# - BAYSYS -
# University of Manitoba & Manitoba Hydro

## Field Report:
## Churchill River and mobile ice survey
## February 1 to February 15, 2017
## Churchill, Manitoba

Participants:
Team 1: David Babb (CEOS), Dr. Jack Landy (CEOS) and Nic Zilinski (CEOS)
Team 3: Gabrielle Deslongchamps (Laval), Lisa Matthes (CEOS) and Laura Dalman (CEOS)
Team 4: Dr. David Capelle (CEOS) and Dr. Nicolaus Xavier Geilfus (CEOS)
Team 5: Dr. Kathleen Munson (CEOS)

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# Introduction:

BAYSYS, or the Hudson Bay System Study, is a 4-year project that will examine the role of freshwater in Hudson Bay and the extent to which climate change and hydroelectric regulation have and will continue to influence its timing, distribution and influence on the chemical, physical and biological systems in the Bay. The project is co-led by the University of Manitoba and Manitoba Hydro, with colleagues from the Universities of Northern British Columbia, Québec à Rimouski, Alberta, Calgary, Laval and Trent collaborating.

A series of focused field programs will take place within Hudson Bay during 2017 to provide a time series of winter and summer observations in Hudson Bay. The first of these field programs was a winter survey of the Churchill River estuary and mobile ice pack offshore from Cape Churchill in Southwestern Hudson Bay. Nine participants from four of the five teams that comprise BAYSYS spent two weeks in Churchill to conduct in situ sampling of the ice and underlying water column, while also deploying an array of autonomous equipment to collect a longer temporal dataset of key variables both in the estuary and in the mobile ice pack. Scientists stayed at the Churchill Northern Studies Centre (CNSC) who provided snowmobiles for the estuary sampling (Sites in Figure 1), while two A-Star helicopters form Great Slave Helicopters were used to access the offshore ice pack (Sites in Figure 2).


Figure 1: Ice and water sampling in the Churchill river estuary and Button Bay. CTD casts were taken at the same sites. The river site includes water sampling only.


Figure 2: Ice and water sampling (S) on the mobile ice in Hudson Bay. CTD casts were taken at the same sites and at separate CTD stations (C).

## Study Area:

This study took place on the mobile ice pack offshore from Cape Churchill in southwestern Hudson Bay. The study area was confined by a maximum flight radius of 150 km from the Churchill Northern Studies Center that is located 28km east of Churchill (white circle Figure 1). The study area is comprised of a mix of landfast and mobile ice with a large lead located along the landfast ice edge, furthermore there are large shallow tidal flats and a large input of freshwater from the Churchill River that influence the area. This freshwater typically flows out of the Churchill River Estuary to the west-northwest along Cape Churchill.

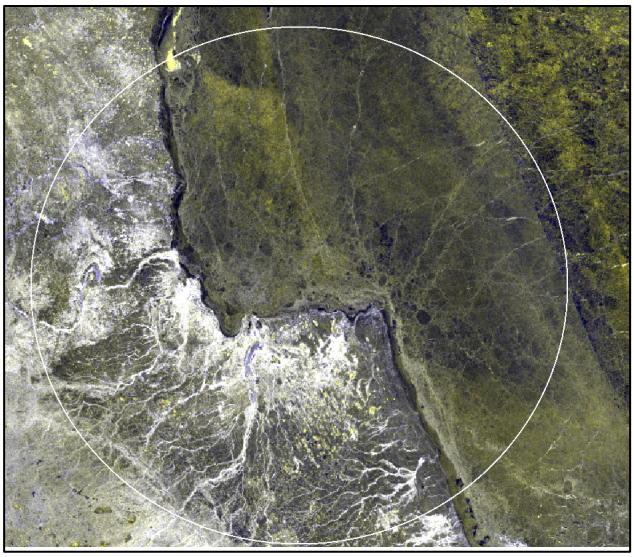


**Figure 3: Radarsat scene over the study area from January 29, 2017. White circle displays the 150 km work radius. Thanks to Dean Flett and Alex Manore from the Canadian Ice Service for this image.**

Within this project we are specifically interested in sampling the ice and water column, and deploying an array of autonomous equipment on the mobile ice pack, while collecting water samples along the landfast ice to track the fate of the under-ice fresh water layer. The mobile ice is located offshore from the landfast ice that forms along Cape Churchill and varies in width from 1-2 km up to 5-6 km. Between the landfast and mobile ice is a large lead that opens and closes according to the surface winds, and can thus change quickly. The mobile ice pack is in near constant motion as a result of surface winds, ocean currents, sea slope, the Coriolis force and internal stresses that arise due to ice floes interacting with each other. Ultimately the combination of these forces creates a dynamic ice pack that is comprised of large pans of ice that have thermodynamically thickened, large rubble fields that are completely ridged with no discernable pans, areas of open water, and areas of new ice that were recently areas of open water where new ice has formed and is thickening. Like any mobile ice cover the ice pack can either thicken dynamically, through ridging and rafting events, or thermodynamically, through the accretion of sea ice along the underside of the ice due to the vertical temperature gradient (cold atmosphere, warm ocean). Dynamic thickening is especially strong along the edge of the landfast ice where the Stamukhi builds as the mobile ice pack is continuously pushed against the landfast ice. From personal accounts we know the Stamukhi along Cape Churchill is quite large, meaning that it also extends quite far below the water level as well and may trap buoyant freshwater under the landfast ice

## Logistical Summary:

The research team was comprised of 9 persons

- David Babb – Chief Scientist – Team 1 - Research associate with Dr. David Barber at CEOS studying sea ice dynamics and thermodynamics.
- Dr. Jack Landy – Team 1 – Postdoctoral Research fellow with Dr. David Barber at CEOS studying sea ice thermodynamics and remote sensing of sea ice.
- Nicholaus Zilinski – Team 1 – Undergraduate student in the faculty of Engineering at the University of Manitoba, NSERC summer student with Dr. Ryan Galley at CEOS developing an inexpensive Ice Mass Balance buoy.
- Gabrielle Deslongchamps – Team 3 – Research associate with Dr. J.E. Tremblay at U. Laval studying the biological availability of nutrients in the water column.
- Lisa Matthes – Team 3 – PhD candidate with Dr. C.J. Mundy and Dr. Jens Ehn at CEOS studying the optical properties of the sea ice-covered water column and their relation to biological productivity.
- Laura Dalman – Team 3 – M.Sc student with Dr. C.J. Mundy and Dr. David Barber at CEOS studying under-ice algae.
- Dr. David Capelle – Team 4 – Postdoctoral Research fellow with Dr. Tim Papakyriarkou at CEOS studying the Carbon system in Hudson Bay
- Dr. Kathleen Munson – Team 5 – Postdoctoral Research fellow with Dr. Fei Wang at CEOS studying contaminant chemistry in Hudson Bay
- Dr. Nicolas Xavier Geilfus – Team 4/5 – Research Associate with Dr. Fei Wang and Dr. Soren Rysgaard at CEOS studying the Carbon system in Hudson Bay.

Two A-Star 350 B2 helicopters were hired from Great Slave Helicopters in Yellowknife to support the research program. Two Pilots, Jon Talon and Patrick Robert, and one mechanic, Peter Murdoch, ferried two machines to Churchill from Yellowknife on February 6th, 2017. We subsequently had 8 consecutive days of great weather and worked on the ice each day from February 7th to 14th, 2017.

