	6	352	x				CAA1	93	600	6	725	x			
BB1	41	700	1	389			x		CAA1	97	10	1	764			x	
BB1	41	500	2	390			x		CAA1	97	30	2	765			x	
BB1	41	300	3	391			x		CAA1	97	100	3	766			x	
BB1	41	200	4	392			x		CAA1	97	200	4	767			x	
BB1	41	30	5	393			x		CAA1	97	400	5	768			x	
BB1	41	10	6	394			x		CAA1	97	600	6	769			x	
BB3	55	700	1	455	x				CAA2	110	600	1	904			x	
BB3	55	500	2	456	x				CAA2	110	400	2	905			x	
BB3	55	300	3	457	x				CAA2	110	200	3	906			x	
BB3	55	100	4	458	x	x			CAA2	110	100	4	907		x	x	
BB3	55	50	5	459	x				CAA2	110	30	5	908			x	
BB3	55	10	6	460	x				CAA2	110	10	6	909			x	
BB3	59	700	1	497			x		CAA3	120	10	1	1017	x			
BB3	59	500	2	498			x		CAA3	120	30	2	1018	x			
BB3	59	300	3	499			x		CAA3	120	100	3	1019	x	x		
BB3	59	200	4	500			x		CAA3	120	200	4	1020	x			
BB3	59	30	5	501			x		CAA3	120	400	5	1021	x			
BB3	59	10	6	502			x		CAA3	120	600	6	1022	x			
									CAA3	125	10	1	1061			x	
									CAA3	125	30	2	1062			x	
									CAA3	125	100	3	1063			x	
									CAA3	125	200	4	1064			x	
									CAA3	125	400	5	1065			x	
									CAA3	125	600	6	1066			x	
									CAA4	144	10	1	1183	x			
									CAA4	144	30	2	1184	x			
									CAA4	144	60	3	1185	x	x		
									CAA4	144	80	4	1186	x			
									CAA4	144	120	5	1187	x			
									CAA4	144	160	6	1188	x			
									CAA4	147	10	1	1210			x	
									CAA4	147	30	2	1211			x	
									CAA4	147	60	3	1212			x	
									CAA4	147	80	4	1213			x	
									CAA4	147	120	5	1214			x	
									CAA4	147	160	6	1215			x	
									CAA6	155	10	1	1279	x			
									CAA6	155	30	2	1280	x			
									CAA6	155	100	3	1281	x	x		
									CAA6	155	150	4	1282	x			
									CAA6	155	190	5	1283	x			
									CAA6	155	240	6	1284	x			
									CAA6	158	10	1	1309			x	
									CAA6	158	30	2	1310			x	
									CAA6	158	100	3	1311			x	
									CAA6	158	150	4	1312			x	
									CAA6	158	190	5	1313			x	
									CAA6	158	240	6	1314			x	
									CAA7	166	10	1	1379	x			
									CAA7	166	30	2	1380	x			
									CAA7	166	60	3	1381	x			
									CAA7	166	100	4	1382	x	x		
									CAA7	166	160	5	1383	x			
									CAA7	166	190	6	1384	x			
									CAA7	169	10	1	1421			x	
									CAA7	169	30	2	1422			x	
									CAA7	169	60	3	1423			x	
									CAA7	169	100	4	1424			x	
									CAA7	169	160	5	1425			x	
									CAA7	169	190	6	1426			x	

5.1.6 Anthropogenic Iodine in the Arctic Ocean

Principle Investigator: Jack Cornett

Department of Earth Sciences, University of Ottawa

Background / summary
Measurements of ^{129}I provide evidence for Atlantic-origin water labeled by discharges from European reprocessing plants and 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).

Sampling/Methodology
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.

5.1.7 Natural distribution of stable N and O isotopes in nitrate

Principal Investigator: Markus Kienast
Cruise Participants: Nadine Lehmann

Department of Oceanography, Dalhousie University

Introduction and objectives
The nitrogen cycle has a central role in marine biocheochemistry. Nitrogen is not only a limiting factor for biological productivity, but also has a strong influence on the cycling of other elements, such as carbon and phosphorus. One way to study nitrogen transformation is by determining the nitrogen and oxygen isotopic composition of nitrate. $\delta^{15}N$ of nitrate is mainly controlled by N2 fixation and denitrification. The internal cycling of nitrogen (i.e. ammonification, nitrification, and NO3- assimilation), on the other hand, only shows little effect on nitrate $\delta^{15}N$. Those internal processes, however, strongly affect the ratio of $^{18}O/^{16}O$ in nitrate. The $\delta^{15}N$ and $\delta^{18}O$ signatures of dissolved nitrate do not only give you insights into biogeochemical cycling but further allow you to track water masses. Water masses carry a distinct isotopic signature depending on their provenance, their circulation pattern and the transformations of oceanic fixed N occurring along their pathway. Next to salinity and temperature measurements, this isotopic signature provides a tool that allows the identification of a distinct body of water. Therefore, coupled N/O isotope measurements, on the one hand, give you information about the marine nitrogen cycle and help you distinguishing between N-cycling processes that might overlap each other and, on the other hand, can be used to elucidate the origin and history of water masses.

The Arctic Ocean plays an important role in the global oceanic nitrogen cycle. Water with a low N:P ratio enters this ocean basin from the Pacific, transits through the Bering Strait and the Beaufort Sea and eventually flows into the North Atlantic Ocean. How those waters are modified in terms of their N and O isotopic signature as they pass the Arctic throughflow has yet to be explored. The goal of our group is to analyze and interpret depth profiles of nitrate $\delta^{15}N$ and $\delta^{18}O$

along the transect. Those $^{15}N/^{14}N$ and $^{18}O/^{16}O$ measurements will help identifying the main water masses along the transect. They will also be used to characterize the geochemical modifications and the cycling of nitrogen within those waters as they move through the Canadian Archipelago into the Labrador Sea.

Methodology
Seawater samples for analyses of stable nitrogen and oxygen isotopes in nitrate, nitrite and nitrous oxide were obtained as outlined in table 5.1.7.1. Samples for nitrate and nitrite analyses from below 200m depth were collected unfiltered in 60mL square Nalgene bottles. Samples from the upper 200m were filtered through a 25mm diameter 0.45µm filter and collected in 60mL Nalgene bottles. Aliquots for $\delta^{15}N/\delta^{18}O$ in nitrate were stored immediately at -20 ºC. Samples for $\delta^{15}N/\ \delta^{18}O$-nitrite were analyzed in terms of NO2- concentration using Griess reagents and measurements of absorbance at 540 nm. Nitrite concentrations at all stations were below the limit for further analyses. Stable isotope analyses will be conducted at the Granger lab in Connecticut.

User Experience
a) very satisfied
b) satisfied
c) very satisfied
d) very satisfied
e) very satisfied

Table 5.1.7.1: List of water samples taken for stable nitrogen isotopes during leg 2 of the Canadian GEOTRACES expedition

Station	Event	$^{15}N/^{18}O$ of NO_3^-	$^{15}N/^{18}O$ of NO_2^-	$^{15}N/^{18}O$ of N_2O
K1	1	x		
	3	x		
	6	x	x	x
LS2	14	x		
	21	x	x	
	28	x		
BB1		x	x	x
BB3	53	x	x	x
BB2	71	x	x	x
CAA1	94	x	x	x
CAA2	109	x	x	x
CAA3	124	x	x	x
CAA4		x	x	x
CAA5	131	x	x	x
CAA6		x	x	x
CAA7		x	x	x
AN312	179	x		
AN314		x		

5.1.8 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, δ^{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 A) 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.

Intercalibration samples for pH, alkalinity, C13 and O18 were collected at station K2. pH, alkalinity and C13 samples were poisoned with Mercuric chloride; O18 didn't undergo any treatment. pH and alkalinity samples were stored in the refrigerated container until the return of the ship to Quebec City.

Recommendations

As the sampling was intense due to the loss of two weeks of work, alkalinity titrations had to be conducted until the last minute before the next sampling in order to avoid building a back log in the analyses. We had to interrupt the analysis and go to the rosette area several times to see what was going on, or, phone the people in the rosette control room. Therefore, we recommend the installation of a tv screen in the aft labs so the people can know when the rosette is getting out of

the water so we can avoid to lose time by going up stairs several times while the rosette is still in the water and avoid disturbing those who work in the rosette control room by calling them.

Station	Position		Depths sampled (m)
	Lat(N)	Lon(W)	
K1	60 ^{o} 27.218	056 ^{o} 32.884	1600, 1500, 1400, 1200, 1000, 800, 700, 600, 500, 400, 300, 200, 150, 100, 50, 30, 10
LS2	60 ^{o} 26.480	056 ^{o} 32.071	1500, 1400, 1200, 1000, 800, 700, 600, 500, 400, 300, 200, 150, 100, 50, 30, 10
BB1	66 ^{o} 51.502	059 ^{o} 4.450	1000, 800, 700, 600, 480, 300, 200, 150, 100, 50, 30, 10
BB2	72 ^{o} 45.396	066 ^{o} 59.470	2250, 2100, 1900, 1600, 1500, 1400, 1200, 1000, 800, 600, 500, 400, 300, 220, 100, 75, 71, 50, 25, 10, Surface
BB3	71^{o} 24.661	068 ^{o} 34.810	1000, 800, 700, 600, 500, 400, 300, 200, 150, 100, 50, 30, 10
CAA1	74^{o} 31.267	080 ^{o} 34.526	600, 400, 300, 200, 150, 120, 100, 80, 60, 40, 30, 10
CAA2	74^{o} 18.812	080 ^{o} 30.294	600, 400, 300, 200, 150, 120, 100, 80, 60, 40, 30, 10
CAA3	73^{o} 49.032	080 ^{o} 29.261	600, 400, 300, 200, 150, 120, 100, 80, 60, 40, 30, 10
CAA4	74^{o} 7.274	091 ^{o} 30.437	150, 140, 120, 100, 80, 60, 40, 30, 10
CAA5	74^{o} 32.245	090 ^{o} 48.094	250, 220, 190, 160, 140, 120, 100, 80, 60, 40, 30, 10
CAA6	74^{o} 45.536	097 ^{o} 27.078	250, 190, 140, 100, 80, 60, 40, 30, 10
CAA7	73^{o} 40.363	096 ^{o} 31.318	200, 140, 100, 80, 60, 40, 20, 10
AN312	69^{o} 9.896	100 ^{o} 41.771	Bot, 40, 30, 20, 10, 5
AN314	68^{o} 58.079	105 ^{o} 27.263	Bot, 60, 50, 40, 30, 20, 10, 5

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

Principle Investigator: Helmuth Thomas
Cruise Participants: Jacoba Mol, Helmuth Thomas

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[*]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: One further objective of our work, was to supply incubation experiments, carried out by Dr Tortell's and Dr Levasseur's groups (C. Hoppe, R. Hussherr, M. Lizotte) with experimental conditions of the carbonate system, to verify baseline and incubation manipulations of the carbonate system and pH.

c: 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.

d: In the Canadian Arctic Archipelago, 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 5.1.9.1. 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 5.1.9.1. 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 5.1.9.1: 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
K1	56.12406	-53.37285	14 July 2015
LS2	60.44138	-56.53458	17 July 2015
BB1	66.8583	-59.07419	3 August 2015
BB3	71.41096	-68.57981	5 August 2015
BB2	72.75668	-66.99101	7 August 2015
CAA1	74.52102	-80.57575	10 August 2015
CAA2	74.31352	-80.50492	10 August 2015
323	74.15607	-80.46952	11 August 2015
324	73.97910	-80.45936	11 August 2015
CAA3	73.81712	-80.48758	12 August 2015
CAA5	74.53742	-90.80146	12 August 2015
CAA4	74.12130	-91.50579	14 August 2015

CAA6	74.75884	-97.45111	15 August 2015
CAA7	73.67269	-96.52192	16 August 2015
312	69.16498	-100.69637	17 August 2015
314	68.96842	-105.46186	18 August 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 CDOM, DOC, humic substances, thiols

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Introduction and Objectives
One of the major complications in the understanding of the Trace elements and isotopes (TEI) distributions is the binding with dissolved organic matter (DOM). Marine DOM contains a continuum of ligands with varying affinities for metal ions including Fe(III), Cu(II), Zn(II), Hg(II) and Al(III). Trace element distributions cannot be interpreted fully if the sources and distribution of the main ligands are not better understood. In previous studies, the similarity of vertical profiles of bioactive and potentially toxic trace metals and humic-like fluorescence suggested that the humic-like fluorophore is a major factor in controlling iron solubility and the dissolved iron concentration in deep waters [Nakabayashi 2001; 2002; Tani et al., 2003; Nakayama et al., 2009]. Humic-like and fulvic-like can also function as metal complexing ligands forming stable complexes (e.g. [Kogut and Voelker, 2001]). Similarly, the presence of glutathione-like substances in ocean waters [Le Gall and van den Berg, 1998] and the high stability constants with copper [Leal and van den Berg, 1998] and mercury [Han et al., 2008] suggest that thiol complexes can be important in metal solubility. To date, we know little about the source, dynamic and composition of the organic ligands in marine waters.
The sampling focused on the concentrations and composition of organic ligands that are critical for interpreting the distributions of TEIs in the water column. We proposed to employ organic tracers of rivers, in situ production and early diagenetic processes to the polar mixed layer, the halocline and deep waters; measurements would include colored dissolved organic matter

(CDOM), humic substances (fluorescence and electrochemistry) and thiol analysis (electrochemistry). These tracers would allow us to identify sources and processes that control the distributions of important ligands of key TEIs. The combined approach that encompasses marine DOM characterization and associated trace metal speciation (core measurements in the GEOTRACES program) will provide data needed to parameterize and conceptualize relations between the DOM cycle and the solubility of TEIs in seawater.

Methodology

Our major onboard activity was sample collection and filtration at each TM Rosette cast. Waters were collected from the TM rosette and then filtered using pre-combusted (450 °C for 4 h) GFF filters. After filtration, samples were stored in dark and 4 °C fridge.

We have also collected and filtered DOC samples for Dr D. Hansell (Univ Miami).

Sampling details

All samples for CDOM, humic substances (HS) and thiol analysis were filtered through a GFF filter and stored in 60 mL amber glass vials at 4 °C. The samples designated for humic susbtances and thiol analysis using voltammetry were acidified to pH around 2 using HCl immediately after filtration.

Samples for DOC analysis were taken using 60 mL transparent glass vials in leg 2 and 60 mL amber glass vials in leg 3b.

Note: all samples below 200m were not filtered.

Detailed sampling information can be found below in table 5.1.9.1 and 5.1.9.2.

Table 5.1.9.1 Rosette Sampling in leg 2

leg	Station	Event	Sample number	Targeted Depth (m)	Niskin/ GoFlo	Designated Analysis
2	K1	9	121	1600	1	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	125	1400	5	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	126	1200	6	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	127	1000	7	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	128	800	8	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	129	600	9	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	130	500	10	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	131	400	11	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	132	300	12	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	134	200	14	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	137	100	17	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	138	90	18	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	139	70	19	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	140	50	20	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	142	30	22	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	143	20	23	CDOM (Gueguen)/DOC (Hansell)
2	K1	9	144	10	24	CDOM (Gueguen)/DOC (Hansell)

2	LS2	16	183	2600	4	CDOM (Gueguen)/DOC (Hansell)
2	LS2	16	187	1999	10	CDOM (Gueguen)/DOC (Hansell)
2	LS2	18	199	1000	2	CDOM (Gueguen)/DOC (Hansell)
2	LS2	18	202	800	5	CDOM (Gueguen)/DOC (Hansell)
2	LS2	18	206	500	9	CDOM (Gueguen)/DOC (Hansell)
2	LS2	18	209	300	12	CDOM (Gueguen)/DOC (Hansell)
2	LS2	25	269	200	1	CDOM (Gueguen)/DOC (Hansell)
2	LS2	25	270	150	2	CDOM (Gueguen)/DOC (Hansell)
2	LS2	25	271	100	3	CDOM (Gueguen)/DOC (Hansell)
2	LS2	25	276	30	8	CDOM (Gueguen)/DOC (Hansell)
2	LS2	25	280	10	12	CDOM (Gueguen)/DOC (Hansell)
2	BB1	40	377	200.5	1	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB1	40	379	149.5	3	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB1	40	380	100	4	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB1	40	382	47	6	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB1	40	384	21.5	8	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB1	40	387	11	11	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB1	34	311	1000.5	1	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB1	34	313	800	3	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB1	34	315	700	5	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB1	34	316	599.5	6	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB1	34	318	500	8	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB1	34	319	400	9	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB1	34	321	300	11	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB3	57	485	199.6	1	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB3	57	487	148.4	3	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB3	57	488	99.9	4	CDOM, HS/thiol (Gueguen)/DOC (Hansell)

2	BB3	57	490	49.9	6	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB3	57	492	30.1	8	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB3	57	495	10.2	11	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB3	54	443	1000.7	1	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB3	54	445	800	3	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB3	54	447	699.7	5	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB3	54	448	600.5	6	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB3	54	450	490	8	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB3	54	451	398.5	9	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB3	54	453	299.6	11	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB2	69	537	N/A	1	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB2	69	540	N/A	4	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB2	69	541	N/A	5	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB2	69	542	N/A	6	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB2	69	543	N/A	7	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB2	69	544	N/A	8	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB2	69	545	N/A	9	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB2	69	546	N/A	10	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB2	69	547	N/A	11	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB2	69	548	N/A	12	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB2	82	693	N/A	6	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	BB2	82	699	N/A	12	CDOM, HS/thiol (Gueguen)/DOC (Hansell)

2	CAA1	92	708	N/A	1	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA1	92	709	N/A	2	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA1	92	710	N/A	3	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA1	92	711	N/A	4	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA1	92	715	N/A	8	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA1	92	719	N/A	12	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA1	95	751	N/A	2	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA1	95	753	N/A	4	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA1	95	755	N/A	6	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA1	95	757	N/A	8	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA1	95	759	N/A	10	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA1	95	760	N/A	11	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA2	108	868	N/A	1	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA2	108	869	N/A	2	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA2	108	870	N/A	3	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA2	108	871	N/A	4	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA2	108	872	N/A	5	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA2	108	873	N/A	6	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA2	108	874	N/A	7	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA2	108	875	N/A	8	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA2	108	876	N/A	9	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA2	108	877	N/A	10	CDOM, HS/thiol (Gueguen)/DOC (Hansell)

2	CAA2	108	878	N/A	11	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA2	108	879	N/A	12	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA3	117	982	N/A	1	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA3	117	983	N/A	2	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA3	117	984	N/A	3	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA3	117	986	N/A	5	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA3	117	987	N/A	6	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA3	117	989	N/A	8	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA3	117	993	N/A	12	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA3	123	1025	N/A	1	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA3	123	1027	N/A	3	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA3	123	1029	N/A	5	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA3	123	1032	N/A	8	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA3	123	1033	N/A	9	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA3	123	1035	N/A	11	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA5	130	1073	N/A	2	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA5	130	1075	N/A	4	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA5	130	1076	N/A	6	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA5	130	1077	N/A	7	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA5	130	1080	N/A	10	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA5	130	1081	N/A	11	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA5	136	1139	N/A	1	CDOM, HS/thiol (Gueguen)/DOC (Hansell)

2	CAA5	136	1140	N/A	2	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA5	136	1141	N/A	3	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA5	136	1142	N/A	4	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA5	136	1144	N/A	8	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA5	136	1148	N/A	12	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA4	149	1241	N/A	2	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA4	149	1242	N/A	3	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA4	149	1243	N/A	4	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA4	149	1244	N/A	5	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA4	149	1245	N/A	6	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA4	149	1248	N/A	9	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA4	149	1251	N/A	12	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA6	160	1340	N/A	2	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA6	160	1341	N/A	3	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA6	160	1342	N/A	4	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA6	160	1343	N/A	5	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA6	160	1344	N/A	6	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA6	160	1346	N/A	8	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA6	160	1347	N/A	9	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA6	160	1350	N/A	12	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA7	168	1410	N/A	2	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA7	168	1411	N/A	3	CDOM, HS/thiol (Gueguen)/DOC (Hansell)

2	CAA7	168	1412	N/A	4	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA7	168	1413	N/A	5	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA7	168	1414	N/A	6	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA7	168	1416	N/A	8	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA7	168	1417	N/A	9	CDOM, HS/thiol (Gueguen)/DOC (Hansell)
2	CAA7	168	1420	N/A	12	CDOM, HS/thiol (Gueguen)/DOC (Hansell)

Table 5.1.9.2 Underway sampling in leg2 (Note: All underway sampling are designated for surface CDOM distribution analysis)

