Fisheries and Oceans Pêches et Océans

Beaufort Marine Hazards

2012 Field Expedition Report

CCGS Sir Wilfrid Laurier

September 18 – October 5, 2012

Institute of Ocean Sciences Cruise 2012-21

Pacific Geoscience Centre Cruise 2012-004

Humfrey Melling – Chief Scientist

Supported by

Fisheries and Oceans Canada, Geological Survey of Canada

Federal Programme on Energy Research and Development (PERD B21-002, B21-003)

Beaufort Region Environmental Assessment (BREA: Beaufort Sea Observatories)

Monterey Bay Aquarium Research Institute (MBARI), ArcticNet

Cover picture:

Foredeck of CCGS Sir Wilfrid Laurier during the Leg-3 science programme. Equipment from left to right: IKU grab, Huntec seismic towed body with suspension system, coring winch (background), Huntec winch (black), ROV winch (yellow umbilical), core lab (blue shipping container), mooring anchors (train wheels).

Beaufort Marine Observatories

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Arctic Patrol Leg #3, CCGS Sir Wilfrid Laurier

September 18 – October 5, 2012

Personnel

15 scientists embarked at Cambridge Bay on September 18.

Via CCG crew-change flight from Victoria:

Humfrey Melling and Ron Lindsay, from DFO at the Institute of Ocean Sciences, Sidney BC

Jo Poole, from Square Wave Marine Technology

Peter Neelands and Greg Middleton, from the Geological Survey of Canada, Sidney BC

Via commercial carrier:

Phillip Osborne, Greg Curtiss and Sebastien Donnet, from Golder Associates, Vancouver

Via Summit Air charter Dornier aircraft from Yellowknife:

Scott Dallimore, Kim Conway, Michael Riedel from the Geological Survey of Canada, Sidney BC

Charles Paull, Dale Graves and Alana Sherman from MBARI, Santa Cruz CA

Graham Standen from GeoForce Consultants, Dartmouth NS

All disembarked via helicopter at Deadhorse AK on October 5

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 increase the scientific value, contribute to the critical mass needed to justify the gearing up for 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 2012 had three components:

1) A continuing study in collaboration with Natural Resources Canada and Monterey Bay Aquarium Research Institute to assess the hazard of gas hydrates for drilling and production; this study will exploit a variety of techniques to characterize the marine and geologic setting of natural seeps of methane at the seabed and the underlying deposits of solid gas hydrate and permafrost;

2) A collaborative effort with ArcticNet to support continued ocean monitoring by instruments on sub-sea moorings in the new deep-water lease blocks in the Canadian Beaufort Sea;

3) A new observatory using recording sonar on sub-sea moorings to obtain detailed data on ice conditions and hazards at the Amauligak site at the 32-m isobath north of Kugmallit Bay.

The present expedition is lead by Fisheries and Oceans Canada from the Institute of Ocean Sciences. It embodies the interests and collaboration of several other organizations:

- Canadian Programme of Energy Research and Development: Northern Regulatory Research Programme: Changing sea ice constraints on hydrocarbon development in Canada's Arctic (NRCan via PERD B21.002)
- Canadian Programme of Energy Research and Development: Regional assessment of geohazards related to deep water hydrocarbon development, Beaufort Sea outer shelf/upper slope (NRCan via PERD B21.003)
- Geological Survey of Canada: Pacific Geoscience Centre (Scott Dallimore): Marine geohazards
- 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 Jim Overland): Same interest as CRREL
- ArcticNet: Beaufort Region Environmental Assessment (AANDC via BREA)

Objectives

One primary objective of this expedition was the recovery, servicing and re-deployment of internally recording instruments on sub-sea moorings – “ocean observatories”. 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, acoustic back-scatter from plankton and sedimentation. There were 8 moorings for recovery during this leg (2 of about 650-m length; others less than 100 m) and 12 for deployment (including 3 of about 650-m length).

The other primary objective was the investigation of features on the seabed identified through study of a detailed bathymetric map of the outer shelf and slope of the Beaufort Sea acquired by multi-beam sonar. The map is the outcome of surveys funded by Government and the oil industry during the last few years. The investigation involved use of a Huntec shallow seismic profiling system, an ROV for visual exploration, piston and gravity corers and bottom grabs for sediment sampling.

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. Properties of surface water were to be measured continuously in water pumped from one of the ship’s sea bays to the main lab (temperature, salinity, chlorophyll fluorescence). The CTD probe with added sensors for dissolved oxygen, light transparency and chlorophyll fluorescence was to be used to measure ocean profiles, mainly at the sites of sub-sea moorings.

Ocean Observatories

Observations by autonomous instruments on oceanographic moorings provide continuous year-round ocean data that complement the detailed but short-lived surveys conducted from ships. The moorings enable affordable long-term, monitoring of the oceans that surround Canada.

DFO’s long-term sites (ocean observatories) are on the Mackenzie shelf north of the Delta and on the Chukchi Plateau. Activity this year includes the additional new ocean observatories, five in deeper water over the continental slope and one in shallower water in the Kugmallit sea valley. The former are supported by Aboriginal Affairs and Northern Development Canada as part of the Beaufort Region Environmental Assessment and other partners. All enhance the multi-national Arctic Ice Monitoring Project (AIM), active under the umbrella of the Arctic Climate System Study, the Climate and Cryosphere Study and the International Arctic Ocean Observing System, sponsored by the WCRP (World Climate Research Program) and the International Arctic Science Committee (IASC).

Through careful choice of instruments for moorings we are acquiring intriguing and ecosystem-relevant views of the polar ocean at times when humans cannot be there. Upward-looking sonar at the top of the mooring measures ice thickness and topography, revealing the presence of ridges, level ice and ecologically important leads; during the summer months, the sonar switches into a second mode to measure storm waves and surges (important to ocean mixing, to safety on shore and at sea). Doppler sonar positioned near the seabed measures ice drift and ocean current at all depths, revealing opening and closing of the flaw lead in winter and the upwelling of nutrient rich water into the photic zone. The strength of the echoes received by Doppler sonar reveals the ever changing distribution of zooplankton in the water column. Ambient sound recorders provide continuous recordings of sounds from marine mammals (e.g. bowhead, beluga, bearded seal, walrus), human activity (e.g. aircraft, shipping, distant seismic survey) and natural processes (ice fracture, ridge building, wind waves, blowing snow, seabed gas venting). Sediment traps sample the rain of settling particles, some of which are organic material linked to biological processes and others which are terrigenous matter supplied via erosion from river banks, shorelines and the seabed. Conventional sensors for seawater temperature and salinity revealed the seasonal cycles in shelf-water properties driven by heating, cooling, freezing and weather events.

The oceanographic moorings comprising BREA's ocean observatories were all long taut-line assemblies, with in-line buoyancy and steel deadweight anchors. The following instruments were supported by these moorings at various depths in the water column:

- Ice Profiling Sonar (IPS) at 60-m to measure ice draft, supported in a cage with 8 Viny 12B3 floats
- 150 kHz Quarter Master ADCP at 150-m to measure ice velocity & current at 8-m depth intervals
- 75 kHz Long Ranger ADCP at 480-m to measure current at 16-m depth intervals; both QM & LR ADCPs were housed in 40-inch floats of syntactic foam (Flotation Technologies)
- Nortek Aquadopp DW (AQD) current meters at 100-m intervals below 500-m depth
- Brancker XR420 conductivity-temperature loggers
- 2 Technicap PPS 3/3-24S 24-cup sediment traps between the IPS & LR-ADCP at BR-A, BR-G & BR-1
- Acoustic transponding releases in tandem on each mooring, for location and recovery
- 1-MHz Nortek Aquadopp profiling current meters (AQP) at the bottom of moorings BR-B-11 & BR-02-11 to record current and acoustic backscatter at 2-m intervals to 14 m above the seabed
- Sequoia LISST 100X laser diffraction systems near the AQP measuring particle size & concentration
- 2-MHz Nortek Aquadopp 3000 current meters at BR-A-11 & BR-G-11, for 3D currents near the seabed

Study of Geological Hazards beneath the Beaufort Sea

With imminent plans for exploratory hydrocarbon drilling on the outer shelf and slope of the Beaufort Sea, there is a need to identify and understand the offshore geological hazards that may constrain these plans.