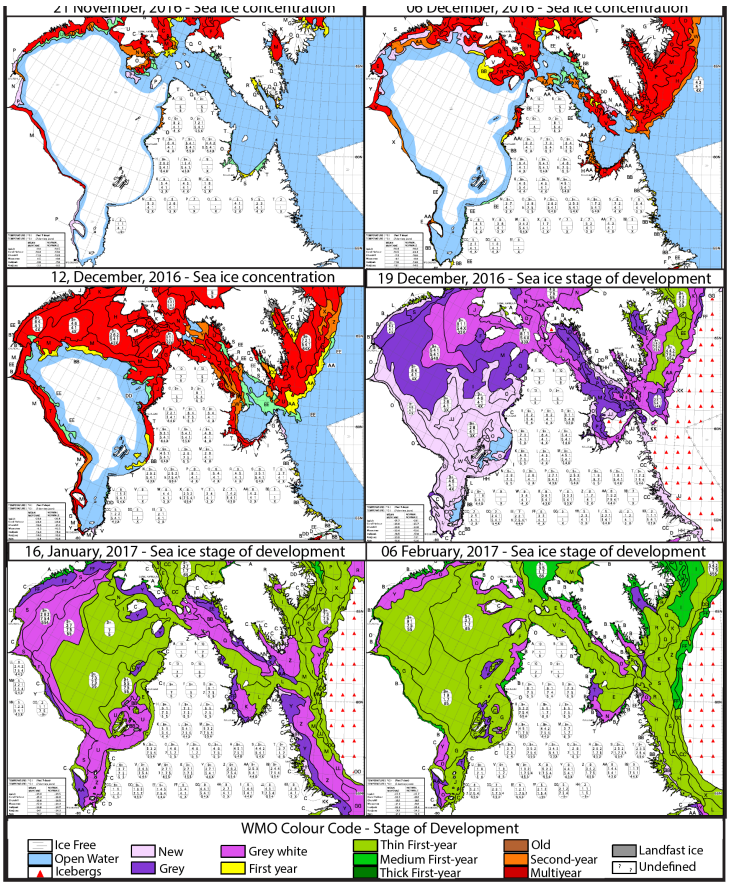
The helicopters required 18.5" (47 cm) of sea ice in order to shut down the engines on the ice. At each landing site one scientist would hop out with a manually operated 2" auger and drill until they reached 18.5" depth (pre-marked on each auger). If the ice were thinner than 18.5" they would return to the helicopter and look for a new floe; but if the ice were thicker than 18.5" they would drill two more holes to ensure the floe was suitably thick. Helicopters would also start up every hour to keep the engines warm out on the ice.

All 12 members of the team stayed at the Churchill Northern Studies Center, located 28 km east of Churchill. Lodging, food, lab space and logistical support were provided by CNSC, specifically the scientific Director LeeAnn Fishback. The helicopters parked in the CNSC parking lot over night and would typically make a fuel run to the airport first thing in the morning or right after returning from the ice depending on daylight.

## Ice conditions in the study area:

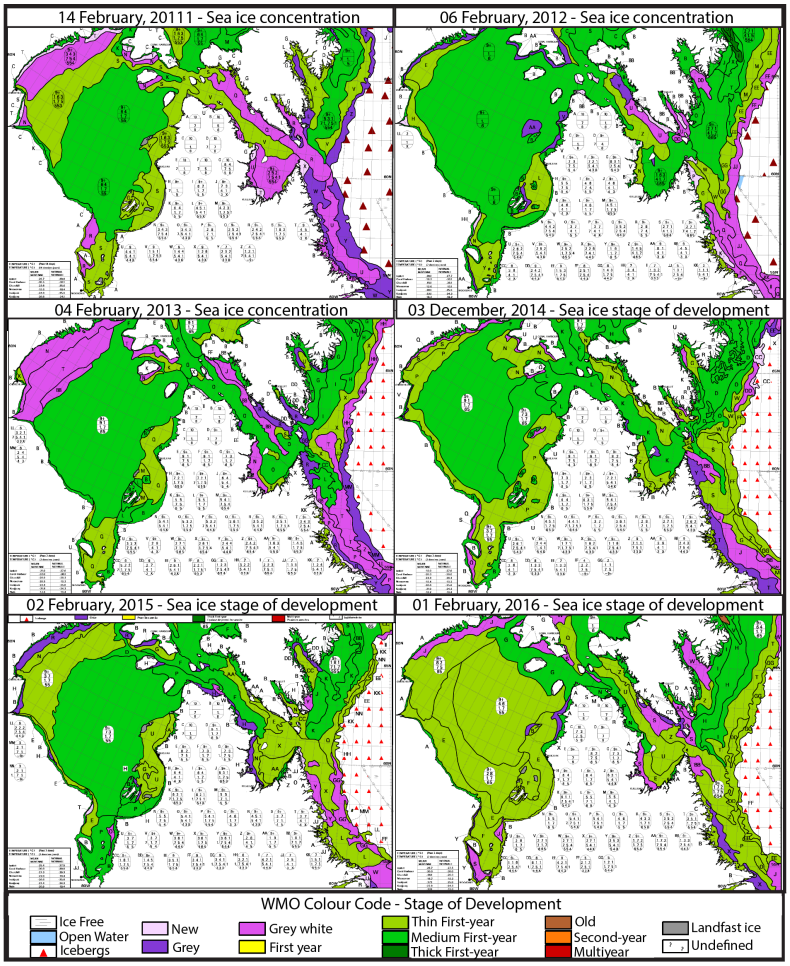
The ice cover in Hudson Bay is seasonal, meaning that it melts out every summer. Fall freeze-up typically begins around mid-November in northwestern Hudson Bay and progresses to the southeast, eventually covering the entire Bay by early to mid-December. During Fall 2016, freeze-up within Hudson Bay was delayed. Using weekly ice charts from the Canadian Ice Service we can see that the landfast ice around the Bay began forming in mid to late November (Figure 4). Freeze-up proceeded through Northwestern Hudson Bay until the entire Bay became ice covered around December 19. Note that once the Bay froze over in mid-December we have switched from presenting ice charts displaying sea ice concentration to those displaying stage of development. Concentration can still be gleaned from the ice egg code for each polygon, but stage of development is more descriptive of the seasonal growth of the ice cover. On December 19 the entire Bay was covered with sea ice, however it was predominantly new ice (light purple), Grey ice (dark purple) and Grey white ice (purple). Through January and into February we see the seasonal transition towards thicker ice types as the existing ice cover within Hudson Bay thickens through both thermodynamic and dynamic processes. By the start of our helicopter survey the Bay was predominantly covered by Thin First-year sea ice which the CIS characterizes as being 30-70cm thick.

**Figure 4: CIS ice charts during winter 2016-2017 over the study area**



Northwesterly winds are most common over our study area and contribute to the semi-permanent formation of a lead along the fast ice edge in Northwestern Hudson Bay. This lead or polynya, depending on the size, is obvious in the ice chart from February 6, 2017 as the band of Grey-white ice that separates the narrow band of landfast ice from the Thin First-year ice pack. This lead varies according to the winds, but under strong northwesterly winds the lead can extend 100s of km's and essentially push the older thicker ice types out of the study area (Figure 3). Looking at ice charts from our study period during recent years we can see that generally the lead remains within 10s of km's of the northwestern coast of Hudson Bay (e.g. 2012, 2014, 2015, 2016), however in 2011 and again in 2013 strong northwesterly winds caused the lead to open quite wide and form a large polynya across all of Northwestern Hudson Bay. In 2011 we likely would have found suitable ice near Cape Churchill, however in 2013 we likely wouldn't have found suitable ice to land on within range of the helicopters.

**Figure 5: CIS ice charts over the study area during the 6 previous years**



## Team 1 – Climate and Marine System

Participants: David Babb, Dr. Jack Landy, Nicholaus Zilinski

The objectives for Team 1 were to conduct CTD's in the offshore marine environment and under the landfast sea ice to identify the under ice freshwater layer, and to deploy an array of autonomous equipment to track the seasonal evolution of the dynamic and thermodynamic nature of the ice pack. Beyond these tasks David and Jack collected several Radarsat and Sentinel scenes over the study area that were used to target potential study sites and will subsequently be used to provide broader context to our observations. Radarsat imagery will continue to be collected over the drifting array every week in collaboration with the Canadian Ice Service, and opportunistic Sentinel imagery over the study area will also be collected.

Task 1: Conduct CTD's in the offshore marine environment and under the landfast sea ice to identify the under ice freshwater layer.

Starting with the landfast ice. A CTD survey was conducted via helicopter from the mouth of the Churchill River Estuary to the northeast corner of the landfast ice off of Cape Churchill with two additional CTD's done near the mouth of the estuary on the mobile ice pack. Starting from the Estuary to Cape Churchill 7 CTD's (West to east: EST4, Fast4, Fast5, Fast6, Fast3, Fast2 and Fast 1) were collected at variable intervals depending on flying conditions. Overall we see a large freshwater river plume at Est4 that gradually diminishes as you move west through Fast4 and Fast5 before ultimately disappearing by Fast 6. A freshwater signal was also detected at MB10 in the offshore mobile ice pack, but the other offshore site (STM3) that was located to the northwest of the Churchill River Estuary shows a completely marine signal. The final 3 stations (Fast 1, 2 & 3) also show a completely marine signal with salinities of 32.5. Overall it appears that the freshwater from the Churchill River is partially retained behind the stamukhi and funneled westward under the landfast ice, but that within 30 km's the freshwater is lost to the Bay. A portion of this signal is present in the area just beyond the stamukhi. Furthermore the water column at each site is at or very near the freezing point.

