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Beaufort Marine Hazards

2010 Field Expedition Report

CCGS Sir Wilfrid Laurier

September 21 – October 11, 2010

Institute of Ocean Sciences Cruise 2010-35

Humfrey Melling – Chief Scientist
Fisheries & Oceans Canada

Supported by the Federal Programme on Energy Research and Development
Projects 122-3 & GH-05

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Cruise Leg #3, CCGS Sir Wilfrid Laurier

September 21 – October 11, 2010

Personnel

9 embarked at Cambridge Bay on September 21

Humfrey Melling, Svein Vagle and Ron Lindsay, from DFO at the Institute of Ocean Sciences

Jo Poole, from Square Wave Marine Technology

Scott Dallimore and Kim Conway, from the Geological Survey of Canada at the Institute of Ocean Sciences

Charlie Paull, Dale Graces and Alana Sherman, from the Monterey Bay Aquarium Research Institute

6 disembarking at Herschel Island, via helicopter to Inuvik, on October 6 (Dallimore, Vagle, Conway, Paull, Graves, Sherman)

3 disembarking at Nome AK on October 11 (Melling, Lindsay, Poole)

Overview

The Institute of Ocean Sciences (DFO) is engaged in long-term collaborative studies in the Pacific sector of the Arctic Ocean. The ongoing focus is monitoring of the physical properties of sea ice and the upper-ocean waters. The activity addresses issues of environmental protection, maritime safety, ocean variability and climate change. Our goal is not only to detect and describe changes in the Arctic marine environment, but also to understand why changes are occurring and whether they will continue into the future.

The core programme is supplemented to a varying degree each year by activities proposed by collaborators in areas of overlapping scientific interest. Such collaborative activities contribute to the critical mass needed to justify an annual expedition, facilitate the efficient use of ship time and spread the logistic risk associated with inclement ice and weather conditions over several projects.

The supplementary programme for Sir Wilfrid Laurier's Leg 3 in 2010 was a project with Natural Resources Canada and Monterey Bay Aquarium Research Institute to assess the hazards for hydrocarbon drilling and production related to the presence of sub-sea gas hydrates. This study used a variety of techniques to characterize the marine and geologic setting of natural seeps of methane at the seabed and of the underlying deposits of solid gas hydrate and permafrost.

The present expedition was lead by Fisheries and Oceans Canada from the Institute of Ocean Sciences in Sidney BC. It embodied the interests and collaboration of various other organizations:

- Canadian Programme of Energy Research and Development: Northern Regulatory Research Programme: Decadal variability in offshore hazards (PERD 122-3)
- Canadian Programme of Energy Research and Development: Gas Hydrate Programme: Marine gas hydrate hazards in the southern Beaufort Sea (PERD GH-05)
- Geological Survey of Canada: Pacific Geoscience Centre (Scott Dallimore): Marine gas hydrates
- Monterey Bay Aquarium Research Institute, California (Charlie Paull): Marine gas hydrates
- US Army Cold regions Research Engineering Laboratory (CRREL: Dr Jackie Richter-Menge): Arctic ice thickness monitoring (AIM) and factors controlling the ice-mass balance
- US National Oceanic and Atmospheric Administration (NOAA: Dr John Calder & Dr Jim Overland): Same interest as CRREL

- Applied Physics Laboratory, University of Washington (Dr Mike Steele): Ocean temperature & autumn freeze-up of the Beaufort Sea
- International Arctic Buoy Program (IABP: Dr Ignatius Rigor)

Participating government departments were Fisheries and Oceans Canada and Natural Resources Canada (Geological Survey of Canada).

Objectives

One of the principal objectives of this expedition was the recovery, servicing and re-deployment of internally recording instruments on sub-sea moorings. The instruments had operated autonomously for 12 months, recording observations of ice thickness, ice ridging, ice drift, storm waves, storm surge, ocean current, temperature, salinity, ambient sound and acoustic back-scatter from plankton. There were six moorings for recovery during this leg and five for deployment.

The other principal objective was investigation of recently discovered methane seeps on the Beaufort seabed and their relationship to sub-sea permafrost, pingo-like features and buried gas hydrates. Techniques included underway surveys (high frequency sonar to measure rising methane bubbles, low frequency to reveal structure within sediments), rosette casts for seawater sampling, gravity-coring for sediment sampling, ROV dices for video reconnaissance of seeps and for sampling escaping gas.

A secondary objective was the mapping of selected properties of seawater, both continuously at the surface along the path of the ship and from surface to seabed at selected locations, principally the sites of sub-sea moorings. Properties of surface water were to measured continuously in water pumped from one of the ship's sea bays to the main lab (temperature, salinity, chlorophyll fluorescence, dissolved O_2, CO_2 and CH_4). The primary instrument for use in seawater mapping was a CTD probe with added sensors for dissolved oxygen, light transparency and chlorophyll fluorescence.

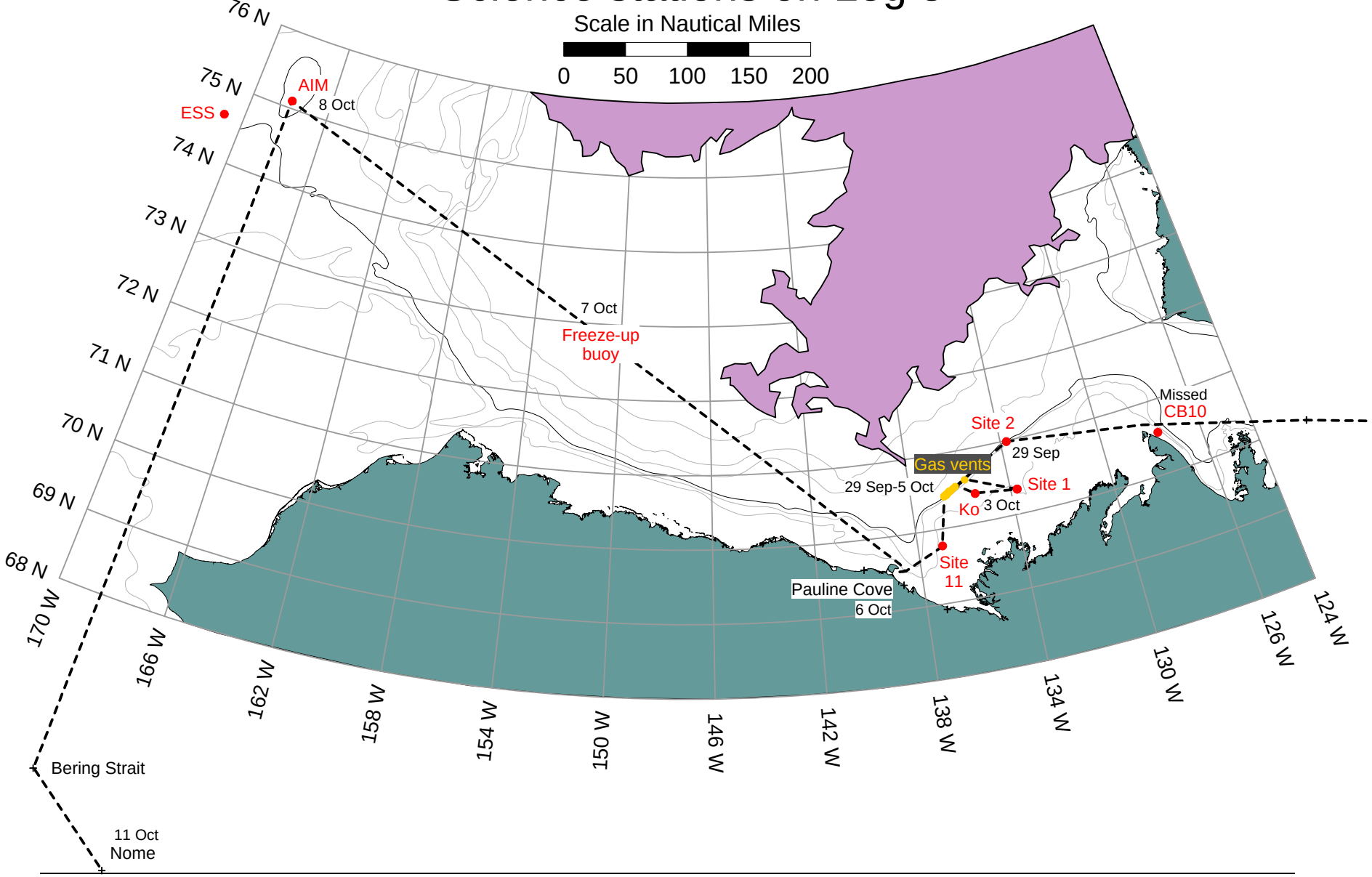
Completed Tasks

The map on the following page summarizes the ship's activity within the Beaufort and Chukchi Seas. The dashed line is the ship's track; annotation indicates dates of activity along the track. Circles indicate the sites of instrumented moorings, with the number of moorings noted if more than one. The shaded area approximates the domain of pack ice at greater than 4 tenths concentration on 27 September 2010.

The following list summarizes our activities and accomplishments:

- Two drifting buoys measuring surface weather under the auspices of the International Arctic Buoy Programme (IABP) were retrieved from locations on the Alaskan North Slope. This activity was completed during the inbound leg of Sir Wilfrid Laurier in late July
- Four moorings (3 with Doppler sonar and 1 with a tide gauge) were recovered on behalf of the Canadian Hydrographic Service in waters adjacent to King William Island (Jenny Lind Bay, James Ross Strait, Simpson Strait). The sites of two additional moorings (tide gauges in Jenny Lind Bay and Oscar Bay) were searched, but the installations had disappeared.
- Five sub-surface oceanographic moorings, deployed in October 2009, were recovered from the Canadian Beaufort Sea and one the northern Chukchi Sea. All instruments yielded a full records of observations
- ADCP compasses were calibration by rotation on shore at the spit on Herschel Island.
- Instruments were deployed for a another 12-month period on five sub-surface oceanographic moorings, four in the Canadian Beaufort Sea and one in the northern Chukchi
- A prototype satellite reporting drifting buoy, with sensors to measure cooling of the upper ocean during freeze-up, was deployed in open water of the south-western Canada Basin, on behalf of the Applied Physics Laboratory (University of Washington)
- Six CTD casts were completed at sites of oceanographic moorings. The CTD with extra sensors recorded pressure, temperature, conductivity, dissolved oxygen, light transmission and chlorophyll fluorescence.

CCGS Sir Wilfrid Laurier, 2010 Arctic Patrol
Science stations on Leg 3



- One cast with the CTD-rosette at a methane-seep site. The CTD was interfaced to a Contros spectroscopic dissolved methane sensor, and samples were taken for laboratory analysis of dissolved methane, for sensor evaluation
- Continuous measurements of salinity, temperature and chlorophyll fluorescence in surface water drawn from the ship's sea-bay, at 10-second intervals along the Arctic cruise track (18 days), and continuing on to Victoria from Nome via Dutch Harbor AK (12 days)
- Continuous measurements of dissolved gas concentration (N2, O2, CO_2) in surface water drawn from the ship's sea-bay at intervals along the Arctic cruise track (18 days), and continuing on to Victoria from Nome via Dutch Harbor AK (12 days)
- Approximately 350 km of track were surveyed near the edge of the shelf in the Canadian Beaufort Sea by sonar for the delineation of gas seeps (50 and 200-kHz sonar) and of underlying structures within the sediments (12-kHz sonar)
- 8 dives by the Phantom ROV were completed at 4 sites (0634H, 0634D, 0466A, Kopanoar). The purpose of the dives were to explore and document seabed morphology, to find and photograph plumes of bubbles (probably methane) emerging from vents in the seabed and to sample the emerging gas, if possible
- 33.25 hours of high definition digital video of the seabed were acquired using the Phantom ROV
- 8 samples of escaping gas were acquired at seep sites, one near the shelf edge (0634D) and the other at Kopanoar pingo-like feature.
- 26 sediment cores were acquired using a gravity corer at 7 sites. Approximately 20 m of core were obtained. Pore waters were sampled at typically 20-cm intervals in 10 of the cores.

Additional samples of gas were taken via escapement from cores of gas-saturated sediment

Methods

Moorings

Oceanographic moorings are recovered via acoustic activation of an electro-mechanical hook that separates the buoyant part of the mooring from a deadweight anchor, allowing the former to float to the surface for retrieval. The moorings have no surface manifestation; because of high risk from moving ice, the moorings have no components at depths less than 25-30 m. Our moorings were equipped with tandem releases for increased reliability. A successful recovery is contingent on the ship being able to reach the site (not always practical in heavy ice) and on having an ice-free pond over the mooring in which it can surface. Since the moorings of this project are simple, they can be recovered and deployed within relatively small ice-free patches. We completed a careful assessment of risk based on ice cover and acoustic ranging before each decision to release.

When the acoustically activated releases are inoperable, because of electronic or battery failure or biological fouling, the mooring must be recovered via dragging. In such circumstances, grappling gear (heavy chain, large open hooks and small line-snagging grapnels) is deployed via the A-frame on 3/8" 3x19 wire from a work winch (Swann 50-hp) mounted near the port rail. Typically 2000 m of wire is laid in a triangular loop around the mooring of about 100-m scale: the first set is into the direction of the combined wind-current effect on the ship's drift, commencing down wind of the mooring site; this is followed by a straight-line set tangential to mooring site at a distance appropriate to mooring depth and capability for controlling the ship's position; at the apex, the ship's propulsion is stopped and wire is paid out at the speed needed to maintain a vertical wire angle as the ship drifts; the second leg is at 30-40° to the first leg, turning to port with the wire on the starboard side, bringing the wind onto the starboard quarter; the 'drift down' follows a line on the opposite side of mooring until well beyond it (200-600 m in 30-50 m water depth; at this point the ship holds station as the wire is winched back in.

It is necessary to calibrate compasses on the Work Horse ADCPs near their location of use because the geomagnetic field in the Beaufort and Chukchi Seas is weak. We measure the non-linearity in the compass'

response to changing azimuth under carefully controlled conditions. This year the compass swings were done at Pauline Cove on Herschel Island, using a precise turntable designed and built at the Institute of Ocean Sciences. Two personnel with their equipment reached the island by ship's boat. The task was completed in less than two hours.

The mooring team used the 'tween-decks space in the hold of CCGS Sir Wilfrid Laurier to prepare mooring components, to disassemble recovered equipment, to stage and assemble new moorings before deployment. Preparation of the instruments for moorings was carried out in a cleaner space, a 20-foot laboratory container installed for this expedition on boat deck (starboard side) where the CCG barge is usually carried.

Water Property Measurements

A CTD (Sea Bird SBE9/SBE11) and rosette sampler (24x10-litre Model 1010 Niskin bottles, General Oceanics) was operated from the boom roughly amidships on the boat deck (port side). It was lowered on steel-jacketed conducting cable by the Hawboldt winch (this year under manual wire-speed control). The rosette was lowered to within 5 m of the seabed (distance measured by sonar altimeter).

The CTD provided continuous profiles of temperature, salinity, dissolved oxygen, light transmission and chlorophyll fluorescence. The rosette was used for only one cast this year, to acquire samples for dissolved methane analysis; a Contros dissolved methane sensor was interfaced to the CTD for this one cast. The time required to complete a rosette cast is 15-30 minutes, depending on water depth. The subsequent allowance for drawing samples and re-arming the rosette is 30-60 minutes, depending on the numbers of bottles filled and of samples to be drawn from each bottle.