The outer shelf is underlain by thick terrestrial permafrost which has been flooded by relatively warm seawater via rising sea level since the Ice Age. Since deeper waters were never exposed to the cold atmosphere during the Ice Age, the permafrost disappears beyond about the 110-m isobath, which is slightly past the shelf break in the Beaufort.

Gas hydrates are ices wherein some of the water molecules in the crystal lattice have been replaced by methane molecules, or occasionally by hydrocarbon gases of higher molecular weight (ethane, propane, butane, etc). Gas hydrates are not stable at normal atmospheric pressure and temperature; under such conditions they decompose spontaneously into methane and water. However, they do exist as stable solids at higher pressure and/or lower temperature. Gas hydrates exist beneath the Beaufort Sea in two circumstances, as conventional marine gas hydrates in the deep water over the continental slope where high pressure (more than 30 atmospheres) makes them stable, and as permafrost gas hydrates in shallow water over the continental shelf where low temperature and slightly higher pressure (more than 3 atmospheres) bring stability. Exploration for conventional hydrocarbons is occurring in both these hydrate-prone zones.

Warming and possible thawing of the permafrost as a consequence of the flooding may weaken surface sediment causing subsidence and slope failure. Gas hydrates associated with permafrost (shallow gas hydrates whose stability is controlled by low temperature) will also be affected, with similar consequences for seabed stability and possible release of free gas. Between the outer edge of sub-sea permafrost (near 110 m) and approximately 200 depth, gas hydrates are absent, but they recur further offshore in deeper water in conventional form, where their stability is controlled by high pressure. Such deposits may be associated with several wide (1 km) flat circular features seen on the seabed in sonar imagery.

Recent field studies, including those conducted from Sir Wilfrid Laurier in 2003 and 2010, have documented release of methane from the seabed of the outer shelf and slope. Gas discharges have been observed from Pingo-Like Features (PLFs) on the shelf, from an area of widespread instability (including large landslides) at top of the continental slope transition near 100-m depth and from large conical expulsion features on the upper slope. From these observations, we infer that this is a unique geologic setting where the liberation of free gas and pore water, with associated strength reduction and deformation of subsurface sediments, is occurring via permafrost and gas hydrate degradation.

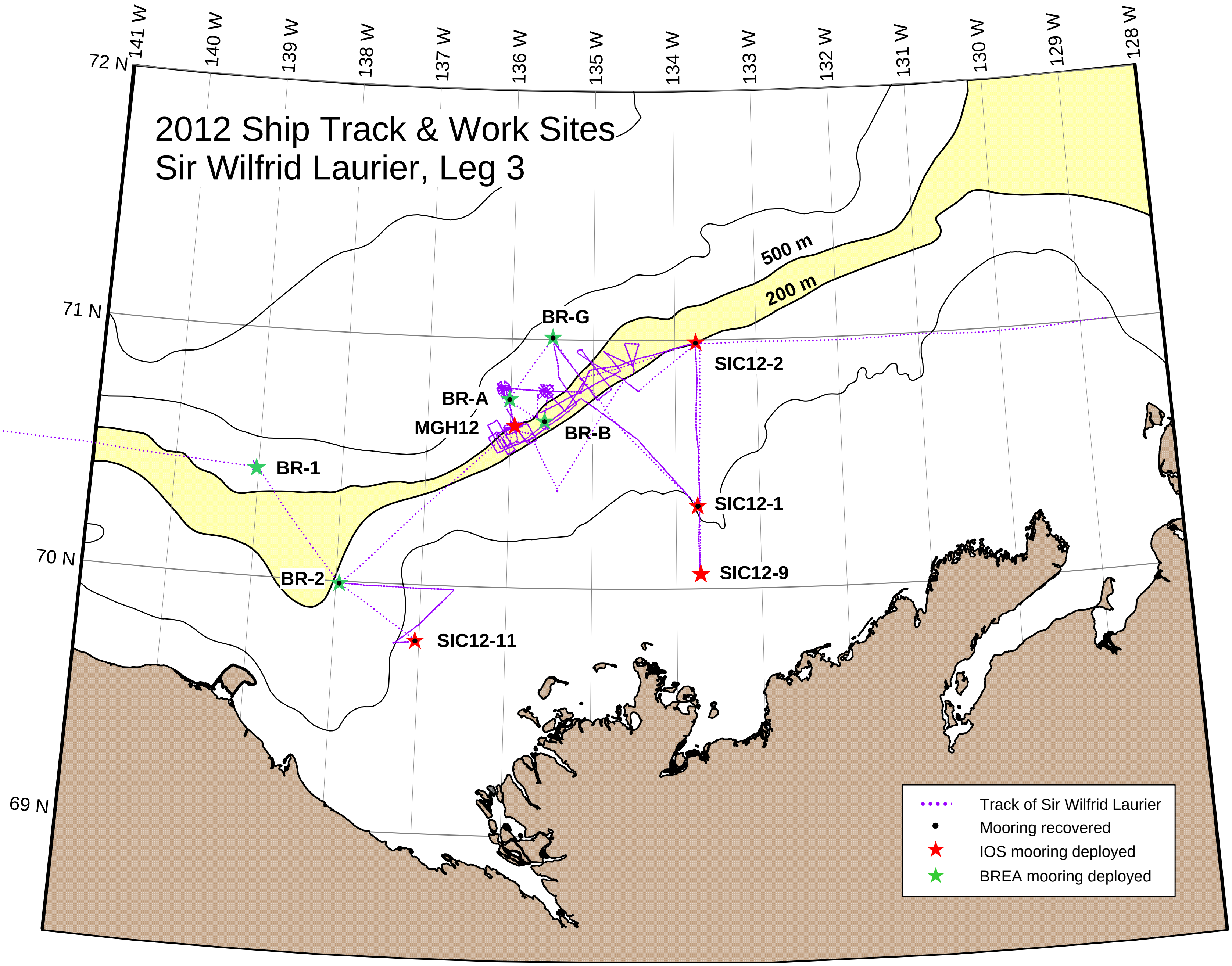
The marine geohazards component of the Laurier's science programme this autumn studied methane seeps on the Beaufort seabed and their relationship to sub-sea permafrost and hydrates, pingo-like features and marine geohazards. Objectives during the 2012 study from Sir Wilfred Laurier were the assessment of methane venting and seabed instability associated with disturbed gas hydrate, and the investigation of possible occurrences of unique biological communities at vent sites. Ultimately, the project will advise the regulatory process concerning the hazards of gas hydrates for oil drilling and production.

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; symbols mark work sites. The dark shaded area approximates the domain of pack ice at greater than 4 tenths concentration on 3 October 2011. The lighter area extending beyond it delineates new ice on the same date..

The following list summarizes our activities and accomplishments:

- 4 short oceanographic moorings that form DFO's long-term observatories in the Beaufort Sea were successfully recovered after 12 months at sea. All instruments yielded full data records
- 4 longer oceanographic moorings that form BREA's new observatories in the Beaufort Sea were successfully recovered after 12 months at sea
- 6 short oceanographic moorings were deployed as an enhanced implementation of DFO's long-term observatory programme in the Beaufort Sea
- 5 short oceanographic moorings were deployed as an enhanced implementation of BREA's observatory programme in the Beaufort Sea
- 1 mooring was deployed on the Coke Cap expulsion feature carrying instruments to measure the release of gas from the structure and its varying thermal environment during the next 12 months
- 16 CTD casts were completed, principally at sites of oceanographic moorings. The CTD with extra sensors recorded pressure, temperature, conductivity, dissolved oxygen, light transmission and chlorophyll fluorescence.
- Measurements of salinity, temperature and chlorophyll fluorescence in surface water drawn from the ship's sea-bay, at 10-second intervals along the science cruise track (16 days), and continuing on to Victoria from Prudhoe Bay via Dutch Harbor AK (15 days)
- 950 km of survey using the Huntec shallow seismic system (3-kHz chirp sonar) operated from a submerged towed body and the 12-kHz ship-mounted sonar to detect rising gas bubbles
- 9 piston cores, 20 gravity cores and 2 IKU grabs
- 8 dives of the ROV at 8 sites of interest, in water depth ranging between 100 to 780 metres, each yielding 2-4 hours of seabed video, for a total of survey track of 4 km.