Leg	Sample	latitude	Longtitude	Date	Time	Location	Designated Analysis
2	Loop 1	49.495	66.288	20150711	12:48	Benthic lab	CDOM
2	Loop 2	50.814	65.446	20150711	17:49	Benthic lab	CDOM
2	Loop 3	50.814	64.12	20150711	22:27	Benthic lab	CDOM
2	Loop 4	49.526	60.543	20150712	8:04	Benthic lab	CDOM
2	Loop 5	49.552	59.16	20150712	12:32	Benthic lab	CDOM
2	Loop 6	50.46	57.517	20150712	18:27	Benthic lab	CDOM
2	Loop 7	51.26	56.375	20150712	22:25	Benthic lab	CDOM
2	Loop 8	53.121	54.353	20150713	8:11	Benthic lab	CDOM
2	Loop 9	54.123	54.048	20150713	13:17	Benthic lab	CDOM
2	Loop 10	55.216	53.421	20150713	19:06	Benthic lab	CDOM
2	Loop 11	56.816	52.476	20150715	21:53	Benthic lab	CDOM
2	Loop 12	58.066	54.337	20150716	9:02	Benthic lab	CDOM
2	Loop 13	59.176	55.381	20150716	15:02	Benthic lab	CDOM
2	Loop 14	60.125	56.531	20150716	20:08	Benthic lab	CDOM
2	Loop 15	61.236	56.542	20150718	23:27	Benthic lab	CDOM
2	Loop 16	63.421	57.449	20150719	11:00	Benthic lab	CDOM
2	Loop 17	64.479	58.106	20150719	16:09	Benthic lab	CDOM
2	Loop	62.031	65.022	20150720	11:01	Benthic lab	CDOM

	18						
2	Loop 19	61.527	67.157	20150720	15:56	Benthic lab	CDOM
2	Loop 20	62.156	70.099	20150720	21:42	Benthic lab	CDOM
2	Loop 21	62.416	77.042	20150721	10:32	Benthic lab	CDOM
2	Loop 22	62.113	78.336	20150721	15:11	Benthic lab	CDOM
2	Loop 23	61.143	78.467	20150721	20:55	Benthic lab	CDOM
2	Loop 24	60.083	78.258	20150722	11:13	Benthic lab	CDOM
2	Loop 25	59.353	78.328	20150722	16:05	Benthic lab	CDOM
2	Loop 26	59.204	78.551	20150722	21:23	Benthic lab	CDOM
2	Loop 27	58.492	79.159	20150723	10:53	Benthic lab	CDOM
2	Loop 28	59.188	79.097	20150723	15:45	Benthic lab	CDOM
2	Loop 29	59.281	78.441	20150723	20:44	Benthic lab	CDOM
2	Loop 30	60.059	78.248	20150730	21:24	Benthic lab	CDOM
2	Loop 31	62.391	77.576	20150731	11:55	Benthic lab	CDOM
2	Loop 32	62.472	74.445	20150731	17:52	Benthic lab	CDOM
2	Loop 33	62.681	72.561	20150731	22:22	Benthic lab	CDOM
2	Loop 34	62.021	69.097	20150801	10:58	Benthic lab	CDOM
2	Loop 35	61.441	66.247	20150801	16:38	Benthic lab	CDOM
2	Loop 36	62.021	64.571	20150801	21:49	Benthic lab	CDOM
2	Loop 37	63.28	59.536	20150802	11:23	Benthic lab	CDOM
2	Loop 38	64.133	59.172	20150802	15:34	Benthic lab	CDOM
2	Loop 39	65.201	59.186	20150802	20:32	Benthic lab	CDOM
2	Loop	67.707	58.441	20150803	23:03	Engine Room	CDOM

	40						
2	Loop 41	69.031	59.063	20150804	11:57	Engine Room	CDOM
2	Loop 42	70.086	59.266	20150804	16:55	Engine Room	CDOM
2	Loop 43	71.054	62.001	20150804	22:39	Engine Room	CDOM
2	Loop 44	73.014	68.598	20150808	22:38	Engine Room	CDOM
2	Loop 45	73.581	75.541	20150809	9:45	Engine Room	CDOM
2	Loop 46	74.247	79.129	20150809	16:12	Engine Room	CDOM
2	Loop 47	74.113	87.711	20150812	12:38	Engine Room	CDOM
2	Loop 48	74.346	94.085	20150814	8:16	Engine Room	CDOM
2	Loop 49	74.139	96.349	20150815	10:01	Engine Room	CDOM
2	Loop 50	72.061	96.022	20150816	15:24	Engine Room	CDOM

5.1.10 Biogenic Gases, Ocean Acidification, Primary Production and Photo-physiology.

Principal Investigator: Philippe Tortell[1]
Cruise Participants: Philippe Tortell[1], Nina Schuback[1], Clara Hoppe[2], Tereza Jarnikova[1], Dave Seminiuk[1]

[1]*Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia*
[2]*Alfred Wegener Inst., Bremerhaven, Germany*

Introduction and objectives
Marine phytoplankton play a vital role in the global biogeochemical cycles of nutrients and climate-active gases. Primary production removes CO_2 from surface waters, and leads to the accumulation of O_2 and dimethylsulfide (DMS), while bacterial respiration in sub-surface waters leads to the production of methane (CH_4) and nitrous oxide (N_2O). These gases (CO_2, DMS, CH_4 and N_2O, in particular), influence the atmospheric radiative balance, thereby affecting global climate. It is thus important to understand the biogeochemical controls on primary productivity and CO_2, DMS, CH_4 and N_2O cycling in marine waters. To date, there have been relatively few studies of these gases in high Arctic marine waters, and it is presently unclear how primary productivity and gas cycling may respond to future changes in surface ocean conditions, including increased acidity and temperature, reduced sea ice cover and changing light levels and surface water stratification. Our research project was designed to examine these questions. In particular, our work was designed to address the following specific objectives:

1) Generate high spatial resolution maps of surface water concentrations and sea-air fluxes of CO_2 and DMS across different hydrographic domains in Subarctic and Arctic waters. Relate variability in surface water gases to other environmental conditions (e.g. chlorophyll a, sea ice cover, mixed layer depths, *etc*.)
2) Use high resolution $\Delta O_2/Ar$ (biological oxygen saturation) measurements to map the spatial distribution of net community production (NCP). Couple these NCP estimates with continuous measurements of phytoplankton photo-physiology derived from Fast Repetition Rate Chla Fluorometry (FRRF).
3) Map the distribution of surface water concentrations of DMSP and DMSO (reduced sulfur compounds derived from DMS)
4) Quantify gross primary productivity in surface waters, based on measured rates of carbon uptake and photosynthetic electron transport, and examine the light-dependency of these rates. Use the results to examine the electron requirements for carbon fixation ($\phi_{e,c}$).
5) Conduct CO_2 and light controlled manipulation experiments to examine phytoplankton physiological and ecological responses to altered seawater CO_2 concentrations and irradiance levels.

Operations conducted during the Leg / Methodology

We used a wide range of analytical and experimental techniques to conduct our work. Surface gas measurements were conducted using automated purge and trap gas chromatography (PT-GC; for DMS/P/O), and membrane inlet mass spectrometry (MIMS; for CO_2, $\Delta O_2/Ar$, and DMS). These instruments were set up in the forward filtration lab, and programmed to operate autonomously, sampling from the ship's seawater intake, with automated calibration sequences. Photo-physiological measurements (e.g. variable Chl*a* fluorescence, F_v/F_m, and cross sectional absorption area, σ) were also measured from the ship's seawater intake (forward filtration lab) using an FRRF equipped with a flow-through measurement cuvette. Discrete depth profile samples for CH_4 and N_2O measurements were collected from the Amunsden Rossette, for subsequent mass spectrometric analysis at UBC.

Primary productivity was assessed at all of the major stations using short-term (2 hour) ^{14}C incubation assays, and with FRRF measurements of photosynthetic electron transport rates. Samples were collected from several depths in the upper water column and processed immediately. For both of these assays, measurements were conducted over a range of light levels to generate photosynthetic light curves. A variety of other samples (e.g. total and size fractionated chla, HPLC analysis of photosynthetic pigments) were collected to support the productivity measurements.

We conducted two CO_2 and light manipulation experiments, using deck-board incubations. Water for these experiments was collected using the trace metal clean rosette or from a surface water pump. Water for incubations was collect near stations K1 and BB3. Phytoplankton were allowed to grow in 8L bottles placed in incubators with different light screening (~ 50% and 20% of surface irradiance levels), with continuous bubbling with either 400 or 1200 ppm CO_2 gas mixtures. Phytoplankton growth rates were followed by daily measurements of chla and nutrient concentrations, and additional photo-physiological measurements were made using FRRF. When phytoplankton had consumed ~ 75% of the nutrients in bottles, most of the volume was

removed (for use in a variety of physiological assays), and replaced with 0.2 μm filtered water. This dilution approach was used to prolong the incubation experiments and observe more subtle ecological changes (e.g. species shifts) across the different treatments. Water removed from the incubation bottles was sampled for measurements of Chla (total and size fractionated), POC, accessory photosynthetic pigments (via HPLC), DNA/RNA, flow cytometry, and iron uptake rates (using ^{55}Fe) and primary productivity (using ^{14}C and FRRF).

Preliminary results

Figures 5.1.10.1 and 5.1.10.2 below show the distribution of various hydrographic properties and biogenic gases across the cruise track. As shown in these figures, we observe large gradients in all surface water properties. Over much of the cruise track, surface waters were under-saturated in CO_2 (creating a favourable gradient for oceanic CO_2 uptake) and exhibited biologically-induced O_2 supersaturation ($\Delta O_2/Ar > 0$). NCP estimates will be derived from these data using information on surface wind speeds and mixed layer depth estimate, as will estimates of sea-air CO_2 and DMS fluxes. DMS concentrations varied by a factor of ~ 10, with sharp gradients often coinciding with rapid changes in pCO_2 and $\Delta O_2/Ar$. Across the cruise track, strong hydrographic fronts (i.e. rapid changes in salinity or surface temperature), were often associated with productivity hot-spots, suggesting a potential role for physical nutrient supply in stimulating surface water productivity.

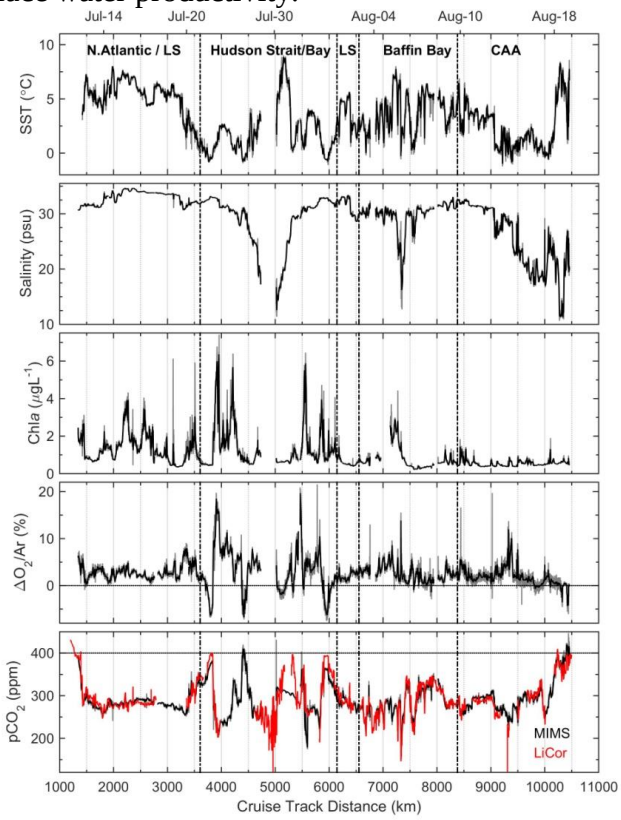

Figure 5.1.10.1. Spatial distribution of various hydrographic parameters and biogenic gases across the cruise track. Note that horizontal lines on the pCO_2 and $\Delta O_2/Ar$ plots represent atmospheric saturation values. Note also that the data presented here have only received a very preliminary quality control, and do not necessarily represent the final processed values.

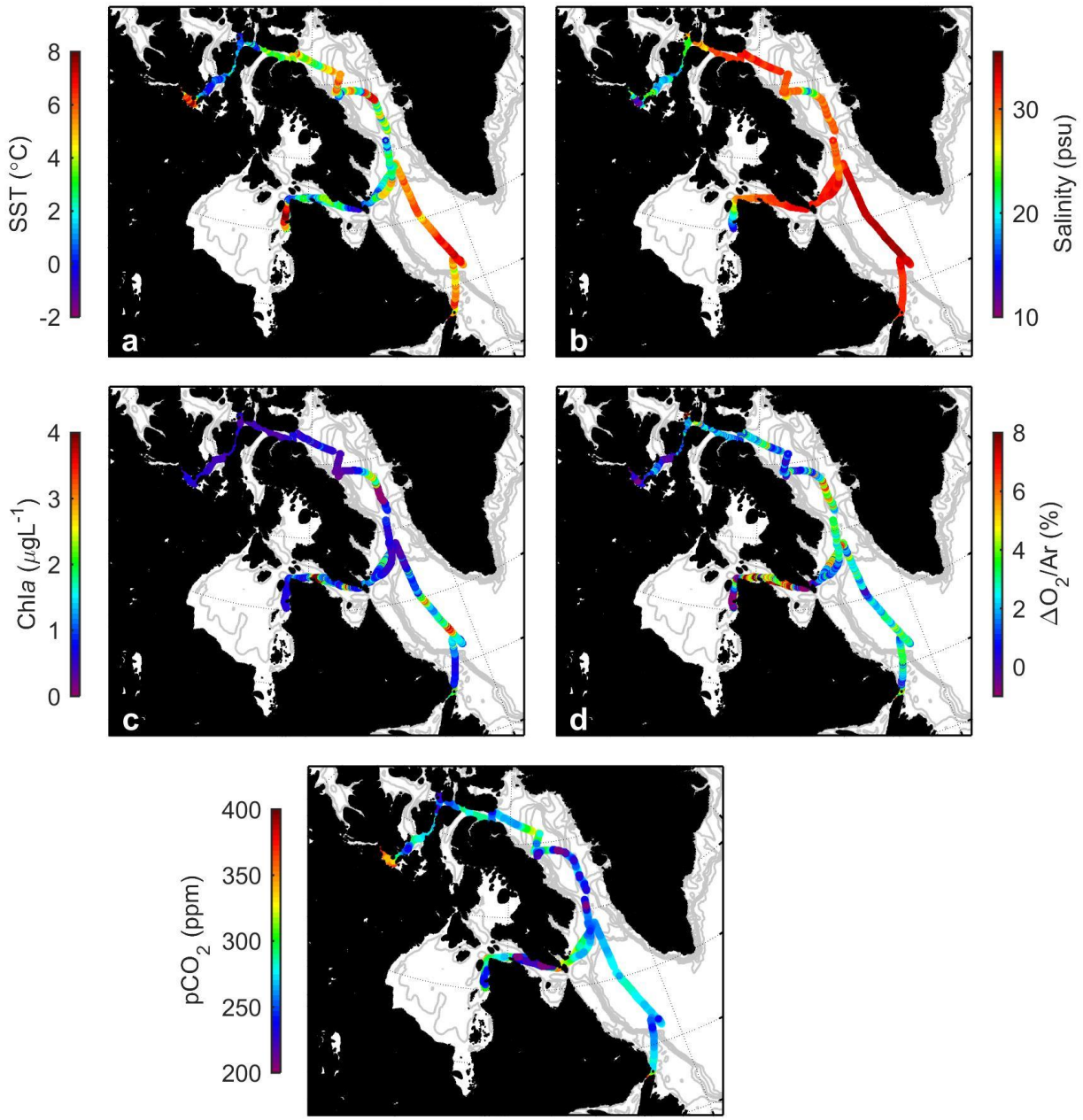

Figure 5.1.10.2. Spatial distribution of gases and hydrographic properties along the cruise track.

Figure 5.1.10.3 (below) shows the distribution of various photo-physiological properties (measured by FRRF) along the cruise track. Over much of the cruise track, we observed strong diel (day-night) cycles in phytoplankton photo-physiology. For example, the mid-day decrease in variable chlorophyll fluorescence (Fv/Fm), is indicative of a down-regulation of

photosynthetic light harvesting capacity during periods of high light. This is a mechanism used for photo-protection.

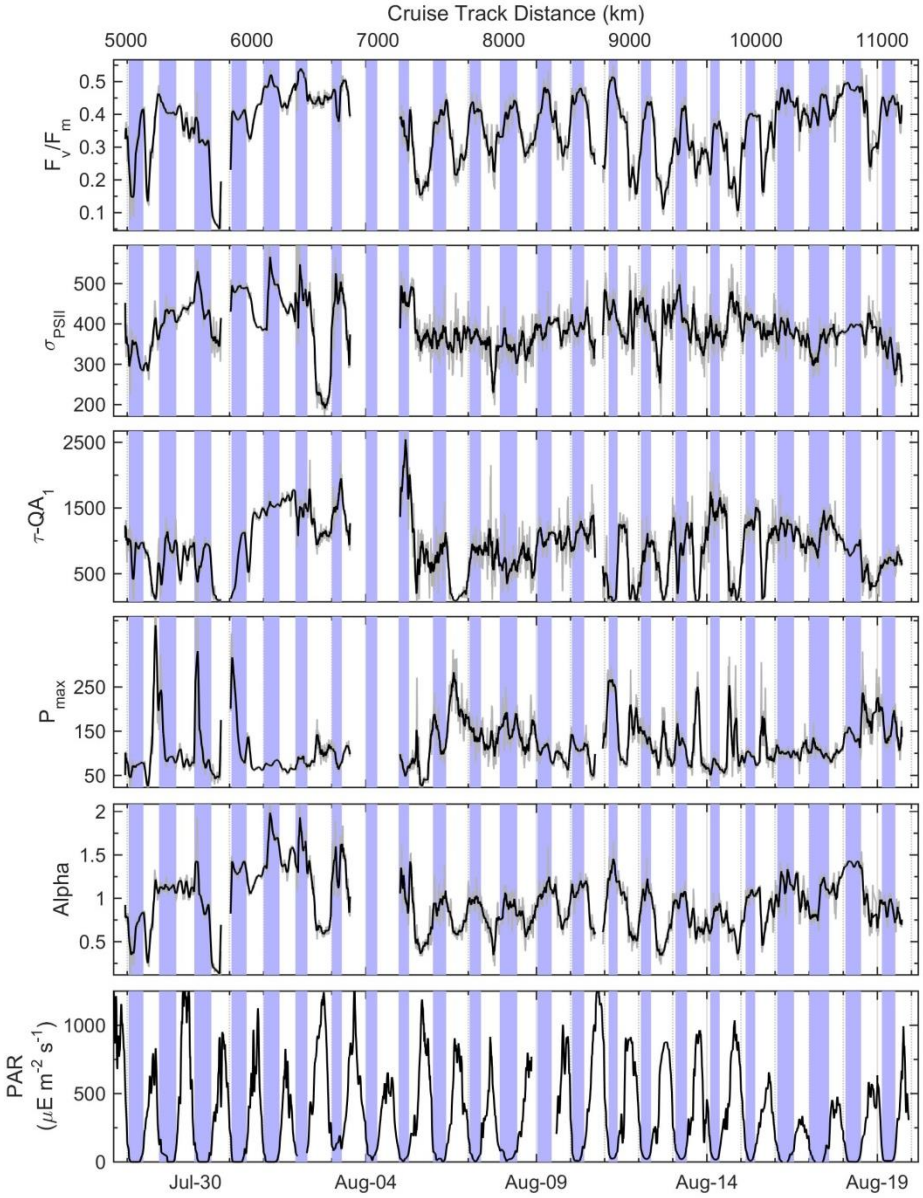

Figure 5.1.10.3. Continuous underway measurements of photoplankton photo-physiological properties measured using fast repetition rate fluorometry (FRRF). The bottom panel shows surface irradiance cycles, while other panels show a range of other photo-physiological characteristics of surface water phytoplankton. For example, variable fluorescence (Fv/Fm), is used as a measure of the photosynthetic efficiency of electron capture in Photosystem II (PSII). This variable is often down-regulated during mid-day periods of high irradiance as a means of photo-protection. The variables Pmax and Alpha represent the maximum (light saturated) electron transport rates and initial light-dependent slopes derived from rapid light curves.