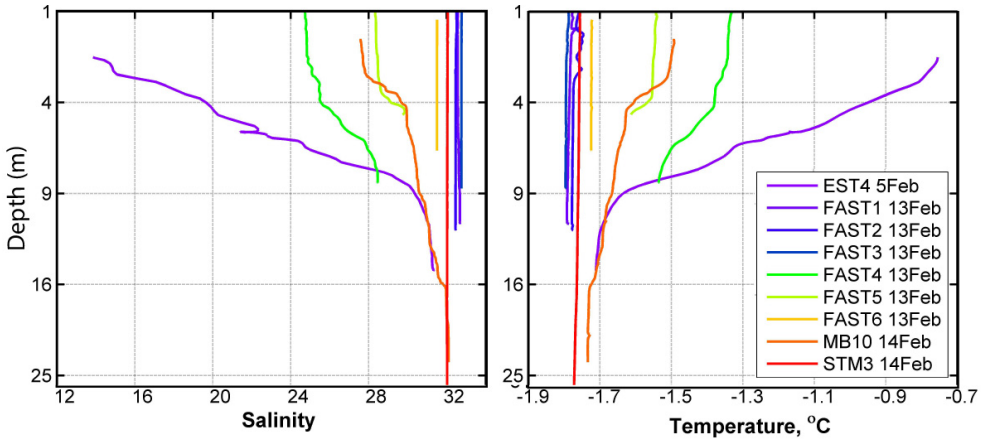



**Figure 6: CTD profiles from the landfast ice and offshore near the Churchill River Estuary**

Moving onto the offshore area, we present 7 additional CTD's from the mobile ice pack and the three furthest west CTD's from the landfast ice. In the offshore area we find a clear marine signal through the unstratified water column. Once again all profiles show the water column at the freezing point. All profiles show no vertical stratification indicating a well-mixed water column. Interestingly there is substantial horizontal variability in the salinity of each profile, with the highest salinity being present in the 3 profiles collected under the western end of the landfast ice. A first guess at this is that these sites are influenced by brine rejection from the nearby lead where brine enriched waters may be tidally pumped under the landfast ice. Future work with physical oceanographers should help to elucidate these mechanisms.

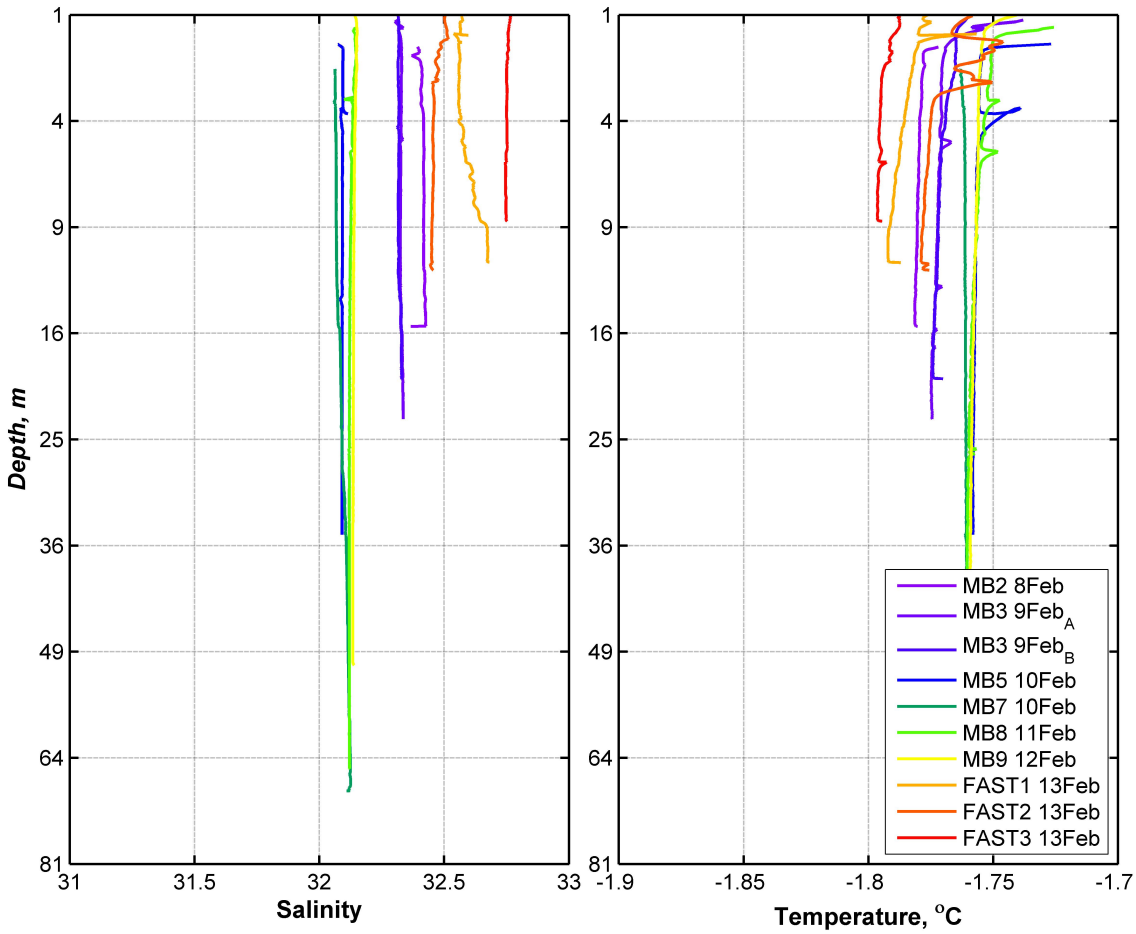



**Figure 7: CTD profiles from the offshore marine area.**

Task 2: Deploy an array of autonomous equipment to track the seasonal evolution of the dynamic and thermodynamic nature of the ice pack

Four different autonomous systems that all use the Iridium communications network were deployed on the mobile ice.

- Ice drift beacons (x14): built by Solara Communications and David Babb from CEOS. The ice beacons simply transmit their GPS location every hour to an online data portal, allowing us to track the drift of individual ice floes and the relative drift of ice beacons deployed in pairs or in arrays. The beacons are enclosed within a 20" long tube comprised of 6" internal diameter Drain Water Ventilation PVC (DWV-PVC) with a sealed cap at the bottom end and a waterproof screw on cap at the upper end. An internal frame comprised of acrylic rods and PVC sheets houses the batteries and iridium/GPS unit. The beacon is deployed into a 10-12" deep 8" auger hole that anchors the beacon in the ice and keeps the batteries partially insulated from extreme air temperatures. Live data can be accessed through the Solara online data portal where the transmission frequency can also be adjusted.

**Figure 8: Ice beacon deployed on a mobile ice floe. Approximately 12" is visible above the snow.**

Note that one ice beacon unit (IMEI 300134010906880) was built into a larger surface float with a line suspended below that had 4 Alec CT sensors and 2 HOBO pressure transducers attached. CT sensors were set at 2m (#1583), 4m (#1592), 8m (#1574), and 16m (#1300), depths while the pressure transducers were at 1.68 m (#11013571) and 18m (#11013570) depth. None of the data from the CT or pressure transducers will be telemetered, but the plan is to recover this buoy with the Amundsen this June and download 5 months of continuous data from the 6 sensors. There is a chance that this buoy will remain in the ice until we recover it, but there is also a chance the ice floe it is on will melt out. As a result the buoy was deployed with 4 large floats attached around the PVC tubing to provide flotation but also ensure that it stays upright and continues to transmit its position.

- CEOS Ice Mass Balance buoy (x1): A prototype of the new CEOS IMB built in house by Nic Zilinski, Ryan Galley and David Babb. The system measures air temperature, air pressure, snow depth, ice thickness and a vertical temperature profile through the ice into the surface water, and transmits hourly data via Iridium. The system historically was based on Campbell Scientific's CR1000 data logger and associated Loggernet software, however this new version runs off of an Ardueno and uses various components to communicate with the various sensors. The entire system was mounted on a steel tripod and anchored to the ice with ice screws and a central mast for the under water sounder.