2012 Ship Track & Work Sites
Sir Wilfrid Laurier, Leg 3
141 W
140 W
139 W
138 W
137 W
136 W
135 W
134 W
133 W
132 W
131 W
130 W
129 W
128 W
72 N
71 N
70 N
69 N
500 m
200 m
BR-G
SIC12-2
BR-A
MGH12
BR-B
BR-1
SIC12-1
SIC12-9
BR-2
SIC12-11
Track of Sir Wilfrid Laurier
Mooring recovered
IOS mooring deployed
BREA mooring deployed

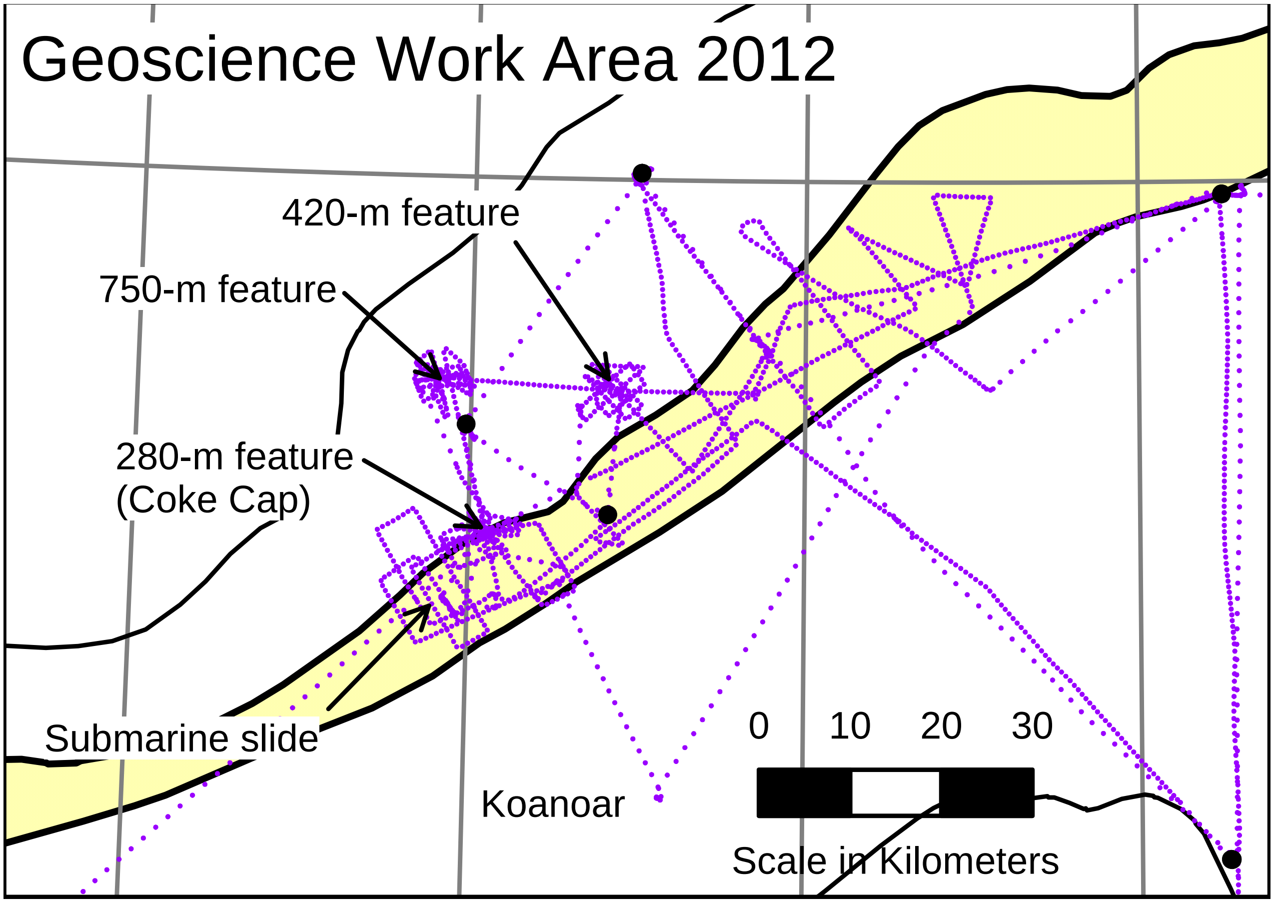


Figure 1. Geoscience work area during Leg 3 of Laurier's 2012 Arctic Patrol. Close spacing of plotted ship's positions is indicative of a survey line, at which time the ship's speed was reduced to less than 5 kt to tow the Huntec submerged body.

Activities of the Science Programme

Observations while Underway

Pumped seawater system

Continuous measurements of basic ocean properties at about 2-m depth were acquired using a thermo-salinograph and a "gas box", both of which incorporate electronic sensors to measure the properties of water pumped from a sea bay. The sensors (Sea Bird SBE45/SBE38 for temperature, salinity and chlorophyll fluorescence) and the computers for logging data on through-flowing seawater were installed against the aft wall in the main science laboratory. The exception was a thermistor at the seawater intake to measure temperature before water was heated by contact with ship's machinery.

Water was piped to the lab 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 in 2010 to be 30-60 seconds. 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.

These measurements provided routine mapping of basic properties of ocean surface waters, useful to place more elaborate site-specific observations in a variable regional context. The properties of interest were sea-surface temperature, salinity, dissolved oxygen, carbon dioxide, nitrogen and methane and chlorophyll fluorescence.

From time to time we withdrew samples of seawater via the manifold in the science lab. These samples were stored and transported to IOS for analysis.

The flow rate through the system was adjusted to about 4.8 litres per minute. Slower flows did not properly flush the fluorescence sensor..

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 high power rating and low frequency of this sounder provides the capability to measure full ocean depths via a hull-mounted 12-kHz sonar transducer.

Unfortunately, the out-dated Simrad sounder does not allow access digital to the detected echo strength. During this mission we connected an IOS sounder with digital recording capability to the hull-mounted transducer via the installed cable to the hydrography lab. This sounder was used to record echoes from gas bubbles rising through the water column from vents at the seabed.

This sounder was operated in tandem with the Huntec (below).

Sub-bottom profiling using the Huntec deep-tow body

The Huntec 3.5-kHz sub-bottom profiler is a deep-towed geophysical system. It was deployed from the foredeck of Sir Wilfrid Laurier via a pulley suspended from the derrick over the starboard side. The tow-fish, which has been widely used for many years and is proven to be very stable under tow, was monitored continuously during operation to ensure that its depth and position did not compromise navigation. The optimal ship's speed was about 4.5 knots.

With a starboard-side deployment of the tow fish, all turns to complete the mapping pattern were to starboard. The necessary adjustments to the tow depth during turns (and also with shoaling of the seabed) were made using the electrically powered controlled Huntec winch mounted on the port side of the well deck near the foc'sle. The Huntec system was operated by an experienced contractor (Geoforce Consultants Ltd) from within the 20-foot green-container workshop on the foredeck.

Huntec surveys were conducted during off hours. The length, orientation and spacing of survey lines varied with the geological feature under study. Since core sites were selected with guidance from Huntec surveys, such surveys were the first stage of the geophysical investigation.