Primary productivity measurements (Figure 5.1.10.4) enabled us to further characterize the photosynthetic light dependency of phytoplankton assemblages. We obtained excellent results with both ^{14}C assays, and with FRRF measurements of electron transport rates (ETR)

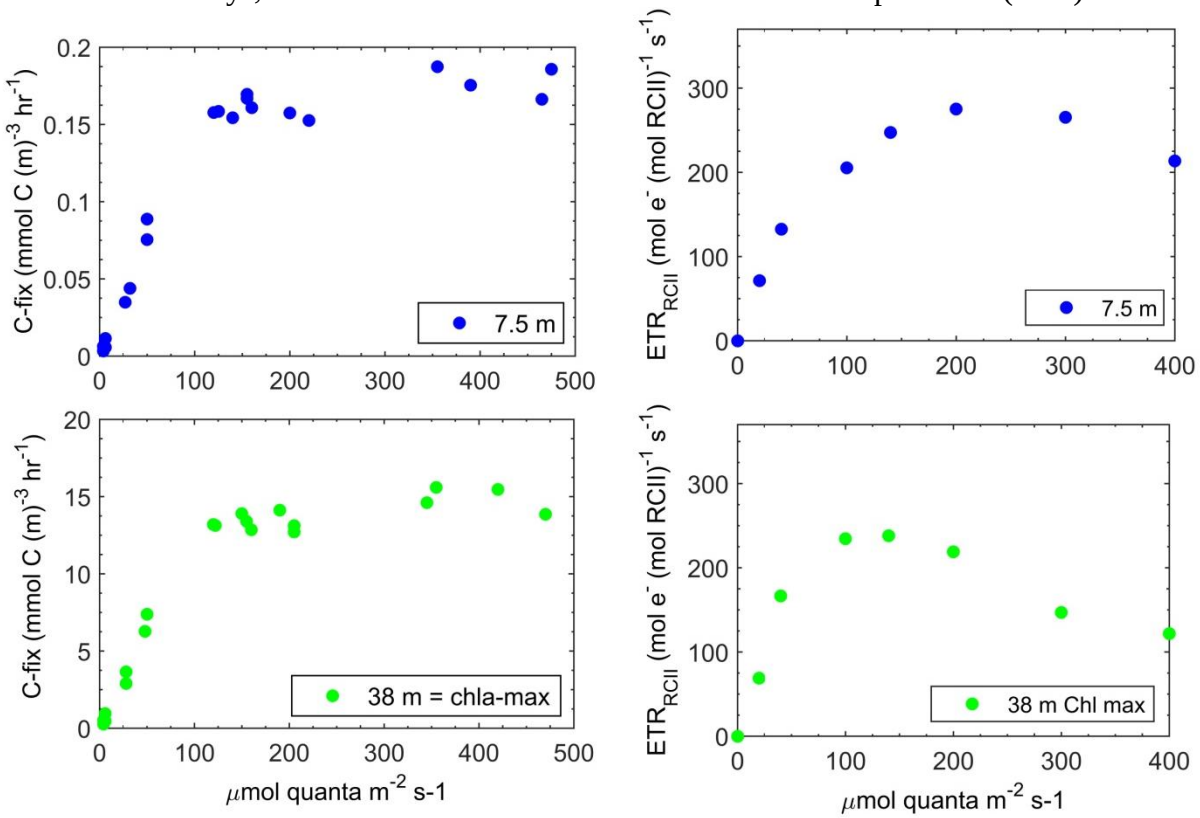

Figure 5.1.10.4. Rates of gross primary productivity determined from ^{14}C bottle assays (left hand panels), and from FRRF measurements of electron transport rates (ETR). Results are from Station K1 in the southern Labrador Sea. The curves show a characteristic saturation behavior as a function of irradiance. Bottom panels show data from the deep chlorophyll max, while top panels show results from the surface mixed layer assemblages (7.5 m sampling depth). Compilation of our productivity measurements from all stations will provide valuable information on primary productivity in Arctic waters, and its light-dependency.

Finally, preliminary results from our two deck-board incubation experiments (Figures 5.1.10.5 and 5.1.10.6) demonstrated clear effects of CO_2 and light manipulations in one experiment, with much smaller effects in the second experiment.

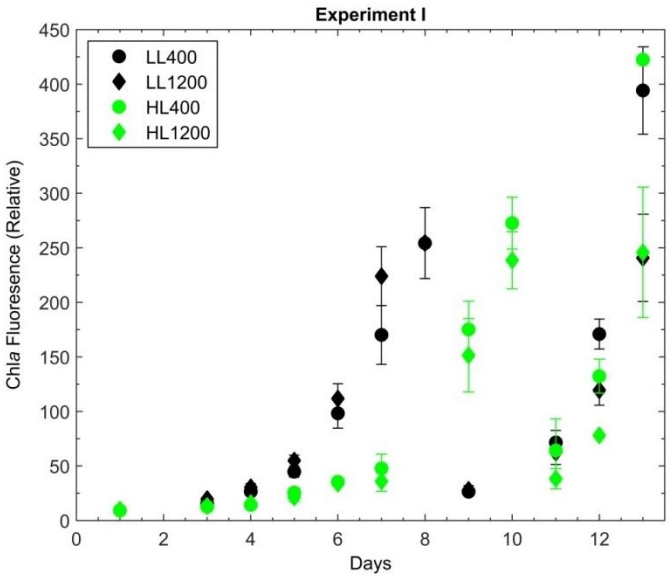

Figure 5.1.10.5. Time course of phytoplankton biomass (chlorophyll a) in the first CO_2 - light incubation experiment. LL and HL represent low and high light treatments, respectively, while the numbers refer to the CO_2 level (in ppm) used for each treatment. In this first experiment, we observed an initial decrease in growth rates of the high light treatment, with only a small CO_2 effect. We have a suite of other physiological and biochemical measurements that will help to understand the mechanisms underlying these responses.

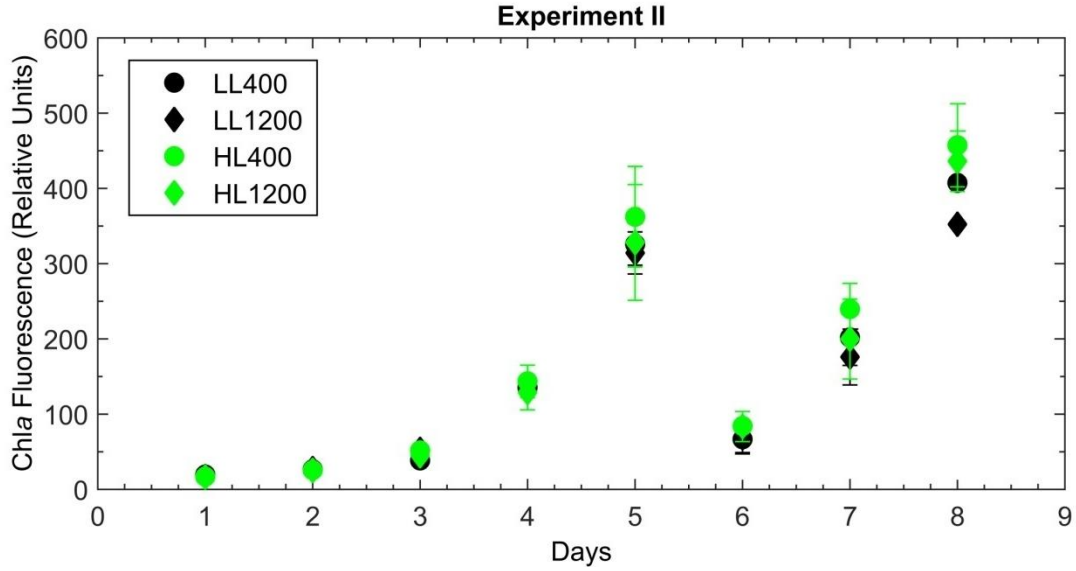

Figure 5.1.10.6. As for Fig. 5.1.10.5, but for the second incubation experiment. In this experiment (water collected near Station BB3), we did not observe any significant effects across the light or CO_2 treatments.

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: Our group initially intended to work through DFO to find suitable ship-time on a Coast Guard Ice breaker. This proved extremely challenging, and we thus decided to pursue a partnership with ArcticNet for shared time on the Amundsen. The communication with ArcticNet regarding ship-time possibilities and scheduling was open and clear.

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: We held a joint GEOTRACES / ArcticNet planning meeting in Oct., 2014, where many of the logistical details (including a site visit to the ship) were worked out. Information regarding all aspects of the expedition, lab space, cargo, travel etc. was extremely clear and provided in a timely manner. Keith Levesque is to be commended for his outstanding work.

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.
9. Satisfied
Comments: We experienced a range of technical issues with a variety of ship-board equipment (winches, cranes, moon pool hydraulics etc.). These presented some minor delays, but were all quickly rectified by the excellent engineering staff. On at least one occasion, crew were asked to put in over-time hours to resolve time-sensitive problems. We did find it rather cumbersome to run gas lines from the containers on the foredeck to the forward filtration lab. Perhaps some kind of sleeve could be put in place to make it easier to slide gas lines through. I also found that the seawater supply to the forward filtration lab (and other parts of the ship) has a lot of rust coming through. I'm not sure how this could be addressed in the future.

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: In general, all of the crew and science staff conducted their operations in a highly safe and well planned manner. I did have some minor concerns related to the need to move a lot of (potential heavy) boxes with samples to the various ship-board laboratories down relatively steep stairways. It would be helpful (though perhaps impractical) to have some kind of system set up to move boxes between levels of the ship. Additionally, it was somewhat challenging to get into / out off the upper storage containers on the flight deck to access boxes mid-cruise. I realize that the material in these containers is not typically meant to be accessed at sea, but the system currently in place seems to rely on a somewhat unstable step ladder.

e) What is your overall level of satisfaction regarding your experience conducting research on board the *Amundsen* this year?
5. Very satisfied
Comments: The ship and its crew are superb, and I look forward to more voyages on the Amundsen in the near future.

5.1.11 Marine biogenic silica dynamics and the natural variations in silicon isotopes in Arctic Ecosystems

Principal Investigator: Diana Varela
Cruise Participants: Karina Giesbrecht

School of Earth and Ocean Sciences, University of Victoria

1 Introduction and Objectives

Diatoms, microscopic algae with siliceous cell walls, account for up to 40% of the annual marine biological carbon fixation and for a significant portion of the export of carbon from the surface to the deep ocean (Nelson et al., 1995), both important processes regulating atmospheric CO_2 concentrations. Diatoms are the largest consumers of dissolved Si ($Si(OH)_4$) in the oceans, generating, through the photosynthetic process, a strong coupling between the marine cycles of silicon, carbon, nitrogen and phosphorus (Si, C, N and P). However, relative to the C, N and P cycles, current knowledge of the processes affecting marine Si dynamics is limited.

In order to better understand ecosystem-level responses to climate-induced oceanic changes, it is critical to evaluate the role of diatoms in the marine cycling of Si and the coupling between that cycle and other processes such as carbon fixation, transfer through the food web and export. This is especially true in the high-latitude oceans where changes in marine ecosystem from climate variability have already been documented (Li et al, 2009).

Natural variations in Si isotopes ($\delta^{30}Si$) can be used to quantify $Si(OH)_4$ uptake in and supply to ocean surface waters (Fripiat et al., 2011) and identify water masses (Varela et al., IPY Conference abstract, 2012). They provide a novel and powerful proxy for studying Si cycling over broad spatio-temporal scales (Varela et al., 2004), and can be used to reconstruct nutrient utilization histories (Beucher et al., 2008). During Canadian IPY-GEOTRACES, $\delta^{30}Si(OH)_4$ in the Canada Basin at >1000 m depth were the heaviest ever measured in marine deep waters, and reflect the influx of relatively heavy intermediate waters form the Atlantic Ocean with some local amplification due to the biological pump (Varela et al., IPY Conference abstract, 2012).

The specific objectives of for this cruise were two-fold: (1) to describe the marine biogenic silica ($bSiO_2$) dynamics of the upper water column and investigate the linkage between the marine cycling of Si, C and N using measurements of dissolved nutrients, particulate C, N and $bSiO_2$ concentrations, and uptake rates of $Si(OH)_4$, C, nitrate (NO_3^-) and ammonium (NH_4^+), and (2) to characterize the natural variations in the $\delta^{30}Si$ composition of both $Si(OH)_4$ and $bSiO_2$ throughout the Canadian Arctic.

2 Methodology

Objective (1): Marine $bSiO_2$ dynamics and Si:C:N ratios

At the stations listed in Table 5.1.11.1, samples to investigate marine $bSiO_2$ dynamics and Si:C:N ratios for particles and uptake rates were collected from 12-L Niskin bottles on the CTD-Rosette. Seawater samples were collected at 6 optical depths (100, 50, 30, 15, 1 and 0.2% of surface irradiance) as determined by Marjolaine Blais (PI: Michel Gosselin) using a separate cast with a PAR sensor. Many thanks go to Marjolaine for this!

At each depth, samples were collected for the measurement of $bSiO_2$ concentrations, net $bSiO_2$ production rates and ^{32}Si, ^{13}C, and ^{15}N uptake rates. At one depth (50% irradiance), size-fractionated measurements of ^{13}C and ^{15}N uptake rates were also conducted. Samples for dissolved nutrients (NO_3^-, PO_4^{3-}, and $Si(OH)_4$) and NH_4^+ were also collected and analyzed in duplicate by Isabelle Courchesne and Gabrièle Deslongchamps (PI: Jean-Éric Tremblay). Their immense help and expertise is much appreciated!

Table 5.1.11.1. List of stations where incubations were conducted, and the measurements performed.

Station	**$bSiO_2$ collected**	**Incubations performed**
K1		$^{13}C/^{15}NO_3$
LS2	x	^{32}Si, net $bSiO_2$, $^{13}C/^{15}NO_3$, $^{15}NH_4$
BB1	x	^{32}Si, net $bSiO_2$, $^{13}C/^{15}NO_3$, $^{15}NH_4$
BB2	x	^{32}Si, net $bSiO_2$, $^{13}C/^{15}NO_3$, $^{15}NH_4$
BB3	x	^{32}Si, net $bSiO_2$, $^{13}C/^{15}NO_3$, $^{15}NH_4$
CAA1	x	^{32}Si, net $bSiO_2$, $^{13}C/^{15}NO_3$, $^{15}NH_4$
CAA2	-	-
CAA3	x	^{32}Si, net $bSiO_2$, $^{13}C/^{15}NO_3$, $^{15}NH_4$
CAA4	-	-
CAA5	x	^{32}Si, net $bSiO_2$, $^{13}C/^{15}NO_3$, $^{15}NH_4$
CAA6	x	^{32}Si, net $bSiO_2$, $^{13}C/^{15}NO_3$, $^{15}NH_4$
CAA7	x	^{32}Si, net $bSiO_2$, $^{13}C/^{15}NO_3$, $^{15}NH_4$

Seawater was collected in acid-washed 250mL, 500mL, and 2L polycarbonate bottles for ^{32}Si uptake, ^{13}C and ^{15}N uptake, and net $bSiO_2$ incubations respectively. Samples for ambient $bSiO_2$ concentrations were collected in acid-washed 2L polypropylene bottles.

Samples for gross $bSiO_2$ production were spiked with the radioisotope ^{32}Si (0.1 µCi/mL activity, Los Alamos National Laboratories) following the method of Krause et al. (2011). Samples for net $bSiO_2$ production were incubated for 24-48 hrs following a method similar to Demarest et al. (2011). Samples used for the determination of C assimilation rates were inoculated using $NaH^{13}CO_3$ (99% purity, Cambridge Isotopes Laboratories) isotope tracer stock with the target ^{13}C enrichment of each sample being <10% of the total ambient DIC. Samples for NO_3^- and NH_4^+ uptake rates were inoculated using $Na^{15}NO_3$ and $^{15}NH_4Cl$ (^{15}N salts were 98% purity, Cambridge Isotopes Laboratories) with the final ^{15}N enrichment target for each being approximately ≤10%. A dual-tracer method was employed for the C assimilation and NO_3 uptake rate samples, wherein one bottle was spiked with both ^{13}C and $^{15}NO_3$.

All incubation samples were placed in a temperature-controlled on-deck incubator (cooled with surface flowing seawater) in tubes screen with blue and neutral density photographic film to simulate the in-situ irradiance and approximate wavelengths from the sampling depths. Samples were incubated for 24 hours (or up to 48 hours for net $bSiO_2$).

At the end of incubation, samples were terminated by gentle filtration, and the filters were dried at either room temperature for 24 hours (^{32}Si), or at ~60˚C for 48 hours (net $bSiO_2$, ^{13}C and ^{15}N) until further analysis on shore following the cruise.

Objective (2): Natural variations in $\delta^{30}Si$ of $Si(OH)_4$ and $bSiO_2$
Seawater samples (2-4 L) for $\delta^{30}Si(OH)_4$ were collected from the rosette at discrete depths and stations listed in Table 5.1.11.2 below. Samples were filtered through a 0.6µm polycarbonate membrane filter, and particles retained on the 0.6 µm filters were dried at ~60˚C for 48 hr.

Dried filter samples will be analyzed on shore for $bSiO_2$ concentrations. The filtered seawater was collected into acid-washed 1L filtration flasks, and stored in acid-washed 1L high-density polyethylene or 2L polypropylene bottles at 4˚C. Samples will later be analyzed on shore for the $\delta^{30}Si$ composition of $Si(OH)_4$.

Samples for $\delta^{30}Si$-$bSiO_2$ were also collected onto 0.8µm Supor membrane filters using large volume in-situ pumps at discrete depths at the stations listed in Table 5.1.11.2 below. Filters were dried at ~60˚C for 48 hr. Dried samples will be analyzed on shore for $bSiO_2$ concentrations and the isotopic $\delta^{30}Si$-$bSiO_2$ composition.

Table 5.1.11.2. Stations and depths where $\delta^{30}Si$ samples were collected

Station	**$\delta^{30}Si(OH)_4$ and $bSiO_2$ depths (approximate depths from rosette)**	**$bSiO_2$ and $\delta^{30}Si$-$bSiO_2$ depths (from large-volume pumps)**
K1	10, 30, 100, 200, 300, 500, 1000, 1600, 2000, 2150, 2750, 3000 m	no samples collected
LS2	10, 30, 100, 200, 300, 500, 1000, 1600, 2000, 2500, 3000, 3500 m	10, 30, 300, 1000, 2500
BB1	10, 30, 100, 200, 300, 500, 700, 800, 1000 m	10, 30, 200, 300, 500, 700
BB2	10, 30, 100, 200, 300, 500, 1000, 1600, 2100, 2250 m	10, 30, 200, 500, 1600, 2300
BB3	10, 30, 100, 200, 300, 500, 700, 800, 1000 m	10, 30, 200, 300, 500, 700
CAA1	10, 30, 60, 100, 120, 200, 400, 600 m	10, 30, 100, 200, 400, 600
CAA2	10, 30, 60, 100, 120, 200, 400, 600 m	10, 30, 100, 200, 400, 600
CAA3	10, 30, 60, 100, 120, 200, 400, 600 m	10, 30, 100, 200, 400, 600
CAA4	10, 30, 40, 60, 80, 100, 120, 150 m	10, 30, 60, 80, 120, 150
CAA5	10, 30, 60, 100, 120, 160, 220, 250 m	10, 30, 100, 150, 190, 230
CAA6	10, 30, 60, 100, 120, 160, 220, 250 m	10, 30, 100, 150, 190, 230
CAA7	10, 30, 60, 100, 120, 140, 180, 200 m	10, 30, 60, 100, 160, 190

Additional sampling and collaborations
Objective (1) – Size fractionated chlorophyll *a* concentrations and 24 hour ^{14}C assimilation rates were measured at all of the same irradiance depths and stations by Marjolaine Blais (PI: Michel Gosselin). This will facilitate a direct comparison between the ^{13}C and ^{14}C rate measurements. Measurement of 24 hour ^{18}O production rates were performed at all of the same irradiance

depths and stations by Amanda Timmerman (PI: Roberta Hamme), further expanding on the suite of productivity measurements conducted onboard. A similar set of measurements in the Antarctic resulted in a publication by Brzezinski et al. (2003).
Objective (2) – Small volume (~50mL) $\delta^{30}Si(OH)_4$ samples from fifteen Arctic rivers were collected by Kristina Brown. There is currently only a single published measurement of the $\delta^{30}Si(OH)_4$ composition or river water from the Canadian Arctic (Mackenzie River; Pokrovsky et al., 2013).
Ocean acidification – ^{32}Si and $^{15}NO_3$ uptake rates following a similar method described in objective (1) above were measured at the end of each of the two ocean acidification experiments run by Clara Hoppe and Nina Shuback (PI: Phillipe Tortell).

3 Preliminary Results

No analyses were performed on the ship, so no preliminary results are available at this time.

4 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.)

5. 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.

4. 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

4. Satisfied

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5.1.12 Dissolved gas measurements to compare primary production methods and quantify denitrification rates

Principal Investigator: Roberta Hamme
Cruise Participants: Amanda Zimmermann

School of Earth and Ocean Sciences, University of Victoria

Introduction and objectives
The ocean plays a key role in controlling the atmospheric carbon dioxide concentration and thus climate change through the carbon cycle. Phytoplankton take up carbon dioxide and produce organic matter through primary production. The export of organic matter from surface waters to the deep provides a removal of carbon from the atmosphere. The high latitudes, such as the Arctic Ocean, are rapidly warming due to anthropogenic processes. However, what role warming has on the Arctic Ocean, and our ability to predict the future trajectory is still unclear due to poor understanding of the current chemical, physical and biological processes.

We have taken three approaches on this cruise to characterize the mechanisms that sequester carbon from the surface ocean and atmosphere, focusing on processes of ocean productivity, the nitrogen cycle, and the solubility pump.

Productivity: There are multiple standard methods to estimate primary production, and we focused on nine methods in collaboration with other research groups. There are challenges in determining the accuracy of the methods because each measures a different "fraction" of productivity (e.g. gross, net, uptake of nutrients). Our goal with this work is to look for consistent differences between the methods and uncover possible sources of bias. Amanda collected samples for oxygen/argon ratio (a measure of net community production), triple oxygen isotope and 24-hour ^{18}O incubations (both measures of gross production). In collaboration with Diana Varela's research group, 24-hour incubations were conducted for ^{13}C, $^{15}NO_3$ and $^{15}NH_4$. Michel Gosselin's research group did ^{14}C incubations from the same casts as well. Lisa Miller (IOS) and Roger Francois (UBC) took samples for ^{234}Th to quantify the carbon export flux. We will look at satellite algorithms post-cruise to compare with all the shipboard methods.