The underway surface-water measurement systems (Sea Bird SBE45/SBE38 for temperature, salinity; and chlorophyll fluorescence and the custom "cooler" for gas tensions were set up in the aft section of the main science lab, using water piped there from a sea bay via a pump in the engine room. The time delay between the entry of water at the sea bay and its arrival at the manifold in the science lab is critical to the accurate mapping of small ocean features. The delay was estimated via the following calculation:

> The pump is a Moyno positive displacement screw pump.
>
> The length of piping (best approximation) is 107' = 32.6 m
>
> The inside diameter of the pipe is 1" = 2.54 cm, creating an interior volume of 16.5 litres.
>
> The water flow at slowest pump speed (12 Hz) is 18 litres per min, capable of flushing the piping from pump discharge to faucet in about 55 s. The corresponding flow speed is 0.6 m/s.
>
> The water flow at fastest pump speed (60 Hz) is 90 litres per min, capable of flushing the piping in about 11 s. The corresponding flow speed is 3 m/s.

The warming of water between the engine room and the lab was measured and is appreciable (several tenths of a degree). The warming of water between the environment and the sensor in the engine room is not known.

Digital recording of acoustic backscatter (50 & 200 kHz)

Gas bubbles, flocs and zooplankton are all strong water-column targets for high-frequency sonar systems. The first, and possibly all three targets, are indicators of the existence of methane escapement locally from the seabed.

Laurier's two hull-mounted transducers are tuned to acoustical frequencies of 50 and 200 kHz. These sounders were uncalibrated (in terms of target strength. They are normally wired to the Skipper echo sounders on the bridge, but the CCG/CHS have recently installed cross-over switches to share their use with Science. When permissible, we operated one of the ship's hull-mounted sonar transducers from an echo sounder installed in the hydrography lab. With a sounder designed for scientific applications, we were able to digitally record the echoes from the full water column alongside ship's navigational data.

Digital recording of acoustic backscatter (12 kHz)

A Simrad sounder operating at an acoustic frequency of 12 kHz is installed on CCGS Sir Wilfrid Laurier. The hull-mounted 12-kHz sonar transducer provides the capability to measure full ocean depths. The high power rating and low frequency of this sounder provide the capability to penetrate several tens of metres of sediment at shallow ocean depth. This permitted "shallow seismic" visualization of layering and geological structures beneath the seafloor. The science party provide a custom built echo sounder (Ocean Acoustics Group, IOS) which had digital echo recording capability. It was connected to the 12-kHz transducer via cabling already installed to the hydrography lab.

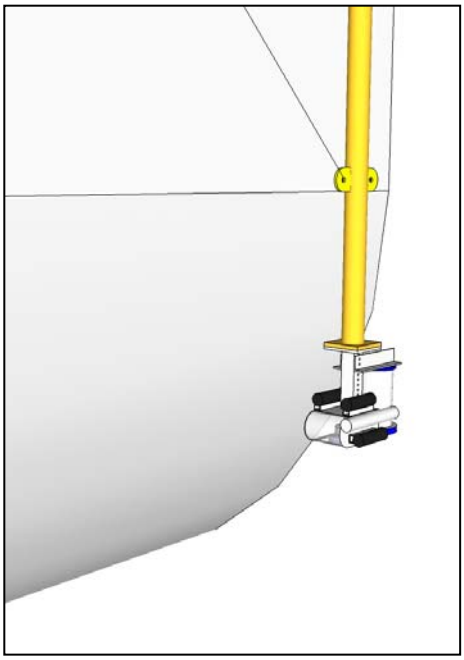


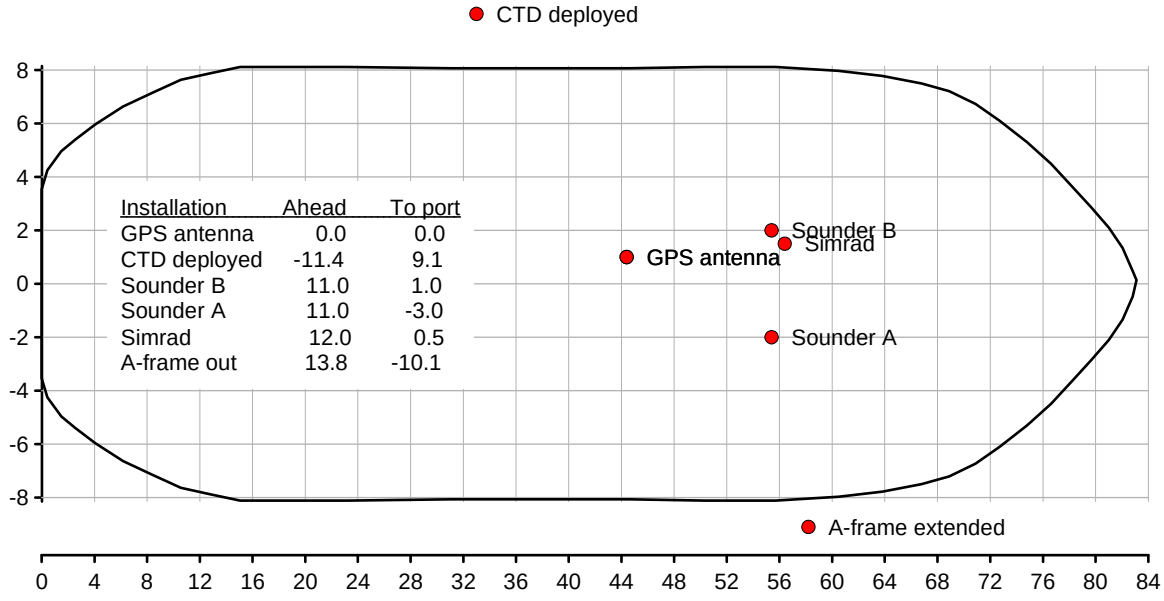
Figure 1. Strut installation, port side well deck, CCGS Sir Wilfrid Laurier, with shoe for mounting scientific sonar.

Surveys at reduced speed

Gas bubbles from under-water seeps are strong targets for high-frequency sonar. The strength of the target at any particular frequency depends on the number of bubbles per cubic metre and on the size of the bubbles. By operating backscatter-calibrated sonar at 50 and 200 kHz, we are able, in principle, to measure the number of bubbles and their size distribution. By operating Doppler sonar, we are able to measure the ascent speed of the bubbles. These variables in combination provide the rate of gas flow from a seep.

For the surveys planned during this leg, IOS built a vertical strut for the deployment of scientific sonar (see figure). It was mounted temporarily from the rail of CCGS Sir Wilfrid Laurier, tested from CCGS Sir Wilfrid Laurier in June 2010 and demonstrated to be practical for operation at slow speed (up to 5 knots), weather and ice permitting. A shoe at the bottom of the strut, about 5-m depth, provided mounting for 300-kHz Doppler sonar, a CTD and two backscatter-calibrated sonar transducers.

Surveys with the strut-mounted sonar were conducted during the night, when ship's personnel were unavailable for deck work.



Locations relative to the GPS antenna (along-ship, athwart-ship; accuracy of 1 m) of the following installations used for surveys: the two transducers used by the Skipper navigational sonar, the 12-kHz transducer used by the Simrad sonar, the sonar strut mount, the rosette station and the fore-deck A-frame (if any net hauls are done). Sounder B is the transducer available for use of science.

Sediment cores from the seabed

A gravity coring apparatus was used to acquire short columns of sediment for inspection, classification and analysis. It was deployed via the A-frame using 3/8" 3x19 steel wire and a 50-hp work winch. Cores were acquired at and near some of the sites where gas is venting at the seabed. The selection of sites for coring was based on interpretation of existing survey data – seismic surveys, exploration bore holes, mapping by swath-imaging sonar (CCGS Amundsen), 3 kHz sub-bottom profiling. The gravity corer achieved a maximum penetration of 1.66 m. The time required to collect a core was 15-30 minutes, depending on water depth.

A 10-foot workshop container, secured on the port side of the well deck, was used as the staging point for the coring activity – storage for core liner, recently acquired cores, the coring tool box, coring supplies; work area for the chop saw, liner splitter, core temperature measurement, etc. The container was equipped with hazard sensors for methane (CH_4) and hydrogen sulphide (H_2S).

Core pore waters were sampled via small holes drilled through the liner. The cores were then transferred to the walk-in cooler in the hold, for transport back to Victoria. Post-field phase analyses includes sedimentology (particle size, composition), chemistry of pore water and pore gas, isotopic composition of material and radiocarbon dating of macrofossils.

Dives by Remote Operated Vehicle (ROV)

A remotely operated underwater vehicle was utilized for close inspection of the seabed and of bubble plumes emerging from vents in the southern Beaufort Sea. The Phantom ROV was provided by the Monterey Bay Aquarium Research Institute (MBARI). The Phantom can be used relatively easily from a ship of opportunity in an Arctic setting. We did not have a track-point navigation system for the Phantom for this work.

The flexible umbilical of the ROV was cable-tied to a heavily weighted (500 lb) wire hanging vertically from the A-frame on the well deck. About 30 metres of unsecured umbilical at the bottom end provided roaming freedom for the ROV. This configuration minimized the risk of entangling the umbilical in ship's equipment. The depth of the clump weight was controlled by the 50-hp work winch on instruction from the ROV operator. The "green container" workshop on the well deck was the control centre for ROV operation.

The weight was lowered to within about 5 m of the seabed for the ROV's exploration to begin. CCGS Sir Wilfrid Laurier held station while the ROV explored the seafloor within roaming distance of the weight. The ship then moved a few tens of metres to provide access to a new area.

The ROV is equipped with high resolution underwater cameras, rotary side-scanning sonar, a solenoid-activated apparatus for collecting samples of venting gas and a Contros sensor for measuring of dissolved methane concentration. The scanning sonar and camera were used for orienteering relative to the clump weight, for seabed reconnaissance, for seeking bubble plumes and for biologic assessment (unique communities?).

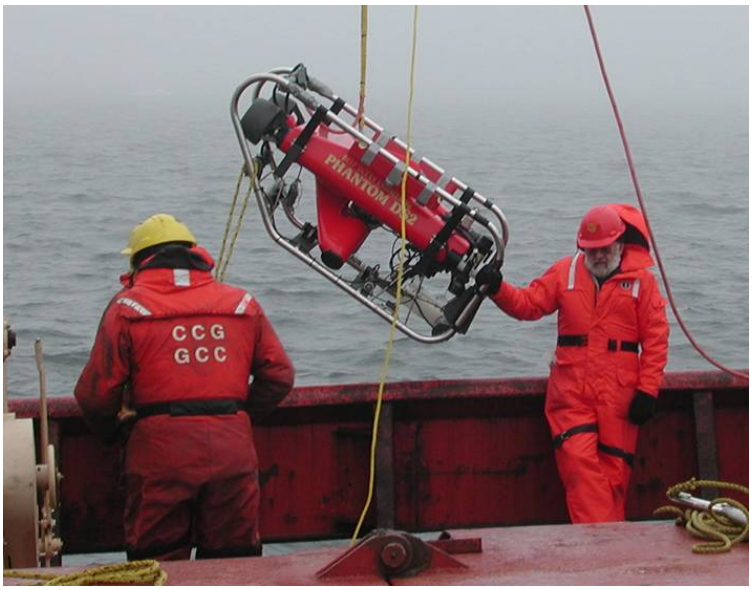
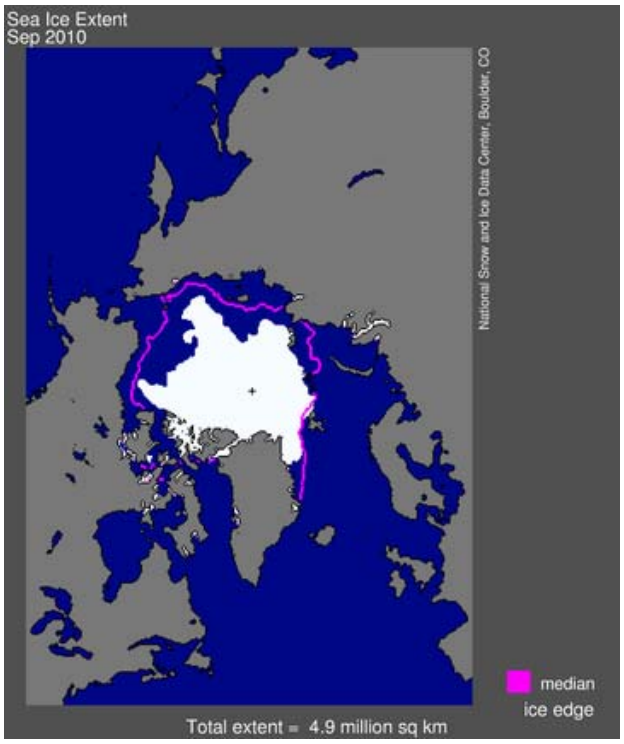


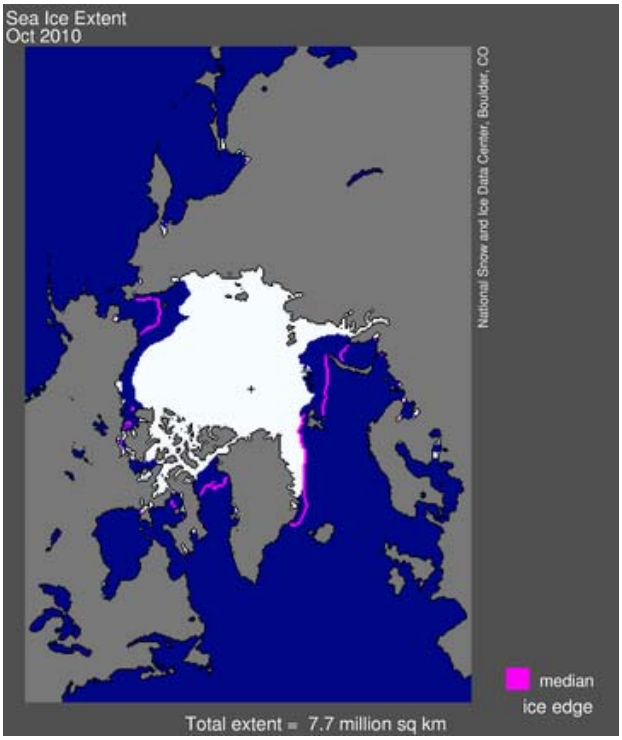
Figure 2. Phantom ROV of the type used in 2010. Our unit was equipped with scanning sonar topside near the forward end and gas-sampling apparatus in a supplementary undrrcarriage.

Ice conditions across the Arctic, September-October 2010

The maps below displays the average extents of pack ice during September and October 2010, measured from satellite using microwaves (http://nsidc.org/data/seaice_index/). As for the last few years, the ice edge was well to the north of its 30-year median position (magenta line) everywhere in our operating area. CCGS Sir Wilfrid Laurier only briefly encountered pack ice (near 150º W) during the homebound leg of the Arctic Patrol.

As in 2007 and 2008, the principal northward retreat of the ice edge from its climatology median position occurred in the Western Chukchi Sea, the East Siberian Sea and the Laptev Seas. The minimum extent of Arctic ice in mid September was 4.6 million square kilometres, 12% higher than the record minimum of 2007. In this representation, ice extent is the area within which the concentration of ice is at least 15%. Although this definition is consistent throughout the time series, concentration determined by this means can be low by several tenths during the warm months, through the effect of melt ponds on the ice surface.





Impact of ice and weather conditions

Ice had no direct impact on completion of the science plan for 2010. CCGS Sir Wilfrid Laurier was able to reach all locations without difficulty.