About 950 line kilometres were surveyed using the Huntec system. It performed well and provided providing sub-bottom profiles of excellent quality.

Figure 2. Huntec towed body used for shallow seismic surveys.

CTD and Rosette Casts

The CTD-rosette was deployed to measure vertical profiles of temperature and salinity (and other variables) at the site of each mooring. In situations where the delay between recovery and redeployment exceeded 12 hours, a second CTD profile was taken at the mooring site. The time required to complete a CTD cast was about 15 minutes.

The 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 (under manual or automatic 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 sampling rosette was not used to collect water samples this year.

We use the CTD profile to calculate an accurate depth profile of sound speed, essential to the accurate calibration of ice thickness derived by sonar.

Sediment from the Seabed

Samples of sediment were collected via three methods, grab sampling, gravity coring and piston coring.

An IKU grab was used to collect bulk samples of surficial sediment. Solid carbonate concretions, shells and coarse granular material were of interest. The grab was deployed at sites that had been identified as candidates for the presence of such material through inspection using the ROV

The collection of long sediment cores was variously accomplished using a short gravity corer, or using a gravity corer in tandem with a long piston corer. The piston coring apparatus (Benthos Systems , 1-tonne core head) was deployed via the derrick and the A-frame on the foredeck of Sir Wilfrid Laurier. A 50-HP work winch mounted on the port side was used to lower the apparatus on ½” steel wire to the seabed. This is the first time that such equipment has been deployed from Sir Wilfrid Laurier.

A10-foot workshop container on the port side of the well deck was the staging area for coring activity – storage for core liner, recently acquired cores, tools, supplies – and a work area for the chop saw, liner splitter, temperature measurements, etc. The container was equipped with hazard sensors for methane and hydrogen sulphide.

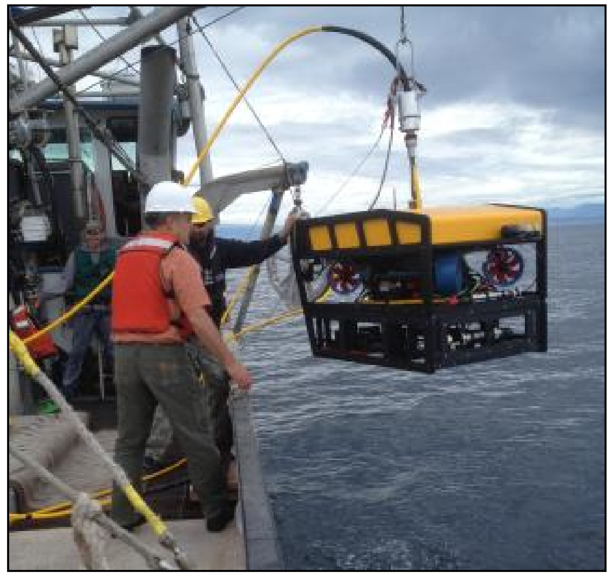
Cores were acquired at and near sites where gas was venting at the seabed. The initial selection of sites was based on interpretation of a rich source of legacy data – industry’s seismic surveys and exploration bore holes, recent mapping by swath-imaging sonar and 3 kHz sub-bottom profiling.

Samples of pore water were withdrawn at intervals from all collected cores. Small holes drilled in the liner for the extractions were sealed and the core sections were transferred to cool storage 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.

The gravity corer acquired shorter columns of near-surface sediment for classification and analysis. Conditions varied from relatively hard shelf sediment to soft mud around pingo-like features, allowing penetration of 1-4 m.

Cores were collected in water as deep as 750 m, requiring about 60 minutes. The time to extract a collected core and prepare the apparatus was up to 90 minutes.

Dives by Remote Operated Vehicle (ROV)



The remotely operated underwater vehicle pictured at the right was used for close inspection of the seabed and of escaping bubbles at sites of gas venting. The ROV, built recently by the Monterey Bay Aquarium Research Institute (MBARI), was specifically designed for Arctic ship-of-opportunity operations. Its attributes and dive depth (1000 m) were much improved beyond those of the Phantom ROV used from Sir Wilfrid Laurier in 2003 and 2010. It was equipped with high-definition underwater cameras, imaging sonar and a gas sampling apparatus.

The purpose of the dives was to document the release of gas at the seabed and to acquire samples for analysis at their source. In the process, we evaluated methods for ROV application to this research, experience to be used to develop improved techniques for future studies.

We completed ROV surveys at 8 locations where intriguing seabed features or gas plumes had been identified. The cameras and imaging sonar were used to for gas vents whose emissions had been detected by ship-based sonar. Once located, the ROV's cameras were used to appraise the character of gas release (bubble size and frequency of emissions) and to map the gas release site, determining for instance whether gas was released from orifices or cracks in the sea bed, whether unique chemo-synthetic biological communities were linked to the vents and whether methane-derived authigenic carbonates could be seen.

The gas sampling apparatus captured bubbles in an inverted funnel as they rose from the seafloor; it subsequently reversed the formation of gas hydrates by heating the collection funnel and then withdrew the natural gas into a 125-ml pre-evacuated cylinder which was sealed at ambient pressure. The apparatus collected samples of volume large enough to allow complete characterization of the gases. It bypasses the undesirable fractionation of composition that normally occurs via degassing during sample recovery.

In deploying the ROV, the flexible load bearing umbilical was weighted (200 lb) to hang vertically from a block suspended over the starboard side via the main derrick. Between 10 and 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 weight was controlled by the purpose built umbilical winch, with the best depth being about 10 m above the seabed. Sir Wilfrid Laurier held station while the ROV explored the seafloor within roaming distance of the weight. The ship was then be moved a few tens of metres to provide access to a new area.

Figure 3. Electrically powered winch used to control the umbilical during dives by the ROV. The winch was mounted just forward of the hatch with a lead to a block suspended from the ship's derrick over the starboard side.

Oceanographic Moorings (DFO & collaborators)

Eight oceanographic moorings were recovered at seven sites. Three sites were in shallow (less than 120 m) water on the continental shelf and four were in deeper (160-700 m) water on the continental slope. The sub-surface moorings supported electronic instruments to measure and record data on ice thickness and ridging, storm waves, sea level, ocean current, temperature, salinity, plankton density, sedimentation, turbidity, ambient sound and marine mammal calls. The instruments had operated autonomously during the last 12 months, recording new data at intervals of 1 second (for ice) or 30-180 minutes (for ocean variables). All moorings were equipped with tandem release assemblies to provide redundant capability in acoustic ranging and detachment from the anchor.

In shallow (less than 50 m) water on the shelf of the Canadian Beaufort Sea, we must use short moorings to support instruments close to the seabed, remote from the hazards of moving ice. In deeper water (Beaufort shelf edge and beyond) we can secure instruments on a single taller mooring, provided no component extends above 30-35 m depth.

Twelve moorings were deployed at ten sites, the seven original sites plus three new ones. In most cases, recovered moorings were replaced using duplicate instruments and components to minimize the demand on ship time.

Recovery of moorings

Oceanographic moorings were recovered via acoustic activation of the 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 30 m. Our moorings were equipped with tandem releases for increased reliability. A successful recovery was 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 could surface.

The recovery of a mooring in ice-prone waters sometimes requires that the ship wait near the site until an opening in the drifting pack ice is appropriately positioned. The need to access particular locations and to wait for suitable ice conditions for mooring recovery can demand patience, tactical flexibility and luck.

In 2012, we had no need to stand by for ice. However, difficult conditions linked to strong wind and high waves were encountered and delay and inefficiency were the consequences. In the absence of obstruction by ice or weather, our moorings can be recovered in 30-60 minutes.