Nitrogen cycling: Denitrification transforms "fixed-nitrogen" (nitrate, nitrite, ammonia, urea, etc.) to biologically inert N_2 gas. This removes biologically available nitrogen from the ocean. It has been suggested that denitrification rates are higher than inputs of fixed-nitrogen to the ocean, leading to nitrogen further limiting primary production. To characterize denitrification in the Arctic where rates are thought to be high, we collected N_2/Ar ratio samples where a high ratio will indicate denitrification.

Solubility pump: The deep ocean contains more carbon than the surface due to both physical processes (the solubility pump) and biological ones. Our last goal involves determining how close gases are to equilibrium with the atmosphere when water masses move into the deep ocean

by making observations of noble gases which are only affected by physical processes. For this cruise, we sought to characterize the noble gas concentrations of the major water masses in Labrador Sea and Baffin Bay.

Operations conducted during the Leg/methodology
N_2/Ar and O_2/Ar will be analyzed on the same sample. They were collected from the standard hydrography rosette into pre-evacuated flasks through CO_2-flushed tubing to prevent atmospheric contamination. In the laboratory at University of Victoria, samples will be cryogenically purified on a vacuum line and analyzed against a standard of similar composition on an isotope ratio mass spectrometer. These samples were collected at the following stations and depths:

K1: 1500, 1200, 600, 50±, 30, 10± m
LS2: 700, 500, 300, 200, 100, 10± m
BB1: 700, 500, 300, 200, 100, 10±, 6 m
BB2: 1500, 1000, 500, 300, 100, 10± m
BB3: 700, 500, 300, 200, 100, 10± m
CAA1: 600, 100, 60, 40±, 10±, 5 m
CAA3: 600, 100, 60, 40±, 10±, 6 m
CAA4: 100, 60, 40±, 10± m
CAA5: 250, 100, 60, 40±, 10±, 7 m
CAA6: 250, 100, 40±, 10± m, surface
CAA7: surface

Triple oxygen isotope samples were collected in duplicate within and below the mixed layer. Samples were collected from the standard hydrography rosette into pre-evacuated 500mL flasks through CO_2-flushed tubing to prevent atmospheric contamination. Samples will be cryogenically and chromatographically purified on a vacuum line and analyzed against a standard of similar composition on an isotope ratio mass spectrometer for the 16, 17 and 18 oxygen isotopes:

K1: 30, 10± m
LS2: 50±, 10± m
BB1: 50±, 10± m
BB2: 17, 6 m
BB3: 30, 10± m
CAA1: 35, 5 m
CAA3: 20, 6 m
CAA4: oxygen max, 10± m
CAA5: 20, 7 m
CAA6: 14 m, surface
CAA7: 11 m, surface

^{18}O incubations were collected in triplicate at 6 light depths (100, 50, 30, 15, 1 and 0.2%) at K1, LS2 BB1, BB2, BB3, CAA1, CAA3, CAA5, CAA6, CAA7. Light levels were determined on a

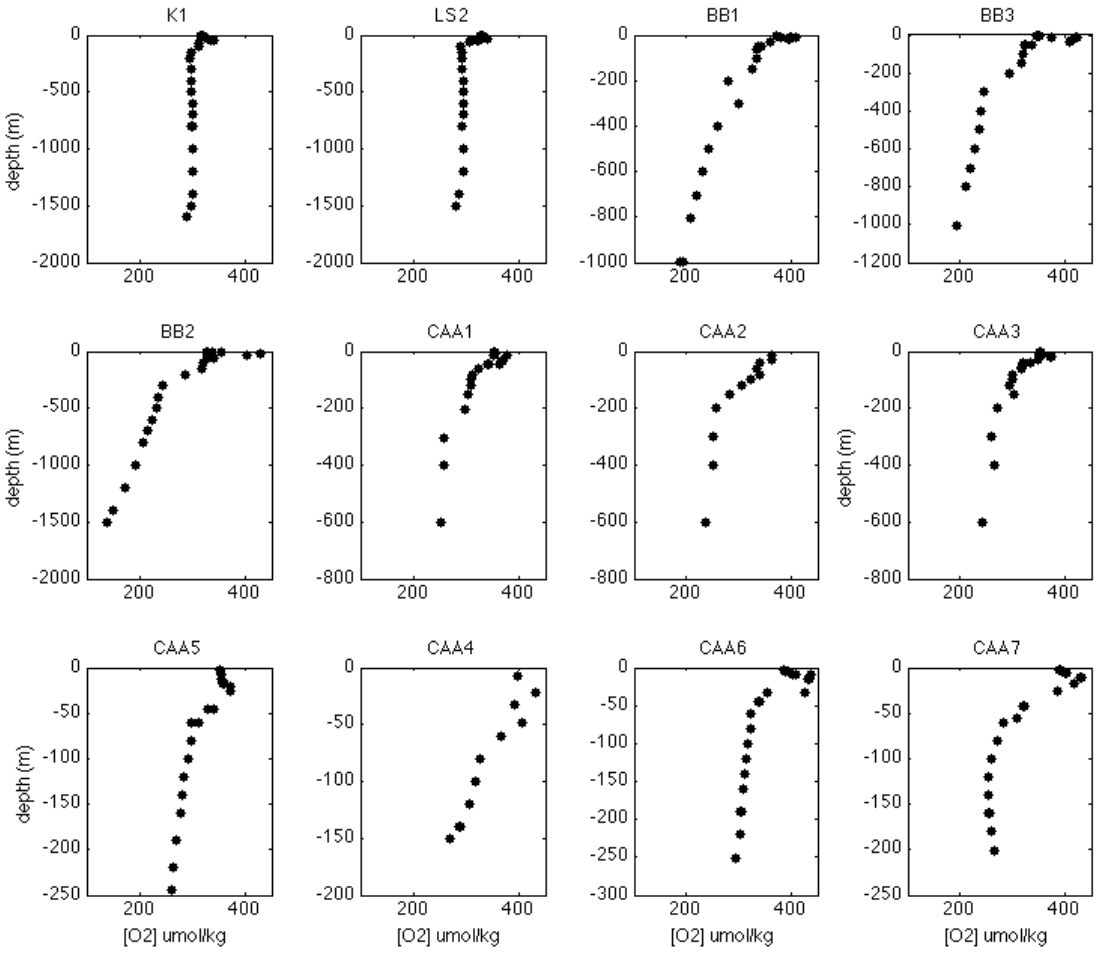
separate PAR cast measured by Marjolaine Blais (Michel Gosselin's research group). Samples were spiked with ^{18}O labeled water and incubated for 24 hours under a constant flow of seawater. The light levels were simulated using tubes covered in neutral density film. After 24 hours, the samples were collected into pre-evacuated flasks through CO_2-flushed tubing to prevent atmospheric contamination and will be analyzed at the University of Victoria with a similar method to the N_2/Ar and O_2/Ar samples.

Noble gas samples were to characterize deep-water masses. Samples were collected from the standard hydrography rosette into pre-evacuated flasks through CO_2-flushed tubing to prevent atmospheric contamination. In the laboratory at University of Victoria, samples are cryogenically purified on a vacuum line and analyzed at the following stations and depths:

K1: 1500, 1200, 600 m
BB2: 1500, 1000, 500 m

Dissolved oxygen samples were taken from the GEOCHEM casts at every depth and all stations. They were titrated onboard using a Mettler Toledo DM 140-Sc probe within 30 hours of collection.

Preliminary results
The figure below shows the preliminary oxygen concentration profiles from the 12 stations. Results from the other analyses will not be available for a few months.



4. User experience

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

Satisfied

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

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.

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

5.1.13 ^{234}Th for export production

Principal Investigator: Lisa Miller[1]
Cruise Participants: Cheng Kuang[2], Maureen Soon[2]

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

Introduction and objectives
The purpose of this measurement is to estimate the export flux of carbon, which can then be compared to the multiple productivity measurements performed at each of the stations

Operations conducted during the Leg/methodology
The deficit of Thorium-234 in surface water has been widely used as a tracer of particle flux from surface water. Th-234 flux estimated from this deficit is converted to carbon flux using the POC/Th-234 ratio measured on particles. To limit the number of samples to be analyzed, one sample integrated over the upper 100m (by mixing five 2L samples collected at constant interval within the upper 100m) were processed on-board. Total Th-234 was obtained by MnO2 co-precipitation on 2L of the composite samples. Particles were obtained both by filtering 6 – 8 L of the composite samples, by taking a sub-sample from the large volume pump filter deployed just under the mixed layer. A Nylon mesh was also positioned on top of the latter to capture the large sinking particles. The samples were then mounted and send as soon as possible for Beta-counting at the Institute of Ocean Science.

Table 5.1.13.1: Samples taken for ^{234}Th measurements

Station	12L sample	LVP
K1	x	
LS2	x	x
BB1	x	x
BB2	x	x
BB3	x	x
CAA1	x	x
CAA2	x	x
CAA3	x	x
CAA4	x	x
CAA5	x	x
CAA6	x	x
CAA7	x	x

5.1.14 Genomics

Principal Investigator: Julie LaRoche
Cruise Participants: Nadine Lehmann

Department of Oceanography, Dalhousie University

Introduction and objectives

Operations conducted during the Leg/methodology
Water samples for DNA/RNA analyses were collected at each GEOTRACES station. Samples were taken at ~12 depths per station, distributed over the whole water column. Approximately 4 liters of seawater per depth were collected directly from the niskin into collapsible cubitainers. Sample water was filtered onto 3.0 and 0.2μm Durapore (Millipore) filters using low vacuum (3 kPa). Filters were immediately flash frozen using liquid nitrogen and stored at -80°C until extraction in the laboratory. Molecular analyses will be performed post-cruise at the LaRoche lab at Dalhousie University.

User Experience
a) very satisfied
b) satisfied
c) very satisfied
d) very satisfied
e) very satisfied

5.1.15 XCTD

Principal Investigator: Jane Eert[1]
Cruise Participants: Kristina Brown[2], Pascal Guillot[3]

[1] *Institute of Ocean Science, Sydney BC*
[2]*Woods Hole Oceanographic Institution, Woods Hole MA*
[3]*ArcticNet, Laval University*

Twenty-three expendable conductivity-temperature-depth (XCTD) probes were deployed for the Institute of Ocean Sciences (Scientist: Jane Eert) opportunistically through the Labrador Sea and Baffin Bay. The first XCTD was deployed along the 300m isotbath off the Labrador Shelf. The next 21 XCTDs were deployed at 60-70nm spacing throughout the Labrador Sea and Baffin Bay (Figure 5.1.15.1), and along 2 shelf transects at higher resolution (20-40nm; Figure 5.1.15.1, inset). The 23rd XCTD was deployed in the Canadian Arctic Archipelago at the original station CAA-9.

The diversion of the ship to break ice in Hudson Bay occurred before an XCTD deployment entering into Davis Strait (before station BB1). When the ship resumed operations, travel towards Davis Strait was along the coast of Baffin Bay, XCTDs were resumed again at 70nm intervals after station BB1.

Two high resolution (20-40nm spacing) XCTD transects were carried out in an attempt to capture the southward flowing Baffin currant along the western side of Baffin Bay, one crossing

the shelf towards Clyde River (Figure 5.1.15.1, inset) and another approaching the north section of Lancaster Sound.

Data from the XCTD deployments will be processed at the Institute of Ocean Sciences in Sidney BC.

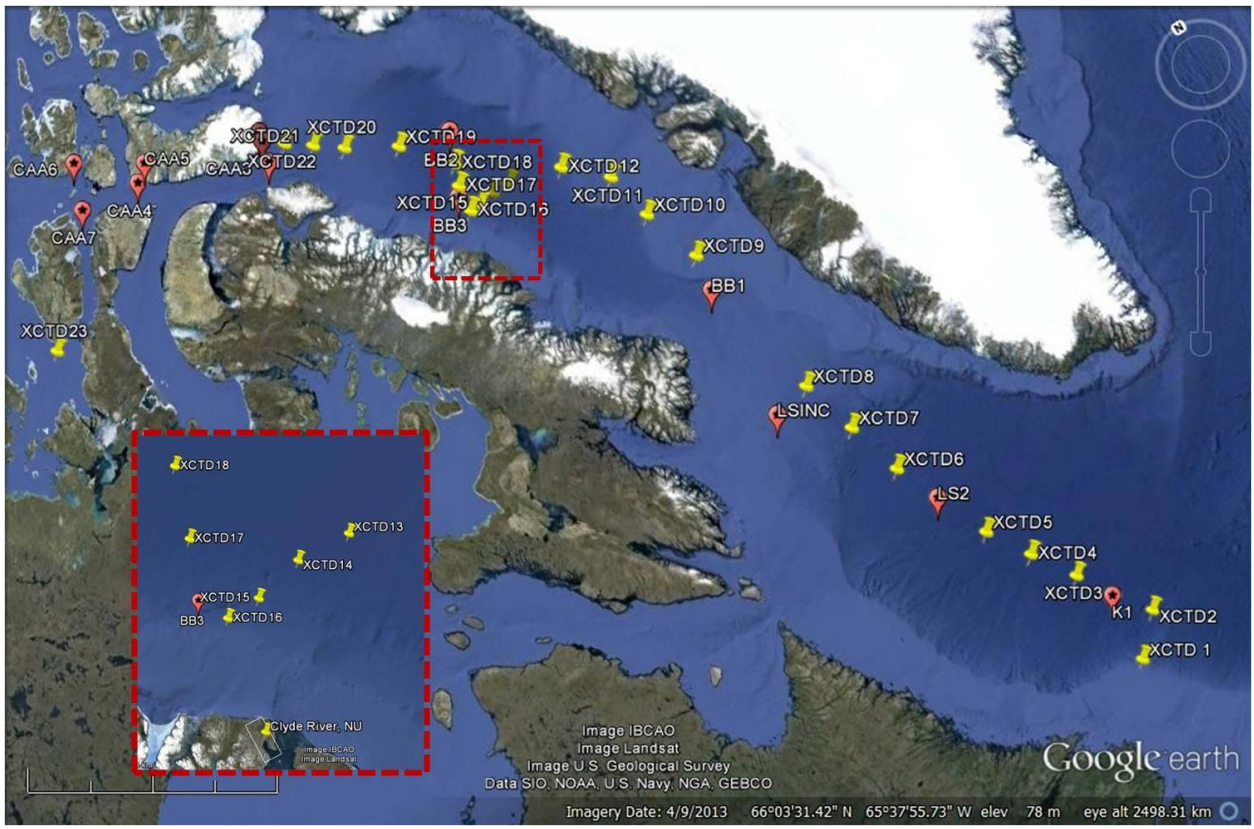


Figure 5.1.15.1. Map of XCTD locations along the Geotraces 2015 (Leg 2) cruise track from the Labrador Sea shelf to the Canadian Arctic Archipelago. Inset plot (red hatched lines): high resolution shelf section towards Clyde River.

5.1.16 Aerosol sampling: Measurement of atmospheric fluxes of trace elements and isotopes in the Labrador Sea, Baffin Bay, Hudson Bay and the Canadian Arctic Archipelago during CCGS Amundsen 2015 Leg 2

Principal Investigators: Bridget Bergquist
Cruise Participants: Priyanka Chandan
Department of Earth Sciences, University of Toronto

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 2, which ran from July – August 2015 gave us an incredible opportunity to study and understand the atmospheric aerosol deposition over the Labrador Sea, Baffin Bay, Hudson Bay and the Canadian Arctic Archipelago from the CCGS Amundsen. The focus 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 2 from July – August, 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
4. Flow funnel attached to the motor
5. Filter holder with a PVC adapter that holds 12-47mm filters

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 5.1.16.1). 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 5.1.16.2). 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 Labrador Sea, Baffin Bay, Hudson Bay and the Canadian Arctic Archipelago. 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. Due to large variation in transit times and station time, aerosols were

strategically collected throughout Leg 2. When the transit time and on station time was significant (>20 hours), aerosols were collected separately during *Transit* and *On Station*. For instance, Sample 1 was collected continuously from Sept-lles in St. Lawrence Strait to Station K1 during Leg 2 over a time period of 50 hours. Based on the Elapsed time indicator installed on the sampler, the bulk aerosols were only collected for ~ 40 hours. The ETI time was 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 5.1.16.1). 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 5.1.16.1. For instance, Sample 6 was collected during transit from BB1 → Clyde River → BB3→ BB2. Due to short *Transit* times, the aerosol sampler remained ON at Clyde River and *On Stations* BB3 and BB2. The details of the aerosol sampling during *Transit* and *On Station* in given in Table 5.1.16.2. 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 5.1.16.1).

The unfortunate delays in the GEOTRACES scientific program owing to Coast Guard operations during Leg 2 in Hudson Bay opened up an opportunity to sample aerosols over Hudson Bay for two weeks in late July. Two samples (i.e. Sample 4 and Sample 5) were collected over a time period of 35-45 hours in Hudson Bay (Table 5.1.16.1). At the end of Leg 2, a total of 9 samples and 3 blanks were collected and stored in individual acid cleaned and pre-labeled petridishes at -20^{o} C.

Table 5.1.16.1: The table below summarizes the date, location and sampling parameters of aerosol samples and blanks on Leg 2.

Samples	Latitude Start	Latitude Stop	Longitude Start	Longitude Stop	UTC Start	UTC Stop	Run time (hours)	ETI (hours)
Sample 1 - Sept-lles- K1	49.36	53.81	-67.01	-54.30	2015-07-11 12:53	2015-07-13 14:48	49.9	39.8
Blank 1 - towards K1	53.81		-54.30		2015-07-13 22:00	2015-07-13 22:05	0.08	
Sample 2A - K1 - LS2	55.62	60.45	-52.37	-56.55	2015-07-15 18:09	2015-07-16 23:34	29.4	4.4
Sample 2B - LS2 - BB1	60.74	64.41	-56.67	-59.19	2015-07-19 0:15	2015-07-19 23:00	22.7	22.7
Sample 3 - LS2	60.45	60.74	-56.55	-56.67	2015-07-17 18:23	2015-07-19 0:05	29.7	8.5
Sample 4 - Hudson Bay	64.16	59.17	-59.60	-79.02	2015-07-20 0:20	2015-07-26 22:53	166.6	45.9
Sample 5 - Hudson Bay	59.19	62.40	-79.03	-77.15	2015-07-26 23:21	2015-07-31 17:18	114.0	37.7
Blank 2 - Hudson Bay	62.37		-78.05		2015-07-31 15:25	2015-07-31 15:30	0.08	
Sample 6 - BB1 -Clyde river - BB3 - BB2	69.03	72.45	-59.07	-66.58	2015-08-04 16:01	2015-08-08 22:06	102.1	67.7
Sample 7 BB3 - Lancaster Sound	72.46	73.53	-67.00	-82.20	2015-08-08 23:36	2015-08-12 9:42	82.1	54.1
Sample 8 CAA3 - CAA7	73.56	71.30	-82.17	-96.43	2015-08-12 10:20	2015-08-16 22:49	108.5	46.6
Blank 3 Lancaster Sound	73.54		-82.21		2015-08-12 10:30	2015-08-12 10:35	0.08	
Sample 9 CAA7 - Kugluktuk	71.24	67.50	-96.56	-115.1	2015-08-16 23:12	2015-08-19 23:22	72.2	17.6

Table 5.1.16.2: A summary of aerosol samples and blanks collected during Transit and On Station on Leg 2

Samples	Transit Sampling		On Station Sampling	
Sample 1	**X**	Sept-IIles - K1		No sampling at Station K1
Blank 1	**X**	Sept-IIles - K1		
Sample 2A	**X**	K1 - LS2		
Sample 2B	**X**	LS2 - BB1		
Sample 3			**X**	LS2
Sample 4	**X**	Hudson Bay	**X**	Hudson Bay
Sample 5	**X**	Hudson Bay	**X**	Hudson Bay
Blank 2			**X**	Hudson Bay
Sample 6	**X**	BB1 - Clyde River - BB3 - BB2	**X**	Clyde River, BB3, BB2
Sample 7	**X**	BB2 - CAA1 -CAA3	**X**	CAA1, 2, 3
Sample 8	**X**	CAA3 - CAA7	**X**	CAA4, 5, 6, 7
Blank 3	**X**	CAA3		
Sample 9	**X**	CAA7 - Kugluktuk	**X**	CAA7, Kugluktuk

Preliminary Results:
The aerosol filter samples were not analyzed or processed during Leg 2. 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.