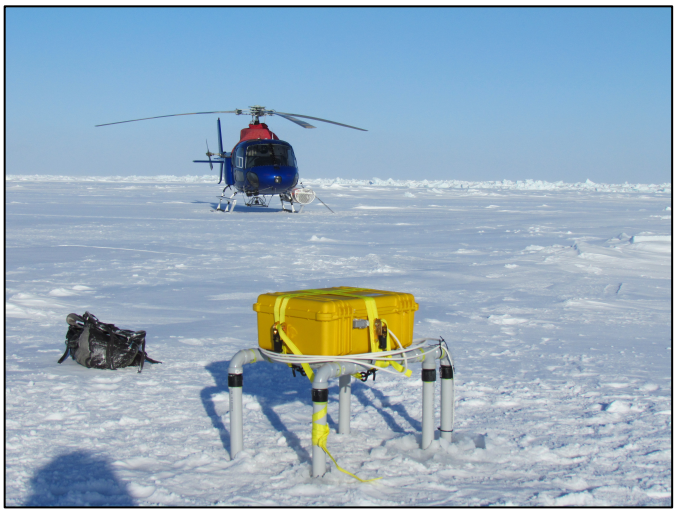
**Figure 9: CEOS IMB deployed on the mobile ice. Note the yellow logger case that houses the batteries and hardware, acoustic snow sounder deployed to the left of the tower, air temperature and pressure shields at the top of the tripod and the iridium antenna at the very top**

- SAMS Ice Mass Balance buoy (x3): Purchased from the Scottish Association of Marine Sciences, the SIMBA unit doesn't use sounders to detect the top and bottom ice interfaces. Instead it relies on a high resolution 4.5 m long temperature string with sensors at 2 cm intervals to provide a vertical temperature gradient through the air, snow, ice and water profile. The system is comprised of a pelican case that houses the batteries, hardware, and iridium/GPS antenna, and a thin temperature string that is simply deployed through a 2" auger hole through the ice with a small weight at the bottom to keep the line taut. A surface stand comprised of 4 PVC (1 ½" inner diameter) legs and 1 temperature string arm was constructed to hold the pelican case above the snow and anchor the temperature string. The pelican case was secured to the stand with two ratchet straps, with attention paid to make sure the metal ratchets were underneath the case as to not interfere with Iridium communications, and to avoid pressure on the Temperature string. Temperatures are recorded every hour (t = 0), then a voltage is applied to each sensor and subsequent temperature readings are taken at t = 15, 30 and 60 s delays. This provides data on the thermal conductivity of the surrounding medium and can further differentiate between air, snow, ice and water.

*Table 1: SIMBA deployment details.*

| | Deployment Date | Ice thickness (snow depth) | Coordinates | Notes |
|---|---|---|---|---|
| SIMBA 01 | February 9, 2017 | 74 cm (5 cm) | 59 08.707<br>93 12.649 | |
| SIMBA 02 | February 12, 2017 | 68 cm (5 cm) | 59 18.284<br>93 06.879 | Deployed with met tower |
| SIMBA 03 | February 10, 2017 | 61 cm (3 cm) | 59 13.658<br>92 55.978 | Deployed with CT line |

*Figure 10: SIMBA deployed on the mobile ice. Note the temperature string runs down through the ice on the furthest right PVC tube.*



- On-ice weather station (x1): The on ice weather station transmits hourly observations of surface winds, air temperature and air pressure to provide information on the atmospheric forcing of the mobile ice pack. The system does not have a GPS, so it was deployed next to an ice beacon (#14) and SIMBA #2. The system uses an electronic compass to correct wind direction for floe rotation, though a second ice beacon (#8) was deployed on the floe to provide direct observations of floe rotation that can then be compared against the compass rotation and ensure observations of wind direction are correct.

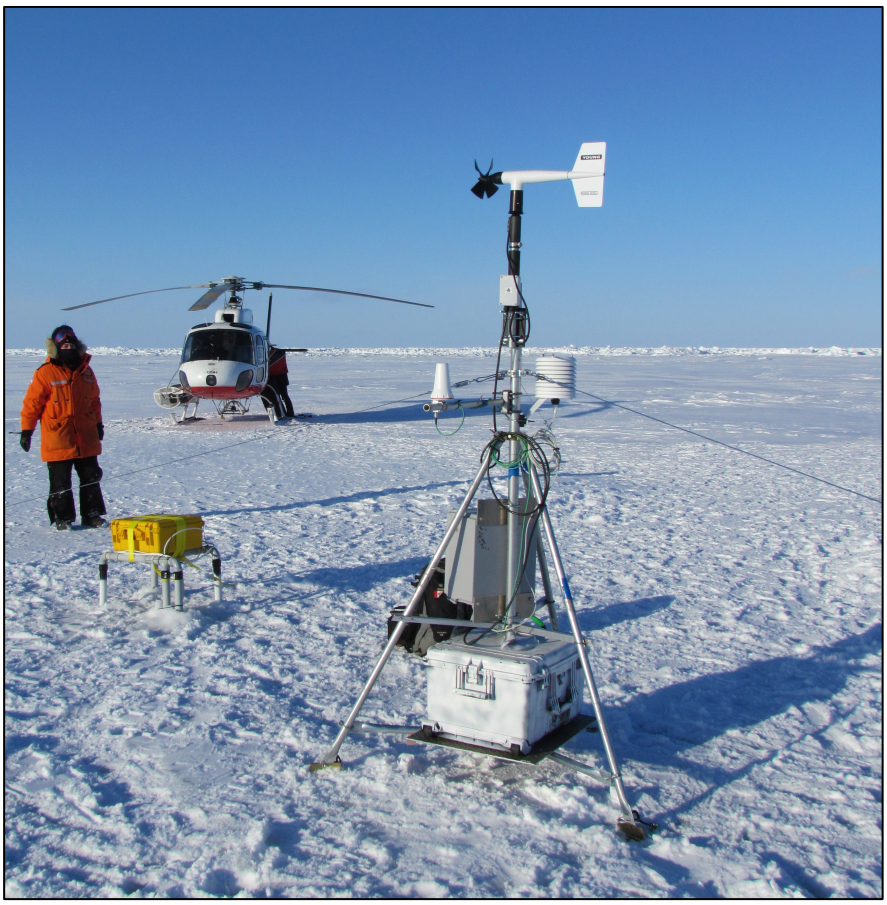


*Figure 11: On ice weather station deployed next to SIMBA 02*

# Team 3 – Marine Ecosystems

Participants: Gabrielle Deslongchamps, Lisa Mathes & Laura Dalman

The availability of light and nutrients controlled by physical oceanic processes and river runoff determine the timing and magnitude of biological productivity. In winter, light transmission through snow covered sea ice is very low while nutrient loading is influenced by different freshwater discharges of unregulated vs. regulated rivers. The aim of team 3 sampling was to collect a winter nutrient baseline of the unregulated Churchill River estuary and offshore marine waters. Simultaneously, light propagation through the ice cover and primary production at the ice bottom and in the water column was measured.

## Sea Ice sampling

### *Ice core sampling*

Ice samples were collected using a 9 cm Mark II Kovacs core barrel. The bottom 5 cm of 3-5 cores were pooled together for each site and the bottom skeletal later (1-2 cm) of 3-5 cores were scraped into 500 mL of filtered seawater. A separate core was taken for analysis of bulk nutrients on the bottom 5 cm. A full core was also taken to measure temperature and salinity for 0-5 cm sections for a full ice profile. These values will be used to calculate percent brine volume.

Figure 12: Left - Temperature measurements of a full ice core, Right - Sampling of bottom ice core after drilling through 70 % of the ice layer by an ice auger.

The bottom 5 cm pooled cores were melted in the dark and 0.2 μm filtered seawater (FSW) was added at a ratio of three parts FSW to one-part ice. The melted pooled cores were then subsampled for the following variables that were filtered on Whatmann GF/F filters, frozen at -80°C and brought south for analyses: chlorophyll *a*, particulate organic

carbon and nitrogen, high-performance liquid chromatography, particulate spectral absorption, and flow cytometry. The scraped cores were then subsampled for the following variables that were either fixed and/or frozen at -80°C for analyses : intracellular nutrients, chlorophyll *a*, particulate organic carbon and nitrogen, algal taxonomy (via visible microscopy) and used for oxygen incubations that are discussed further in a section below. Sample analysis is currently ongoing.

*Under-ice light measurements*

For ice algae available photosynthetic active radiation (PAR, 400 – 700 nm) was measured 10 cm below the ice bottom. A UV-visible hyperspectral radiometer (Cosine RAMSES-ACC, TriOS GmbH, Germany) was mounted to a metal arm and faced upward 1.50 m away from a drilled hole. To calculate light transmission incident radiation and albedo was measured with the same sensor at the ice surface. Ice thickness and snow depth was also recorded.