Indirectly, however, the extreme retreat of the ice opened long fetches for winds on a south-east to north-west axis. We were repeatedly subject to strong winds (30-40 kt) principally from the east, with large (3-4 m) waves on several occasions. Such were sufficient to prevent some types of work on one day, October 5, at the shelf edge near 135ºW in the Canadian Beaufort Sea.

Temperatures were within a few degrees of 0°C for the whole trip, but not so cold as to cause difficulty in operating the CTD/rosette system.

Setbacks

We encountered teething pains with the echo sounders for which transducers were mounted on the new transducer strut.

1. The noise level of the sounders was quite high, at times obscuring weak echoes from targets in the water column. The source of the noise could not be established. Possibilities include: noise generated by flow past the transducers, noise from ship's machinery, noise from strumming of the strut and its support wires, noise from breaking waves. Remediation is required, after identification of the source(s).
2. All nine sounders on board ship operated independently: the ship's 12, 50 & 200 kHz units, the strut-mounted 50 & 200 kHz units and the four 307 kHz units of the ADCP. The result was serious contamination of received signals by other transmissions. We need to place all sounders under a single controller, so that operation of the sounders can be synchronized for minimal interference.

Our new Mark-5 version of the ice profiling sonar, which is tuned to 200-kHz (IPS5-241), proved inoperable in a "dip test". There appeared to be no transmitted pulse, and the noise level of the receiver was unacceptably high. The unit could not be deployed as planned. One of the recovered instruments, an IPS4, was serviced and deployed at Site 1 in its place. In consequence, we will not acquire storm wave observations at Site 1 during 2010-11.

Most of the ORE CART transponding releases recovered after 12 months' deployment suffered appreciable corrosion, despite conscientious use of anodes. The corrosion damage favoured crevices, and was reminiscent of damage seen in early versions of the instrument, which made use of low grade stainless steel. We have evidence from the 2007-08 deployments in the Alaskan Beaufort that the early problems had been solved. Its recurrence in units purchased new in March 2008 for the 2008-09 deployment is troubling. We plan to document the character and extent of damage and to take the issue up with ORE Inc.

The data recoded by one of our legacy T-RDI acoustic Doppler current profilers, NB-ADCP s/n 0464, were mildly corrupted. A complete data record was recovered, although the process was not straightforward. The fault could be a consequence of age; the unit in question was purchased in 1991 and has been operating almost continuously since then, and its data memory is built from archaic UV-erasable ROM chips. We are now testing the instrument to identify the exact cause of the fault.

Signals measured by the Contros sensor of methane dissolved in seawater were puzzling. Our difficulty in interpreting the output of the sensor may in part be a consequence of the slow response of the instrument to change in concentration. We did acquire a careful sequence of measurements by the sensor in vertical profile over a distributed methane source, sampling seawater for later laboratory analysis at various depths, after a generous allowance for equilibration. Analysis of this inter-comparison should throw light onto the value of this sensor in future field studies.

For the second year in succession, a satellite reporting "freeze-up" buoy provided by the University of Washington's Applied Physics Laboratory (manufactured by Clearwater of Massachusetts) failed to work. The buoy has a Service Argos transmitter and electronics linked to a 50-m chain of thermistors that hang beneath it; its purpose is the measurement of cooling surface waters in autumn. This year's unit was an "improved" version of last year's, with similar problems. It failed to yield reasonable values of temperature when tested on deck, and ultimately failed to transmit. Unfortunately this failure occurred some time after its transmissions had been judged effective and the decision had been made to deploy it, despite its other problems.

We were unable to find, on behalf of the Canadian Hydrographic Service, two of the six moorings deployed in the vicinity of King William Island earlier in the summer. The lost moorings had been deployed in shallow bays, marked with a surface floats. It is possible that these marker buoys were snagged by drifting ice, which subsequently dragged the moorings elsewhere. A third mooring of this type, deployed at the western entrance to Simpson Strait, was located and recovered.

An ocean measurement mooring east of Cape Bathurst was not recovered on route because the ship passed by its location during darkness. We did not stand by here until daylight because our scientific work was already appreciably delayed by the mishap of the M/V Clipper Adventurer.

Successes

All instruments on all moorings deployed in the Beaufort and Chukchi Seas in October 2009 were recovered, and all yielded full data records.

The AURAL under-water sound recorder, deployed at Kopanoar pingo-like feature to record the sounds of gas bubbles forming at seeps on the seabed, did just that. This is the first time that the AURAL has been used for this purpose. It is typically deployed to record the vocalization of marine mammals. We plan to analyze the bubble sounds to calculate the rate of gas release, its variation over time and the reasons for such variation.

Our plan to sample gas at seeps at the seabed was extremely successful. We returned with enough samples to deduce the isotopic composition of the gas, its age, its chemical composition and its likely source (biogenic, thermogenic, decomposing gas hydrate, etc.).

We have visual evidence that seabed gas seeps are associated with bacterial mats, which may be unique biological communities – only targeted study will tell.

The close association of active seabed gas venting with vast slump and slide features at the edge of the continental shelf raise questions concerning the relationship between these two phenomena. Is the obvious slope instability related to shallow gas? What is the age of the slide? Is incremental slope failure imminent? These questions are topical in view of the huge investment in oil and gas leases in this area.

Emerging pattern of inter-annual variation in the marine environment

Surface salinity on the margins of the Beaufort & Chukchi Seas

Figure 1 shows the salinity of surface water drawn into the ship's sea-bay during transit between Amundsen Gulf and the Chukchi Sea. Ship's latitude is plotted in the upper frame and near-surface salinity in the lower frame; the abscissa is longitude. Data are shown for 2006 (blue), 2007 (red), 2008 (green), 2009 (yellow) and 2010 (magenta) along similar ship tracks at the same time of year.

The extremes of conditions over the last five years were encountered in 2006 and 2007, with salinity very low in 2006 and 1-2 ppt higher a year later, although much larger differences occurred near 127°-138°W and 150°-162° W. The former zone receives inflow from the Mackenzie River, whereas the latter occurs where the low salinity Alaska Coastal Current enters the Beaufort Sea. Fresh-water apparently accumulated in both these zones in 2006 but not in 2007. In 2008, a broad zone of fresher water was observed between 132°W and 151°W but no low salinity anomaly was measured near the entry of Pacific water at Barrow. Conditions in 2009 near the Mackenzie delta were similar to those in 2006, although the freshest surface water was found further west, centred at 138° rather than 135°. Conditions in 2009 were similar to those in 2008 over most of the remainder of the transect, except that high values between 143° and 151° rivalled those of 2007.

In 2010, the surface salinity of waters to the east of 135°W was near the high end of the five-year span and that to the west of 142°W was near the low end.

In the four prior years, the surface salinity typically decreased with distance from the coast. This gradient implied that fresh water was transported away from the coast in these years accumulated in the Canada Basin. The situation in 2010 is ambiguous: relatively high salinity on the Mackenzie shelf, except near the river mouth, relatively low salinity further west (although perhaps a reflection of having travelled further north across this sector in 2010). However, the tracks from all years converge west of 160°W, supporting the existence of a pool of relatively low salinity here this year.

Four winters' ice drift in the southern Beaufort Sea

Figure 2 displays the displacement of ice moving past Site 1 at the middle of the Mackenzie shelf (70.33°N 133.75°W). The displacement is the result of integrating the velocity of pack-ice movement measured by Doppler sonar. Separate trajectories have been calculated for the winters of 2005-06, 2006-07, 2007-08 and 2009-10, between October 21 and the date in May when ice drifted off this site. No such data were acquired during 2008-09 because of a battery failure in the ADCP at this site.

All displacements are upwelling favourable but there are large variations from year to year in the average drift speed and in the average and consistency of drift direction. Net displacement during the winter of 2005-06 was more or less parallel to the shelf edge whereas that during the second and third winters was biased towards the off-shelf direction by about 20°. The net displacement to May 1 was 520 km during 2005-06, double that during 2006-07 and almost double that again in 2007-08. In 2009-10 the net displacement was approximately the same as in the first year, although directed slightly more offshore. Apparently the strength and persistence of upwelling decreased appreciably between 2007-08 and 2009-10. This change could be a contributor to the lower surface salinity near shore in the fall of 2010.

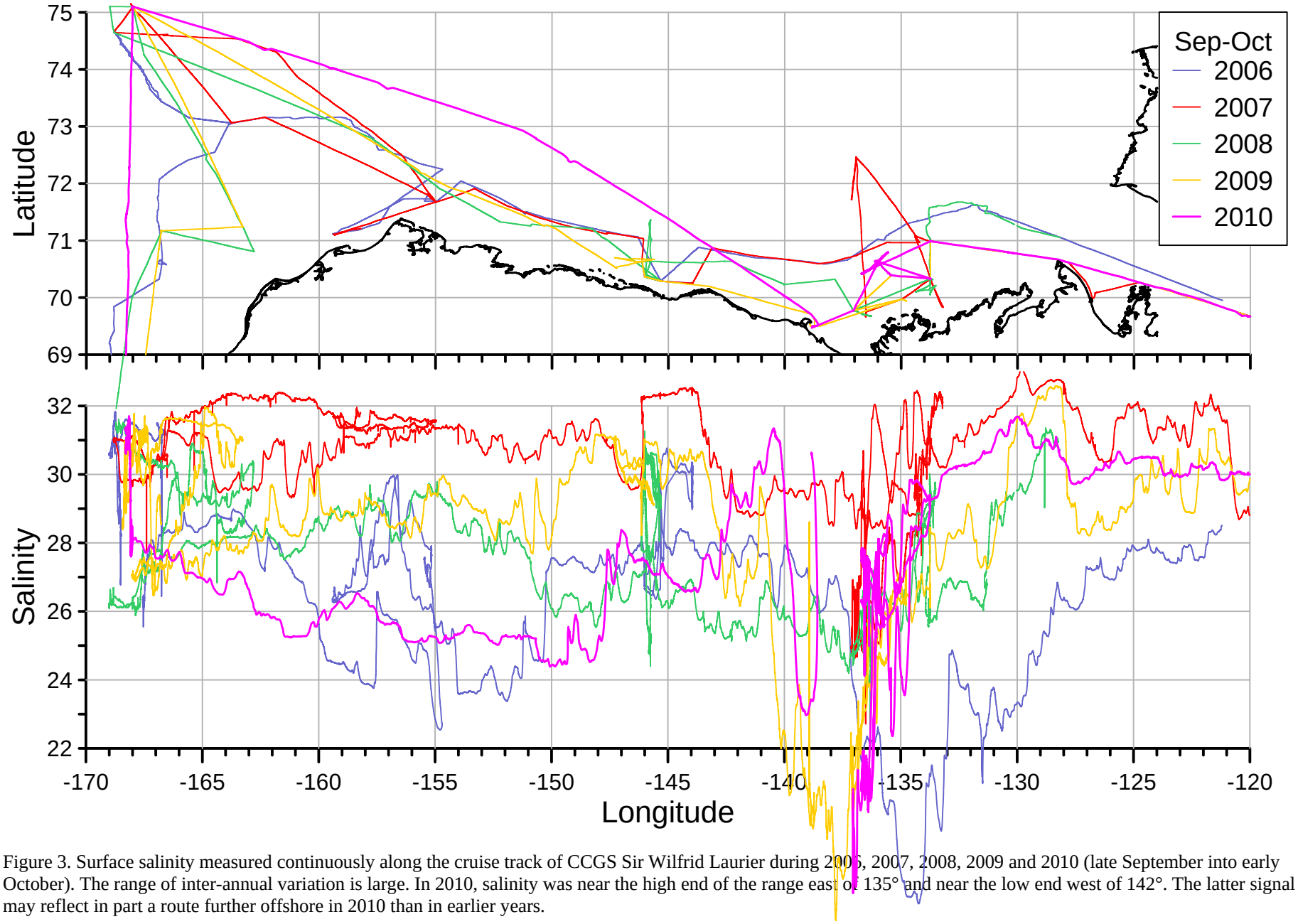


Figure 3. Surface salinity measured continuously along the cruise track of CCGS Sir Wilfrid Laurier during 2006, 2007, 2008, 2009 and 2010 (late September into early October). The range of inter-annual variation is large. In 2010, salinity was near the high end of the range east of 135° and near the low end west of 142°. The latter signal may reflect in part a route further offshore in 2010 than in earlier years.

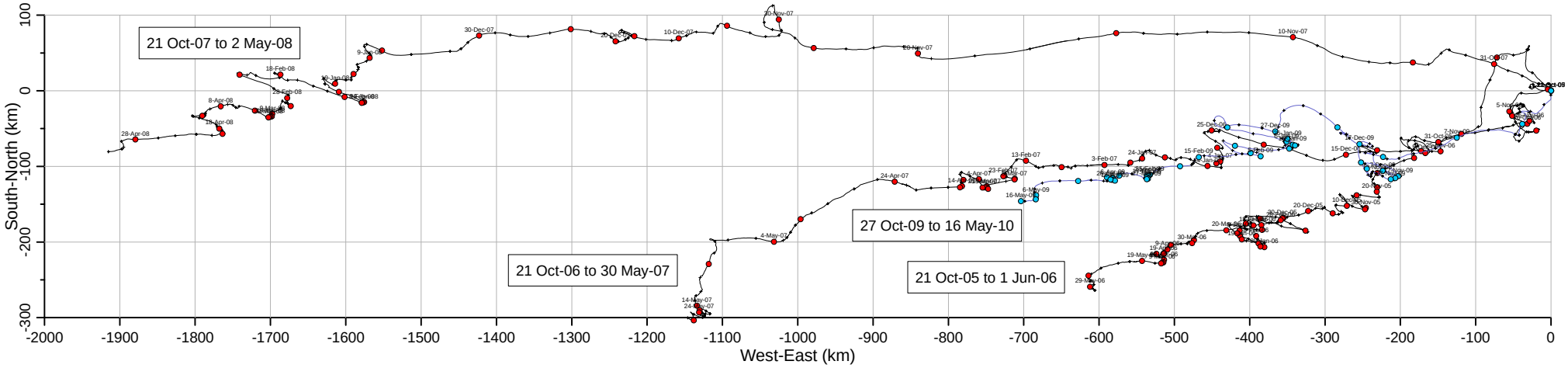
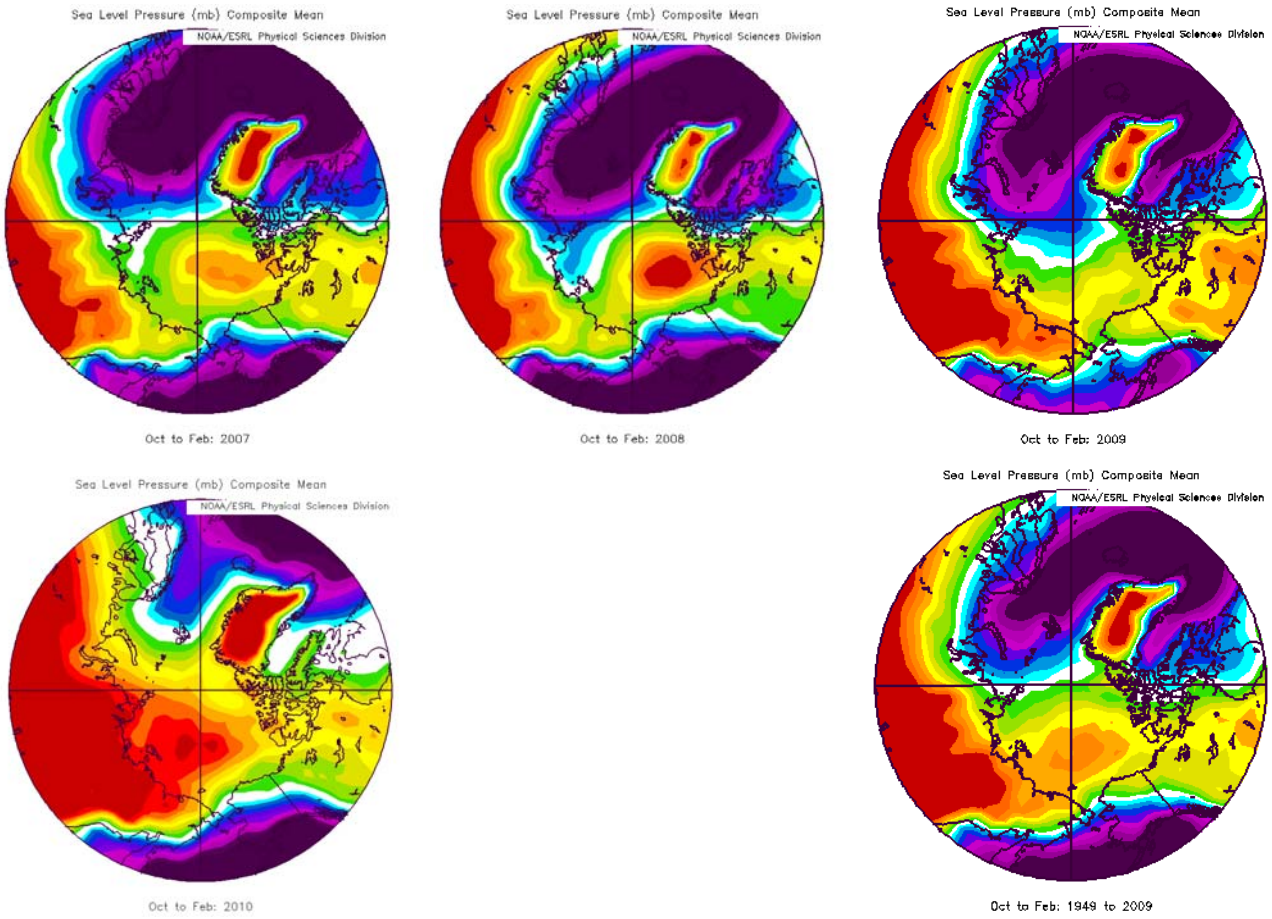


