CASES2004, Leg 4
(0401)
CCGS *Amundsen*
Cruise Report

7 January to 18 February

Edited by Jody Deming

II. Specific Activities

1.Report on the activities of the rosette operator during CASES cruise 0401 (Leg 4)
by Claude Bélanger
On board the NGCC Amundsen,
17 February 2004

My activities consisted mainly in sampling two CTD profiles daily at 12-hour interval (at 06:30 and 18:30) in order to follow the seasonal evolution of the water column while the ship was stationary in the ice at 70° 02.71' N 126° 18.06' W, and in providing biologists and chemists with the volumes of water they requested at specified depths.

Other activities consisted in a fortnightly sampling aiming at following the evolution of the content in O18 (not for on board analysis), and weekly sampling for control of the conductivity and dissolved oxygen probes.

The SeaBird CTD/rosette worked without any major problem. Minor flaws are mentioned in the file 'operator_verbose_log_0401.doc' (\Shares\Rosette\Leg4). One hundred and twenty profiles were recorded, and a number of bottles were fired for 56 of those casts. A list of the casts with date, time, type of cast and simultaneous meteorological conditions is given in the file 'ctdlog_0401.xls' (\Shares\Rosette\Leg4). Plots of the downcasts are provided in the folder '\Shares\Rosette\Leg4\screenplots'. Information on the utilisation of the sampled water and average values around the closing time of each bottle can be found in the folders '\Shares\Rosette\Leg4\rosettesheets' and '\Shares\Rosette\Leg4\btl_files'.

In addition to the semi-diurnal casts, two 13-hour series of profiles at 1-hour interval were recorded in order to help determining if some of the observed variations in the profiles are of tidal origin (for example, variations that could be attributable to a tidally generated internal wave propagating at the picnocline). The first of these series was recorded at spring tides (06 February) and the second one at neap tides (13 February).

The O18 sampling followed a strategy expressed by Robie McDonald in a message to Emmanuelle Rail (rosette operator for Leg 3), i.e. samples collected every two weeks at depths so that the features of the water column are resolved. O18 samples were collected three times (at every second 6-day cycle) at nine depths, and with higher resolution in the upper

part of the water column since O18 is used as a tracer for river runoff. In addition, near surface samples were collected from the ice cover just below the ice-water interface. At all depths, water for determination of the salinity was also sampled.

Samples for a precise determination of the salinity were also collected at every day 1 of the 6-day cycle at the same depths where samples for chemical analysis were taken. The processing of these samples has not been done so far due to persistent and various problems with the salinometer Autosal Guildline s/n 67518. A decision has been taken on 15 February to return this instrument to Guildline for inspection.

The determination of the content in dissolved oxygen by titration has been done weekly for controlling the performance of the oxygen probe SBE 43. Results have shown that the values obtained via titration are slightly higher than those obtained from the probe (differences ranging from 2.4 % to 7.0 %, and averaging 4.7 %). When considering the downcast values instead of the bottle files values, the average difference with the titration is somewhat smaller (average 3.4 %). Our results are very similar to those obtained during Leg 2, that is to say the last leg when this instrument was used (see figure below). It seems however that for samples with a relatively high content in dissolved oxygen, the probe values depart now a little more from a perfect match.

2. Ice-Atmosphere Interactions and Biological Linkages

2.1 Surface meteorology /exchanges & Satellite validation

Cruise participants: Tim Papakyriakou, John Yackel, Peter Taylor, Christina Blouw, Carrie Breneman, Jim Butler, Alexandre Langlois, Owen Owens, Rob Pierson, Sergiy Savelyev, Michael Suitor

Introduction

Physically, an ice cover prevents the direct exchange of energy, mass and momentum between the atmosphere and ocean, thereby impacting physical, chemical and biological processes within both the ocean and atmosphere. Itself, the snow and ice cover is a complicated mixture of ice, water, air, brine, salts and biota, whose proportion and characteristics both affect and are affected by air-sea coupling and biogeophysical processes within both the atmosphere and ocean. The overarching objectives of our sub-group examine different aspects of these relationships and over a variety of space and time scales. With great effort, the participants of Leg 4 established (i) monitoring facilities for meteorological parameters, and surface layer processes and process phenomena including blowing snow and fluxes of heat, water vapour, momentum and carbon dioxide, snow and ice geophysical properties and electromagnetic interaction, and (ii) established sampling protocol for snow and ice chemistry and topographic snow and sea ice macro-feature characterization for satellite validation and bear habitat studies. In the organization of this report we separate these activities into discreet sections, even though the research is highly integrated and collaborative.

Site Locations

Time series sampling was conducted on-board the *CCGS Amundsen* (70° 2.516’ N, 126° 15.894W) and at sites distributed within 1.5 km of the ship (Figure 1). All sites were on a pan of uniformly consolidated seasonal sea ice that ranged in thickness from approximately 80 cm (at the start of Leg 4) to 120 cm (by the end of the Leg). Snow cover was hard-packed and ranged from 2 to 10 cm at the time of site installations. Details regarding snow and ice physical properties are provided in Section @. Distributed sampling for topographic snow

and ice macrofeature characterization occured at sites within approximately 10 km of the ship. The specific locations and nature of the distributed sampling is described in Sections @ and @.