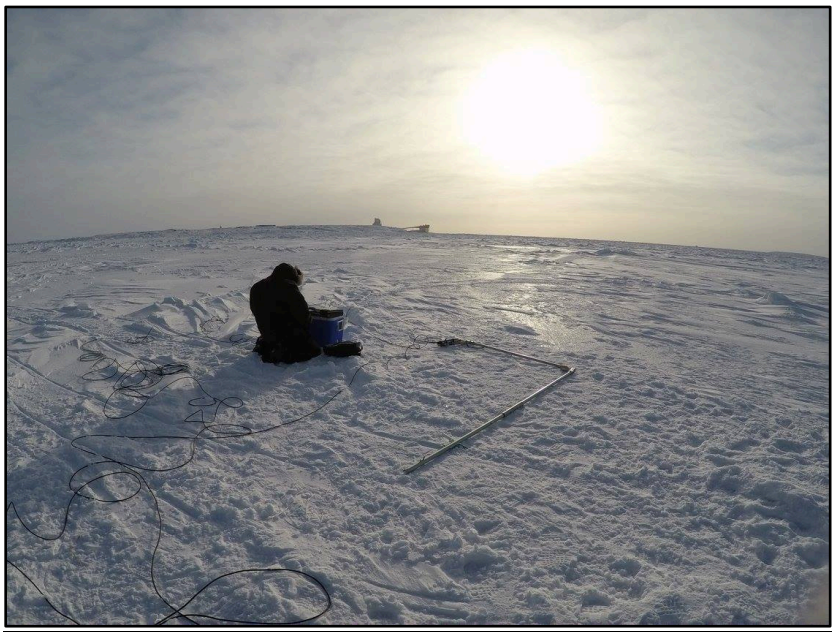


Figure 12: Preparation of under-ice light measurement through a metal arm with an attached radiometer.

Water sampling

Interface water at the ice bottom close to the river estuary and marine water of several depth levels at the offshore sampling sites was collected to characterize the physical, biological and chemical properties of the water column (tab. 1).

Table 2. Water sampling parameters collected by BaySys team 3 (see Appendix 1 for full list of collection depths)

| | |
|---|---|
| CDOM | Colored dissolved organic matter |
| $a_p$ | Particle absorption |
| HPLC | High-performance liquid chromatography for photosynthetic pigments |
| Chl *a* | Chlorophyll *a* concentration |
| Flow Cytometry | Preserved plankton samples (Analysis of pico- and nanoplankton) |
| Lugol | Preserved phytoplankton samples (Taxonomy) |
| FlowCam | Dynamic imaging particle analyzer (Plankton size distribution) |
| POC/N | Particular organic carbon/ nitrogen |
| $NO_3$, $NO_2$, Si, $PO_4$ | Nitrite, nitrate, orthophosphate and orthosilicic acid |
| $NH_4$ | Ammonium |
| DOC/TDN | Dissolved inorganic carbon and total dissolved nitrogen |
| Nat. Ab. $NO_3$ | Natural abundance of nitrate isotopes ($^{18}O$ and $^{15}N$) |
| C/N uptake | Uptake of 15N and 13C |

*Optical characterization of sea ice-covered water column*

Sea ice and the snow cover on top reflect and scatter a high amount of incident solar radiation. The small portion reaching the water column underneath is also scattered and absorbed by particular (algae, detritus) and dissolved organic matter, however their concentration is expected to be low in winter. To characterize the light conditions and inherent optical properties of the upper euphotic zone of Hudson Bay, two UV-visible spectral radiometers (spherical RAMSES-ASC, TriOS GmbH, Germany) were lowered through a hole at four mobile ice floes offshore. Measurements were taken from the surface to a depth of 30 m every 0.5 m, roughly, while one sensor was facing upwards, the other one downwards to record total irradiance. Surface radiation was measured with another UV-visible spectral radiometer (Cosine RAMSES-ACC, TriOS GmbH, Germany) and albedo and light transmission were calculated afterwards.
Inherent optical properties of the water column were investigated in terms of particle absorption, pigment concentration and the content of particulate organic carbon and nitrogen. Water for filtration was sampled by a Niskin bottle at six different depth levels (if possible): Ice interface water, 5 m, 10 m, 20 m, 30 m and above the bottom. For laboratory analysis of particle absorption ($a_p$) by spectrophotometry, of photosynthetic pigment concentration by high-performance liquid chromatography (HPLC) and of particular organic carbon and nitrogen (POC/N) concentration, water samples of 1 or 2 L

were filtered and stored at -80 °C. Colored dissolved organic matter (CDOM) will be analyzed through spectrophotometry from 40 mL prefiltered water samples of each depth.

*Characterizing the size distribution of the present micro- and nanophytoplankton*

Water samples (200 mL) from three depths (interface, 10 m, bottom) were preserved with Lugol's solution for later microscopic analysis. Furthermore, particles in the water from the same depth levels were directly analyzed by automated imaging technology (FlowCam, Fluid Imaging Technologies, INC., USA). The FlowCam as a dynamic imaging particle analyzer examines a fluid under a microscope which is pumped through a flow cell. An integrated camera takes images of particles within the fluid and characterizes them in terms of particle size and shape. For this project, water samples of 10 mL were pre-filtered through a 100 μm mesh to analyze the particle size fraction of phytoplankton between 10 – 100 μm. To get information about the size distribution of plankton smaller than 20 um, water samples of 4 mL were preserved with Glutaraldehyde for later Flow Cytometry analysis.

*Nutrients*

Samples for inorganic nutrients (nitrite, nitrate, orthophosphate and orthosilicic acid) were taken at nine different locations (estuaries and marine sites) to establish detailed vertical profiles. Triplicate samples were pre-filtered through a combusted GF/F filter and stored in acid washed and sample rinsed 15 ml polyethylene tubes. Two samples were immediately frozen at -80˚C and one sample was poisoned with mercury chloride (final concentration of 20 μg/mL). Nutrient concentrations will be determined using standard colorimetric methods adapted from Hansen and Koroleff (2007) with a Bran and Luebbe Autoanalyzer III at Laval University (analytical detection limit of 0.02 μmol $l^{-1}$ for $NO_2$, 0.03 μmol $l^{-1}$ for $NO_3$, 0.05 μmol $l^{-1}$ for $PO_4$ and 0.1 μmol $l^{-1}$ for $Si(OH)_4$).
Subsamples for ammonium ($NH_4$) were taken at all sampling depths. Concentrations were determined upon collection by derivatization with OPA and fluorimetric detection according to Holmes et al. 1999 using a Turner Designs fluorometer (analytical detection limit of 0.02 μmol $l^{-}$).

*Chlorophyll a*

Chlorophyll *a* (chl *a*) was determined with the fluorometrically (Parsons et al. 1984) by filtering 1 liter onto Whatman 25 mm GF/F filters using a low vacuum pressure (10 psi). Each filter was placed in a 20 ml scintillation vial, and pigments were immediately extracted in 10 ml of 90% acetone. Extraction continued during 24 h at 4°C in the dark.

After 24 h, the samples were allowed to warm to room temperature and fluorometric readings were taken before and after acidification using a Turner Designs fluorometer. Chlorophyll *a* concentrations will be calculated according to Parsons et al. (1984).

*Natural abundance of 18O/15N in nitrate*

Water samples for natural abundances of nitrogen and carbon isotopes were also collected. Water was pre-filtered through a combusted GF/F filter and stored in 60 mL Nalgene bottles. Samples were immediately frozen and stored at -80 ˚C. Isotopic analyses will be conducted at Julie Granger's laboratory (University of Connecticut) using the denitrifier method (Sigman et al. 2001; Casciotti et al. 2002).

Incubations

Incubations using oxygen optodes were performed in order to determine primary production. The chambers containing seven bottles (six clear bottles and one dark) were arranged consecutively in a dark chamber with one white-diffuse plexiglass end positioned towards the light source so that each sample bottle received varying light intensities. Each bottle was filled with the scrape sample using a peristaltic pump to avoid bubbles and overfilled to avoid any headspace upon closure with the glass stopper. The glass stopper contained a drilled hole that was approximately equivalent to the diameter of the optode sensors used. Average light intensity of PAR was measured with a scalar PAR probe (Walz model US-SQS/L) in each bottle before and after incubation. Three thermocouples were placed at the front, middle, and back of the chambers to monitor temperature continuously over the incubation period. Samples were incubated for 72 hr with robust Firesting optodes in each bottle continuously measuring dissolved oxygen under constant illumination and mixing via magnetic stir bars.