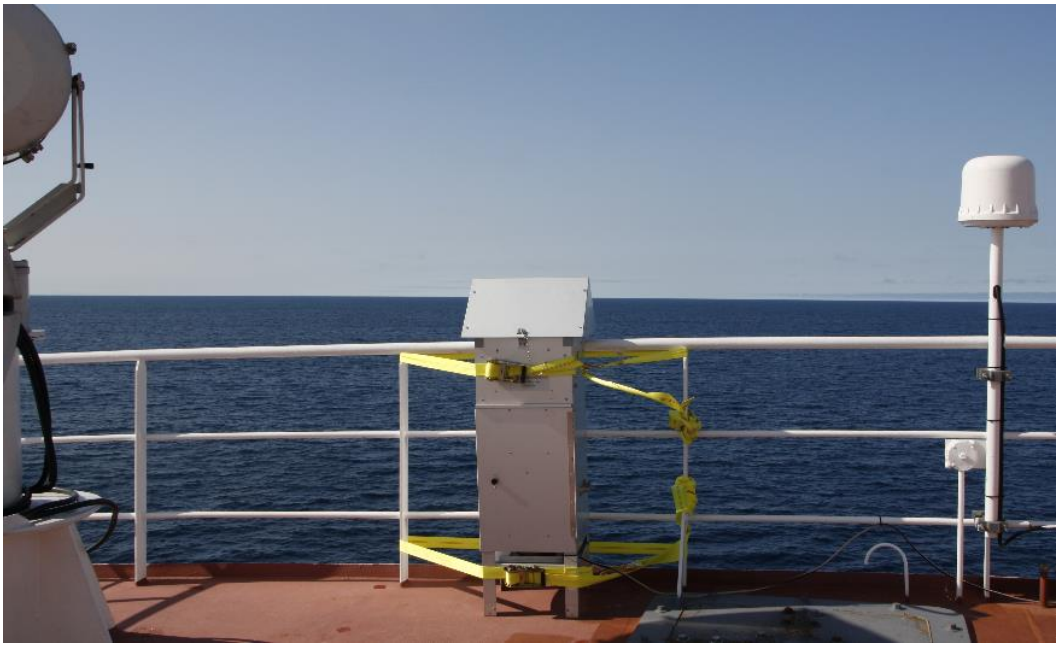


Figure 5.1.16.1: The TISCH volume flow controlled (VFC) high volume aerosol sampler deployed on the bridge deck of the CCGS Amundsen during Leg 2 from July – August, 2015.

Figure 5.1.16.2: The anemometer, which is attached to the aerosol sampler through CR10 datalogger.

Figure 5.1.16.3: The PVC adapter plate that holds 12 – 47mm filter holders (courtesy of Bill Landing)

User Experience:
Overall, I was very satisfied with CCGS Amundsen's operations on Leg 2.
The Captain, Officers and the Crew of the Amundsen were outstanding and very helpful in successfully carrying out aerosol sampling throughout Leg 2. During Station K1, aerosol motor broke down due to sea salt spray and subsequent water damage. The ship's crew including the electrician helped me in replacing the motor and getting the aerosol sampler up and running in a short period of time. In my opinion, the TISCH aerosol sampler can be continuously deployed for an extended period of time. However, during bad weather and high waves, the sampler should be turned off and the motor must be protected from the sea salt spray and water damage. As previously mentioned, the aerosol sampling was carried out strategically to maximize the

aerosol collection. This was because of short transit times and large On station times. Throughout Leg 2, the Captain and the officers accommodated my request to position the ship in forward wind on stations such that the wind remained in sector. This allowed me to collect aerosols both during *Transit* and *On Stations*.

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. Very Satisfied*

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5.1.17 River Sampling

Principal Investigator: Kristina Brown[1]
Cruise Participants: Kristina Brown[1], Roger Francois[2]

[1]*Woods Hole Oceanographic Institution, Woods Hole MA*
[2] *Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia*

River sampling was carried out using the ship's helicopter (Pilot: Martin Dufour) along the ships cruise track as we transited the Canadian Arctic Archipelago (Figure 5.1.17.1). Sampling locations were chosen based on the Canadian Hydrographic Stream Network dataset (Natural Resources Canada), corresponding drainage basin geology from the Geologic Map of North America (USGS, 2005), and the proximity to the cruise track. Fifteen river stations were sampled from August 11th to 19th (Figure 5.1.17.1, Table Rivers 5.1.17.1) for the geochemical parameters listed in Table 5.1.17.2.

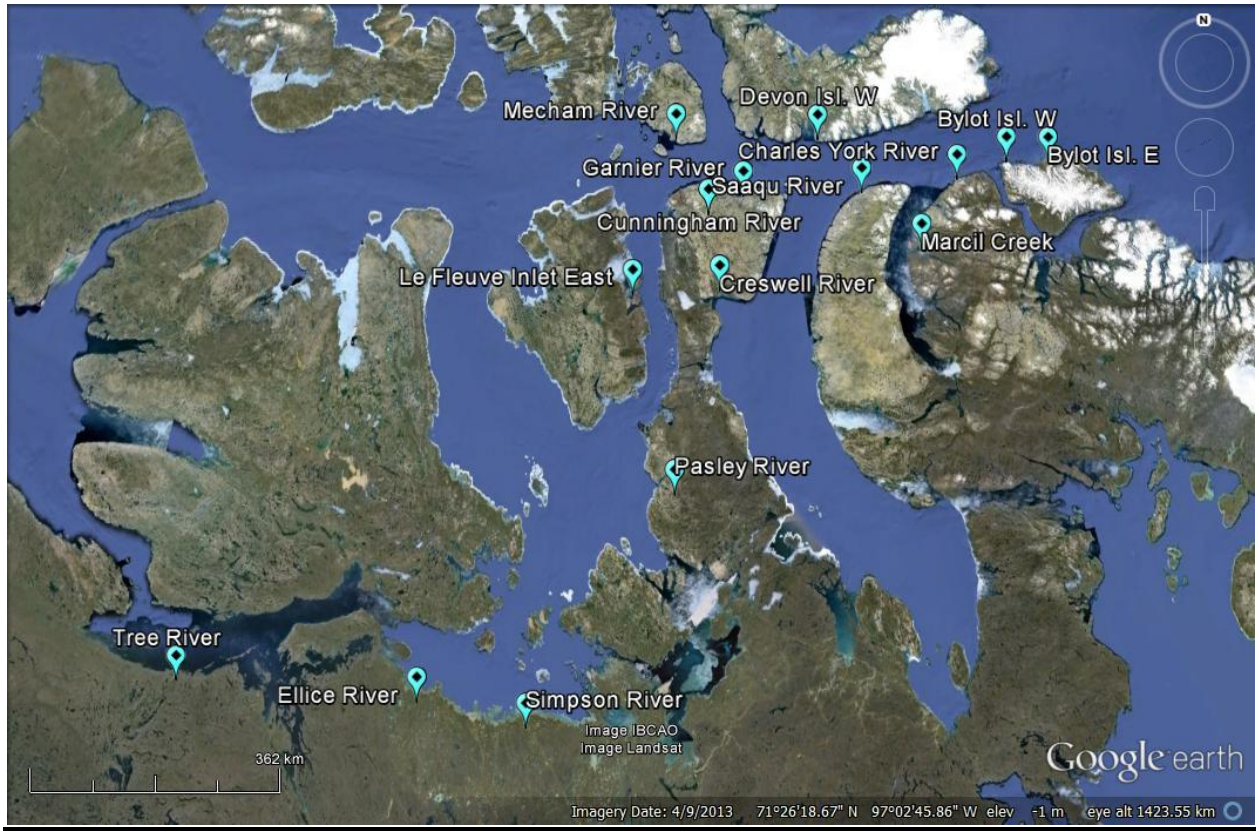


Figure 5.1.17.1. Map of river sampling locations along the Geotraces Leg 2 cruise track through the Canadian Arctic Archipelago.

Table 5.1.17.1 River sampling locations during the 2015 Geotraces (Leg 2) transit via the Canadian Arctic Archipelago.

River Number	**River Name**	**Date Sampled**	**Time (local)**
001	Bylot Island E	August 11, 2015	9:45
002	Bylot Island W.	August 11, 2015	15:00
003	Charles York River	August 12, 2015	5:30
004	Marcil Creek	August 12, 2015	7:21
005	Saaqu Rver	August 12, 2015	9:47
006	Devon Isl. W.	August 12, 2015	15:00
007	Cunningham River	August 13, 2015	16:01
008	Garnier River	August 13, 2015	17:55
009	Mecham River	August 14, 2015	8:45
010	Creswell River	August 16, 2015	11:40
011	Le Fleuve Inlet (East Side)	August 16, 2015	13:49
012	Pasley River	August 16, 2015	20:25
013	Simpson River	August 17, 2015	22:33
014	Ellice River	August 18, 2015	6:41
015	Tree River	August 19, 2015	7:35

Table 5.1.17.2 Geochemical parameters sampled during the 2015 Geotraces Leg 2 transit via the Canadian Arctic Archipelago. Analyses to be carried out at UBC, UVIC, and WHOI.

Dissolved Inorganic Carbon (DIC)	Particulate Organic Carbon (POC)	Nutrients (N, P, Si)	Dissolved Trace Metals (Fe, Mg, Pb, Ga, REE, Hg)
Total Alkalinity	14C and 13C POC	Salinity	Pb-isotopes
pH	Dissolved Organic Carbon (DOC)	Specific Density	Dissolved and particulate Nd isotopes
14C and 13C DIC	14C and 13C DOC	Si-isotopes	Sediments

Figure 5.1.17.2 (a) Roger Francois sampling from the Mecham River, Cornwallis Island; (b) Roger Francois and pilot Martin Dufor at the Tree River.

5.2 ArcticNet

5.2.1 ArcticNet CTD/Rosette

Principal Investigator: ArcticNet
Cruise Participants: Pascal Guillot, Cris Seaton

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 5.2.1.1) 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.

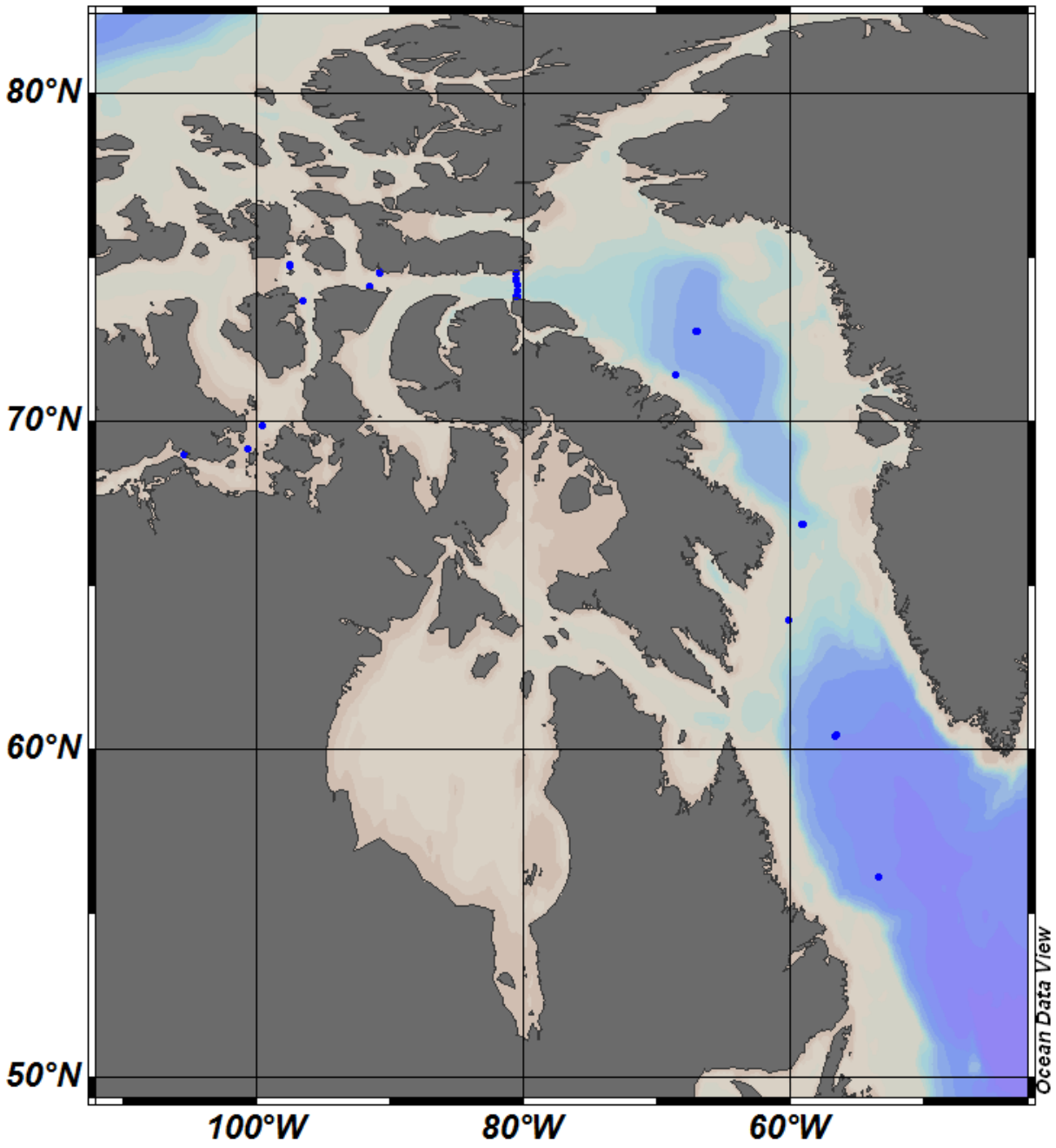
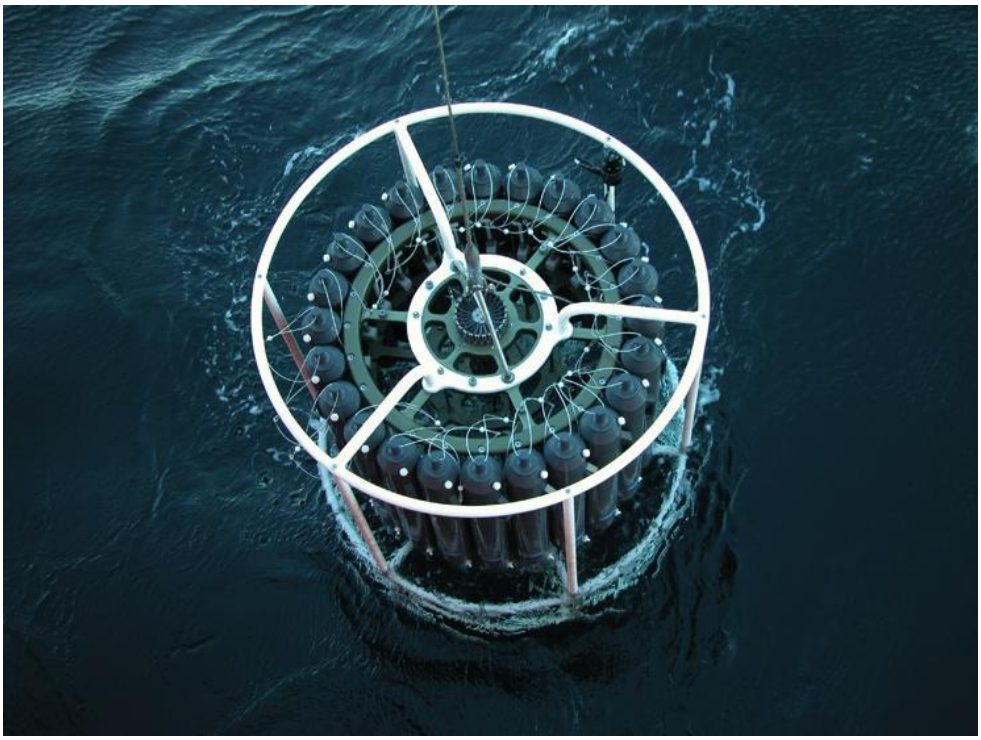


Figure 5.2.1.1 ArcticNet/Geotraces study region in Eastern Canadian Arctic, Leg2.
ArcticNet 1502– Rosette Team Report

Methodology
CTD-Rosette



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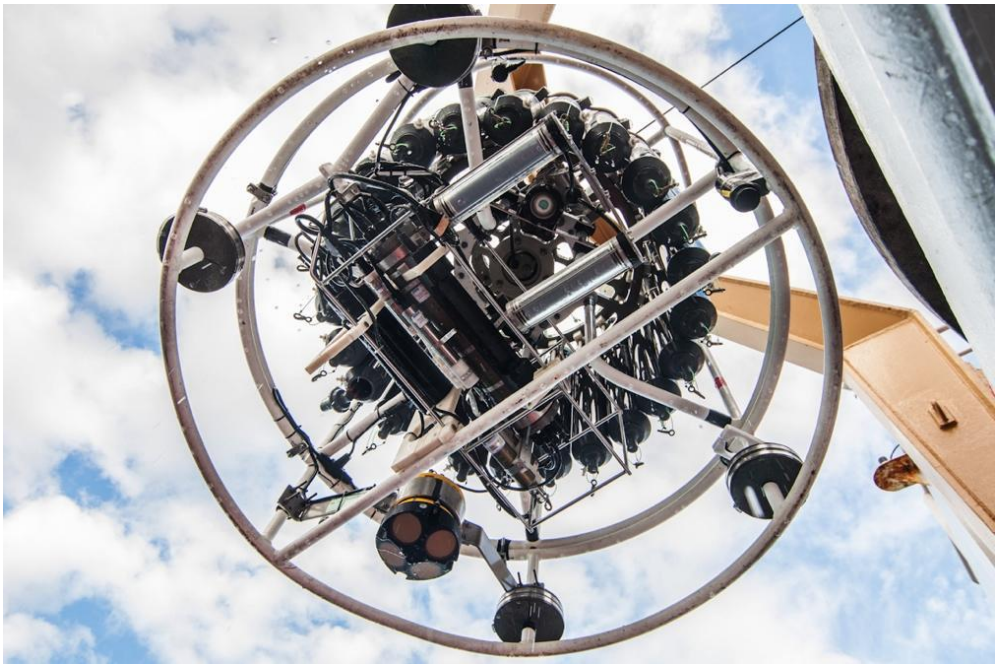
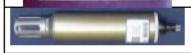
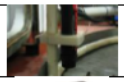


Photo Jessy Barrette©
Fig. 5.2.1.2 The rosette frame is equipped with twenty-four (24) twelve (12) liter bottles and the sensors described in Tables 5.2.1.1 and 5.2.1.2

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 Biospherical	PAR	PAR Dynamic Range: $1.4x10^{-5}$ to 0.5 µE/(cm^2 sec)	7270	19-Dec-2014
	QCR-2200 Biospherical	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

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

Table 5.2.1.2 Sensor specifications

Probes calibration
Salinity:
Seabird CTD
Water samples were taken on several casts 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.

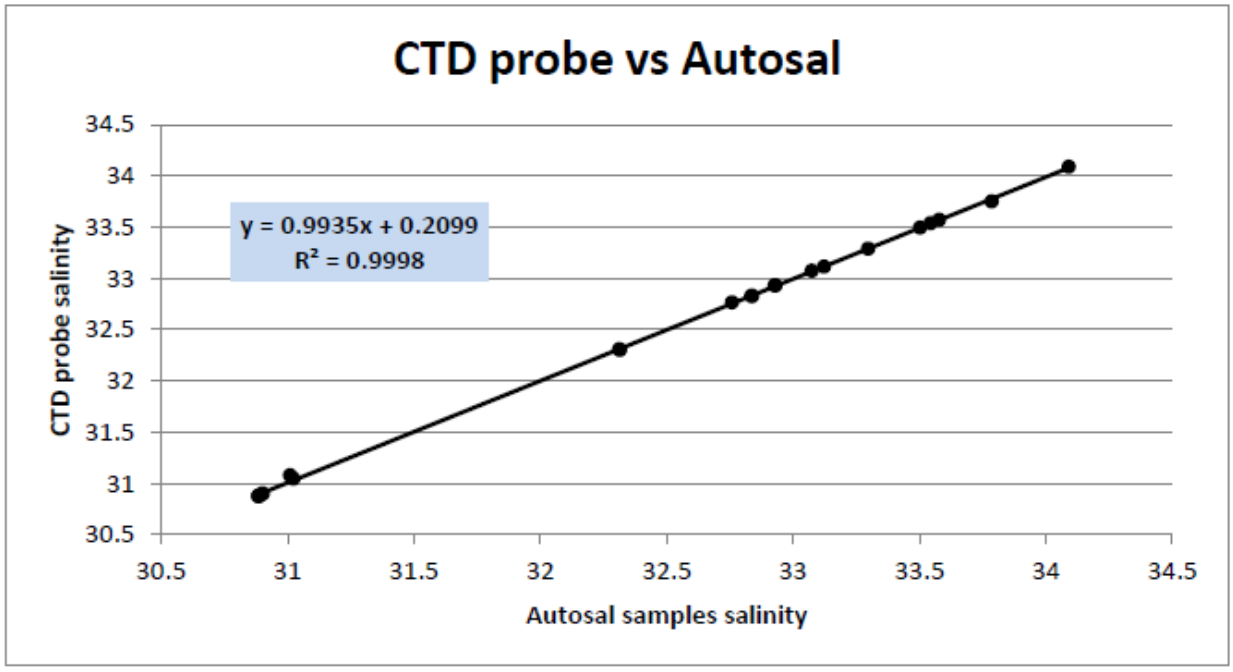


Fig. 5.2.1.3 CTD salinity validation with in situ titrations

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 analysed 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.
A problem occurred at the end of the cruise leading to unreliable data. The electrodes were rinsed with isopropilic alcohol (70 %).

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.