Moorings recovered during Leg 3

Station	Area	Latitude			Longitude			Water depth (m)	Buoyed levels	Instruments
SIC11-2	Shelf edge central	70	59.249	N	133	44.785	W	113	2	IPS5, NB-ADCP, SBE37
SIC11-1	Shelf central	70	19.940	N	133	44.485	W	54	1	NB-ADCP, SBE37
SIC11-1	Shelf central	70	19.932	N	133	44.329	W	55	1	IPS5
SIC11-11	Shelf western	69	46.475	N	137	02.729	W	35	1	W-IPS4, SBE37
BR-A-11	Slope western	70	45.378	N	136	00.828	W	660	4	IPS5, 2xADCP, 4xXR420, 2xTechnicap, AquaDopp
BR-B-11	Shelf edge western	70	40.200	N	135	35.160	W	156	3	IPS5, ADCP, 2xXR420, LISST, AquaDopp
BR-G-11	Slope western	71	00.402	N	135	29.994	W	701	5	IPS5, 2xADCP, 4xXR420, 2xTechnicap, 2xAquaDopp
BR-2-11	Shelf edge western	69	59.466	N	137	57.630	W	157	3	IPS5, ADCP, 2xXR420, LISST, AquaDopp

Deployment of moorings

We work with two types of moorings: 1) short (3-5 m long) moorings that can be lifted completely by the crane, lowered to the surface and released to fall to the seabed; 2) longer (up to 2000 m) taut-line moorings with several levels of instrumentation and floatation, which are assembled on the deck and drawn progressively away from the ship by the FRC (fast-response craft) as components are lifted over the side. The last lift is the release assembly with deadweight anchor, which is dropped when the mooring line is straight (no loops) and no longer attached to the FRC.

The time required to deploy two short moorings was about 15-30 minutes. Longer moorings required between 30 minutes and 2 hours, depending on complexity (number of lifts) and sea state.

It was desirable to determine the resting positions of moorings that were dropped in water deeper than 150 m. To do this, the ship was taken to three locations around the drop site, each about twice the depth from the site, and the slant range to the release transponders was measured acoustically. This triangulation procedure required as much as an hour of additional station time.

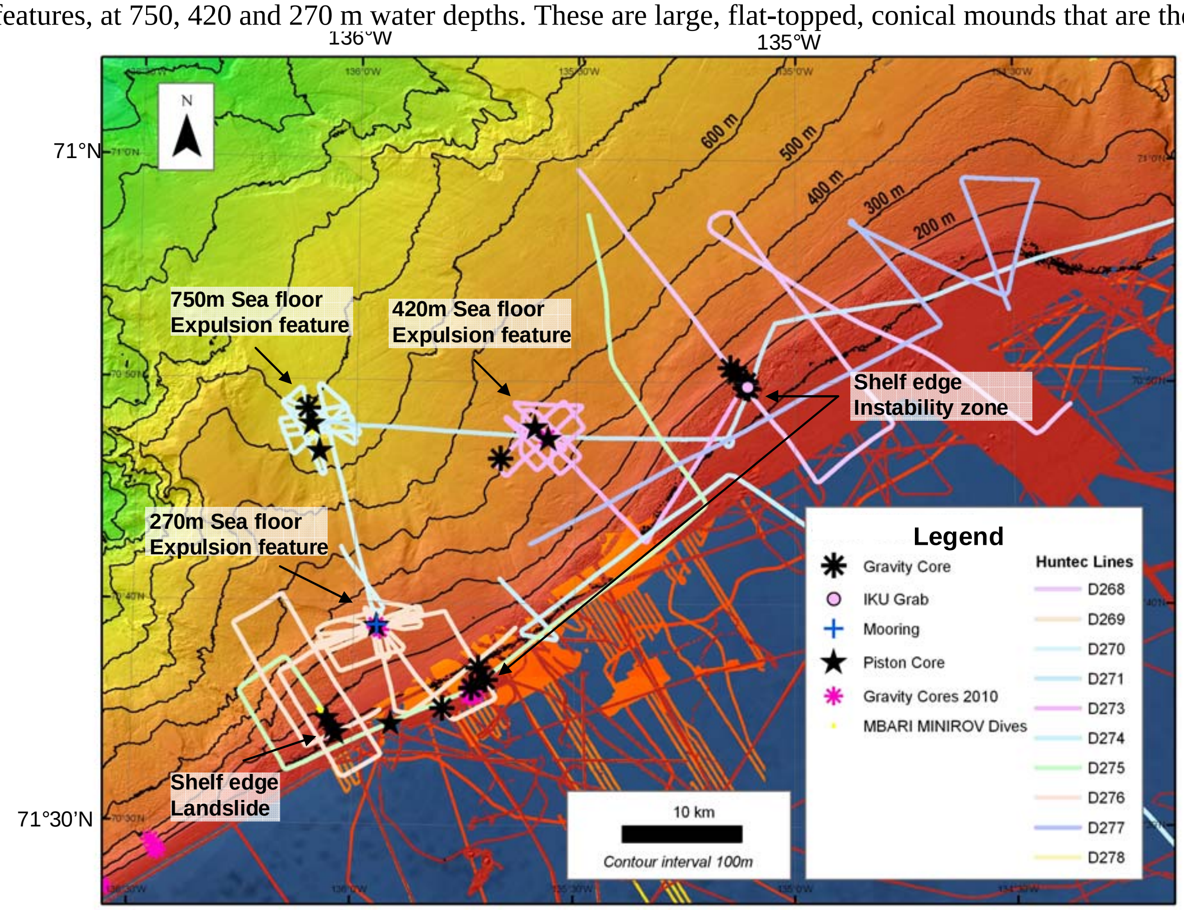
Preparation of moorings

The mooring team used the ‘tween-decks space in the hold of 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 beneath the davits on boat deck (starboard side).

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 for most instruments were completed in the North during a separate, earlier visit. There was no opportunity this year to complete the swing of the compass used at site SIC12-9; this must be done after recovery but before re-furbishing the instrument in October 2013.

Geological studies

Research was focussed on six features on the outer shelf and upper slope. Three were seafloor expulsion features, at 750, 420 and 270 m water depths. These are large, flat-topped, conical mounds that are thought to



be the consequence of upward movement of sediment, pore water and gas from depth. Other sites were associated with a terrain-failure feature at the shelf -slope transition. This zone of instability occupies a broad area with disturbed hummocky topography interspersed with small sediment expulsion features and depressions. Additional Huntec surveys were competed in the Mackenzie Trough to study its surficial geology.

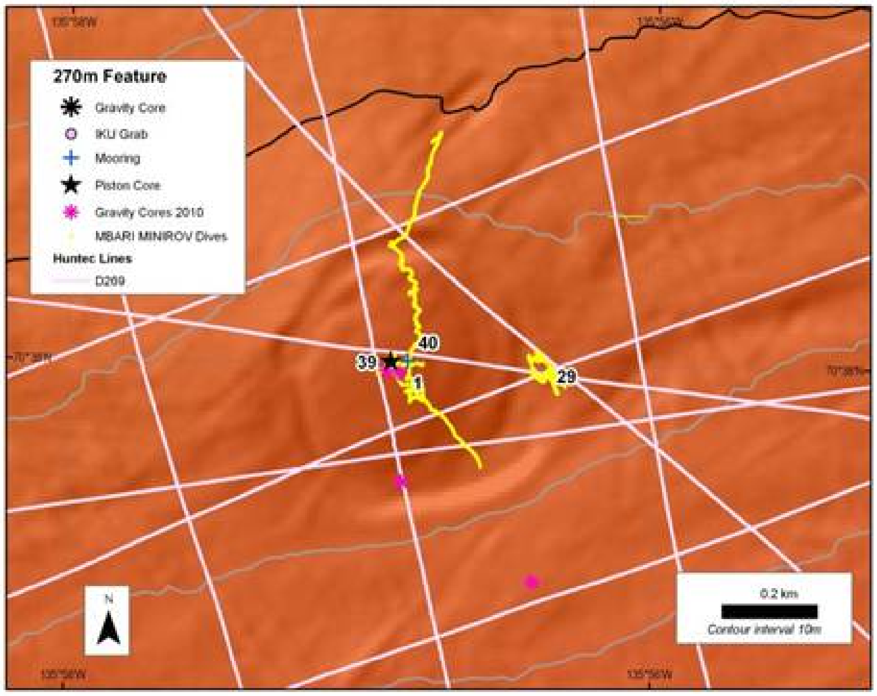


Figure 5. Huntec lines, ROV dives and piston coring over the expulsion feature at 270-m depth.