To determine $NH_4$ and $NO_3$ uptake rates and primary production, surface water samples were incubated under two light intensities (low = 5 µE $m^2$/s and high = 60 µE $m^2$/s) using $^{15}N$ and $^{13}C$ tracers. All bottles were incubated for 24 h at 0˚C. After 24 h, water samples were filtered through a pre-combusted GF/F filters and the filters were dried for 24 h at 60°C for further analyses. Isotopic ratios of nitrogen and carbon from all GF/F filters will be analyzed using mass spectrometry at Laval University.

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# Team 4 – Carbon System

Participants: Dr. David Capelle & Dr. Nix Geilfus

## Background

The objectives for Team 4 were to provide baseline measurements of wintertime carbon system parameters in the Churchill river and marine end-members, as well as the estuary, where river and marine water mix. This information can be used to estimate the supply of Carbon system parameters to the estuary and Hudson Bay system during winter.

Little is known about the Carbon system during winter in Hudson Bay. Riverine supply of nutrients and carbon may lead to accumulation of DIC in estuaries, which could cause sea-air $CO_2$ flux and acidic conditions, but may also help stimulate spring phytoplankton blooms which draw down atmospheric $CO_2$. Ice formation/melt can also affect the cycling and exchange of $CO_2$ between the atmosphere and underlying seawater. The melting of Carbon-rich permafrost may release both $CO_2$ and $CH_4$ to the water that drains into the Churchill River. We therefore measured the $^{13}$C-DIC and $CH_4$ concentrations in the river, estuary and marine water. We also use $^{18}$O to estimate the contributions of meteoric vs. seawater in each water and ice sample.

This information will be used to improve the accuracy of current carbon budgets in Hudson Bay, and to inform future projections of these parameters under various future scenarios related to hydroelectric demand, freshwater inputs, and sea-ice concentration.

## Water sampling

Water samples were collected from the Churchill River (near the pumphouse), estuary (EST#1), and 2 marine sites (Marine#1 and Marine#2) between February 2 and 14. The following water depths were sampled where possible: under-ice, 5m, 10m, 20m, 30m, 50m, Bottom.

Water was collected using a cyclone pump or Niskin bottle from under the ice, and using a Niskin bottle for deeper depths. Water was transferred using flexible tubing into one 300mL and one 500mL BOD bottle, overfilling each bottle and taking care not to introduce air bubbles. The BOD bottles were stoppered and transported in coolers to the lab for processing.

One BOD bottle was poisoned with 200µL saturated $HgCl_2$ and re-sealed at the lab, for DIC/TA analysis. The second (500mL) BOD bottle was subsampled at the laboratory into smaller bottles within 1-3 hours for DIC/TA, $^{18}$O, $^{13}$C-DIC, salinity, $CH_4$, $N_2O$, and $O_2$/Ar. Subsampling was performed with a 50mL glass syringe with a short piece of plastic tubing on the end. The syringe was rinsed with sample water before subsampling, and care was taken to keep the syringe and tubing free of bubbles during subsampling.

## Ice Core sampling

Ice cores were collected from the Churchill River estuary and two marine sites using a Kovacs 9" diameter Mark II core barrel. Ice cores were transported to the lab in plastic bags (in the dark), and segmented into 5cm sections in upper and lower 15cm, 10cm sections above/below.

Ice core sections were individually vacuum sealed and melted overnight at room temperature in the dark, then sampled for all DIC/TA, $^{18}O$, salinity, parameters, using a 50mL glass syringe with tubing on the end to transfer water from vacuum bags to sample containers. The salinity and temperature of melted sections were measured using a salinity probe, which was calibrated using milliQ water and 35 psu salinity standard.
All water samples were stored at room temperature in the dark during transport back to the University of Manitoba.

DIC/TA

One 300mL and one 500mL glass BOD bottle were filled using flexible tubing from either a Niskin bottle or cyclone pump, taking care to avoid introducing bubbles and overfilling. These were stopped without headspace in the field and transported in sealed coolers with hot water bottles to the lab for processing.
At the lab, 3mL of water (1%) was removed from the 300mL BOD bottle, which was then poisoned with 200µL of saturated $HgCl_2$ solution, and sealed using a pre-greased glass stopper. DIC/TA samples with be measured at both the Institute of Ocean Sciences in Sidney, BC, by Dr. L. Miller's group.

A second set of DIC/TA samples were collected in 5 x 12mL exetainers, to be measured at the University of Manitoba for intercalibration.
A glass syringe with a ~10cm length of plastic tubing was pre-rinsed with sample water from the 500mL BID bottle, and used to transfer water from the BOD to the exetainers. Each exetainer was filled to the top, and poisoned with 20µL of saturated $HgCl_2$ before being sealed with no headspace.

Samples were stored in the dark at room temperature.

$^{18}O$

Sample water for $^{18}O$ was collected from the 500mL BOD bottle using a pre-rinsed glass syringe. One 13mL plastic vial and one 2mL glass exetainer were each filled and sealed with screw caps and parafilm, with no headspace. 13mL samples will be measured at McGill University in Montreal, QC by Dr. A. Mucci's group. 2mL samples will be measured at the University of Manitoba.

Salinity

Water for salinity was poured from the 500mL BOD bottle into a 125 glass bottle with a conical screw cap. The bottle was filled to the bottom of the neck, capped, and parafilmed. Salinity from water column samples will be measured using a salinometer at Fisheries and Oceans Canada in Winnipeg, MB. For ice core samples, salinity was measured with a salinity probe only.

$CH_4/N_2O/O_2/Ar$

Water was transferred using a pre-rinsed glass syringe to 2 x 60mL glass serum bottles. Each bottle was filled to the top, poisoned with 40µL of saturated $HgCl_2$, and crimp-sealed with no headspace. $CH_4$, $N_2O$, $O_2$, and Ar will be measured at the University of Manitoba. $CH_4$ will be measured using GC-FID, $N_2O$ using GC-ECD, and $O_2$/Ar by mass spectrometry.

$^{13}$C-DIC

Water was transferred from the 500mL BOD bottle to one 50mL amber glass serum bottles with screw caps. The bottle was filled to the top, poisoned with 20µL saturated $HgCl_2$, capped with no headspace, and parafilmed. $^{13}$C-DIC will be measured at McGill University in Montreal, QC by Dr. A. Mucci's group.

Comments/Issues

The cyclone pump flow rate was very high, causing bubble entrainment inside BOD bottles. This was only an issue in the Churchill river, and marine site#1. At all other sites, the Niskin bottle was used for 1m depth water sampling.

A thin layer of ice formed inside BOD and serum vials collected at the Churchill River site during sampling. This was not a problem at subsequent sites due to the use of a tent with heater during water sampling.

A heater was needed to warm up the Niskin (spigot and especially the release-trigger). The Niskin leaked slightly at estuary site. A hairdryer or electric car-cabin heater (Lil' Buddy - Canadian Tire), with generator was required to heat the Niskin between casts.

One of the auger motors leaked fuel from the carburetor, and was often difficult to start. The second auger head suffered a broken recoil starter, and could not be repaired. It was important to have spare auger motors, and extra blades for the core barrels and augers.

It was recommended that we keep the augers outside instead of bringing them inside at the end of each day, to prevent water condensation in the fuel tanks.

The accommodations and laboratory facilities at the CNSC were excellent. Dr. Fishback, the staff and volunteers of the CNSC were extremely helpful in assisting us with our day to day needs, including providing us with supplies and transportation. We are particularly grateful for the help of a local guide, Len, for his assistance in navigating the landfast ice on snowmobiles and for loaning us a 10" auger.

The helicopter pilots, Jon and Pat, and their mechanic, Pete, were extremely cooperative, and transported us safely to and from our study regions safely and without any delays. They also provided assistance with site selection and sampling operations, for which we are extremely grateful.

A great deal of help with sample preparation and collection was provided by Kathleen Munson, Gabrielle Deslongchamps, Nix Geilfus, Marcos Lemes, Emmelia Wiley, and Odile Crabeck.

# Team 5 – Contaminants

Participants: Drs. Kathleen Munson and Nicholas-Xavier Geilfus

The objective for Team 5 was to determine total mercury (THg) and methylated mercury (MeHg) concentrations in ice and water across the gradient between the Churchill River and marine waters of Hudson Bay during the winter period of minimal river flow.