Figure 4. Trajectory of ice drift past Site 1 on the Mackenzie shelf during the winters of 2005-06, 2006-07, 2007-08 and 2009-10. All tracks start at the left on or about October 21. The net westward drift from that date until May 1 of the following year was 520 km in 2005-06, 1010 km in 2006-07, 1900 km in 2007-08 and 600 km in 2009-10. The average direction of drift was least favourable for upwelling during 2005-06 and most so during 2007-08. The upwelling favourable phase during 2007-08 was weakening by mid January and had essential ceased by late February. Upwelling favourable drift was quite pronounced after the middle of April in the spring of 2007.

Meteorological insights

The frame at the right below shows the 60-year average distribution of sea-level air pressure. On average, high pressure dominates the entire western Arctic. The average trans-polar drift (green shading) joins the Laptev Sea to Ellesmere Island.

Recent anomalies in atmospheric pressure and winds are important factors underlying present anomalous ice and ocean conditions in the southern Beaufort Sea. The frames below display the atmospheric pressure at sea level averaged over the months from October through February for the winters of 2006-07 through 2009-10. Red depicts high pressure and purple low pressure. Conditions in the North Atlantic sector were quite similar during the first three winters, but the Aleutian low moved south in 2008-09 relative to earlier years. The Aleutian low again encroached on Alaska in the winter of 2009-10, but low pressure on the European side retreated back into the Norwegian Sea. The result was a pattern of sea-level pressure during the 2009-10 winter that was closer to the long-term mean (lower right frame) than any of the other three.



However, air pressure over the central Arctic was high in 2009-10 relative to the long-term mean. The dome of high pressure over the Beaufort Sea was further west and not as isolated from the high pressure over eastern Siberia than in 2006-07 and 2007-08. The pressure gradient indicates only light easterly winds in the eastern Beaufort Sea during 2009-10, consistent with the slow drift of ice shown earlier. Easterlies were stronger across the northern Chukchi Sea. Wind blew across the central Arctic towards the south-eastern Beaufort, not directly towards the Canadian Archipelago as in the usual pattern. This change will likely have affected the trans-polar drift ice drift towards Fram Strait during last winter.

Ship of opportunity for Remotely Operated Vehicles (ROV) in the Arctic

Backgound

One goal of cruise 2010-35 was assessment of Arctic ROV use for geological research from a ship of opportunity. The trial was planned around photographic documentation of methane release sites on the continental shelf in the Beaufort Sea. The logistics to conduct this program required a five month commitment of the ROV. The geology/ROV activity occurred between September 30 and October 3, but the geology team was on board for much longer, September 21 to October 6. Clearly, the realities of operating on the margin of the Arctic Ocean require considerable commitments of both hardware and personnel.

Two different areas of possible gas seeps were visited in the Beaufort Sea, one near the shelf edge in 80-120 m water depth where numerous water column acoustic anomalies have been mapped and the other at the Kopanoar pingo-like-feature (PLF; Paull et al., 2007) on the mid-shelf (depths 40-60 m).

Documentation that gas venting is occurring from both of these areas was provided by the ROV's video cameras. Samples of the escaping gas were also collected from both the shelf edge and mid-shelf areas, which will enable the nature of the gas to be established and potentially the "age" of the gas to be determined. Observations made on the style of gas escape and the appearance of the seafloor where the gases were emanating. The ROV observations suggest that the gas that is venting near the shelf edge is coming out in small amounts, but over a wide area. Conversely, vigorous gas venting from a focused vent was observed at the Kopanoar.

Video images of the seafloor and pre-existing high-resolution multibeam surveys show unusual seafloor textures near the shelf edge. These textures appear to occur in areas of widespread erosion. We are evaluating the possibility that the fine-scale seafloor topography and widespread gas venting near the shelf edge are both related to the decomposition of relict permafrost.

Remotely Operated Vehicle

The ROV for this operation was a Phantom S2 built by Deep Ocean Engineering and operated by MBARI. On this cruise it carried a Sony HD Video Cam Recorder (16 Gig Card), Insite Nova Camera (recorded topsides), Falmouth Scientific Instruments (FSI) Micro CTD, and gas sampling equipment (Gulper and Gas Coils).

The gas sampling equipment (Gulper and Gas Coils) was developed by Dr. William Ussler and Mr. Larry Bird at MBARI specifically for this cruise. The sampler was a coil of clear 3/8" inside diameter plastic tubing wrapped around a spool with valves on both ends. One side was plumbed to a funnel, which could be rotated by the ROV. The other side was connected to a Gulper, a spring driven syringe with a throw that pulled in 1.7 litres of water. The assembly allowed fluid to be sucked from the funnel into the coils when the gulper springs were released, capturing gas accumulated under the inverted funnel. Gas trapped within the coils can expand as the ROV surfaces, but air locks within the coils prevents the trapped gas from escaping. Gas was transferred into 250 ml bottles underwater, sealed with Belco Stoppers and crimp seals and left in the cooler to be offloaded in Victoria.

The ROV also carried a Contros CH4 Sensor and Contros Battery Pack, which had been purchased by the Geological Survey of Canada (GSC). Data from the Contros sensor was sent to the surface where it was displayed real time and logged.

Working setup

The ROV control module was installed within a heated van on the well deck. The double door at one end of the van allowed the ROV to be pulled in out of the (cold and snowy) weather for storage and servicing. Availability of this inside work area was essential for this operation.

The tether drum was mounted on the port side of the well deck. This drum held the slightly positively buoyant 1,200-foot long ROV tether cable. The drum was manually spooled but equipped with a hand brake.

The ROV tether fed across the deck to a small A-frame on the starboard side. A block provided by the SWL was used to raise the clump weight from this A-frame. The clump weight was a 300-lbs bundle of heavy chain. It was over-boarded using a 3/8" wire run through a block (both provided by SWL), which was also mounted on the A-frame.

For launch, the ROV was picked off the deck and over-boarded on the starboard side forward of the A-frame using the ships 20-ton boom. The ROV was lifted using a piece of spectra line that ran along the first 5 m of the tether. Once in the water the ROV was decoupled at the lift point and swum out on the surface about 30 m perpendicular to the ship. At this point the tether was connected to the clump weight, which was lowered in stages to within a few metres of the seabed. Because the ROV was ballasted to be slightly positive, the ROV was powered down at the same rate. The tether was connected to the wire with tie-wraps (spaced a few meters apart) as line was paid out.

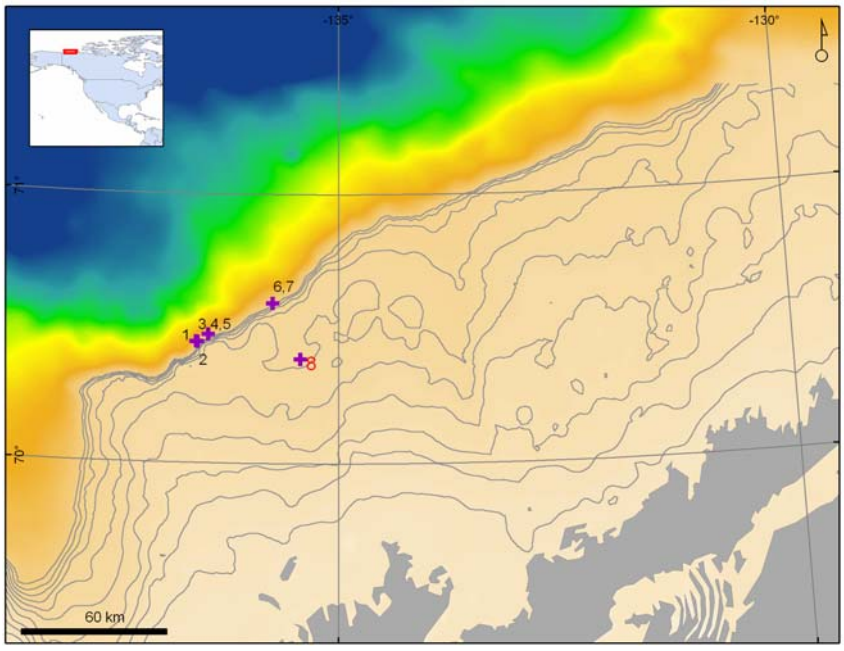
The ROV operations required the continuous support of the four crew members in addition to the MBARI team. This included a winch operator, a person to spool the tether drum, one to operate the A-frame and one to tie-wrap the clump weight and ROV tether together.

The recovery procedure was essentially the reverse. However, additional care was given to make sure the ROV surfaced in the open water off the starboard beam, rather than under the ship. When the ROV was sighted on the surface, the SWL would turn to starboard to generate a lee for the ROV recovery. The bow thruster was not used during recovery.

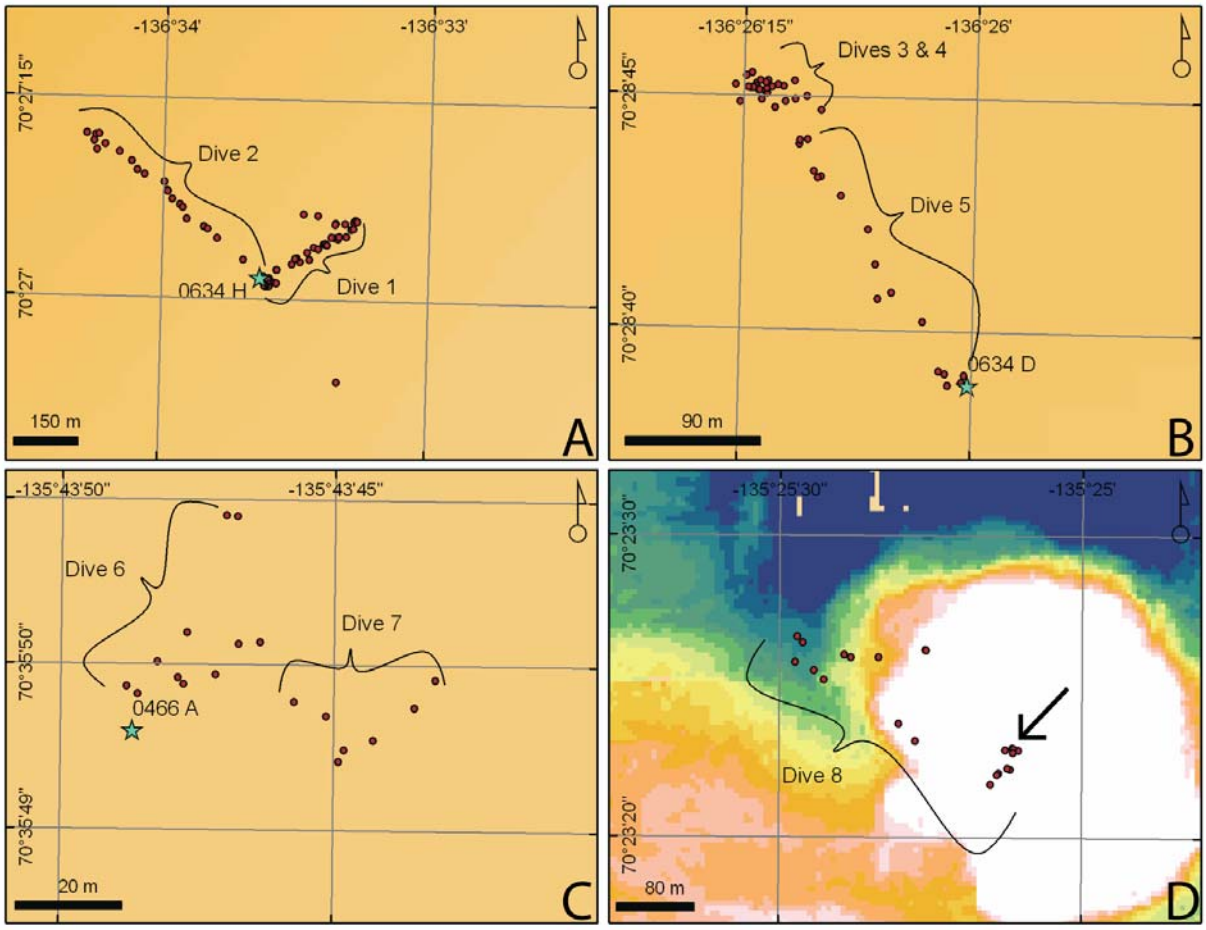
A tracking system was not used to navigate the ROV with respect to the ship. The positions of the ship's GPS antenna were logged, and can be corrected for the displacement to that of the A-frame, if required. However, the slack from the clump weight permits an uncertainty of up to 30 m in the ROV's position which is not known. Dysfunction of the ROV's magnetic compass up near the geomagnetic pole created another challenge to accurate navigation.

Dive Sites and Observations

Eight ROV dives were completed, seven to investigate three areas of seeps along the shelf-edge identified in 200 kHz multibeam sonar surveys of 2009 by Prof. John Hughes-Clarke (UNB). We identified UNB sites 0634H, 0634D and 0466A as our prime targets for investigation. The first two sites (Dives 1-5; at 0634H and 0634D) were both within a broad zone where multiple acoustic anomalies had been mapped. The third shelf edge site (0466A; Dives 6-7) was in an area studded with topographic bumps. One of these features (50 m across and 3 m high) was investigated during dives 6-7. The last dive (Dive 8) was at the Kopanoar PLF, in a mid-shelf setting (Figure 1 and 2D).