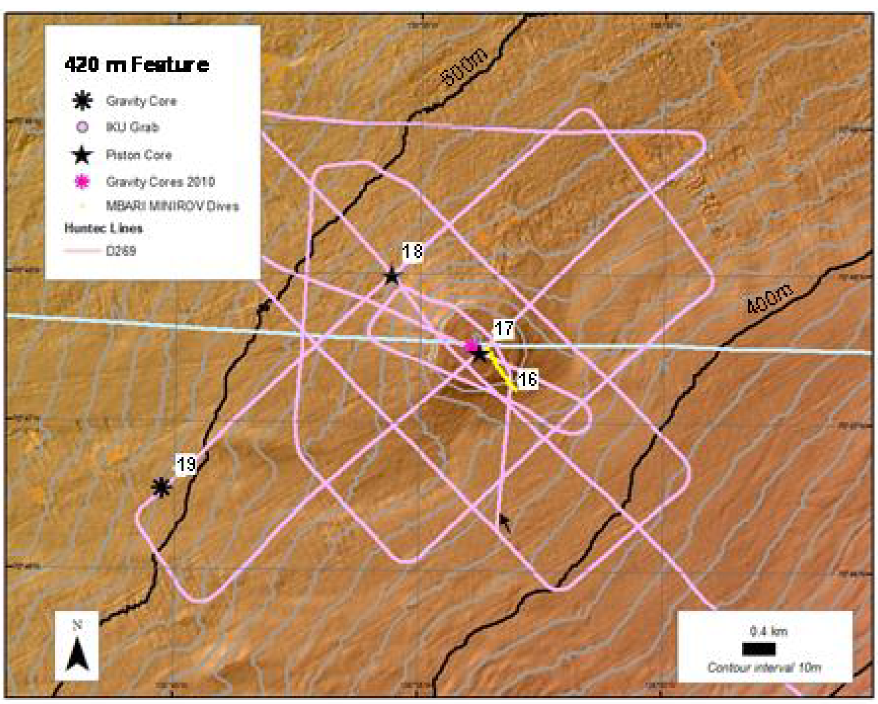


Figure 4 . Huntec lines, ROV dives and piston coring over the expulsion feature at 420-m depth.

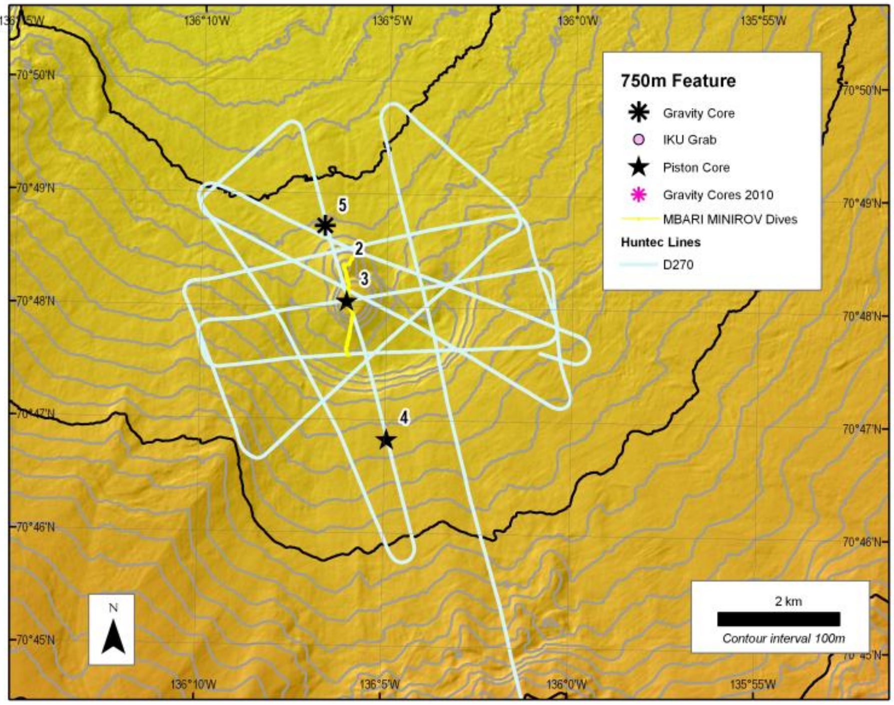


Figure 6 of Huntec lines, ROV dives and piston coring over the expulsion feature at 750-m depth.

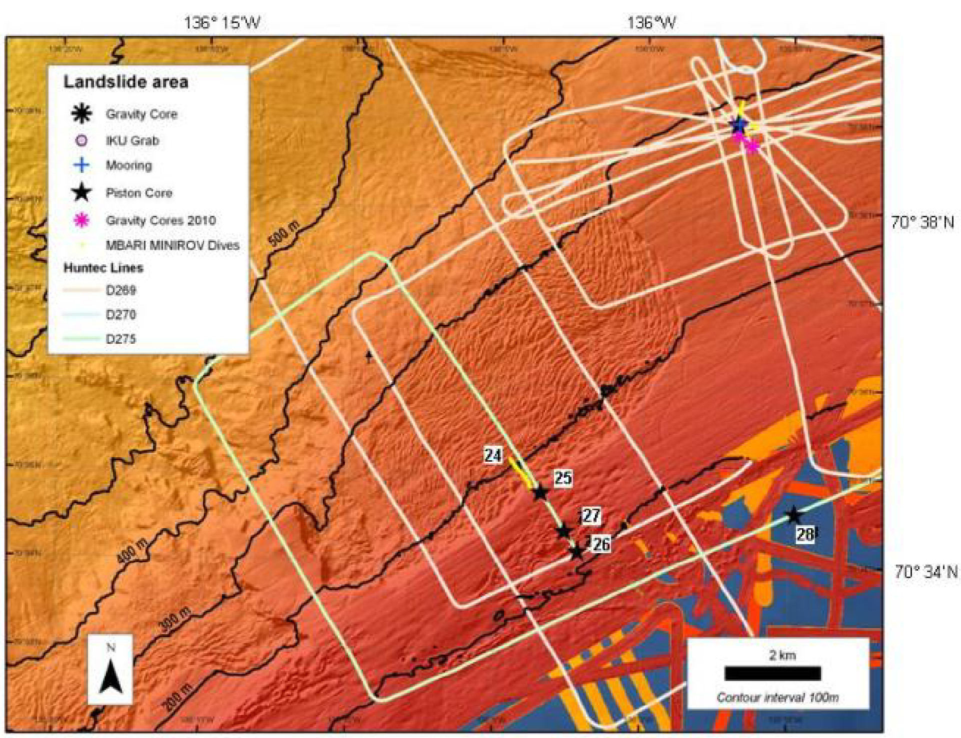


Figure 7. Huntec lines, ROV dives and piston coring over the shlf-edge landslide feature.