The diversion of the Churchill River to augment the Burntwood-Nelson River System for hydroelectricity production reduced Churchill River flow to approximately a quarter of its pre-diversion volume. However, despite this lower water volume, concentrations of THg and MeHg are higher in Churchill River water than in Nelson River water (Kirk et al, 2008). In addition, THg in the Churchill River is primarily found in its dissolved form (Kirk et al, 2008), which may impact the persistence of THg from riverine sources and its potential for transformation to the biaccumulating chemical form MeHg in estuarine and marine waters of Hudson Bay.

The goal of constraining the wintertime riverine source of THg and MeHg is to determine its importance relative to other potential sources into Hudson Bay, including marine waters, atmospheric, snowmelt, and how these are tempered by the seasonal sea ice boundary between the atmosphere and the marine water column.

## Water Sampling

Surface water from the Churchill River was collected by dipping bottles through the 8” auger hole in the ice wearing clean vinyl gloves.

Water sampling from estuary and marine sites was accomplished by deploying a 2.5 L Niskin bottle from a metered line with a Teflon-coated messenger. All water sampling was accompanied by CTD deployment immediately prior to deployment of the Niskin bottle. The Niskin bottle deployment required a 10” auger hole through which the Niksin bottle in the cocked position and trigger mechanism were lowered down by hand. At the desired sampling depth, the Teflon coated messenger was released gently to minimize splashing of water. The line was then raised and the Niskin bottle was observed to determine whether the messenger successfully triggered the closure of the bottle. At times, we observed the freezing of water on the spring in the trigger mechanism. The freezing of the spring would result in a bottle misfire as the depressed trigger would block the top of the Niskin bottle from closing.

In order to prevent both the freezing of the spring as well as the spigot and valve, water was most often sampled within the Eskimo brand ice-fishing tent using either a hair dryer or a Little Buddy brand car heater to thaw Niskin bottle components prior to deployment.

Samples were collected in 250 mL amber glass bottles. Bottles were rinsed with sample water prior to filling, filled to the shoulder, capped, and double bagged. Bagged

samples were transferred to the lab at CNSC in coolers with hot water bottles to prevent freezing. Care was taken to avoid cross contamination with sampling equipment and personnel involved in DIC/TA sampling and preservation, which requires use of high concentrations of $HgCl_2$ as a preservative agent.

Ice Sampling

Ice cores were collected using the 9 cm Mark II Kovacs core barrel in conjunction with teams 1, 3, and 4 from 2 mobile ice floes. Cores were bagged in core bags, labeled in the field, and transferred to CNSC. Cores were cut with a metal Japanese saw into 5 cm portions outside of the CNSC main building (ambient temperature < -20 °C) in order to prevent thawing. All edges of each core section were then trimmed with ceramic knives to remove ice that came into contact with the core barrel or the metal saw. Trimmed sections were double bagged in new Ziploc bags and kept at room temperature in order to melt.

After melting indoors in Ziploc bags, the ice core sections were processed identically to water samples.

Sample Processing

Ideally, the processing of trace metal samples is carried out in clean room environments under HEPA-filtered, or equivalent, air supply. Because no certified clean room was available at CNSC, all sample processing for THg and MeHg, storage of sampling gear, and storage of samples were performed in separate lab room from the main portion of the laboratory, where $HgCl_2$ was used as a preservative for DIC/TA samples. The last lab bench in the CNSC "clean room" was selected in order to minimize both proximity to areas where $HgCl_2$ was used and foot traffic that might increases movement of air and particulates.

A small tent was constructed out of plastic sheeting on lab bench to minimize falling dust or particles into open bottles during filtration and preservation. All sample filtration and preservation equipment was kept within this small tent throughout the duration of the field program.

Double-bagged samples were removed from coolers. Outer bags were removed and samples in inner bags were transferred to the lab bench tent and opened to remove sample bottles. Either a separate 250 mL bottle or ~125 mL of a sample were filtered through Thermo Scientific Nalgene disposable analytical filtration (0.45 μm, 47 mm) units using a Nalgene hand pump under 5 – 10 psi pressure. Filtration unit and filtrate collection bottles were rinsed 3x prior to filtrate collection. Filter cups were kept covered as much as possible during filtration.

Filters were removed, stored in PetriSlides (EMD Millipore) marked with filtered volume, and stored at -20 °C.

Unfiltered and filtered water and ice samples were preserved to 0.5% HCl (concentrated HCl, JT Baker) and stored in coolers in the dark until transfer to the University of Manitoba for future analysis.

## References:

Kirk JL, St. Louis VL, Hintelmann H, Lehnherr I, Else B, Poissant L (2008) Methylated mercury species in marine waters of the Candian High and Sub Arctic. Enivron. Sci. Technol. 42:8367-8373.

# Appendix A: Work Schedule

| Sunday | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 |
| | | | KM, NG, LD, LM, DC arrive | Sampling from the pump house | Weather day | Estuary sampling and CTD's<br>LM, LD, NG, DC<br><br>DB, JL, NZ, GD arrive |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| | Helicopters arrive at CNSC | Helo day 1<br>Ice recon flights w/ DB, JL, KM, NG<br><br>CTD1, Beacon15 | Helo day 2<br>AM: Ice recon flights w/ DB, JL, KM, NG<br><br>PM: returned to PS1 1 for CEOS IMB deployment, ice sampling | Helo day 3<br>AM: Returned to PS1 for water sampling w/ DC, KM, LM,<br><br>PM: Extended the ice survey NE w/ JL, DB, NG, LD, SIMBA01 Beacon array | Helo day 4<br>AM: Ice team SIMBA03<br>CT Line<br>CTD<br>Beacons<br><br>PM: Water team Water sampling PS 2 | Helo day 5<br>AM: Water team<br><br>PM: CTD Transect along the Landfast ice from Cape Churchill to Churchill Estuary<br><br>NZ departs for WPG |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| Helo day 6<br>AM: Ice team DB, JL, LM, NG, Met Tower SIMBA02 Beacons<br><br>PM: | Helo day 7<br>Landfast ice sampling and CTD profile w/ GD, DB, NG<br><br>* Blue Helo maintenance | Helo day 8<br>AM: Water team<br>CTD<br>Light profile<br>Water sampling<br><br>PM: CTD transect just beyond Landfast ice near the Estuary | JL, NG, LD, LM depart for WPG | DB, DC, KM, GD depart for Thompson | | |