Locations of ROV dives 1 to 8 from the Sir Wilfrid Laurier in the Beaufort Sea in 2010. Dives 1 to 7 were located along the shelf edge. Dive 8 was on the Kopanoar PLF.



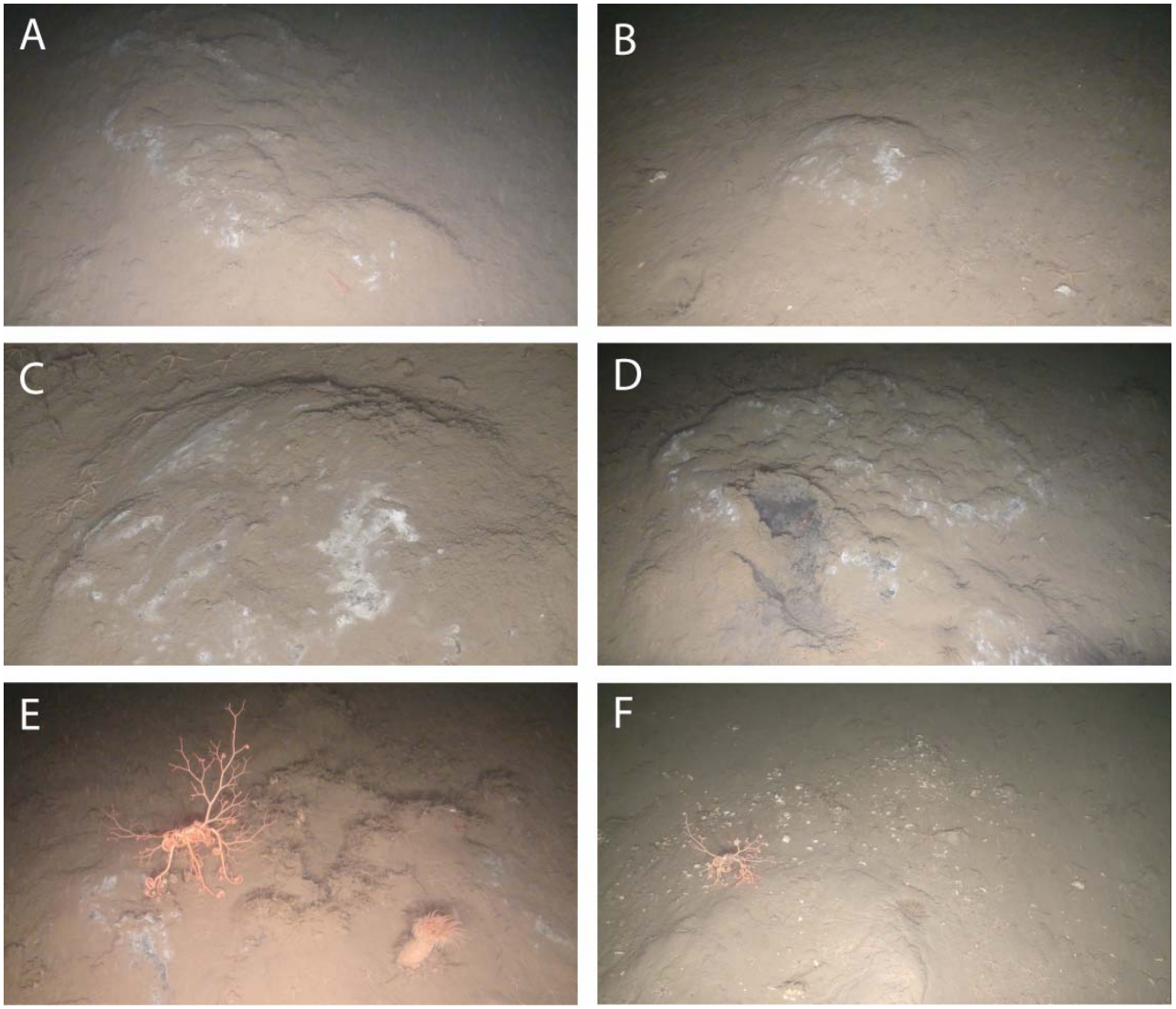
Locations of CCGS Sir Wilfrid Laurier during the Phantom ROV dives in October 2010. Part A shows coverage of ROV dives 1 and 2; part B dives 3 to 5; part C dives 6 and 7. Positions of water column acoustic anomalies (0634H, 0634D, and 0466A) of the Blasco et al., Seep Catalog are indicated in parts A, B, and C respectively. Part D shows location of ROV dive 8 at the Kopanoar PLF. Location of vigorous gas venting is indicated with arrow.

The ROV was able to document gas bubbles escaping from the sea floor in all four areas of operation. Samples were collected during dives 3, 4, and 8 (Table 1). Measurements of the composition, stable isotope ratios and ^{14}C content of the contained methane are planned. The style of venting observed in the three areas along the shelf edge (Figure 2A, 2B, and 2C) consisted of scattered bubbles rising from multiple sites scattered over a broad area. Vigorous venting was observed on dive 8 from near the crest of the Kopanoar PLF.

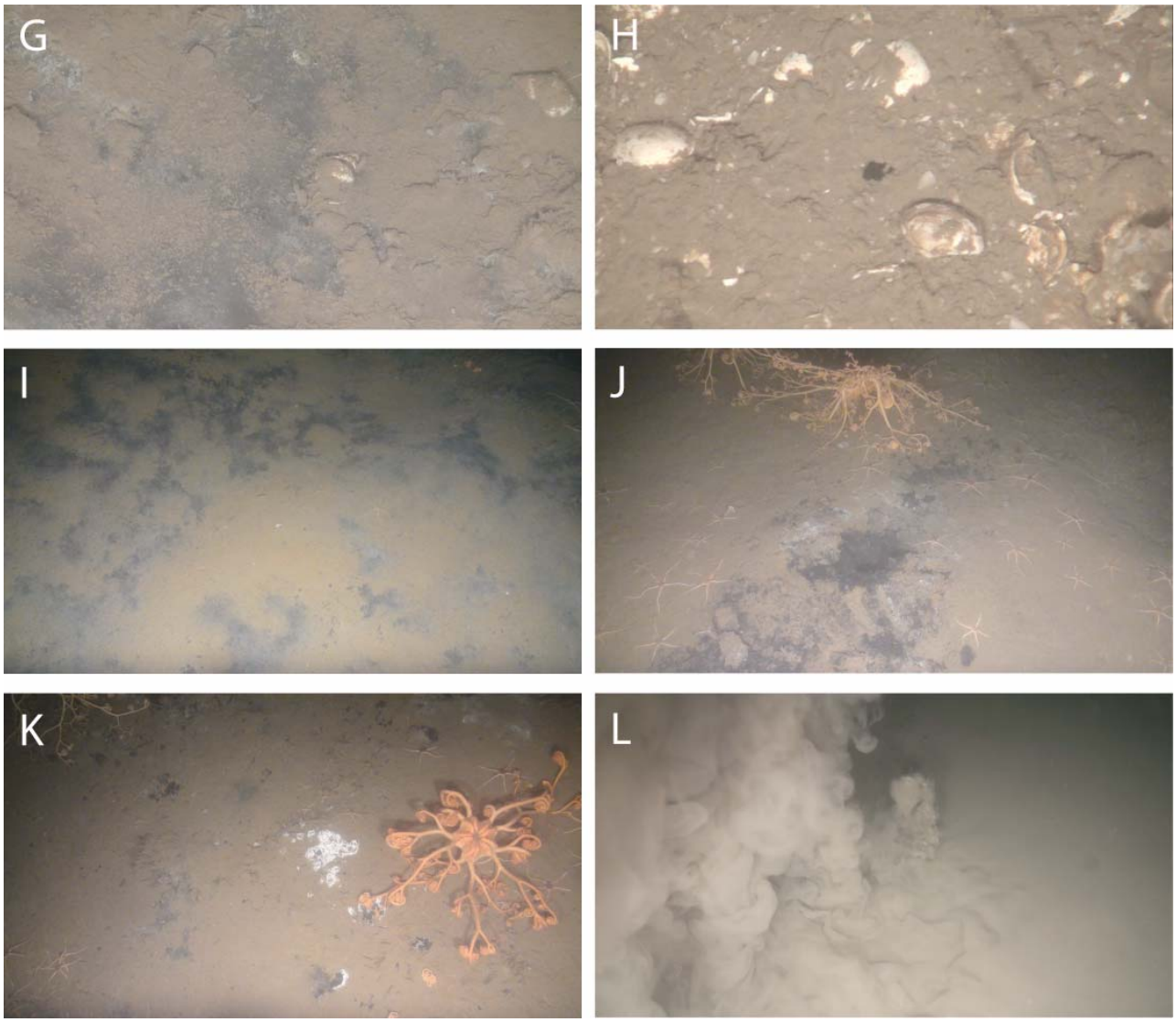
Images of the seafloor that are characteristic of dives 1-7 are illustrated in the figures. Among the observations that are notable include frequent white areas that appear to be microbial mats. Occasionally gas bubbles were observed to emanate from beneath such mats. Slightly elevated areas were observed that might explain the patches of increased backscatter observed in the multibeam data surrounding these sites. This seafloor texture was distinct from that along the shelf edge in other areas investigated. The topography could indicate scattered patches of erosion resistant material. A few beds of bivalve shells (Figures 3F and 4G-H) were seen. Both the individual shells and the local environment appear similar to the beds of Calyptogena clams, the most visually obvious component of the chemosynthetic biological communities that commonly surround seafloor methane rich environments. The sediments that underlay much of the seafloor in the areas of diffuse gas venting were observed to be distinctly black in colour, suggesting that highly reduced sediments are widespread.

The combinations of the distinctive seafloor textures, occurrence of bacterial mats, shells beds suggestive of chemosynthetic biologic communities, diffuse seafloor venting of gas and widespread occurrence of reducing sediment in the immediate subsurface is atypical of the shelf edge environments elsewhere. However, the shelf edge along the Arctic Ocean is very poorly explored and this may be among the first areas investigated where ongoing erosion is exposing recently decomposed sections of the relict permafrost zone.

Another unique observation was made on dive 8 on Kopanoar (Figure 4L). Here the gas venting was carrying enough sediment up into the water column to generate a significant sediment cloud. To our knowledge this is a phenomenon that has not been observed previously.



Video frame grabs from ROV Dives 1-5 showing seafloor near the shelf edge within the area mapped to have multiple water column plumes. The seafloor in this area is characterized by isolated small mounds and ridges. The field of view for parts A-E is estimated to be ~3 m along the lower edges of these images. The total seafloor relief on the illustrated features is estimated to be ~50 cm (maximum in C). These positive relief features are commonly associated with white patches on their surface that are interpreted as being bacterial mats (A-E). Part E shows both a basket star and an anemone. The existence of the anemones indicates a firm substrate underlying the mounds. Parts D and F show black sediment exposed at the seafloor. When the seafloor in this area is disturbed, similar black sediment is seen to underlay broad areas surrounding the mounds. Part F shows a bed of bivalves that appear to be in growth position within black sediment.



Video frame grabs from ROV Dives 5-8. Parts G and H show bivalve shells, some appearing to be in growth position. Part I, J, and K come from ROV Dive 7. Periodic gas bubbling was observed coming from all three areas. Part J shows hole surrounded by a patch of black sediment. Apparently this hole was made by a gravity core collected earlier that day. Part L shows an area where vigorous gas venting occurs near the crest of Kopanoar PLF. The escaping gas is entraining sediment and producing the water column sediment clouds.

26 gravity cores were obtained in the areas where the ROVC dove along the shelf edge, yielding cores up to 166 cm in length. Seventy-five pore water samples were extracted from these cores using rhizon samplers. Chloride and sulphate concentrations will be measured on these samples, potentially helping to assess the proximity of decomposing permafrost and the depth to the sulphate methane transition zone. The cores are yet to be opened, but it is anticipated that they will provide ground truth control that will complement both the ROV observations and existing survey data. We hope to find material in the core that for dating with ^{14}C.

ROV lessons learned

Logistical effort required to use even a small ROV in the Arctic is substantial. Because the ship was working in a remote location without port facilities, equipment was committed from the time of loading in Vicotira in June to the ship's return in late October. This issue would become more problematic if one were using a larger more capable ROV for which there is much competing demand.

Subzero bottom water temperatures had a notable effect on battery operated components. For example, the Gulper initially did not fire with the normal alkaline battery configuration. This problem was remedied this by using 4 lithium batteries wired in parallel. The batteries back for the Contros CH_4 sensor also discharged considerably faster than anticipated.

The magnetic compass on the ROV, which is adequate for operations in lower latitudes, was ineffective near the magnetic north pole.

The low and variable salinity of the surface waters in this Arctic region necessitated additional buoyancy and frequent ballasting checks.

The lack of a sampling arm on the ROV was frustrating. For example even an individual sample of the shell beds (Figures 3F and 4G-H) would have allowed these biologically communities to be studied. However, small ROV's are not generally equipped with mechanical arms capable of extensive seafloor sampling.

Paull, C.K., Ussler, W., Dallimore, S.R., Blasco, S.M., Lorenson, T.D., Melling, H., Medioli, B.E., Nixon, F.M., and McLaughlin, F.A., 2007, Origin of pingo-like features on the Beaufort Sea shelf and their possible relationship to decomposing methane gas hydrates: Geophysical Research Letters, v. 34, no. 1.

Ocean Moorings for the CHS

Overview

The sequence and timing of activity was dictated by the demands of escorting the M/V Clipper Adventurer under tow by the tug Alex Gordon.

Locations were visiting in the sequence: Jenny Lind Bay, James Ross Strait east then west, Oscar Bay, Simpson Strait and Gladman Point.

One water-level recorder was recovered, from Gladman Point. The water-level recorders at Jenny Lind Bay and Oscar Bay were not recovered, despite extensive searches. We believe that these installations, tethered to marker floats at the surface, were carried away by ice that was moved into and out of the bays by variable winds. We were not able to download data from the recovered gauge because we did not have the proper interfacing equipment.

All three Sontek ADCPs were recovered. Unfortunately, the records from both sites in James Ross Strait were very short (15 h in the east, 20 h in the west) because of limited data storage – recorder memories had not been cleared of data from prior deployments. The data record from Simpson Strait appears to be complete.

File information:

James Ross Strait (east)	s/n 2604	JR1001.arg	191 kb	7x 3-m cells
James Ross Strait (west)	s/n 2575	JR2001.arg	255 kb	8x 3-m cells
Simpson Strait	s/n 3074	BASIC002.arg	565 kb	7x 3-m cells

Site Notes

Jenny Lind Bay

The weather was good here – light wind and rippled sea – but the visibility was at times poor (0.5 miles in fog). There was a modest number of old-ice floes in the bay at the time of our visit.

We spent 3 ½ hours here on the morning of the 24th. Our initial search was carried out from the FRC at the deployment locations, then in widening circles and finally along the eastern shore of the bay. When visibility improved, we sent up the helicopter with three observers for a through search of the bay, adjacent waters outside and the shoreline. Finally we dove on the deployment site with our Phantom ROV and spent 30 minutes searching the seabed with the scanning sonar and cameras.

We were unsuccessful in finding the marker float or the gauge.

James Ross Strait (east)

Our weather here was very good – west wind at 7 kt, patches of sunlight through a broken stratocumulus deck, lightly rippled sea & 15-mile visibility.

We started work here after lunch and had the pop-up buoy released and the tripod on board within half an hour.

We noted however, that the small emergence of the float and its dark grey colour could have seriously delayed its sighting in less good conditions. Also, the shackle attached to the top of the float is much too small for easy grappling from a small boat.