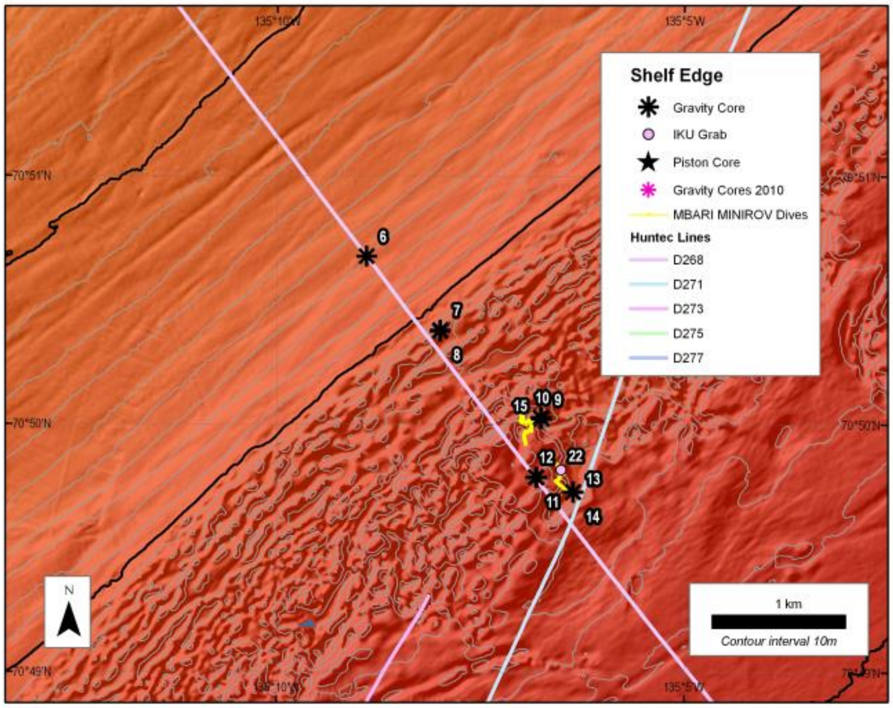
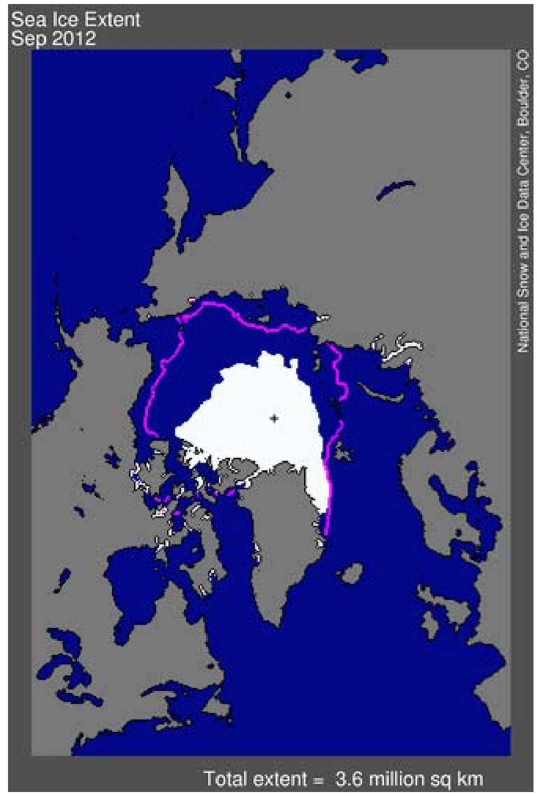


Figure 8. Huntec lines, ROV dives and piston coring over the shelf-edge instability zone.

Figure 9. Huntec lines, ROV dives and piston coring over the shelf-edge instability zone.

Ice conditions across the Arctic, September 2012



The map at the right displays the average extent of pack ice during September 2012, measured from satellite via the thermal emission of microwaves; ice and water have greatly different emissivities (http://nsidc.org/data/seaice_index/). In the data set from NSIDC, ice extent is the area within which the concentration of ice is at least 15%. As for the last few years, the ice edge in September 2012 was well to the north of its 30-year median position (magenta line) everywhere in our operating area. Sir Wilfrid Laurier encountered no pack ice. Only off the east coast of Greenland was the edge of sea ice close to its long-term median position at this time. Conditions this year were similar to those in September 2011 in this respect.

Ice extent reached its annual minimum of 3.29 million km^2 on 16 September, a value 18% below the previous record of 4.05 million km^2 on 18 September 2007. The average extent of ice during September was 3.6 million square kilometres.

Impact of ice and weather

Ice had no direct impact on completion of the science plan in 2012. However, long fetches for wind, created by the extreme retreat of ice, did allow a persistent swell in our working area which was supplemented at times by a moderate wind sea.

On 22 September in Amundsen Gulf, Sir Wilfrid Laurier was slowed to 3-4 kt by a 40-kt head wind and 4-m seas. Swell and wind the next day at Site 2 were judged too high to attempt planned mooring work. On 27 September, a day-long loop through Sites 2, 1 and 9 was largely unproductive because of 25-kt wind and swell; moorings could not be recovered or deployed at Sites 2 and 1, but two short moorings at Site 9 were placed successfully. On 2 October, an attempted ROV dive at Coke Cap was aborted because of hazardous sea state and excessive ship's drift with 25-kt south-east wind; piston coring was also impractical, but useful seabed samples were collected with the less cumbersome gravity corer. .

Air temperature was typically in the 3-5°C range for the whole trip – no complaints here. The normal range at this time of year is about 5°C lower.

Setbacks

Erratic logging of thermo-salinograph data

When logging of data from the thermo-salinograph was re-started at Cambridge Bay, the Acer laptop computer crashed repeatedly within a few minutes of initiation. Things went better when the Acer was replaced by a Lenovo laptop; logging could be fault-free for as long as 24 hours, but sooner or later (digital) noise appeared on all channels; however the Lenovo computer did not crash.

Experimentation revealed that this noise could be eliminated simply by stopping and re-starting the SeaSave logging programme. A loss of synchronization with the serial data stream was thus suspected. The KeySpan USB-serial connection was then replaced with a Aten Model UC-232A, with no improvement. A Dynex DX-UBDB9 was then tried, with no improvement. Finally, the use of an Easy Sync ES-U-1001-R100 adaptor did cure the problem. The Acer was returned into service with no ill effect. Apparently, the FTDI chip used in the Easy Sync adapter is better compatible with Sea Bird equipment than is the Aten chip in the others.

A different fault arose when the GPS feed via LAN to the logging computer failed shortly after we left the ship. The position became "frozen" at 71.62900°N, 157.48516°W after 15:16 utc on October 6 when just past Barrow AK. The failure occurs in the file: Start-up on 05Oct (At 146 36 W).hex. In consequence, the ship's position will have to be borrowed for the TSG during Laurier's journey home (samples every 5 seconds). The TSG data are fine.

Malfunctions of moored instruments

Narrow-band ADCP s/n 506 at SIC11-2:

The data in this instrument was recorded in 96 files. Only files numbered 81 and higher were of the expected length (293 kb). Lower numbered files were of various lengths: all those numbered evenly contained no data; those with odd numbers contained varying amounts of data. No data were lost; indeed the first ensembles in odd numbered files were frequently duplicates of data in the preceding odd numbered file. Since only the first 2-Mb of recorded data were affected in this way, malfunction of the memory card in the first slot is suspected.

Incomplete data recording during October 2011 through September 2012

In most cases the instruments placed on BREA moorings returned full records from the 12-month deployment. However shorter records were acquired by some instruments because the battery capacity was insufficient; these included two LISSTs and a Long Ranger ADCP, each operating about 8 months, and two Quartermaster ADCPs which stopped after 10-11 months.

Corrosion of stainless steel

Corrosion was again an issue with stainless shackles on Technicapp sediment traps. The cause appeared to be contact with a galvanized pear ring used for lifting the trap, which was not isolated from the stainless support post and shackle. This problem was corrected before re-deployment.

All anodes on the LISST cage (mooring BR-B-11) were consumed via corrosion, allowing some damage to the LISST housing (anodized aluminum) and to the stainless steel pins that secure the bio-block motor. The anodes on the instrument itself were only partially corroded.

No samples from a sediment trap

The motor of the lower sediment trap on mooring BR-G-11 flooded. The carousel was positioned at cup #1 beneath the funnel opening and did not turn further. The funnel was clogged with sediment.