# Appendix B: Sampling Schedule

| Date | Station | Long (N) | Lat (W) | Bottom depth [m] | CTD (Seabird) | Light | Deployment (Beacons, Buoys) | Ice sampling | Water sampling |
|---|---|---|---|---|---|---|---|---|---|
| 03-Feb-17 | Churchill River | | | | | | | | Dissolved and particulate THg, MeHg, DaveC sampling |
| 04-Feb-17 | Button Bay | 58 48.500 | 94 17.200 | | | | CT | | Surface water |
| 04-Feb-17 | Est-1 | 58 47.442 | 94 12.625 | | | | CT | | Surface water |
| 04-Feb-17 | Est-2 | 58 47.608 | 94 11.976 | | | | | T, S, Chl a, POC/N | |
| 05-Feb-17 | Est-1 | 58 47.437 | 94 12.716 | | x | | | T, S, Chl a, POC/N, Ap, Nutrients, Taxonomy, Flow Cytometry | Interface water |
| 05-Feb-17 | Est-2 | 58 47.613 | 94 11.955 | | x | | | | |
| 05-Feb-17 | Est-3 | 58 47.758 | 94 11.346 | | x | | | | |
| 05-Feb-17 | Est-4 | 58 47.813 | 94 10.842 | | x | | | | |
| 06-Feb-17 | Button Bay | 58 48.161 | 94 16.920 | | x | Under-ice arm | | T, S, Chl a, POC/N, Ap, Nutrients, Taxonomy, Flow Cytometry | Interface water |
| 06-Feb-17 | Est-1 | 94 12.625 | 94 12.625 | | | Under-ice arm | | | |
| 06-Feb-17 | Est-3 | 58 47.758 | 94 11.346 | | | | | T, S, Chl a, POC/N | |
| 06-Feb-17 | Est-4 | 58 47.813 | 94 10.842 | | | | | T, S, Chl a, POC/N | |
| 07-Feb-17 | Pan 1 | 59 04.701 | 92 06.647 | | x | | | | Surface water |
| 08-Feb-17 | Pan 2 | 58 44.281 | 93 49.092 | | x | | Beacon | | |
| 08-Feb-17 | Pan 3, Marine 1 | 58 55.040 | 93 23.412 | | x | | Beacon, IMB | T, S, Chl a, POC/N, Ap, Nutrients, Taxonomy, Flow Cytometry, dissolved and particulate THg and MeHg (DaveC) | Hg, Interface water |
| 08-Feb-17 | Pan 4 | 58 58.562 | 93 22.600 | | | | Beacon | | Hg |
| 08-Feb-17 | Pan 5 | 59 01.552 | 93 21.072 | | | | Beacon, IMB | | |
| 09-Feb-17 | Pan 3, Marine 1 | 58 54.576 | 93 16.973 | | x | Under-ice arm, Full profile | Beacon recovery | | *Depths: Interface, 5, 10, 15m* Chl a, POC/N, Ap, Nutrients, HPLC, Taxonomy, Flow Cytometry, |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | dissolved and particulate THg and MeHg DaveC |
| **Date** | **Station** | **Long (N)** | **Lat (W)** | **Bottom depth [m]** | **CTD (Seabird)** | **Light** | **Deployment (Beacons, Buoys)** | **Ice sampling** | **Water sampling** |
| 09-Feb-17 | Pan 6 | 59 08.707 | 93 12.649 | | x | | SIMBA 01 | | |
| 09-Feb-17 | Pan 7 | | | | | | Beacon | | |
| 09-Feb-17 | Pan 8 | | | | | | Beacon | | |
| 09-Feb-17 | Pan 9 | | | | | | Beacon | | |
| 10-Feb-17 | Pan 10 | 59 02.618 | 93 03.970 | | x | | | | |
| 10-Feb-17 | Pan 11, Marine 2 | 59 13.658 | 92 55.978 | | x | | CT, SIMBA 03 | Chl a, POC/N, Ap, Nutrients, Taxonomy, Flow Cytometry, dissolved and particulate THg and MeHg (DaveC) | Interface water |
| 10-Feb-17 | Pan 12 | | | | | | Beacon | | |
| 10-Feb-17 | Pan 13 | | | | | | Beacon | | |
| 10-Feb-17 | Pan 14 | | | | | | Beacon | | |
| 10-Feb-17 | Pan 15 | 59 12.327 | 92 50.687 | | x | | Beacon | | Surface water |
| 11-Feb-17 | Pan 11, Marine 2 | 59 10.050 | 92 50.692 | | x | Under-ice arm, Full profile | | T, S | *Depths: Interface, 5, 10, 20, 30, 50, 70m* Chl a, POC/N, Ap, HPLC, Nutrients, Taxonomy, Flow Cytometry, dissolved and particulate THg and MeHg DaveC, |
| 11-Feb-17 | Pan 16 | 58 50.644 | 93 14.979 | | x (Bad data) | | | | |
| 11-Feb-17 | Pan 17 | 58 49.016 | 93 08.307 | | x (Bad data) | | | | |
| 11-Feb-17 | Pan 18 | 58 48.871 | 93 21.555 | | x (Bad data) | | | | |
| 11-Feb-17 | Pan 19 | 58 50.885 | 93 32.390 | | x (Bad data) | | | | |
| 11-Feb-17 | Pan 20 | 58 51.286 | 93 43.874 | | x (Bad data) | | | | |
| 11-Feb-17 | Pan 21 | 58 48.017 | 93 54.190 | | x (Bad data) | | | | |
| 12-Feb-17 | Pan 22 | 59 10.469 | 93 12.190 | | | | Beacon | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 12-Feb-17 | Pan 23, Marine 3 | 59 18.284 | 93 06.879 | | x | Full profile | 2 Beacons, SIMBA 02, Met tower | | *Depths: Interface, 5, 10, 20, 30, 50m* Chl a, POC/N, Ap, HPLC, Nutrients, Taxonomy, Flow Cytometry |
| **Date** | **Station** | **Long (N)** | **Lat (W)** | **Bottom depth [m]** | **CTD (Seabird)** | **Light** | **Deployment (Beacons, Buoys)** | **Ice sampling** | **Water sampling** |
| 13-Feb-17 | Pan 24 (Stn 1 Transect) | 58 49.184 | 93 07.720 | | x | | | | Depths: Interface, 5m, bottom |
| 13-Feb-17 | Pan 25 (Stn 2 Transect) | 58 49.894 | 93 18.378 | | x | | | | |
| 13-Feb-17 | Pan 26 (Stn 3 Transect) | 58 49.649 | 93 28.843 | | x | | | | |
| 13-Feb-17 | Pan 27 (Stn 4 Transect) | 58 47.960 | 94 11.291 | | x | | | | |
| 13-Feb-17 | Pan 28 (Stn 5 Transect) | 58 46.902 | 94 01.133 | | x | | | | |
| 13-Feb-17 | Pan 29 (Stn 6 Transect) | 58 50.678 | 93 46.479 | | x | | | | |
| 14-Feb-17 | Pan 30, Marine 4 | 58 50.116 | 94 01.400 | | x | Full profile | | | *Depths: Interface, 5, 10, 20, 23* Chl a, POC/N, Ap, HPLC, Nutrients, Taxonomy, Flow Cytometry, dissolved and particulate THg and MeHg |
| 14-Feb-17 | Pan 31 (Stn 7 Transect) | 58 49.920 | 94 12.976 | | x | | | | Surface water |
| 14-Feb-17 | Pan 32 (Stn 8 Transect) | 58 50.909 | 94 18.366 | | x | | | | Surface water |
| 14-Feb-17 | Pan 33 (Stn 9 Transect) | 58 53.335 | 94 11.866 | | x | | | | Surface water |

# Appendix C: Story from the field

By: Nic Zilinzki.
Posted on the CEOS website at
http://umanitoba.ca/faculties/environment/departments/ceos/outreach/1395.html

What began as an undergraduate summer NSERC research position, resulted in the extraordinary opportunity to fly by helicopter onto sea ice in Hudson Bay. The goal, to deploy the research project I was a part of, a CEOS designed ice-mass balance buoy. Since arctic sea ice plays a large role in the global climate, acting as a heat sink, influencing ocean circulation, as well as being a major contributor to the earth's albedo. We can understand these relationships best through monitoring changes in the thickness and extent of sea ice, known as ice-mass balance, and using GPS to illuminate sea ice dynamics.

For me, one of the most valuable aspects of the field campaign was being able to see a project through from design, to manufacturing, to deployment. I joined a team from CEOS headed to Churchill, Manitoba, where we stayed at the Churchill Northern Studies Center (CNSC). CNSC is an amazing facility equipped with labs, great food, and perfect spots for viewing auroras. The group had a diverse scientific background, studying water and ice chemistry, biology, and physics. This gave me a chance to see how science is done from a variety of different vantage points. The group needed to collect water and ice samples, collect light measurements from below the ice, as well as deploy ice-mass balance buoys and weather stations, sounds easy enough, right? However, even the simplest task becomes difficult in the arctic, from screwing together equipment to getting a motor started, the cold weather doesn't play nice.

The first field day for me was going onto the land fast ice just off Churchill. It was a balmy -35°$C$ which made the -15°$C$ back in Winnipeg feel like shorts weather. Luckily, I was well prepared by CEOS members on what to wear, so the cold was no problem, although you feel like a large marshmallow with all those layers on. We weren't deploying my buoy that day so I was just there to help whoever needed it. I took part augering and collecting ice core samples, which is more physically demanding than I expected since the ice cores are taken manually. The real test is keeping calm when you realize the 1 meter ice core sample you just took is now stuck and it doesn't look like it's coming out.

BAYSYS
Mobile ice survey – February 2017

After a few days in Churchill the pilots arrived that would bring us out onto the mobile sea ice. They met with us and planned which floes we would attempt to land on. Then the day came to deploy my ice-mass balance buoy, not only had I never been in a helicopter, but my first time would be landing on ice we didn't know for sure was thick enough to hold us. It was a bit unnerving at first, but after seeing how skilled the pilots were, it quickly set any worries to rest. As we flew out over the ice of the Hudson Bay, the landscape was amazing. It was a vast mixture of open water, ice floes and ice ridges. I went out in the afternoon, so we didn't have much time to set up my buoy as the sun was setting, we had to get things right the first time. After pulling all the equipment out I realized I had forgotten to wire one of the sensors properly and I'd have to do it out on the ice, quickly. Fortunately, I had a lot of great help from Dave Babb and the team and got the buoy set up and working. We returned to CNSC in the helicopters where I could celebrate mission accomplished, my summer project had been seen through to the end… and it even worked!