James Ross Strait (west)

The weather was the same at this site, which we reached at mid afternoon on the 25th. We spent 6 minutes repeatedly transmitting the release code before the pop-up float was spotted at the surface. This is not normal, and suggested either a problem in acoustical communication or in the let-go mechanism of the release.

The tide was running at about 1 kt at this time. We were very surprised that the float disappeared from view very shortly after it was spotted, pulled down to a depth of 15-20 feet by the flow. We then spent two hours fishing for the float with a grapple, and did secure it once, only to lose it when pulled vertical to the surface. We decided to wait for a slackening tide to allow the buoy up, finally seeing it just break the surface in fading light about 2 hours later.

We were lucky to get this one. Without a pinger or transponder on the mooring, we would have had no idea whether it was there not, had we not seen it briefly at the surface.

Oscar Bay

Weather conditions were excellent during the visit to this location via the FRC in the late afternoon of the 25th. There was no marker buoy at the deployment site and nothing visible on the surface of the bay. We subsequently searched along the shoreline, and dragged a grapple repeatedly across the target location during the course of the hour-long search. Nothing was found.

Simpson Strait

We reached this location early on the 26th. Weather conditions were not good – a 20-kt north wind, -3ºC, overcast skies and a grey sea with a good chop – but the current was slack. We spent almost an hour transmitting the release code and moving the ship to different positions relative to the mooring before the float finally popped into view. Again we suspect either a problem in acoustical communication or in the let-go mechanism of the release. It is also possible that the battery in the deck box was not up to scratch; Ron switched to ac power shortly before the successful release.

Gladman Point.

This recovery went the way things should. We came, we saw, we recovered.

Suggestions

Moorings with marker floats

There is clearly a technological shortfall with these. To my knowledge, CHS deployed 2 of these last year and lost 1, and deployed 3 this year and lost 2. The locations where installations were lost are those most likely to be invaded by ice from Victoria Strait. I recommend that you brainstorm about how to reduce or eliminate this apparent vulnerability.

Some options:

Use a string of small floats rather than a single large float as a surface marker. Our experience shows such to be less likely to snag on ice.

Add a pinger – or better a transponder – to the mooring so that one can determine whether the mooring is anywhere in the area

Use a pop-up assembly, and position this well beneath the reach of ice – perhaps at 20-m depth.

Use a short taut-line mooring at similar depth. The money you need for a transponding release could be available via savings gained by eliminating the spider and pop-up assembly.

ADCP Moorings with pop-up buoys

This mooring has a number of shortcomings for this environment: no way of determining whether the mooring is still in the area, too little buoyancy in the pop-up float, too little line with the pop-up float (both factors contribute to submergence in 1-kt current), poor visibility of the pop-up float, difficulty of grappling the float, possible unreliable let-go mechanism of the CART release.

Some options:

Add a pinger – or better a transponder – to the mooring so that one can determine whether the mooring is anywhere in the area

Get rid of the syntactic infill of the pop-up float. This stuff is really heavy. PVC end caps on an air space would give a lot more lift, and are quite practical for the low pressures at which you work. Alternatively, you could tie a cluster of small fishing floats (footballs from Viny) above the rope canister.

Add more line for the pop-up. I suggest using a length equal to twice the water depth.

Cover the entire surface of the float with silver reflective tape, or use white PVC, or add a flag on a short whip.

Put a large (6” diam) ring instead of the shackle at the top pf the float, to facilitate grappling. It is best that this stands on edge rather than lying flat.

Work in a pleasant Great Lakes environment to determine the best stand-back distance and deck-unit power setting for good communication with the CART in shallow (25 m) water. Having too much signal around may not be what is causing the problem in getting a release, but it is worth a try. Remember too, that we cannot back off too far or we will not see the float – 1 cable (200 m) is about the maximum.

Talk to ORE about the release mechanism. We have been using CARTs that have a swing-away release hook. In the first units we bought, the parts were so close fitting that the rotation of the release cam had to be exactly right before the hook would pull open. I persuaded that to change the design so that the two sides of the slot in the cam were flared, so that the hook would swing free even with a few degrees of misalignment of the cam. The release mechanism used by the pop-ups might benefit from the same concession to the real world of siltation, bio-fouling, etc.

Consider switching to a short taut-line mooring. The money you need for a transponding release could be available via savings gained by eliminating the spider and pop-up assembly. Such moorings are much easier to deploy and recover. If you need a mooring that holds the Sontek at constant heading, we have a solution for that within the taut-line concept.

Thanks to CCGS Sir Wilfrid Laurier

This was a typical scientific expedition on CCGS Sir Wilfrid Laurier. There was the usual stream of problems challenges but nothing sufficient to induce serious delay or cancellation of planned activity. Ice was not a problem anywhere. The weather was not the best, but poor conditions caused only modest shortfall in achievement.

I thank Captain Mark Taylor and the Laurier's White Crew for their commitment to and roles in completing our work. This was an end-of-an-era trip, the last under the leadership of Captain Taylor, who retires at the end of 2010.

I note in particular the competence and courage of the FRC team, who had the boat out working in difficult and very unpleasant conditions, to the obvious benefit of our activities.

Also worthy of special mention is Peter Boerkamp, who went far beyond the call of duty in diagnosing and correcting a wide variety of electronic, computer and network problems that came our way: cables to distribute ship's navigation data to scientific work stations, precision soldering in ROV repairs, video telemetry system for depth sounder data to the "green container", independent relay system for alternate triggeringof the 50 and 200 kHz sounders, RF cables and antenna for VHF radio located inside boat-deck container lab, oversight of continued operation of the water sampling system in the forward lab.

Issues of Concern 2010

Ship's interest

We encountered no issues of serious concern during the conduct of science on Leg 3 of the Laurier's Arctic Patrol in 2010.

Science's interest

1) The noise level of echo-sounders deployed on the new strut was quite high, at times obscuring weak echoes from targets in the water column. Identify the source of this noise and remediate.
2) All nine sounders on board ship operated independently, causing serious interference. Place all sounders under a single controller, so that operation of the sounders can be synchronized for minimal cross talk..
3) Diagnose and correct faults in IOS's new Mark-5 version of the 200-kHz ice profiling sonar – no transmitted pulse, high receiver noise level
4) Identify the cause of the unacceptable corrosion of new ORE CART transponding releases after 12 months' deployment. Document the character and extent of damage and to take the issue up with ORE Inc. for correction.
5) Identify and correct the cause of data format errors in our NB-ADCP s/n 0464 acoustic Doppler current profiler.
6) Assess the utility of the Contros dissolved methane sensor

Issues surviving from earlier years

1) Institute a routine test procedure for Y-cables and bulkhead connectors associated with use of external supplementary batteries for Work Horse ADCPs
2) Both the seawater pump and the seawater drain for the thermo-salinograph operation freeze up when surface water reaches freezing temperature; if such data are to be of routine interest, this issue needs attention (and money).

Narrative

21 September, Tuesday

Science team of 9 joins CCGS Sir Wilfrid Laurier at Cambridge Bay via the crew-change flight, leaving Victoria at 08:00. Temperature on arrival -1°C. Light flurries.

22 September, Wednesday

Sir Wilfrid Laurier on standby at Cambridge Bay, awaiting tow of a damaged cruise ship, M/V Clipper Adventurer, presently here under repair. Introductory meeting of science team. Set-up and preparation of science equipment.

23 September, Thursday

Sir Wilfrid Laurier on standby at Cambridge Bay, awaiting posting of a bond by the owners of the M/V Clipper Adventurer.

24 September, Friday

Sir Wilfrid Laurier weighs anchor at 02:30, eastbound. At Jenny Lind Bay at 09:00 to recover CHS tide mooring. Search of the deployment location, the bay and its shoreline via FRC & helicopter. Seafloor search of the deployment location using the Phantom ROV. Abandon site without recovery after 3 hours.

Sir Wilfrid Laurier eastbound for Simpson Strait at 12:30.

25 September, Saturday

Sir Wilfrid Laurier completed transit of Simpson Strait at 01:30. Standby for Clipper Adventurer to catch up under tow.

At location of CHS current measuring mooring in eastern James Ross Strait at 12:45. Recovery completed within half an hour.

At location of CHS current measuring mooring in eastern James Ross Strait at 14:50. Current 1 kt setting west. Several release commands required before mooring let go. Float sighted briefly at the surface before pulled under by the current. Repeated attempts from the FRC to grapple the submerged float were unsuccessful. Eventually recovered at 18:30 when the float surfaced at slack tide.

FRC dispatched to nearby Oscar Bay to retrieve a tide mooring. Nothing found.

Depart southbound.

26 September, Sunday

At location of CHS current measuring mooring in western Simpson Strait at 08:00. Recovery completed with difficulties after 2 hours.

Move ship up to Gladman Point, where FRC dispatched to recover a tide mooring. Mission successful and FRC back on board by 10:40.

Depart westbound.

27 September, Monday

Sir Wilfrid Laurier recovering channel marker buoys at Cambridge Bay at 07:00. Task complete at 11:30. Ship westbound.

28 September, Tuesday

Sir Wilfrid Laurier in Dolphin and Union Strait at 06:30.

29 September, Wednesday

Wind to 35 kt overnight. Because Sir Wilfrid Laurier passed Cape Bathurst before first light, a mooring here was not recovered.

Sir Wilfrid Laurier reached mooring site 2 at the shelf edge north of Tuktoyaktuk at 15:15. Mooring retrieved in 20 minutes, and replacement set out by 16:40. CTD cast.

Sir Wilfrid Laurier reached the location of the methane study near 136°W just before midnight.

30 September, Thursday

Running track lines at low speed (4-5 kt) until daybreak for systematic mapping of bubble sources by sonar – acoustics strut deployed.

At site 634-H at 07:00. ROV operated for site reconnaissance until 12:00.

Acquisition of sediment cores at this site 13:00-15:00.

ROV deployed again 15:30-19:00.

Running bubble mapping lines at low speed overnight.

1 October, Friday

At site 634-D at 07:00. ROV operated for site reconnaissance until 12:300.

Acquisition of sediment cores 13:00-14:30.

ROV deployed again 15:00-18:30.

Running bubble mapping lines at low speed overnight.

2 October, Saturday

At site 466-A at 06:00. ROV operated for site reconnaissance 07:00-09:00, when one of the ROV's motors was damaged by ingesting a basket star.

Acquisition of sediment cores 10:00-14:00.

ROV deployed again at 15:00.

Running bubble mapping lines at low speed for most of the night, breaking off in the early hours for transit to mooring site 1.

3 October, Sunday

At Site 1, light improving, at 07:45. Wind NE 25 kt, swell.

Two moorings recovered by 08:20. Technical problems with turn-around of equipped delayed the completion of re-deployments until 11:00.

Underway westward to Kopanoar at 11:30. Arrived at 14:00.

Recovery of AURAL mooring complete at 14:35.

ROV deployed for site reconnaissance and gas collection 15:00-18:30. Some vigourous gas vents seen here!

Sir Wilfrid Laurier the methane study area during the evening, to commence sonar mapping of the scarp and slide area overnight.

With continued strong (25G35 kt) wind, track lines were planned to run upwind and downwind, not cross-wind. Despite this, the quality of data acquired was not good – frequent loss of signal as bubble sheets passed under the ship.

4 October, Monday

Continued strong (30 kt) east wind. Tough rough to deploy and recover the ROV, as planned.

Switch to sediment coring at the Coke Cap site, completed at 13:30.

Conditions remain too rough for ROV or rosette operation.

Plan to standby here overnight, for possible opportunity to dive on Coke Cap tomorrow.

Continue sonar mapping of the scarp and slide area overnight, again with compromise for wind and sea conditions.

5 October, Tuesday

The day dawned with continuing strong (25 kt) east wind and rough seas. Continue standby for possible improvement.

Carried out a rosette cast at Coke Cap under difficult conditions for the rosette, and for ship handling. The rosette carried the Contros methane sensor, which was allowed to stabilize for several minutes before collecting a sample at depth within and above the bubble cloud.

Departed southbound at 13:00. Arrived at mooring site 11 at 17:40.

Mooring recovered by 17:55 and the replacement was dropped at 19:00.

Sir Wilfrid Laurier continued overnight to Herschel Basin.

6 October, Wednesday

The day dawned overcast, with 15 kt east wind, freezing drizzle and flurries.

Weather placed us into standby for good flying conditions. The ship's helicopter was to fly south from here, and the 6-member geology team was to be picked up by helicopter out of Inuvik.

Weather cleared sufficiently to permit flying by early afternoon. Departures completed.

On shore at the spit to calibrate the compass of one Work Horse ADCP.

Sir Wilfrid Laurier westbound by 15:00.

7 October, Thursday

North of Point Thompson at 07:00, bound northwest to the AIM mooring site.

A freeze-up buoy was deployed on behalf of the Applied Physics Laboratory of the University of Washington at 18:30, in open water near 73°N 151°W. A CTD cast was made to 300 m depth here, the deepest of the trip.

8 October, Friday

Near 74° 00'N 159° 30'W, having just passed R/V Mirai on an opposing heading.

At the AIM site at 18:30, still in daylight because the location is well to the west of the ship's time zone. The mooring was released and the top half on board by 19:00.

The lower half drifted under the transom under difficult conditions of wind and sea. Fortunately, with two boats deployed, the snag was cleared and the mooring on board by 19:50.

The replacement was dropped at 21:15, and Sir Wilfrid Laurier turned to the south following completion of a CTD cast.

9 October, Saturday

In transit towards Nome.

Royal Arctic Yacht Club regatta at 13:00, in wind, snow squalls and 2-m seas. Science boats did not triumph.

10 October, Sunday

Morning: 69°N 168° 18'W. Sea temperature up 6°C in the last 12 hours.

Continued transit towards Nome

11 October, Monday

09:00, at anchor off Nome.

FRC in to meet with US Immigration at first light, breaking ice in the inner harbour (-5°C with clear skies).

IOS personnel left the ship after lunch for return flights via Anchorage and Seattle to Victoria, arriving at about midnight.