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 leg2 log book

Cast	Event	Station	Date début UTC	Heure UTC	Lat. (N)	Long. (W)	Fond (m)	Prof. cast (m)
001	004	K1	14 / 07 / 15	09 : 58	56 ° 7.271	053 ° 22.385	3310	500
002	006	K1	14 / 07 / 15	13 : 14	56 ° 7.290	053 ° 22.211	3309	1000
003	006	K1	14 / 07 / 15	13 : 35	56 ° 7.399	053 ° 22.264	3309	1600
004	008	K1	14 / 07 / 15	20 : 33	56 ° 7.060	053 ° 22.915	3312	1500
005	009	K1	14 / 07 / 15	23 : 48	56 ° 7.313	053 ° 22.313	3312	1600
006	015	LS2	17 / 07 / 15	08 : 15	60 ° 27.216	056 ° 32.884	3023	700
007	021	LS2	17 / 07 / 15	23 : 26	60 ° 26.575	056 ° 32.071	3016	1500
008	023	LS2	18 / 08 / 15	04 : 44	60 ° 25.370	056 ° 34.063	3028	700
009	026	LS2	18 / 07 / 15	13 : 25	60 ° 26.686	056 ° 33.346	3028	200
010	032	Incubation	20 / 07 / 15	01 : 51	63 ° 57.126	060 ° 6.618	480	203
011	036	BB1	03 / 08 / 15	09 : 11	66 ° 51.435	059 ° 3.701	1040	500
012	039	BB1	03 / 08 / 15	14 : 52	66 ° 51.457	059 ° 3.995	1039	1000
013	043	BB1	03 / 08 / 15	23 : 34	66 ° 51.332	059 ° 3.438	1038	1000
014	053	BB3	05 / 08 / 15	20 : 45	71 ° 24.544	068 ° 35.761	1243	1000
015	056	BB3	06 / 08 / 15	03 : 44	71 ° 24.653	068 ° 36.205	1251	1000
016	061	BB3	06 / 08 / 15	12 : 39	71 ° 24.918	068 ° 36.791	1272	300
017	063	BB3	06 / 08 / 15	15 : 39	71 ° 24.539	068 ° 35.864	1252	300
018	071	BB2	07 / 08 / 15	19 : 43	72 ° 45.224	066 ° 59.599	2371	1500
019	073	BB2	08 / 08 / 15	00 : 58	72 ° 44.964	067 ° 0.131	2346	1000
020	078	BB2	08 / 08 / 15	10 : 24	72 ° 45.097	066 ° 59.665	2369	300
021	081	BB2	08 / 08 / 15	13 : 42	72 ° 45.040	066 ° 59.988	2369	300
022	091	CAA1	09 / 08 / 15	22 : 17	74 ° 31.280	080 ° 34.292	635	625
023	094	CAA1	10 / 08 / 15	03 : 37	74 ° 31.333	080 ° 33.841	632	600
024	096	CAA1	10 / 08 / 15	06 : 47	74 ° 31.316	080 ° 34.834	633	613
025	098	CAA1	10 / 08 / 15	12 : 01	74 ° 31.094	080 ° 33.880	636	300
026	100	CAA1	10 / 08 / 15	15 : 15	74 ° 31.411	080 ° 33.980	634	200
027	102	CAA1	10 / 08 / 15	17 : 00	74 ° 31.258	080 ° 34.073	636	300
028	104	CAA2	10 / 08 / 15	19 : 15	74 ° 19.254	080 ° 29.743	698	300
029	106	CAA2	10 / 08 / 15	21 : 39	74 ° 18.956	080 ° 29.836	1464	300
030	109	CAA2	10 / 08 / 15	23 : 33	74 ° 18.860	080 ° 31.191	702	600
031	111	CAA2	11 / 08 / 15	04 : 00	74 ° 19.074	080 ° 29.755	700	690
032	112	CAA2	11 / 08 / 15	05 : 44	74 ° 19.207	080 ° 30.358	700	685
033	113	AN323	11 / 08 / 15	07 : 14	74 ° 9.482	080 ° 28.327	789	780
034	114	AN324	11 / 08 / 15	09 : 11	73 ° 58.892	080 ° 27.924	773	760
035	116	CAA3	11 / 08 / 15	12 : 13	73 ° 48.928	080 ° 29.249	674	300
036	119	CAA3	11 / 08 / 15	16 : 22	73 ° 49.114	080 ° 29.536	687	300
037	122	CAA3	11 / 08 / 15	22 : 04	73 ° 49.086	080 ° 28.933	690	200
038	124	CAA3	11 / 08 / 15	23 : 53	73 ° 49.120	080 ° 29.365	690	600
039	126	CAA3	12 / 08 / 15	04 : 21	73 ° 49.031	080 ° 30.325	673	665
040	127	CAA3	12 / 08 / 15	05 : 59	73 ° 49.106	080 ° 29.944	687	663
041	129	CAA5	12 / 08 / 15	21 : 40	74 ° 32.374	090 ° 47.652	259	239
042	131	CAA5	12 / 08 / 15	22 : 55	74 ° 32.251	090 ° 48.108	254	243
043	133	CAA5	13 / 08 / 15	02 : 54	74 ° 32.350	090 ° 47.899	259	250
044	135	CAA5	13 / 08 / 15	04 : 32	74 ° 32.324	090 ° 48.386	257	250
045	139	CAA5	13 / 08 / 15	14 : 13	74 ° 31.955	090 ° 48.145	241	231
046	141	CAA4	13 / 08 / 15	17 : 38	74 ° 7.354	091 ° 29.941	181	160
047	143	CAA4	13 / 08 / 15	18 : 53	74 ° 7.306	091 ° 30.775	178	168
048	146	CAA4	14 / 08 / 15	01 : 18	74 ° 7.260	091 ° 30.707	177	157

049	148	CAA4	14 / 08 / 15	05 : 12	74 ° 7.500	091 ° 29.600	193	150
050	150	CAA4	14 / 08 / 15	06 : 54	74 ° 7.460	091 ° 30.174	186	176
051	152	CAA6	14 / 08 / 15	19 : 25	74 ° 45.539	097 ° 27.384	253	243
052	154	CAA6	14 / 08 / 15	20 : 48	74 ° 45.404	097 ° 27.131	249	242
053	157	CAA6	15 / 08 / 15	01 : 37	74 ° 45.576	097 ° 27.134	260	250
054	159	CAA6	15 / 08 / 15	05 : 29	74 ° 45.260	097 ° 27.448	246	190
055	161	CAA6	15 / 08 / 15	08 : 48	74 ° 45.444	097 ° 27.281	260	250
056	163	CAA7	15 / 08 / 15	21 : 09	74 ° 39.920	096 ° 35.590	214	204
057	165	CAA7	15 / 08 / 15	22 : 26	74 ° 39.973	093 ° 33.463	211	192
058	167	CAA7	15 / 08 / 15	02 : 16	73 ° 40.373	096 ° 31.429	219	200
059	170	CAA7	16 / 08 / 15	07 : 14	73 ° 39.610	096 ° 32.131	218	210
060	171	CAA7	16 / 08 / 15	09 : 22	73 ° 39.832	096 ° 32.173	222	190
061	173	VS	17 / 08 / 15	10 : 49	69 ° 52.607	099 ° 32.416	138	129
062	175	AN312	17 / 08 / 15	18 : 12	69 ° 9.886	100 ° 41.395	59	50
063	177	AN312	17 / 08 / 15	19 : 23	69 ° 9.974	100 ° 41.963	59	40
064	179	AN312	17 / 08 / 15	20 : 41	69 ° 9.892	100 ° 41.801	60	50
065	181	AN314	18 / 08 / 15	16 : 13	68 ° 58.133	105 ° 27.697	79	69
066	183	AN314	18 / 08 / 15	17 : 43	68 ° 58.049	105 ° 27.260	79	69
067	185	AN314	18 / 08 / 15	18 : 09	68 ° 58.267	105 ° 27.554	78	58

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.

Problems encountered with the CTD-Rosette

Several bottles were replaced for spigot or leaking problems.

The fluorescence Seapoint sensor sn 3114 were replaced by sensor sn 3120 after the cast 038.

The Isus nitrate sensor were replaced.

A new mechanical and electrical winch termination was performed before cast 045.

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.

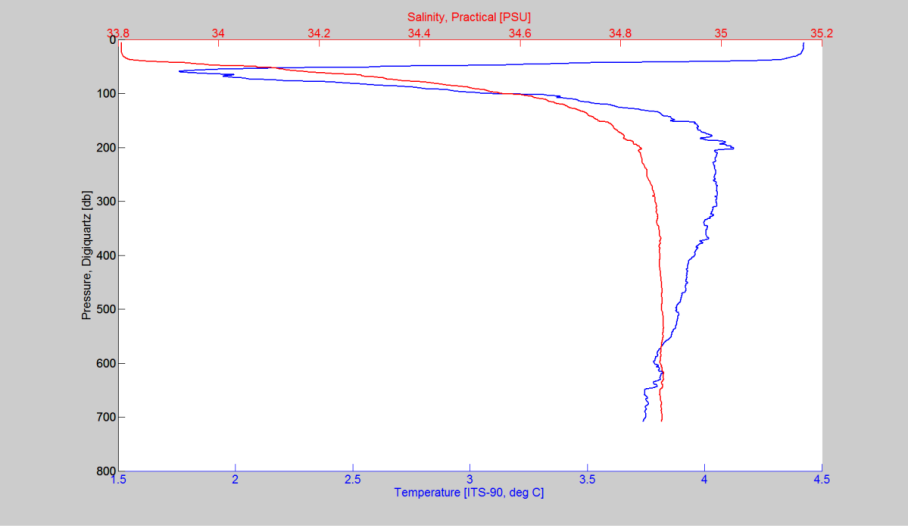


Fig. 5.2.1.4: Example of vertical structure (temperature and salinity) for cast 006

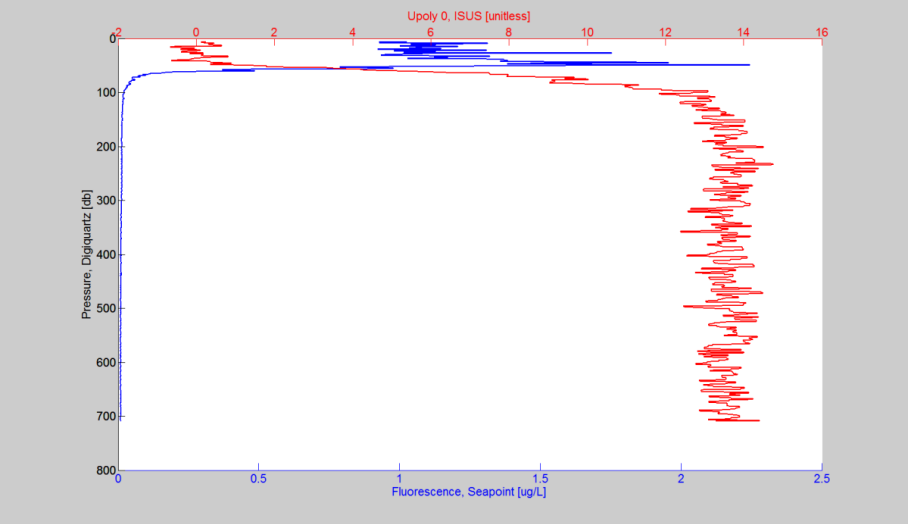


Fig. 5.2.1.5: Example of the vertical structure (nitrate and fluorescence) for cast 006

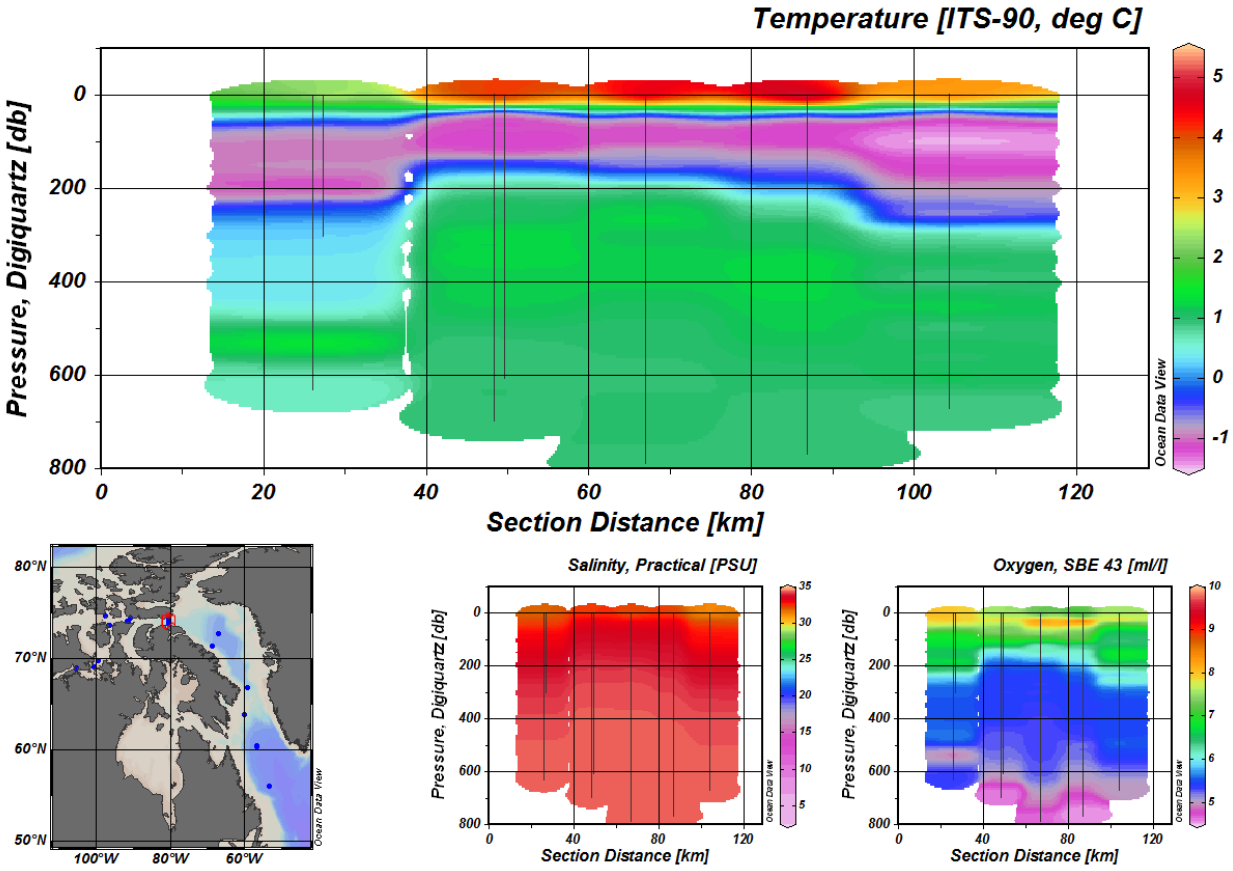


Fig. 5.2.1.6 Evolution of the main parameters along the transect “Lancaster Sound’.

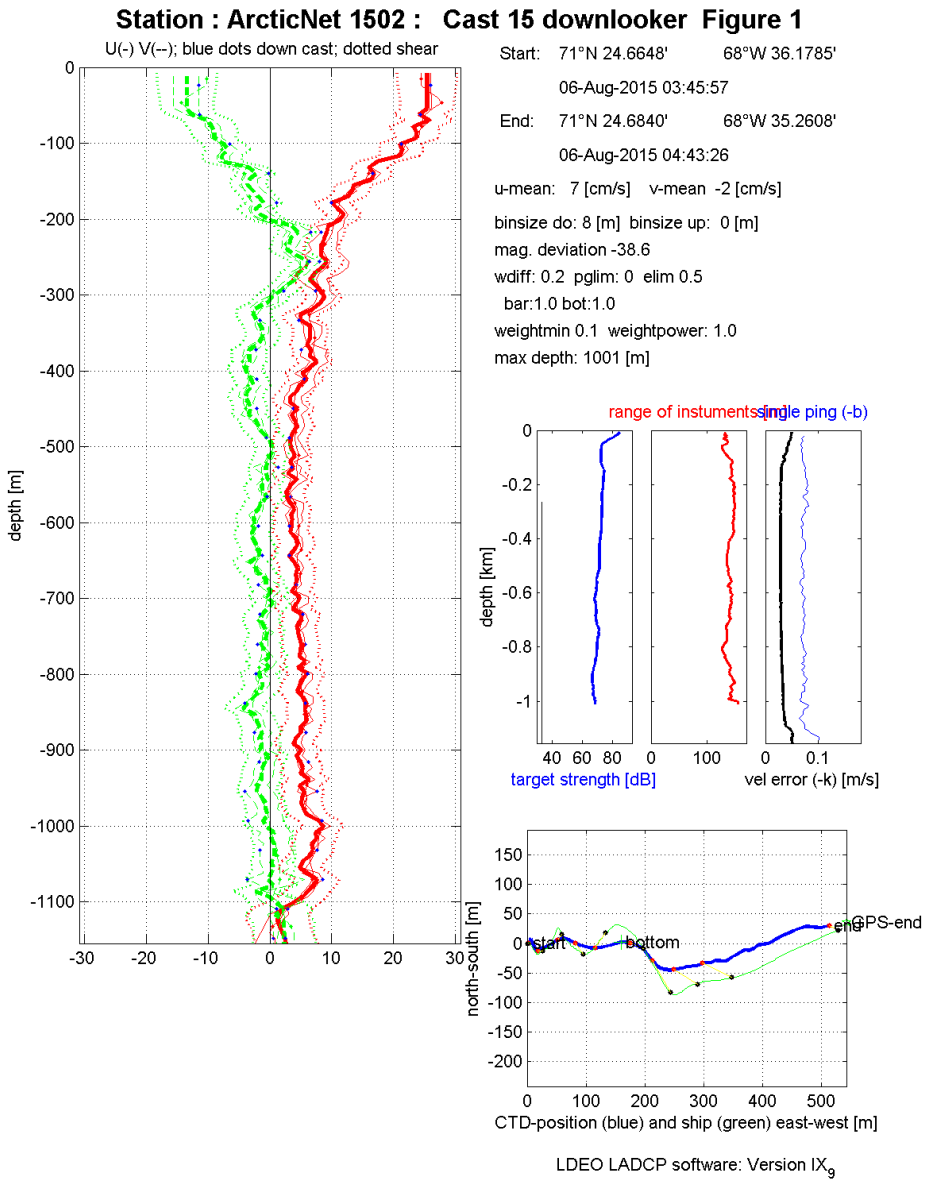


Fig. 5.2.1.7 Example of current velocities for the cast 015 recorded by the LADCP

5.2.2 Marine productivity: Carbon and nutrients fluxes

Principal Investigator: Jean-Éric Tremblay
Cruise Participants: Isabelle Courchesne, Gabrièle Deslongchamps

Department of Biology, Laval University

Introduction and objectives.

The Arctic climate displays high inter-annual variability and decadal oscillations that modulate growth conditions for marine primary producers. Much deeper perturbations recently became evident in conjunction with globally rising CO_2 levels and temperatures (IPCC 2007). Environmental changes already observed include a decline in the volume and extent of the sea-ice cover (Johannessen et al. 1999, Comiso et al. 2008), an advance in the melt period (Overpeck et al. 1997, Comiso 2006), and an increase in river discharge to the Arctic Ocean (Peterson et al. 2002, McClelland et al. 2006) due to increasing precipitation and terrestrial ice melt (Peterson et al. 2006). Consequently a longer ice-free season was observed in both Arctic (Laxon et al. 2003) and subarctic (Stabeno & Overland 2001) environments. These changes entail a longer growth season associated with a greater penetration of light into surface waters, which is expected to favoring phytoplankton production (Rysgaard et al. 1999), food web productivity and CO_2 drawdown by the ocean. However, phytoplankton productivity is likely to be limited by light but also by allochtonous nitrogen availability. The supply of allochtonous nitrogen is influenced by climate-driven processes, mainly the large-scale circulation, river discharge, upwelling and regional mixing processes. In the global change context, it appears crucial to improve the knowledge of the environmental processes (i.e. mainly light and nutrient availability) interacting to control phytoplankton productivity in the Canadian Arctic. Moreover, interest is growing about the implication of environments such as sea ice and melt ponds upon the global Arctic environment. Thereby, the nutrient availability and interactions of these environments need to be studied as well.

The main goals of our team for leg 2 of ArcticNet/Geotraces 2015 were to establish the horizontal and vertical distributions of phytoplankton nutrients and the influence of different processes (e.g. mixing, upwelling and biological processes) on these distributions. This was done in the water column. Auxiliary objective was to calibrate the *ISUS* nitrate probe attached to the Rosette.

Methods.
Samples for inorganic nutrients (ammonium, nitrite, nitrate, orthophosphate, orthosilicic acid) were taken at all rosette stations (Table 5.2.2.1) to establish detailed vertical profiles. Samples were stored at 4°C in the dark and analyzed for nitrate, nitrite, orthophosphate and orthosilicic acid within a few hours on a Bran+Luebbe AutoAnalyzer 3 using standard colorimetric methods adapted for the analyzer (Grasshoff et al. 1999). The ammonium samples were analysed using the fluorometric method of Holmes et al. (1999).