Figure 1. The location of sampling sites in close proximity to the *CCGS Amundsen*.

Micrometeorology and Surface Exchanges of Energy, Momentum and CO_2

A number of posts and towers were installed along a surveyed north-south transect starting at approximately 250 m south of a parcoll shelter at Takatuk (Site F in Figure 1). The arrangement of these structures is shown in Figure 2. The two 10m masts and a cluster of instrumented posts in the foreground of the photograph are associated with a blowing snow experiment. GPS determined locations of the two 10m masts are N 70 02.542 W 126 15.894 and N 70 02.532 W 126 15.894. The southern-most structures (i.e., the tower-antenna towers – one 6m and the other 2.5m) are equipped to monitor the components of the heat and radiation budget and the atmospheric CO_2 flux (Lat-Lon of 70° 2.516'N, 126° 15.894'W). For the purpose of this report, the equipment and dataset associated with the blowing snow project and the surface fluxes (heat, radiation and CO_2) will be be described in separate subsections.

Surface Fluxes

(Tim Papakyriakou and Owen Owens)

Radiation Exchange and Surface Budget

Net all-wave radiation and its components (including incident PAR) were measured at Takatuk (Figure 4). Sensor type and manufacturer are itemized in Table 1. Sensor output was scanned at 3 second increments and stored as 10-minute averages by a Campbell Scientific (model 21X) data logger. AC power to the site powered the logger. Sample data from select sensors appear in Figure 10. Data are available from Jan. 23 onwards. A damaged cable delayed the deployment of reflected surface solar radiation until Feb. 4.

Figure 4. Radiation measurement assemblage south of Takatuk (Photo by Owen Owens).

Down facing radiometers were directed toward the west. The extension arm suspending these radiometers could not be oriented toward the south, because the small tower is positioned along the N-S pedestrian line and tracks would be present in the sensor FOV. A quantum sensor was also deployed flush with the ice surface (under the snow) approximately 10 m east of the radiation tower.

Heat Exchange

The instrumentation associated with heat, water vapour, momentum and CO_2 exchange studies budget is depicted in Figure 5 and itemized in Table 1. An eddy correlation system (Figure 6), consisting of a Campbell Scientific sonic anemometer (CSAT3) and LICOR open-path H2O/CO2 infrared gas analyzer (LI7500), was mounted at 4.35 m above the ice surface and oriented to face 190° from north. Sensor output were scanned at 10Hz by a Campbell Scientific data logger (model 23x) and the raw, high frequency, data were transmitted to the *CCGS Amundsen* by RF telemetry in ten minute intervals. The radio frequency transmitter was maintained above its threshold temperature of –25° by a 60W light bulb that was housed within the logger enclosure.

Figure 5. The 6 m heat budget tower south of Takatuk.

Other sensors on the tower (anemometers, temperature/relative humidity probes, IR transducer) were scanned at 3s increments by a Campbell Scientific data logger (model 10x). Temperature-relative humidity sensors were oriented to the north, while anemometers faced south. The offset for the zeroing of the wind vane (on top of the tower) is –16.7°. Data are available from Jan 22 onwards.

Figure 6. The eddy correlation system (CSAT3 and LI7500) on the heat budget tower.

Ice temperature was continually measured at 10 locations (Table 1) extending from the ice surface to 1m depth from the surface by thermocouple sensors (24 AWG, Type T) imbedded into a 4.08 cm O.D. PVC tube. The sensor junctions were embedded in high conductivity epoxy and inserted into PVC plugs, which were themselves inserted into the PVC tubing so that the sensor tips were flush against the ice wall. Snow temperature was measured at 15 locations at 1.5 cm increments up from the snow base by thermocouple sensors (24 AWG, Type T) that were themselves embedded within 5/32" brass tubes, each 8 cm in length. The snow sensor array (Figure 7) was installed immediately adjacent to the ice temperature string. Sample data from select sensors appear in Figures 8, 9 and 10.

Figure 7. Snow temperature array. Note, sensor spacing in the figure is 3 cm, not 1.5 cm spacing, as used during the CASES' experiment.

Figure 8. Net (Rn; Wm^{-2}) and down-welling radiation fluxes: Rs – short-wave; RL – long-wave (all in Wm^{-2}); PAR ($\mu mol\ s^{-1}\ m^{-2}$).

Figure 9. Time series of ice and air temperature (at the 5 m level) at select depths.

Figure 10. Time series of relative humidity (at 5 m).