Appendix 1: Locations of moorings, Beaufort and Chukchi Seas 2010-11

Retrieved. Autumn 2010

Station	Type	Instruments	Area	Latitude			Longitude			Depth of top float (m)	Water depth (m)	Date IN	Date OUT
DVH09-1a	400 kHz sonar	W-IPS4	Mackenzie shelf	70	19.934	N	133	44.297	W	52	56	28-Sep-2009	03-Oct-2010
DVH09-1b	300 kHz sonar	NB-ADCP, SBE37	Mackenzie shelf	70	19.971	N	133	44.471	W	52	56	28-Sep-2009	03-Oct-2010
DVH09-2	200 & 300 kHz sonar	IPS4, NB-ADCP, SBE37	Mackenzie shelf	70	59.207	N	133	44.906	W	53	112	28-Sep-2009	29-Sep-2010
DVH09-11	900 kHz sonar	W-IPS4, SBE37	Mackenzie shelf	69	46.475	N	137	02.729	W	32	35	30-Sep-2009	06-Oct-2010
DVH09-Ko	Sound recorder	2x AURAL	Mackenzie shelf	70	23.365	N	135	25.100	W	37	42	29-Sep-2009	03-Oct-2010
DVH09-A1	400 kHz sonar	IPS5, XR420	North slope	70	22.002	N	145	59.978	W	28	31	02-Oct-2009	01-Oct-2010
DVH09-A2	600 kHz sonar	WH-ADCP	North slope	70	21.980	N	146	00.101	W	29	32	02-Oct-2009	01-Oct-2010
DVH09-V1	400 kHz sonar	IPS5	North slope	70	37.999	N	146	08.107	W	42	45	04-Oct-2009	01-Oct-2010
DVH09-V2	300 kHz sonar	WH-ADCP	North slope	70	37.999	N	146	08.225	W	44	47	04-Oct-2009	01-Oct-2010
AIM09-1	400 & 300 kHz sonar	IPS4, WH-ADCP, 2x SBE37, AURAL	Chukchi Plateau	75	05.997	N	167	59.978	W	41	162	06-Oct-2009	09-Oct-2010
DVH09-Bu1	400 kHz sonar	IPS5	E Chukchi Sea	71	14.372	N	163	16.852	W	42	45	07-Oct-2009	01-Aug-2010
DVH09-Bu2	300 kHz sonar	WH-ADCP	E Chukchi Sea	71	14.392	N	163	16.812	W	42	45	07-Oct-2009	01-Aug-2010
DVH09-Cj1	400 kHz sonar	IPS5, XR420	E Chukchi Sea	71	10.202	N	166	45.007	W	42	45	08-Oct-2009	01-Aug-2010
DVH09-Cj2	300 kHz sonar	WH-ADCP	E Chukchi Sea	71	10.182	N	166	44.932	W	42	45	08-Oct-2009	01-Aug-2010

Colour Teal backbround for sites within 200 miles of USA coastline
These moorings, placed from CCGS Sir Wilfrid Laurier in 2009, were retrieved from M/V Norseman II in 2010

Placed from CCGS Sir Wilfrid Laurier. Autumn 2010

Station	Type	Instruments	Area	Latitude			Longitude			Depth of top float (m)	Water depth (m)	Date IN	New site for 2009-10
DVH10-1a	200 kHz sonar	IPS4	Mackenzie shelf	70	19.930	N	133	44.304	W	51	55	03-Oct-2010	No
DVH10-1b	300 kHz sonar	NB-ADCP, SBE37	Mackenzie shelf	70	19.937	N	133	44.458	W	51	55	03-Oct-2010	No
DVH10-2	200 & 300 kHz sonar	IPS4, NB-ADCP, SBE37	Mackenzie shelf	70	59.248	N	133	44.784	W	55	114	29-Sep-2010	No
DVH10-11	400 kHz sonar	W-IPS4, SBE37	Mackenzie shelf	69	46.479	N	137	02.726	W	32	35	06-Oct-2010	No
AIM10-1	199 & 300 kHz sonar	IPS4, WH-ADCP, 2x SBE37, AURAL	Chukchi Plateau	75	06.019	N	168	00.042	W	42	163	09-Oct-2010	No

Appendix 2: Locations of CTD/rosette profiles

Consec #	Station	Latitude			Longitude			Depth m	Date	Purpose
2010-35-0001	DVH10-2	70	59.32	N	133	44.43	W	112	Sep 30 2010 00:59:11	CTD
2010-35-0002	DVH10-1	70	19.96	N	133	44.46	W	56	Oct 03 2010 17:32:55	CTD
2010-35-0003	Coke Cap	70	39.01	N	135	56.93	W	288	Oct 05 2010 18:15:04	CTD / Rosette
2010-35-0004	DVH10-11	69	46.46	N	137	02.77	W	35	Oct 06 2010 01:41:43	CTD
2010-35-0005	FB-1	72	47.27	N	150	40.67	W	3825	Oct 08 2010 01:41:37	CTD
2010-35-0006	AIM10-1	75	06.02	N	168	00.55	W	165	Oct 09 2010 04:39:51	CTD

Appendix 3: Locations of CHS moorings near King William Island

Site	Location	LatDeg	LatMin	LonDeg	LonMin	Depth (m)	Release	Code	Instrument
OB	Oscar Bay	69	46.7208	095	50.1595	13.5	Haul up	Yellow buoy	WLR7
JR-2-W	James Ross Strait	69	42.4427	095	46.6454	26.1	Call-up	552 427	Sontek
JR-1-E	James Ross Strait	69	35.3571	095	16.4534	23.1	Call-up	552 442	Sontek
SS-3	Simpson Strait	68	34.3730	097	40.3670	26.9	Call-up	552 461	Sontek
GP	Gladman Point	68	39.0408	097	44.5299	6.0	Haul up	Yellow buoy	WLR7
JLI	Jenny Lind Island	68	38.1250	101	45.1000	15.2	Haul up	Yellow buoy	WLR7

Appendix 4: Locations of sediment cores

Site	Date	Time	Latitude		Longitude		Water Depth (m)	Core Length (m)	Catcher Sample	MBARI Pore Water	Comment
634H	30-Sep-10	19:57	70	27.0231	136	33.6041	89	144	Y	20, 40, 60, 80, 100, 120, 135 cm	Also 8 cm extending beyond catcher
634H	30-Sep-10	20:17	70	27.0506	136	33.4440	90	121	Y	20, 40, 60, 80, 100, 105 cm	15 cm extruded out bottom
634H	30-Sep-10	21:02	70	26.8984	136	33.3333	90	119	Y		
Slide area N of 634H	30-Sep-10	21:30	70	27.1836	136	34.2512	128	123	Y		5 cm extruded
Slide area N of 634H	30-Sep-10	21:50	70	27.2026	136	34.2571	133	166	Y	20, 40, 60, 80, 100, 120, 140, 155 cm	
634D	01-Oct-10	20:30	70	28.6486	136	26.0073	86	35	Y		
634D	01-Oct-10	20:43	70	28.6512	136	26.0045	86	45	Y		5 cm extruded
634D	01-Oct-10	21:10	70	28.7482	136	26.2024	96	92	Y	20, 40, 60, 80, 85 cm	
Slide area N of 634D	01-Oct-10	21:40	70	29.1553	136	26.8883	231	146	Y	20, 40, 60, 80, 100, 120, 135 cm	
466A	02-Oct-10	17:33	70	35.8703	135	43.8082	70	15	Y		
466A	02-Oct-10	17:48	70	35.8813	135	43.9944	69	15	Y		
466A	02-Oct-10	18:02	70	35.8311	135	43.8117	72	90	Y	20, 40, 60, 80 cm	
466A	02-Oct-10	18:23	70	35.8417	135	44.1607	77	65	Y	20, 40, 55 cm	
466A	02-Oct-10	19:21	70	35.9284	135	43.2772	76	140	Y	20, 40, 60, 80, 100, 120, 130 cm	
466A	02-Oct-10	19:42	70	36.1805	135	43.9181	74	55	N		
466A	02-Oct-10	20:04	70	36.1766	135	43.9057	71	0	N		
466A	02-Oct-10	20:23	70	36.1293	135	44.1161	82	120	Y		Background
Coke Cap	03-Oct-10	15:39	70	38.9918	135	56.8166	293	69	N	20, 40, 60 cm	
Coke Cap	03-Oct-10	16:02	70	38.9890	135	56.8671	287	66	N	10, 30, 40, 55 cm	
Coke Cap	03-Oct-10	16:31	70	38.9338	135	56.8578	293	50			
Coke Cap	03-Oct-10	17:28	70	38.9878	135	56.8609	287	6			
Coke Cap	03-Oct-10	17:53	70	39.0008	135	56.8563	286	9			
Coke Cap	03-Oct-10	20:17	70	38.8659	135	56.8563	292	120	Y		Moat
Coke Cap	03-Oct-10	20:45	70	38.7548	135	56.4057	282	135	Y		Background
Site 11	04-Oct-10	00:06	70	47.5152	135	33.9157	428				
Site 11	04-Oct-10	01:11	70	47.5175	135	33.9082	422				

Appendix 5: Notes on the ROV dives

ROV Dive #1: September 30

At Site 0634H (Blasco Seep Catalog)

This is an area near the shelf edge with no significant relief on the multibeam, but associated with a WCA. To the NE some increased backscatter textures were observed on the backscatter data.

07:30 L (14:48 Z): Prepare to launch. No mid-water sonar targets believed to be associated with bubble plumes were seen during the decent (nor at any point during the dive).

15:08 Z: On bottom 89 m water depth. T=-1.09°C Strong current flowing to the ENE parallel to shelf edge. Brittle stars and sea pens abundant, some gastropods also noted. Bottom texture rough – suggesting it is covered by an erosional lag. As moved around saw some angular blocks of firmer sediment that appeared to be have relatively fresh surfaces. Bottom was generally tan. However some patches of white and black were seen. In general the black areas were surrounded by the white halos. Suspect that the white area bacterial mats. When the bottom was disturbed by the ROV, more extensive areas of black were seen under both the mats and some of the tan sediment. Several linear grooves 1- to 3 m wide were seen, which are presumed to be ice plow marks. Sometimes there were ridges of sediments that stood proud of the surrounding seafloor on the side of the grooves. Hummocky sediments filled the grooves. A number of small grooves and were seen, which are presumed to be ice scours. Some associated with holes.

09:28 L: Started to moved toward area of higher backscatter (0634H_B) which was ~200 m to the NE. See some rubble on the bottom, which appears to be a mixture of an erosional lag and locally derived dropstones. Saw one small (~10 cm high) overhanging ledge, suggesting it was the edge of an erosionally truncated ledge.

09:54 L: More rubble, but note that there are more encrusting organisms, suggesting the bottom surface is older.

10:22 L: Note continuation of more surface rubble that may have fallen off the ice.

10:24 L: Nearing site 0634H_B– Saw small mound (<20 cm high, 1-2 m across with black sediment exposed in its interior.

10:53 L: Started to move W toward scarp at shelf edge.

11:16 L: 94 m –Smooth bottom with abundant brittle stars and sea pens as the depths increased. This area is outside the stronger backscatter patch. 11:30 L: Sonar failed- aborted dive. Contros CH4 sensor read less than >3.8 µm during entire dive. Ship switched to coring operations while sonar repaired.

ROV Dive #2: October 1

15:41 L (22:41Z): Dive site slightly off the edge of the shelf break inside headwall scarp of “older” looking slide scar. Will move up slope toward 0634H_A_plume site.

16:00 L: On bottom in 132 m water depth. Bland scanning sonar. Seafloor surface looks depositional. Abundant small brittle stars, some soft corals, and occasional large basket star (Gagona Sephalon ? - identified by Kim Conway). At 115 m - Contros Sensor = 6 µM.

16:38 L: 113 m. Note generally smooth surface but some subtle lee side tailings and grooves that suggest bottom is current swept. Multiple types of starfish and small brittle stars noted as being extremely common. 104 m – At crest of one step and bottom slope observed to flattening out at least locally. See first evidence of ice grooving. 97 m – see first sea anemone on steep wall. 96 m –Bland sonar again. No rubble. Seafloor surface looks depositional and impressed by extensive brittle star and sea pen cover.

17:12 L: See another ice groove. Contros CH4 senor dropping.

17:32 L: Area of slightly rougher bottom. Looks erosional.

17:48 L: 89 m – saw white mat. Saw occasional bubbles coming up from area within white mat. Gulper believed to have been accidentally triggered (however, was not fired upon recovery). Contros sensor software froze up.

18:46 L: Started to recover. Had not made it to overlap with track of Dive #1.

ROV Dive #3: October 1

At 0634D. A plume site. Lots of WCAA seen on the SWL 12 kHz sonar.

08:58 L (15:58Z): Launch ROV. No WCAA seen on ROV sonar during decent. 09:05 on bottom 93 m. Contros CH_4 Sensor = 3.3 µM. Ice scour noted. Small mound ~20 cm higher than surrounding seafloor, ~1 m across noted which had white mat and little holes on its sides which resembled a Swiss-cheese-like texture.

09:29 L: 93 m - See bubbles coming out of small topographic high which was again only ~20 cm higher than the surrounding seafloor, ~1 m across, and ~5 m long. The top of this mound was hummocky and had black sediments surrounded by a halo of white mat. Lowered the gas-sampling funnel to try to collect gas. Gas funnel observed to slowly fill. This was by catching a few bubbles at a time. However, gas was observed to intermittently come out of multiple holes.

10:46 L: Tried to fire Gulper to sample accumulated gas, but Gulper did not work. S^o/oo = 32.2; T= -1.11 Contros CH_4 Sensor = 10µM. Tried to recover gas by launching small boat, but the gas was all lost before the boat recovery effort started. Switched to coring while Gulper failure evaluated. Decided the problem was the temperature and increased the battery power by running a series of batteries in parallel.

ROV Dive #4: October 1

2nd dive of day. At same site as ROV dive #3 - going back to try to sample the gas.

Launch 3:19 PM L.

15:27 L: on bottom at 92 m. S^o/oo =32.2 - See a few escaping gas bubbles almost immediately, but note they are rather intermittently released from any one spot. See several small mounds. Moved over to and relocated site of pervious sampling.

15:40 L: Back at same mound as previous sampling. While still intermittent, area is more favorable and started sampling again with the funnel.

15:54 L: See meniscus of gas within funnel. Contros CH_4 Sensor = 3.6 µM.

16:15 L: Fired Gulper and saw gas slowly enter the coils. End of dive.

ROV Dive #5: October 1

3rd dive of day. Launch near same site (0634D_A_plume) with intention of moving to NW into area of higher backscatter. Surface water T=1.62°C – S^o/oo =27.66 – 87 m water depth.

18:14 L: on bottom. Sea floor looks “wind blown”. See abundant brittle stars, and sea pens, while sonar is bland. Contros CH_4 Sensor = 5 µM.

18:21 L: ROV/ship moving NW. See some small topographic highs, but generally bland bottom.

18:31 L: Still bland bottom on sonar.

~19:00 L: Started to see occasional bivalve shell (Calyptogena ?). Encountered small mound rimmed with shells. Many of the shells are intact. Appears to be a dead CBC.

19:17 L: almost back to site of previous gas sampling.

19:12 L: at site of previous sampling.

19:22 L: 92 m at mound with some gas venting, but moved a few meters over and reoccupied site that was sampling in the morning.

19:35 L: Started sampling is same area as on dive #3, but noted gas appears to be venting more slowly. 20:26 L Fired Gulper. End of dive.

ROV Dive #6: October 2

At 0466A. A_plume, which was identified by Steve Blasco as being area of small PLF. Lots of WCAA seen on the SWL 12 kHz sonar.

08:10 L: Launched ROV. No WCAA seen on ROV sonar during decent.

~08:15 L: On bottom 72 m and seeing abundant brittle stars, plus some other starfish and soft corals. Move toward sonar target. See step extending from 72 m to 68 m. Side is >30° slope. Covered with black Swiss-cheese like texture.

08:18 L: note the top of the ledge is smooth. Periscope up into the water column to look for WCAA on scanning sonar, but found none.

08:38 L: Lost control of thrusters on ROV – aborted dive. Switched to coring while ROV fixed.

ROV Dive #7: October 2

Again at 0466A, a_plume site. Again see lots of WCAA seen on the SWL 12 kHz sonar.

13:59 L: Launch ROV 69 m water depth. Ts=2.83 Ss = 25.73 o/oo. No WCAA seen on ROV sonar during decent.

14:13 L: On bottom in 69 m with abundant brittle stars and some larger basket stars. Bottom looks “wind swept”. Good seafloor sonar targets ahead, but bland sonar near field.

14:16 L: 68.5 m on flank of topographic feature. See that the gentle ramp at the base of the feature is mottled with white, grey, black, and tan sediments. Side of mound again formed by an abrupt steep step that has a distinct fluted “Swiss cheese like” face. Impression is that this face is the face of a truncated bed.

14:24 L: See a few gas bubbles coming out at 68.2 m from part of the mottled area.

14:29 L: 68 m – Tried to sample the gas from a low vent, but gave up as only an occasional bubble was coming out. Again note the steep lower edge of the mound has exposuers of black sediment and Swiss cheese texture.