User experience.
a. Very satisfied
b. Satisfied within the conditions (hold up in Hudson Bay)
c. Very satisfied
d. Very satisfied
e. Very satisfied

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Table 5.2.2.1. List of sampling stations and measurements during leg 2

Stations	**Event**	**NO3, NO2, Si, PO4**	**NH4**	**Urea**	**NO3/NH4/ Urea uptake**	**N2 fixation**	**Nitrifi-cation**	**15N/18 O-NO3**
K1	4	**X**	**X**					
	5	**X**						
	6	**X**	**X**					
	7	**X**						
LS2	15	**X**	**X**					
	16	**X**						
	18	**X**						
	21	**X**	**X**					
	25	**X**						
BB1	34	**X**						
	36	**X**	**X**					
	39	**X**	**X**					
	40	**X**						
BB2		**X**						
		X						
		X						

		X						
BB3	53	**X**	**X**					
	54	**X**						
	57	**X**						
	61	**X**						
	63	**X**	**X**					
CAA1	92	**X**						
	94	**X**	**X**					
	95	**X**						
	98	**X**	**X**					
	102	**X**						
CAA2	104	**X**	**X**					
	106	**X**						
	108	**X**						
	109	**X**	**X**					
323		**X**	**X**					
324		**X**	**X**					
CAA3	117	**X**						
	119	**X**	**X**					
	123	**X**						
	124	**X**	**X**					
CAA4	146	**X**	**X**					
	148	**X**	**X**					
	149	**X**						
	150	**X**	**X**					
CAA5	130	**X**						
	131	**X**	**X**					
	134	**X**						
	135	**X**	**X**					
	136	**X**						
	139	**X**						
CAA6	157	**X**	**X**					
	159	**X**	**X**					
	160	**X**						
	161	**X**						
CAA7	167							
	171							
312		**X**						

314		**X**						
Clara's incub.		**X**						
Rachel's incub.		**X**						

5.2.3 Phytoplankton production and biomass

Principal Investigator: Michel Gosselin
Cruise Participants: Marjolaine Blais

ISMER, Université du Québec à Rimouski, Rimouski, QC

Introduction and objectives.
Primary production plays a central role in the oceans as it supplies organic matter to the higher trophic levels, including zooplankton, fish larvae and marine mammals and birds. Marine polar ecosystems are particularly sensitive to any changes in primary production due to their low number of trophic links (Grebmeier et al. 2006; Moline et al. 2008; Post et al. 2009). The Arctic Ocean is changing as evidenced by the decrease in sea ice thickness and extent (Stroeve et al. 2007; Kwok et al. 2009), the early melt and late freeze-up of sea ice (Markus et al. 2009) and the enhancement of the hydrological cycle (Peterson et al. 2006; Serreze et al. 2006). These environmental changes have already altered the phytoplankton biomass distribution in the Arctic Ocean (Arrigo et al. 2008; Pabi et al. 2008). In this context, the general objectives of our research project are (1) to determine the spatial and temporal variability in production, biomass, abundance and taxonomic composition of the phytoplankton communities, and (2) to determine the role of environmental factors on the phytoplankton dynamics and its variability in Baffin Bay and in the Canadian Arctic Archipelago.

To avoid duplication of measurements with the ones done by GEOTRACES team, our specific objectives for leg 1 were reduced to determine (1) the downwelling incident irradiance, every 10 minutes, with a Li-COR 2 pi sensor; (2) the transparency of the upper water column with a Secchi disk; (3) the underwater irradiance profile with a PNF-300 probe; (4) the chlorophyll *a* and pheopigment concentrations with a Turner Designs fluorometer (3 size-classes: >0.7 µm, >5 µm, >20 µm); and (5) the phytoplankton production using the 14C assimilation method (2 size-fractions: >0.7 µm, >5 µm).

Methodology
At each water column station, we collected water samples with 12 L Niskin-type bottles attached to the CTD-rosette. During the daytime, we determined the depth of the euphotic zone with the Secchi disk and the PNF-300 probe. Size-fractionated (3 size-classes: >0.7 µm, >5 µm and >20 µm) chlorophyll *a* concentrations were measured onboard the ship at each sampling depth with a Turner Designs fluorometer (model 10-AU). Size-fractionated (2 size-classes: >0.7 µm and >5 µm) primary production was estimated at 7 optical depths in the water column (i.e. 100%, 50%, 30%, 15%, 5%, 1%, and 0.2% of the surface irradiance) following JGOFS protocol for simulated

in situ incubation. The other samples collected during this expedition will be analyzed at ISMER. Detailed sampling activities are summarized in Table 5.2.3.1. Our chlorophyll *a* data were shared with Jean-Éric Tremblay's teams for the calibration of the chlorophyll *a* fluorescence sensor and with GEOTRACES team. Our PAR data, downwelling incident irradiance and underwater irradiance profiles, were also shared with GEOTRACES.

Table 5.2.3.1. Sampling operations during leg 1 of the ArcticNet 2014 expedition on board the CCCS *Amundsen*.

			Position		Chlorophylle *a*			Primary production	
Station	Cast	Date	Lat (°N)	Long (°W)	Total	> 5µm	> 20µm	Total	> 5 µm
K1	1	14-Jul-14	56°7.342	53°22.385	X	X	X	X	X
LS-2	6	17-Jul-14	60°27.218	56°32.884	X	X	X	X	X
BB-1	11	3-Aug-14	66°51.397	59°03.544	X	X	X	X	X
BB-3	17	6-Aug-14	71°24.494	68°35.684	X	X	X	X	X
BB-2	20	8-Aug-14	72°45.100	66°59.568	X	X	X	X	X
St. 322 (CAA-1)	25	10-Aug-14	74°31.067	80°34.331	X	X	X	X	X
St. 300 (CAA-2)	28	10-Aug-14	73°19.288	79°29.603	X	X	X	X	X
St. 325 (CAA-3)	35	11-Aug-14	73°48.862	80°28.684	X	X	X	X	X
St.CAA-5	45	13-Aug-14	74°32.004	90°48.119	X	X	X	X	X
St.CAA-4	50	14-Aug-14	74°7.480	90°30.055	X	X	X	X	X
CAA-6 (Ice edge)	55	15-Aug-14	74°45.431	97°27.461	X	X	X	X	X
CAA-7	59	16-Aug-14	73°39.611	96°32.130	X	X	X	X	X
VS (Ice edge)	61	17-Aug-14	69°52.607	99°32.488	X	X	X		
312	64	17-Aug-14	69°09.896	100°41.771	X	X			
314	65	18-Aug-14	68°58.102	105°27.697	X	X	X	X	X

Preliminary results

Chlorophyll *a* concentrations varied from about 25 to 120 mg m-2 in the Labrador Sea and southern Baffin Bay. Large cells (> 5 µm) composed between 20 and 95% of the total biomass (Figure 5.2.3.1).

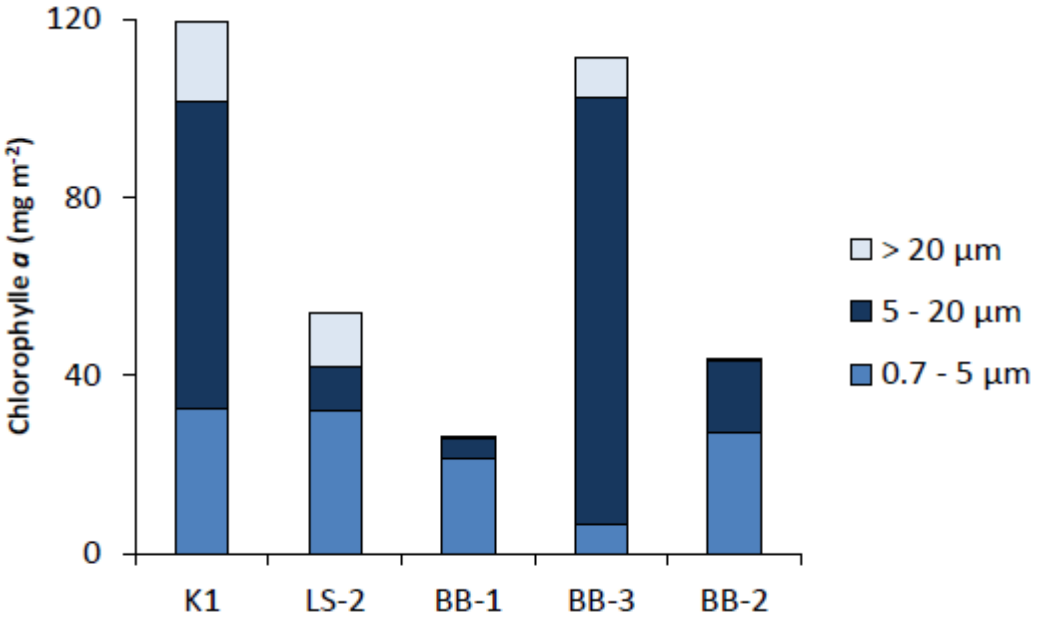

Figure 5.2.3.1. Chlorophyll *a* concentrations integrated over 100 m for different size fractions, 0.7-5 µm, 5-20 µm and > 20 µm, in the Labrador Sea and southern Baffin Bay.

Chlorophyll *a* concentrations varied from about 15 to 175 mg m-2 in the Canadian Arctic Achipelago. Large cells (> 5 µm) dominated biomass at all stations (Figure 2). The station CAA-6 had highest biomass and was close to an ice edge.

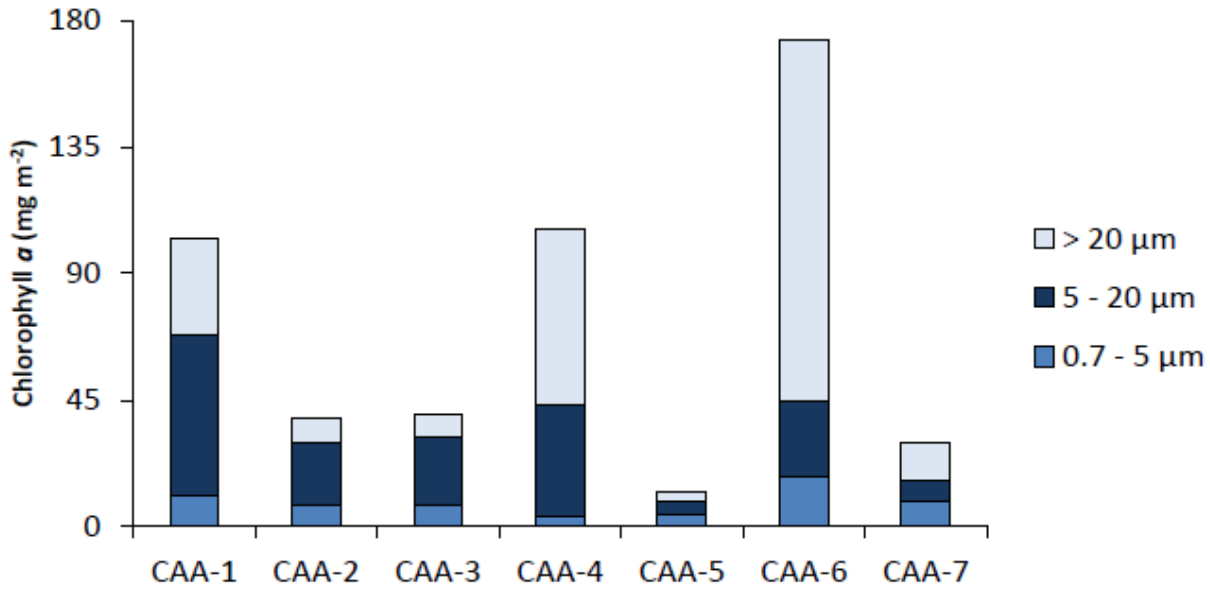

Figure 5.2.3.2. Chlorophyll *a* concentrations integrated over 100 m for different size fractions, 0.7-5 µm, 5-20 µm and > 20 µm, in Lancaster Sound, Barrow Strait and Peel Sound.

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5.2.4 Assessing the impact of ocean acidification and irradiance on phytoplankton bloom development and DMS production in the arctic

Principal Investigator: Maurice Levasseur and Jean-Éric Tremblay
Cruise Participants: Martine Lizotte and Rachel Hussherr

[1]*Biology Department, Québec-Océan/ArcticNet, Université Laval*

Introduction and Objectives

Conspicuous alterations in the Arctic Ocean are underway and include reductions in snow cover as well as sea ice extent and thickness, the occurrence of which is linked to profound modifications in light availability in surface waters below the ice and at its margin. In conjunction, ocean acidification, a phenomenon dubbed "the other CO_2 problem", is amplified in

polar oceans due to the increased solubility of CO_2 in cold water. This study aims to assess the impact of both pH modifications and shifts in light regime on arctic microbial communities and their biosynthesis of the climate-relevant compound dimethylsulfide (DMS) and its algal precursor dimethylsulfoniopropionate.

Operations conducted during Leg 2 and Methodology
Two Bioassay incubations of 10 days were planned in Southern Baffin Bay and Northern Baffin Bay in summer 2015 with the intent on simulating conditions encountered by blooming phytoplankton in a progressively acidified Arctic Ocean (6 levels of decreasing pH) submitted to light fields typical of either under-ice (low-light) or open ocean (high-light).

Due to complications with ship time allocation, we were in the obligation to conduct a first experiment in Davis Straight. For reasons we cannot yet completely understand, this experiment was unsuccessful: phytoplankton biomass (proxied by chlorophyll a concentrations) progressively decreased during the 4 days we sampled and FRRF measurements (conducted by Nina Schuback) confirmed the cellular death of the phytoplankton community. As we saw no signs of recovery after 4 days, even in our control bags, we decided to stop the experiment. A possible explanation for this result could be attributed to light shock as microbial communities were sampled from 55 m depth, approximately 10 m below the deep chlorophyll maximum. Initially, this depth was chosen in order to start the incubations with high concentrations of nutrients (7 µmol of nitrates). Unfortunately, this may have been too deep for the phytoplankton subsequently (and rapidly) exposed to ambient surface light. A suite of tests was also undertaken to improve the methodological procedures related to the acidification protocol. We would like to thank Constance Guignard (Al Mucci team) for her help with alkalinity measurements during this period of troubleshooting.

A second experiment was conducted at station BB-3 (71°24.373'N - 70°11.269'W) on August 6th 2015. The initial acidification was conducted following procedures described in *Guide to best practices for ocean acidification research and data reporting* adding strong acid (HCl 0.02N) and bicarbonate ($NaHCO_3$ 0.3N) in our bags. Added volumes of bicarbonate and acid were calculated by manipulating the carbonate system with the software CO2sys in order to fully mimic "natural" ocean acidification: rise of the total inorganic carbon with constant alkalinity. Although alkanities after initial acidification were not entirely similar due to manipulation biases and the difficulty in properly controlling the concentration of added solutions of $NaHCO_3$ and HCl, target pH's were achieved, as demonstrated in table 5.2.4.1 (note however that these data are not corrected for m-cresol purple dye bias and alkalinity).

Table 5.2.4.1. Differences between the actual pH measured after initial acidification at T1 and the targeted values calculated with CO2sys.

Treatment	**Duplicate**	pH measured at 4.84°C	pH targeted, calculated at 4.84°C
1L (control)	a	7.915	7.944

	b	7.915	
1H (control)	a b	7.935 7.928	7.944
2L	a b	7.780 7.767	7.785
2H	a b	7.754 7.742	7.771
3L	a b	7.638 7.641	7.643
3H	a b	7.620 7.618	7.644
4L	a b	7.445 7.444	7.486
4H	a b	7.390 7.444	7.486
5L	a b	7.336 7.324	7.336
5H	a b	7.291 7.287	7.336
6L	a b	7.141 7.142	7.186
6H	a b	7.162 7.157	7.186

In order to avoid similar problems encountered during the first experiment, we changed our experimental design by adding a mesh on the incubator thereby reducing the incident light. Moreover we added a second 300µm nitex mesh on the bags assigned to the low light treatment: those were already covered with one Mylar D film (which cuts UV-B radiation) and one 300µm nitex mesh which allowed approximately 40% of incident light to pass. The transmittance for the hight light treatment was 80%: these bags were not covered by neither mesh nor mylar.

Furthermore, we took the initial water a bit shallower to prevent any light shock (38 meters) although we had to deal with lower concentrations of nutrients (approximately 5 µmol of nitrates). After filtering the AN rosette water with a 200µm nitex mesh in order to remove mesozooplankton grazers, we filled 12 bags of 10 liters and followed the evolution of each bag by subsampling every day during 10 days.

Finally, another core objective of this cruise was the monitoring of ArcticNet stations for water column budgets of sulfur compounds (DMS, DMSP and DMSO). Unfortunately, this part of our scientific goals was greatly reduced through both equipment failures and reduction in ship time allocated to science. We did however manage to sample a selection of ArcticNet/Geotraces rosette stations located in Lancaster Sound, Baffin Bay and Peel Sound. The following stations

were sampled for total DMSP and dissolved DMSP: CAA1-CAA2-CAA3-CAA4-CAA5-CAA6-CAA7 and 314. Full vertical light profiles (100%, 50%, 30%, 15%, 5%, 1%, 0.2%, sub-chlorophyll maximum (SCM), and 100m) were taken at each of these stations. One of the greatest challenges we met during the cruise was the malfunctioning of an injection valve allowing the transfer of gaseous DMS from a purge and trap system towards a Pulsed Flame Photometric Detector (PFPD) Gas Chromatograph. After having worked very well during the first two weeks of the cruise, it then failed entirely following icebreaking maneuvers in Hudson Bay, making it impossible to analyze samples of oceanic DMS. Although we did not manage to fix the problem we would like to thank the following people for their invaluable help and support during the lengthy troubleshooting period: Brian Roy, Steeve Quirion, David Quirion, Philippe Tortell, Tereza Jarnikova, Jay Cullen and Dave Janssen.

Preliminary results

Despite numerous challenges faced during the cruise, the second incubation experiment met with success. This success is in great part due to incredible collaborations fostered before and during the cruise. Being a two-person team, we could not have measured the entire suite of variables by ourselves and so we wish to extend or heartfelt thanks to a host of people. Isabelle Courchesne and Gabrièle Deslongchamps from the Jean-Éric Tremblay team for their tireless efforts with nutrient analysis. Thanks to their help, we were able to monitor a fast decrease in concentrations of nitrates suggesting uptake and growth by the phytoplankton community. The uptake of nitrate was indeed mirrored by an exponential increase in Chl a between T1 and T5, reaching a plateau until T8, then decreasing thereafter. The physiological state of the phytoplankton cells was followed through FRRF measurements by Nina Schuback (Phil Tortell team) which showed a similar trend as that observed for concentrations of Chl a. Furthermore, thanks to the generosity of Philippe Tortell and Tereza Jarnikova, we were able to make DMS measurements on their underway PFPD Gas Chromatrograph while remaining put on various stations between BB3 and CAA7. Initially low concentrations of DMS (ca. 0.5nM) increased steadily during the course of the experiment, especially in the control bags, to reach levels of ca. 20nM. A core variable measured during the incubations was pH, and this was made possible thanks to a Spectrophotometer generously lent by Lisa Miller from the Institute of Ocean Sciences in Sidney, British Columbia. Alkalinity measurements were conducted onboard by Jacoba Mol and Helmuth Thomas and will be further examined in the coming weeks. Several other variables were sub-sampled and will be analyzed post-cruise in Laval University laboratories: total DMSP, dissolved DMSP, total DMSO, bacterial abundance, flow cytometry, HPLC, phytoplankton taxonomy (Table 5.2.4.2).

Table 5.2.4.2. Variables measured during the 10 day Bioassay incubation experiment (water initially sampled at station BB3)

	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9
pH	✖	✖	✖		✖		✖		✖	✖
DIC	✖	✖			✖					✖
Alcalinity	✖	✖			✖					✖

Salinity	✖									✖
Chl a	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
Nutrients	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
Taxonomy	✖					✖				✖
Cytometry	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
HPLC	✖									✖
DMSPt	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
DMSPd	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
DMSO	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
DMS	✖		✖		✖	✖		✖	✖	✖
FR/RF		✖		✖	✖		✖	✖		✖

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

Satisfied.

Comments: Through a series of events for which none of the personnel onboard had control over, the time allocated for science was drastically cut short. Although this situation could have rapidly turned sour, the crew and science personnel all showed extraordinary resilience and patience. We strongly believe this is largely attributable to the generous and respectful leadership of Captain Alain Gariépy. Acknowledgements are also warmly given to both chief scientist Roger François and Kristina Brown for their tireless work with schedules and planning. Thank you to Pascal Guillot, Chris Seaton, and Thomas Linkowsky for ArcticNet operations, to Boatswains Stéphane Massicotte and Patrick Cloutier and their crew for their invaluable help with, well, everything pertaining to work onboard the ship! A great big MERCI to Gino Gagnon and his team as well as all the stewards for keeping us so well fed and very comfortable during the cruise. Lastly, thank you to Benoit Leblanc for organizing numerous activities onboard it was truly enjoyable from beginning to end.