Table 1. Parameters monitored in association with the heat budget and radiation tower.

a) atmospheric sensors

Variable measured	**Sensor Manufacturer (model)**	**Height from ice (m)**
horizontal wind speed and direction	wind monitor - RM Young® (model 05106 MA)	6.31
horizontal wind speed	3-cup anemometer, Met-One® (model 013a)	1.7, 5.20
temperature and relative humidity	Vaisala (model HMP45C	1.6, 5.12?
global radiation and reflected short-wave	Eppley® pyranometer (model PSP)	TBD ~ 2.2 & 1.8
down-welling and surface emitted long-wave radiation	Eppley® pyrgeometer (model PIR)	TBD ~ 2.2 & 1.8
net radiation	REBS® Q*7	TBD ~ 1.8
PAR irradiance	LI-COR® quantum sensor (LI-190)	TBD ~ 2.2
Surface Temperature	Everest® IRTransducer (Model 4000.4 GL)	TBD ~ 2.2
CO_2 and H_2O concentration	open path IRGA LI-COR® (model LICOR LI-7500)	4.36
wind vector (x, y, and z coordinates)	sonic anemometer – Campbell Scientific®, CSAT3	4.36

b) snow and sea ice

Variable measured	**Sensor Manufacturer (model)**	**Position**

snow temperature	thermocouple sensors (24 awg – type T)	15 sensor at 1.5 cm increments starting at 0.5 cm
ice temperature	thermocouple sensors (24 awg – type T)	-1 cm,-5,-10,-15,-20,-30,-40,-50,-60,-70,-80,-100
PAR transmission (through snow)	quantum sensor (LI-192)	undersnow ~-8 cm

Carbon Flux

Atmospheric

Atmospheric CO_2 concentration was continuously measured using a LI-7500 open-path sensor as part of the eddy correlation system (described above) that was mounted on the heat budget tower (Figure 5). Similarly, eddy correlation estimates of the atmospheric CO_2 flux can be derived using the system. Information on the associated sampling of those ice and ocean pCO_2 and parameters affecting pCO_2 are reviewed below.

Sea Ice and Upper Ocean pCO_2 Concentration and Gradients

Point measures of the CO_2 flux were made through the periodic deployment of gas chambers at the field site, Takatuk.. Chambers were installed directly on an ice surface that had been recently cleared of snow. Air samples were drawn through a septum by syringe from the chamber at two minutes intervals starting at 1 minute after chamber deployment. This sampling frequency lasted for 15 minutes (7 samples), after which samples were extracted every five minutes for up to one hour after the deployment of the chamber. Air samples drawn from the chambers were immediately injected into evacuated 10 ml vials and analyzed on gas chromatograph within 48 hours of sampling. Chamber sampling was confined to periods of low winds – only 20 runs were attempted. Specifications on the gas chromatograph will be appended to this document at a later date.

In-situ measurements of pCO_2 concentration were made following procedures outlined by Kammann et al., (2001) [1]. Probes consisted of silicone tubing closed with silicone septa on both ends and were installed within a PVC tubing (Figure 11). Each PVC tube contained three probes, one between 20-40cm, the other between 60-80 cm and the third between 100-120 cm, thereby stratifying the ice into 20 cm sections. In theory, molecules, such as CO_2, CH_4 and O_2, would diffuse across the porous, semi-permeable membrane allowing the air space within the silicone tube to approach an equilibrium level with the surrounding sea ice. Air was drawn from these probes every second day by syringe through 1/8" tygon tubing and immediately injected into evacuated 10 ml vials for analysis on gas chromatograph. Six PVC probes were installed, three near to Takatuk and three in close proximity to the ship. Silicone probes were also installed into sea water immediately beneath the sea ice cover.

Surface water samples were collected on a once a 4-day cycle for DIC, pH, alkalinity, and oxygen determination. These samples were collected through a core hole with a small salt-water aquarium pump.

Figure 11. Gas sampling probes that were used for *in-situ* pCO_2 determination.

6. Carbon Chemistry Report

Prepared by Michael Arychuk

[1] Kammann, C., L. Grunhage, and H.-J Jager, (2001), A new sampling technique to monitor concentrations of CH_4, N_2O and CO_2 in air at well-defined depths in soils with varied water potential. *Eur. J. Soil Sci.*, 52, 297-303.

Sample Collection:

- Ten seawater water samples were taken every 6 days by a rosette, from various depths, to obtain a profile of the chemistry going on beneath the ice. Samples were collected for dissolved organic carbon (DIC), alkalinity, total organic carbon (TOC), salinity and pH.
- Surface seawater samples were also taken every six days from a hole in the ice approximately 0.6 km from the ship. Samples were collected for dissolved organic carbon (DIC), alkalinity, salinity and pH.
- In total, over 400 samples were collected.

Sample Analysis:

- Samples for dissolved organic carbon (DIC), alkalinity, and pH were analyzed on board the ship.
- Taking into account all quality control and calibration requirements, as well as samples not run from previous legs, over 1200 separate analysis were performed in a six week period.

Data & Results:

- The data set for all analysis is not complete and sampling and analysis will continue for subsequent legs. For this reason, no detailed presentation or discussion of the data can be undertaken at this time.