14:35 L: at 70 m - Contros CH_4 Sensor =66µM and noted quick rise to 300µM, than 600 µM.

14:46 L: 68.7 m.

14:46 L: Again note Swiss cheese sides of feature. Sections on the top are noted to have both patches of orange and white mat covering the bottom interspersed with black sediments.

15:00 L: 69.9 m – Started to move 25 m to ESE and saw disturbed bottom with distinct hole which is believed to be site of a gravity core. The CH4 sensor noted to be dead.

15:11 L: 70.2 m.

15:14 L: 70.7 m – move another 25 m to ESE. Bottom now bland on sonar.

15:19 L: 71 m. Move 25 m to N. Move another 25 m to NW.

15:28 L: 68.6 m.

22:32 Z: 67.5 m.

22:41 Z: 67.5 m – see polygonal pattern in associated with white mats.

23:32 Z: Sense of being lost and scribbling on the bottom while searching for significant venting. Still see WCAA on ships 12 kHz, but none on bottom even when the ROV periscopes.

17:12 L: 68.5 m again see black mottling on side of feature. Than see a few bubbles coming from the flat seafloor on the gentle ramp on the flank of the feature.

17:15 L: 69 m – See few gas bubbles coming out from tan sediment. Note that the site was not associated with black sediment until it was disturbed. Note that bubbles appear to come from here and there, but not focused in discrete vents. Would not predict that gas would come from tan sediments. Appears to be site of diffuse venting, not focused into organized venting conduits.

17:46 L: landed to watch an individual site, not selected because bubbles were sighted.

17:54 L: Saw a few bubbles come out after 8 minutes. No more bubbles seen until pull, starting at 18:00 L.

{During dive #7, the ROV move over the crest of the feature several time. Appears that the bottom on the flanks is in ~71 m and the crest is in 67.2 m. The feature was elongated ENE-WSW. The top of the feature had a depression that was >50 cm deeper (68.7 m). Sonar shows this shape clearly. Impression is that small amounts of gas are escaping here and there from the flanks, sides, and top of the feature. However, not very much gas is coming out in any particular area. Thus, this appears to be an area of diffuse flux, not a focused vent. }

ROV Dive #8: October 3

At Koapanaor. Dive near crest, near whether Scott Dallamore's acoustic listening device was deployed. Fresh batteries in Contros CH_4 Sensor. WCAA seen on the SWL 12 kHz sonar pre-dive.

15:25 L: on bottom, Grey/tan sediment. Contros CH_4 Sensor = 3.5 µM. T=-1.19°C, S o/oo= 25.95. 40.7 m. Smooth surface, punctuated by linear ice scars. Occasional amphipods. Some tracks and trail, some of which ended at amphipod.

15:47 L: moved toward distinct sonar target (22:50 Z – particularly good video) – see it is associated with huge gas vent that is stirring up sediment. Location of gas vent seems to change as we watch it, migrating ~8 m accord the bottom. Gas vent is vigorous enough to carry sediment up into the water column. Moved up off the bottom to sample, as the position of venting is changing to rapidly, and after venting too much sediment is in the water column to see anything with the cameras.

22:54 Z: 31.3 m.

16:02 L (23:02 Z): Gulper fired to sample gas. Contros CH_4 Sensor = 4.2 µM after being soaked in gas bubbles. Returned to bottom and again watch position of venting progress across the bottom in 41 m water depth. Appears to be coming from the edge of a propagating crack.

23:34 Z: move to fly ROV across the sediment plume.

22:34 Z: tried to land on bottom and hold position to see whether plumes could be observed to move on the sonar, but kept getting pulled off bottom. 17:07 L: moving mid-water toward NW edge of PLF.

17:19 L: Landed on flat, apparently featureless bottom near the bottom of PLF's moat, in very murky water. T=-1.18°C, S^o/oo = 32.36 - See some bioturbation. Proceeded on transect to east up the flank of the PLF. Was not able to make out much while transecting over the lower flank of the PLF.

17:29 L: at 63 m.

17:41 L: at 55 m – still murky, but generally smooth appearing bottom. 49 m – see first ice scours. At 45 m depths visibility improved. At 41 m – ice scours and amphipods common.

18:00 L: Recovered ROV in snowstorm. Ship's 12 kHz still seeing WCAA.

Appendix 6: Managing risk of H_2S during sediment coring

Prepared by Scott Dallimore and Kim Conway, Geological Survey of Canada

Geologic Setting

Gravity coring operations are expected to only recover 1.5-3 m or bottom sediments. Grab sampling with a Shipek sampler will be only of the upper 20-30cm of sediment. For all sampling sites the sediment is thought to be composed of Holocene-aged (modern) muds. In some cases pore waters may have elevated methane concentrations. However, this methane is thought to be entirely of biogenic origin, similar to swamp gas in a terrestrial environment. In the deeper water environments of Site II and III, there is a remote chance that small amounts of methane hydrate will be collected in the sediment. We do not expect that the concentrations or rates at which methane would be released from gas hydrate would pose any type of ignition hazard or health risk.

We do not anticipate any detectible concentrations of H_2S as geochemical conditions for its occurrence are not found in the shallow oxygenated environments we will be sampling. We know of no published or anecdotal accounts of H2S occurring in shallow Beaufort Sea sediments.

Coring

In gravity coring, a simple barrel assembly weighted with approximately 300 lbs of lead is lowered into the seafloor at about 1 m/s. We use a core barrel 1.5 or 3 m in length with the core contained within a clear plastic liner. The weight of the corer is about 400 lbs.

The barrel assembly will be broken down and assembled on deck and the liners will be extracted after each coring run. After extracting the cores, we expect to allow the cores to settle for a period of approximately 30min by standing them vertically. We will then lay the cores down on the deck for cutting into 1.5 m long sections. The cores will then be taken to the small blue science container on deck for sub-sampling and storage.

While no H_2S expected to occur in the sediments we will take precautions to periodically sniff for this gas in the cores and monitor the H_2S concentrations in the working space in the small science lab on deck.

As opposed to piston coring, where some internal pressure can build up in the core barrel, gravity coring has a flapper valve to relieve any pressures due to degassing. While we will be cautious to observe for pressure build from sediments within core liners (we will watch for core expansion, cracking, etc) we do not anticipate any unusual hazard should we recover small amounts of gas hydrate core.

We have reviewed the core handling procedures related to H_2S and gas hydrate as outlined in the document entitled “JPT-Coring Handling Procedures” dated 9 December 2009.

We provide the following comment in terms of hazard identification and procedures for the 2010 sampling program aboard the CCGS Sir Wilfred Laurier.

Re: H_2S Hazard issues

According to the JPT-Core Handling Procedures documentation described above, H_2S is detectible as a rotten egg smell 0.1 ppm level with toxicity in 10 ppm (100 times greater than the detectable level).

As recommended by in the JPT document we plan to have available during coring operations two hand held multi gas monitors that can detect H_2S in the 0-500 ppm range. We intend to have one unit on hand on the deck to use in a sniffer mode immediately after core recovery (i.e. pass over core samples directly). The other will be used to monitor the environment in the blue science container on deck where the cores will be sub sampled.

As we do not expect any significant levels of H2S in the shallow Beaufort Sea cores, we propose simply to halt operations should we measure any significant H2S concentrations in the 1-3 ppm range. In other words if we suspect the presence of H_2S from the smell and anoxic character of the sediments, and if we detect 3 ppm H_2S with our M40 gas sensor (a level well below that thought to be hazardous) we will abandon coring operations at the site of concern and move to another location with different geology.

In the event that we have halted operations because of the presence of H_2S we will proceed with processing of the core on the deck after the H_2S concentrations measured with the M40 detector have diminished back to background levels.

Re: Methane hydrate hazard issues

Methane hydrate is only stable at the sea bed at 300 m water depth or deeper. Thus it can only physically occur at sites III and II. While it would be wonderful for the purposes of this project to recover gas hydrate core samples, the reality is that the gravity coring system has little chance of recovering sediments with abundant gas hydrate as they are too strong to be penetrated by the light-weight gravity corer that we are using.

Appendix 7: Recovery of stranded Arctic weather buoys

Average of all 'best quality' positions during 1 June through 5 July 2010

Reporting precision for each position is 0.001 degrees, or 110 m in latitude, 40 m in longitude

Position error circle for best quality has radius of 250 m

Estimated error circle radius for one-month average is 50 m

Chart Datum is WGS84

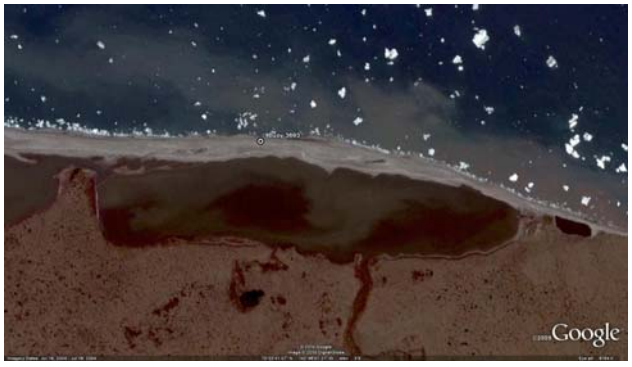
Buoy ID	Near	Near	Owner	Deployed	Latitude deg min	Longitude deg min
5313	Pogik Bay	West of Cape Halkett	Environment Canada	2007	70 52.7963 N	152 46.9182 W
3693	Pokok Lagoon	East of Kaktovik	Norwegian Meteorological Institute	2006	70 02.8454 N	142 46.4333 W

Buoy recovered from Pogik Bay using the helicopter on the morning of 23 July 2010.

Buoy recovered from the beach at Pokok Lagoon using the helicopter on the morning of 25 July 2010.

Both buoys were easily spotted, exactly where expected on the basis of Google Earth mapping (see pictures).

Buoys would not fit in the cargo compartment, but were easily accommodated in the front passenger seat.



Regional Operations Centre
Canadian Coast Guard – Pacific

PACIFIC REGION CCG VESSEL -POST CRUISE REPORT

NAME OF SHIP/PLATFORM: **CCGS Sir Wilfrid Laurier**

DATES: 20 September - 11 October 2009

SCIENCE CRUISE NUMBER: 2010-35 **SHIP'S PATROL NUMBER:**

CHIEF SCIENTIST[S]: Humfrey Melling, DFO/IOS

AREAS OF OPERATION: Beaufort and Chukchi Sea

INTRODUCTION/PROGRAM BACKGROUND:

The Institute of Ocean Sciences (DFO) is engaged in long-term collaborative studies in the Pacific sector of the Arctic Ocean. The ongoing focus is monitoring of the physical properties of sea ice and the upper-ocean waters. The activity addresses issues of environmental protection, maritime safety, ocean variability and climate change. Our goal is not only to detect and describe changes in the Arctic marine environment, but also to understand why changes are occurring and whether they will continue into the future.

The core programme is supplemented to a varying degree each year by activities proposed by collaborators in areas of overlapping scientific interest. Such collaborative activities contribute to the critical mass needed to justify an annual expedition, facilitate the efficient use of ship time and spread the logistic risk associated with inclement ice and weather conditions over several projects.

The supplementary programme for Sir Wilfrid Laurier's Leg 3 in 2010 was a project with Natural Resources Canada and Monterey Bay Aquarium Research Institute to assess the hazards for hydrocarbon drilling and production related to the presence of sub-sea gas hydrates. This study used a variety of techniques to characterize the marine and geologic setting of natural seeps of methane at the seabed and of the underlying deposits of solid gas hydrate and permafrost.

CRUISE OBJECTIVE/OBJECTIVES:

One of the principal objectives of this expedition was the recovery, servicing and re-deployment of internally recording instruments on sub-sea moorings. The instruments had operated autonomously for 12 months, recording observations of ice thickness, ice ridging, ice drift, storm waves, storm surge, ocean current, temperature, salinity, ambient sound and acoustic back-scatter from plankton. There were six moorings for recovery during this leg and five for deployment.

The other principal objective was investigation of recently discovered methane seeps on the Beaufort seabed and their relationship to sub-sea permafrost, pingo-like features and buried gas hydrates. Techniques included underway surveys (high frequency sonar to measure rising methane bubbles, low frequency to reveal structure within sediments), rosette casts for seawater sampling, gravity-coring for sediment sampling, ROV dices for video reconnaissance of seeps and for sampling escaping gas.

A secondary objective was the mapping of selected properties of seawater, both continuously at the surface along the path of the ship and from surface to seabed at selected locations, principally the sites of sub-sea moorings. Properties of surface water were to measured continuously in water pumped from one of the ship's sea bays to the main lab (temperature, salinity, chlorophyll fluorescence, dissolved O2, CO2 and CH4). The primary instrument for use in seawater mapping was a CTD probe with added sensors for dissolved oxygen, light transparency and chlorophyll fluorescence.

DAYS ALLOCATED:

6.5

DAYS OF OPERATION:

21, including CCG tasking and homebound transit time

DAYS LOST DUE TO WEATHER:

1

RESULTS:

All of the objectives of the program were completed. Sea ice cover did not inhibit work this year, but rough seas did. There were no dysfunctional moorings where dragging was required.

RADIOISOTOPE USE:

None.

PROBLEMS [SCIENTIFIC GEAR AND OPERATIONS]:

All nine sounders on board ship operated independently: the ship's 12, 50 & 200 kHz units, the strut-mounted 50 & 200 kHz units and the four 307 kHz units of the ADCP. The result was serious contamination of received signals by other transmissions. We need to place all sounders under a single controller, so that operation of the sounders can be synchronized for minimal interference.

SUCCESSES [SCIENTIFIC]:

All instruments on all moorings deployed in the Beaufort and Chukchi Seas in October 2009 were recovered, and all yielded full data records.

The AURAL under-water sound recorder, deployed at Kopanoar pingo-like feature to record the sounds of gas bubbles forming at seeps on the seabed, did just that. This is the first time that the AURAL has been used for this purpose.

Our plan to sample gas at seeps at the seabed was extremely successful. We returned with enough samples to deduce the isotopic composition of the gas, its age, its chemical composition and its likely source (biogenic, thermogenic, decomposing gas hydrate).

We have visual evidence that seabed gas seeps are associated with bacterial mats, which may be unique biological communities – only targeted study will tell.

PROBLEMS [SHIP'S EQUIPMENT/OPERATIONS/PLATFORM SUITABILITY]:

See: PROBLEMS [SCIENTIFIC GEAR AND OPERATIONS]

SUCCESSES [SHIP]:

CCGS Sir Wilfrid Laurier is an excellent platform for multi-tasked operations that include scientific research in the Canadian Arctic. The advantage of multi-tasking in reducing the average cost per operational science day should not be over-looked.

Cost comparisons with dedicated Arctic science vessels such as Amundsen or USCG Healy are very favourable.

DELAYS [OTHER THAN WEATHER]:

Lengthy delay during tasking of CCGS Sir Wilfrid Laurier in support of M/V Clipper Adventurer, grounded in Coronation Gulf, and for recovery of CHS ocean moorings in vicinity of King Williams Island, not completed during Leg 2.

SAFETY CONCERNS:

None

HAZARDOUS OCCURRENCES:.

None

EVENT LOG:

See "Cruise Narrative" in the preceding science report

SUMMARY/FINAL COMMENTS:

Near the end of the short Arctic summer, as sudden storms and rough seas become frequent and difficult to predict, and daylight hours rapidly get shorter, it is frequently a challenge to complete the science mission objectives. Our special thanks go to the captain, officers and crew, whose interest and commitment allowed us to work so productively.