5.2.5 Zooplankton and Fish Ecology / Acoustic

Principal Investigator: Louis Fortier
Cruise Participants: Caroline Bouchard and Mathieu LeBlanc

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 devices and the echosounder. Additionally, specific field objectives for leg 2 were to collect zooplankton and fish samples and acoustic data to:

1- Document the composition, abundance and biomass of the pelagic fish communities in the North and the West of Baffin Bay (M. LeBlanc, U. Laval)
2- 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)
3- Assess food web structure and dynamics in the Queen Maud Gulf / Victoria Strait region using stable isotopes ($\delta^{13}C$ and $\delta^{15}N$) analysis (M. Falardeau, McGill U.)
4- Study the population genetics of the dominant species (J. Nelson, U. Victoria)

The 2-weeks rerouting of the *Amundsen* to escort commercial ships in Hudson Bay and subsequent changes in the original mission plan precluded our team to fulfill entirely their objectives. Specific objective 1 was only partly reached since all stations in the North of Baffin Bay were not visited during leg 2. If ice and weather conditions allow trawling, our team will try to close this gap during leg 4. Specific objectives 2 and 3 were not entirely reached as many stations planned in the area concerned were cut from the original plan. As the *Amundsen* mission plan includes several stations in the Kitikmeot region during leg 3b, these objectives may be partly fulfilled by the end of 2015. We collected samples in some areas of high importance for the study of genetic population and therefore can consider objective 4 as fulfilled. 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 (relative) success.

Operations conducted during leg 2

- 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 6-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). Ichtyoplankton Net. Rectangular frame carrying two 6-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 when a fish aggregation has been detected by the echosounder 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.

Preliminary results

Beside the zooplankton and fish samples collected (Table 5.2.5.1), leg 2 has been an opportunity for us to test some aspects of our sampling methods. These tests will result in helpful recommendations for our team in the future. Here are three questions to which we started to provide an answer (investigations will continue during legs 3 and 4):

- Is there a clogging problem with the DSN? Zooplankton nets, especially when towed, can get clogged by different organisms (e.g phytoplankton, jellyfish). Net clogging reduces filtering efficiency and thus may resulted in biased abundance estimates. To verify if the DSN get clogged during deployment, we compared the flow indicated by two flowmeters

inside the nets to one installed between the nets. As indicated by higher flows given by the flowmeter installed outside the nets than those installed inside the nets, clogging occurred at stations CAA-3 to CAA-7 and 314; and as expected, the clogging was more important in the 500 µm-mesh net than in the 750 µm-mesh net, exepted for station 314 where flow were equal (Fig. 5.2.5.1). Intense phytoplankton blooms characterized these six stations and surely caused the clogging. To investigate if net clogging may result in biased abundance estimations, we compared the number of Arctic cod larvae collected in the 500 µm-mesh net and the 750 µm-mesh for five stations in which the clogging was more important in the former than in the the latter. Consistently higher larval abundances in the 750 µm-mesh net would indicate a bias. Among the five stations concerned, two had more larvae in the 750 µm-mesh net, one had more larvae in the 500 µm-mesh net, and two had approximatly the same number in both nets (Fig. 5.2.5.1). As such, it is not possible for now to conclude on the effect of net clogging on abundance data.

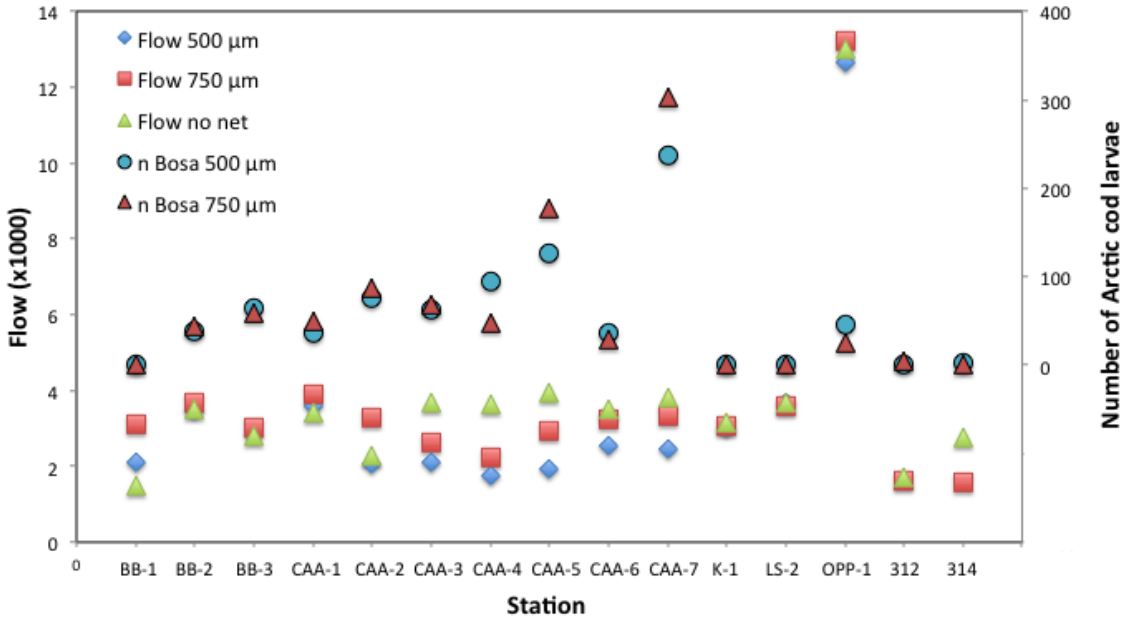

Figure 5.2.5.1. Flow indicated by flowmeters installed on the Double Square Net 1) in front of the 500 µm-mesh net, 2) in front of the 750 µm-mesh net, and 3) between the nets; and number of Arctic cod larvae collected by each net at each station.

- Is cable length/angle a reliable method to estimate sampling depth? During DSN and IKMT deployments, we use the cable length and its angle relative to the horizon to send the sampler at the desired depth. For example, if we target a fish aggregation at 300 m and have an angle of 60°, we will unroll 600 m of cable (the cosinus of 60° being 0.5). However, we discovered that this method tend to overestimate the sampling depth. Indeed, the maximum depth indicated by the mini-CTD (installed on the sampler frame) was often shallower than the depth estimated from the cable length and angle. For example, at stations BB-2 and CAA-1, a cable length of 180 m combined with a 60° angle should have bring the DSN to a 90 m depth but the mini-CTD indicated maximum depth for these casts of 68 m and 67 m, respectively. We first tested the possibility that our mini-CTDs were not accurate (or not correctly calibrated) by attaching two of those

on the ArcticNet CTD-rosette for a 300-m cast and compared the maximum depths given by the instruments. One mini-CTD was accurate while the other underestimated the maximum depth by 6 m, which was not enough to contribute significantly to the differences observed with the cable/angle method. The difference probably arise from curving of the cable in the water column and, for deeper casts (with the IKMT especially), from the large difference in depth a small difference in angle estimation can cause.

- What's the best way to collect mesopelagic Arctic cod? Young adult Arctic cod are often found aggregated in a mesopelagic layer from 200 to 400 m. To sample these small individuals, we deployed the IKMT a first time at station BB-3 in a low-density aggregation visible on the echosonder and collected only one 81-mm Arctic cod. As acoustic data (target strength analysis) indicated a mean fish size in the aggregation of 55 mm, we hypothesized that the IKMT mesh size was too large to efficiently sample these small fish. Hence at station OPP-1 we deployed the DSN in a mesopelagic aggregation of similar density than that of station BB-3, and collected two Arctic cod (80 and 84 mm standard length). At station CAA-1, we deployed the IKMT in a series of four 5-minutes steps separated by ca. 10 m depth (instead of 20 min trawl at the same depth) in a relatively dense aggregation and collected 49 Arctic cod (standard length 81 ± 11 mm). From these preliminary observations, we conclude that the IKMT is effective at sampling the mesopelagic Arctic cod, that its deployment by consecutive steps is a good way to cope with the difficulty in estimating the trawling depth with the cable length/angle method, and that acoustic density values (Sv) greater than -70 dB (at least yellow or green on the echogram) should be detected in order to have a successful IKMT cast.

Table 5.2.5.1. Summary of operations conducted and samples collected during leg 2

Station	Date	5NVS	DSN	IKMT	Beam Trawl
K-1	14-07-2015		×		
LS-2	17-07-2015	×	×		
BB-1	03-08-2015	×	×		
BB-3	06-08-2015		×	×	
BB-2	07-08-2015		×		
OPP-1	09-08-2015		×		
CAA-1	10-08-2015		×	×	
CAA-2	10-08-2015	×	×		
CAA-3	11-08-2015		×	×	
CAA-5	13-08-2015		×		×
CAA-4	13-08-2015		×		×
CAA-6	14-08-2015		×		×
CAA-7	15-08-2015	×	×		
312	17-08-2015	×	×		×
314	19-08-2015	×	×		×

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?
2. Dissatisfied

5.2.6 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*

Introduction
The *ArcticNet* 2015 Amundsen Leg2 cruise took place from July 10th to August 20th 2015. The *Marine Geoscience Lab.* (MGL – Université Laval, Québec) and the Canadian Hydrographic Service (CHS) were onboard and responsible for multibeam data acquisition. The main objective of the mission was to acquire data on water properties in Baffin Bay and in the Canadian archipelago as part of a *ArcticNet-Geotraces* cruise. The *MGL-CHS* team has been mainly involved in mapping the seabed morphology and in acquiring sub-bottom stratigraphy during transits. This cruise report presents the instruments, methods and preliminary results from the Leg 2 cruise.

Material & Methods
Kongsberg EM302 Multibeam Sonar
The Amundsen is equipped with an EM302 multibeam sonar operated with the *Seafloor Information System* (SIS). Attitude is given by an *Applanix POS-MV* receiving RTCM corrections from a *CNAV 3050* GPS receiver. Position accuracies were approximatively < 0.8m in planimetry and < 1m in altimetry. Beam forming at the transducer head is done by using an

AML probe. CTD-Rosette casts, when available, were used for sound speed corrections. During long periods without CTD casts, the WOA09 model was used. Anew Hydrographic Working Station (HWS) was installed by a Kongsberg before the Sea trials and the system worked perfectly during the whole leg.

There were some issues with the echosounder during the leg. First, an electrical problem was detected in the electric circuit between the PU and the transducer head. There was too much current intensity going through the circuit. We ran BIST tests of the systems to get some information on what was going on and e-mailed Kongsberg for them analyze the test results. Kongsberg told us that the intensity wasn't that much problematic but that there were issues with some TX boards. From looking over the BIST results they saw that in TX slots we had errors on board 5, 18, 19, 20, and 21. We did to figure if the errors lied in the boards or in the transducer. The tests revealed that the errors come from the transducer. The errors are probably due to physic problem such as rust or bad connections. Although this problem does not seem to affect data, it is something that should be looked at after the summer mission.

Another problem was the periodical loss of port side beams on data (Fig. 5.2.6.1). It didn't show any logical periodicity as it happened sometime here and then. This problem is probably due to degradation of the port side beams transducers (?). This problem has no link with the electrical problem as it occurred before the electrical problem.

The other problem was the length of the period needed for emitting and receiving in greater depths (> 1000m). The echosounder needed ~6 – 8 seconds to emit and receive its signal. It looks too much as it should take between 2 and 4 seconds depending on depths. We looked for K-sync configurations and the problem does not come from there. We also try to figure out if it was a parameter issue in SIS software. These tests didn't bring any clue on what could delay the system. Still this problem isn't linked with the electrical problem as it happened before it.

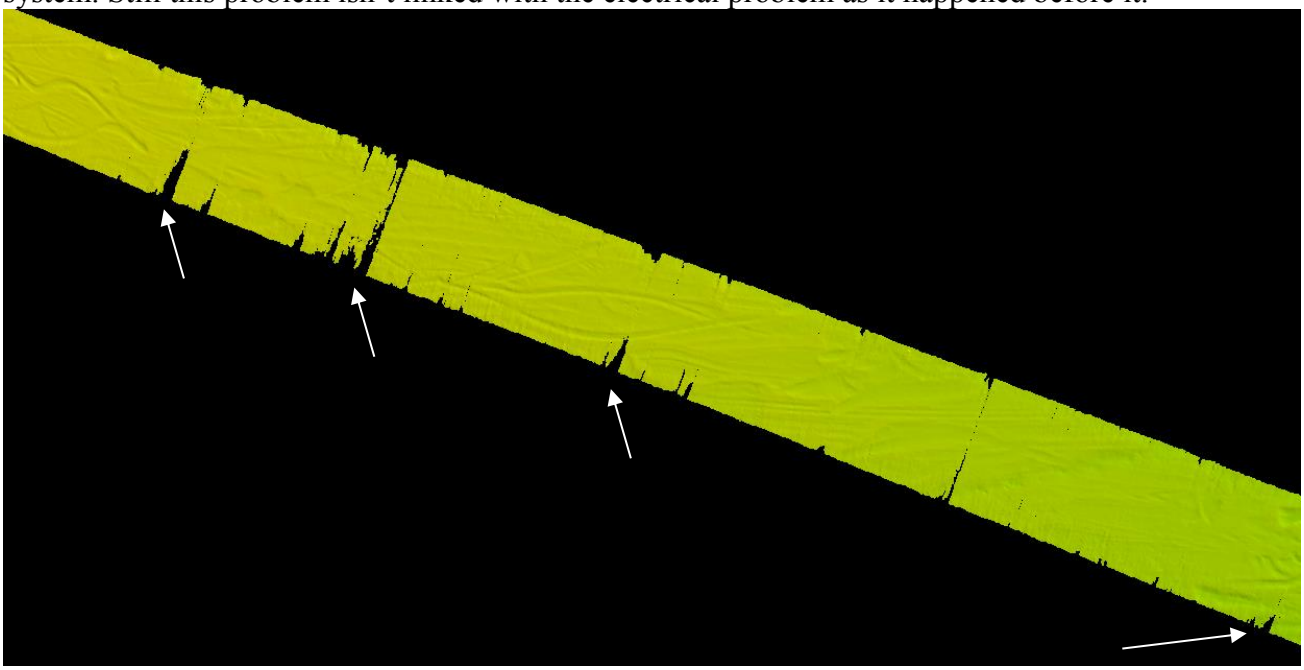

Figure 5.2.6.1. Example of periodical port side beam loss on data.

Knudsen 320BR CHIRP Sub-bottom Profiler
Sub-bottom profiles were acquired by a 3.5 kHz *Knudsen 320-BR* CHIRP. This single beam sonar is capable of imaging sub-bottom stratigraphic profiles of the seafloor.

Field work and preliminary results
All the data acquired during the cruise were pre-processed in real-time using the *CARIS HIPS&SIPS 9.0* software. This pre-processing phase is essential to rapidly detect any anomaly in the data collection.

Transit Mapping
The mapping of the Arctic seabed is an important of the ArcticNet program. Transits routes were surveyed systematically in order to increase the mulitbeam dataset. These data will be shared with the Canadian Hydrographic Service (CHS) to update marine charts and might be useful for future work within the ArcticNet program. Some of the transits lines were deleted due to poor data quality in heavy ice conditions.

Special Project
Since the leg was modified due to Coast Guard duties, no special project was achieved during this leg.

Recommendations for future cruises
Although the cruise was a success in its transit mapping duties, some issues occurred and the following measures should be taken in order to improve the different surveys:

- Improve the communication between the bridge and the acquisition room: It would be very practical to have a permanent UHF radio in the acquisition room to be aware of the activities going on the ship. This could help us to stop logging at stations and restart logging when activities are done. Moreover, this radio could be used during SX90 surveys, MVP deployments, moorings operations, etc. It would mainly be used in *listen* mode, as we do not want to interfere with communications.
- Monitor the electrical problem: It will need an inspection of the transducers at the end of the summer mission.

Acknowledgements
The mapping team acknowledge the crew of the CCGS Amundsen for their help and professionalism during the mission

5.2.7 Autonomous underwater vehicles: Deployment of BioArgo floats

Principle investigator: Marcel Babin
Cruise Participant: Jose Lagunas-Morales

Takuvik, Universite Laval,

Introduction & Objectives

It is in the scientific interest of Takuvik to understand ice-edge blooms, the physical mechanisms responsible for nutrient inputs, the propagation of sunlight (ice floe and water column), ice-edge bloom dynamics and the response of associated phytoplankton species. Ice edge blooms are systematically observed in the Baf fin Bay region. In addition, observations by remote sensing of ocean colour show that the spring blooms now occur 50 days earlier than in 1997. Takuvik has launched a program for the deployment of 20 BioArgo floats in Baf fin Bay and will be responsible for the follow-up of the floats together with the Laboratoire d'Oceanographie de Villefranche (LOV). The latter will host the data collected by the BioArgo floats and make it accessible for public domain through their servers. Takuvik works closely with the LOV, they are both actively involved in the NAOS project which is a French initiative for the development of the Argo network.

The main objective of the activities conducted during 2015 Amundsen's mission was the deployment of four Takuvik's BioArgo floats in the Baffin Bay region, durin station BB2 of Leg 2. The active payload (sensors) carried by by each BioArgo float are : CTD, CDOM, PAR (400-700 nm), Oxygen, Nitrates, Chlorophyle-a, radiometer (λ=380/412, 490, 555 nm) and a transmissiometer (λ=650 nm) will produce valuable data for the scientific community.

Methodology
At station BB2, N 72 45, W 67 00, four geographical coordinates were chosen for the deployment of the BioArgo floats. The Amundsen's barge was used to navigate >2 nautical miles away from the ship taking into account wind and current directions. The operation was divided in two launches were two floats were to be deployed at each occasion. The coordinates of the first deployment were: 1) N 72 44.343, W 66 54.57 and 2) N 72 43.5462, W 66 57.554 . On the 9th of August at 5h45 the loading of the floats to the barge began. By 6h55 the first float (takapm003b) was deployed and the second one (takapm009b) at 7h30, see Figure 5.2.7.1. The barge stayed for 40 minutes close to the second deployment before returning to the vessel. A mechanical problem with the barge's engine prevented this action and the ice-breaker navigated to our location to retrieve us. At this point, our LOV colleagues had verified the status of the floats and noticed that they couldn't immerse since their density wasn't enough. The second deployment was cancelled and a recovery operation on the Amundsen's Zodiac was programmed to 12h00. Edouard Leymarie from the LOV, communicated the GPS points sent by the BioArgo floats, as their routine commands in abnormal situations, to the officer's deck. This information was communicated to us in the Zodiac by VHF and the recovery of the floats was completed by 14h00, see Figure 5.2.7.2.

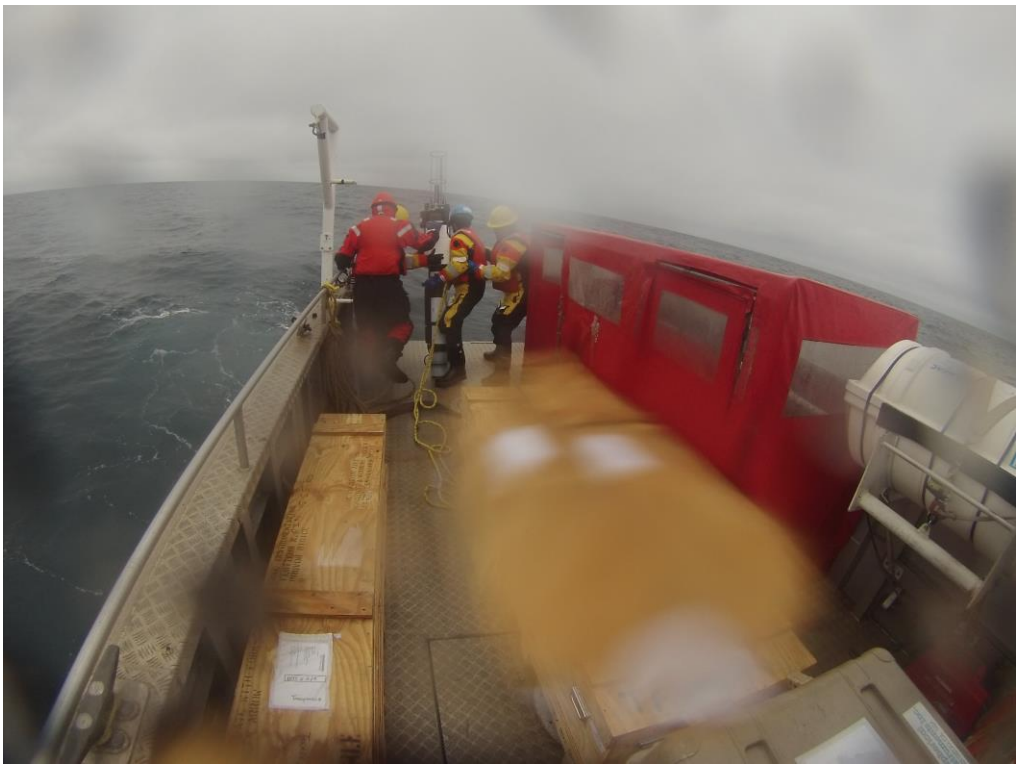
Figure 5.2.7.1. Deployment from the Amundsen's barge


Figure 5.2.7.2. Recovery of the Argo floats on board of the Amundsen's Zodiac

Preliminary results

A major issue regarding ballasting was found to be the cause preventing the immersion of the BioArgo floats. The BioArgo floats need to be re-ballasted accordingly to the conditions met in

Baffin Bay. A thorough analysis of the conditions encountered versus the previous ballasting needs to be conducted by their manufacturer NKE in France. No preliminary results resulted from this operation.

Recommendations

Internet connection was essential for this operation, since BioArgo data are sent systematically to a server and remote access was severely limited, however this is understandable due to the quality of the service available at this latitudes.