Time-variable gain for the 12-kHz sounder

The Simrad hull-mounted 12-kHz transducer was driven via an echo sounder from IOS. Data were logged to a laptop computer using the Sounder.exe programme provided by Svein Vagle. Unfortunately this programme and its interplay with controls on the echo sounder were poorly documented, particularly in relation to gain control. It seemed too easy to saturate the amplifiers leaving very little dynamic range. Moreover, the time-variable gain behaved quite strangely; standard inverse-square and exponential corrections did not seem to be available; it was not clear whether adjustments were prescribed for amplitude or intensity.

The processing overheads within the programme were not documented. This may it difficult to choose operating parameters that optimized the characteristic of the recording for the domain under study.

Although Sounder.exe could replay recorded data, this was only possible for files that closed at the specified size. Files that were smaller because of changes to operating parameters, or system crash, were inaccessible for viewing.

In consequence, the quality of the digital records from this sonar was not good. It is recommended that all these shortcomings before reusing this setup.

Successes

All 8 moorings deployed from Sir Wilfrid Laurier and from Amundsen in 2011 were recovered. All IOS instruments yielded full records of data. Almost all instruments in the larger suite deployed on BREA moorings returned full records; 5 stopped 1-4 months early and only 1, a sediment trap, failed almost immediately after deployment via flooding. Because the risk of loss or malfunction in ocean mooring projects is always present, this year's high level of success is cause for congratulation. The data from these moorings contribute to the continuing record of sea ice and ocean in the Beaufort Sea, which is continuous over 22 years at some sites.

Twelve moorings were placed at 9 sites, as planned. New sites offer the promise of more complete regional coverage in the years to come.

Two BREA moorings delivered the first time-series data from the Beaufort on the size distribution of suspended sediment particles, using the novel LISST instrument.

A 10-m piston-coring apparatus was deployed for the first time from Sir Wilfrid Laurier. It was used for the successful collection of 9 cores. A sample of near-surface sediment was acquired on each of these drops by the gravity corer that is part of the piston-coring apparatus. 11 gravity cores were acquired at other sites. 2 samples were collected using the IKU grab.

8 ROV dives were conducted, yielding hours of video for geological & biological characterization, over a combined survey path of 4 km.

Samples of gas were collected by ROV at in situ pressure from active vents

950 km of Huntec survey were completed, during the first deployment of this apparatus in the Beaufort Sea

Buried glacial till was detected on the upper continental slope and subsequently inspected by ROV video and sampled by the IKU grab. This is direct evidence of the presence of an ice sheet over the Mackenzie shelf during the Ice Age. This discovery throws the previously accepted non-glaciated character of this area into question.

Issues of Concern 2012

<u>Deployment of the piston corer</u>

The piston corer was used with a 30-foot core barrel. It was prepared on supports laid out on the starboard side of the foredeck, where it sat parallel to the rail between the hatch and the A-frame. It was lifted from the deck using two picks on the main derrick; the one doing most of the lifting was attached to the coring weight; the other was attached 2/3 of the way down the barrel. The corer had to be lifted in horizontal position to higher than the A-frame (i.e., 4-5 m) before it could be moved outboard over it, then lowered and secured to the ½-inch wire from the coring winch via the A-frame. Because of the great weight of the apparatus, and its uneven distribution, the manoeuvre was only possible in modest seas.

The practicality and safety of deploying the corer from Sir Wilfrid Laurier could be improved if the corer were stowed and prepared on supports placed between the A-frame and the rail. A safe lift of only a foot or so would then allow the corer to be moved over the side and the barrel promptly lowered into a vertical orientation.

I recommend that this possibility be explored before next use of the piston corer.

<u>Side towing the Huntec fish</u>

The fish can draw the line very close to the hull (and the screws) under certain conditions of wind, tow depth and ship's speed. It should be possible to adjust the trim tabs on the fish sow that it always tows out slightly to starboard.

Possibilities for improved control of the tow-fish should be explored. Some new capability to control how the fish flies should be installed before next use.

Heater in the rosette shelter

Fortunately, we had no reason to use the heater in the rosette shelter during this expedition; air temperature was always above freezing. However, the 4-kW electrical heater that was available in this work are has in the last year been replaced by a much bulkier heat pump. The larger unit impedes work around the sampling rosette and is a possible source of injury. Moreover, warm air is blown sideways from this unit at a height of almost 2 m. the heat therefore completely misses the parts of the rosette most needing it, which are mounted at the bottom of the rosette near deck level. The unit that was replaced directed heat downwards so that it spread over the deck and rose up through the rosette.

I recommend that possibilities for improving this setup be explored before next cold-weather use of the CTD-rosette.

Computer-instrument communication via USB-serial adaptors

As described earlier in this report, we several times encountered difficulties in communicating between scientific instruments and computers using USB-serial adaptors.

In some instances, the difficulties were traceable to the high baud rate – 115.2 kilobaud seems too fast for some laptop/USB-serial combinations. We had repeated difficulties communicating with ASL Environmental’s IPS5 and AWSP5 instruments at 115 kilobaud via USB-serial connections. With these instruments, the user has no control over the baud rate. Perhaps an update to allow user’s control should be sought?

In our most inconvenient malfunction, that in logging data from the thermo-salinograph, the USB-serial adaptor seemed incapable of staying synchronized with the serial data stream from the instrument. Eventually we found a USB-serial and laptop combination that worked with the thermo-salinograph. However, we were fortunate to have options on board that worked.

I recommend that we equip the thermo-salinograph of each ship at least two working options for logging data, so that full records can be obtained from Arctic cruises, even when the system is not monitored by scientists.

Applying paint

Science’s green container lab on the foredeck seems to be shedding paint: a green powder accumulates on the deck around the perimeter of the container during the course of the summer. I suggest exploring the implication of this paint ablation on the durability of this container.

The boom used to deploy sonar transducers at 4-m depth on the port side of the foredeck is rusting badly. It needs to be sand-blasted and painted to inhibit further degradation.

Information where it is needed

Both scientific and ship’s operations during this expedition had need to view information in one place that was collected by sensors in another. Examples include: soundings at 12-kHz sounder, logged in the aft lab but needed on the bridge to guide navigation; visualization of underwater bubble clouds, logged in the aft lab and needed in the green container to guide work with the Huntec system and the ROV, or on the deck to monitor the descent of the piston corer; ROV depth, position and heading, logged in the green container and needed on the bridge to inform ship manoeuvring.

I recommend discussion of possible solutions to these needs that have flexibility to meet changing interests and priorities of diverse scientific studies.

Suggestions from IMG-Golder personnel

The implementation of the mooring activity should be reviewed with the intent of staggering instruments so that those recovered can be brought back from the cruise for servicing and also be available for compass calibration (as needed). Such considerations would makes for a more streamlined process aboard ship in preparing moorings for deployment.

The use of silicone grease and duct tape to protect Impulse bulkhead connectors from corrosion of the power pin on RDI ADCPs appears to be effective in preventing leaks, and should be continued..

Care is required in the deployment of sediment traps in relation to the isolation of stainless steel components. Corrosion of stainless shackles could easily be the cause of mooring separation and loss. The galvanized steel lifting rings that were in direct contact with the stainless support should be removed from the sediment traps and replaced with a rope loop, as was done before deployments this year.

Particular care is needed with stainless steel cages and fittings to provide corrosion resistance and corrosion mitigation. Severe anode corrosion was observed on several stainless cages, especially the LISST cages on BR-B and BR-2. This will be especially important if long term deployments of more than 12 months are considered.

Use of vanes and swivels on all current meters should be considered to minimize variance in current direction during the acquisition of time-average data samples. Spinning of the mooring can compromise the accuracy of current measurement.

<u>Issues surviving from earlier years</u>

- This is needed to lower the heating bill for this container, and increase the level of comfort.
- Institute a routine test procedure for Y-cables and bulkhead connectors associated with use of external supplementary batteries for Work Horse ADCPs
- There was no malfunction from this cause during 2010-11. Apparently, our new practice last year of applying a thin layer of silicone grease to the connector’s seals has been effective in reducing leakage.
- Corrosion of stainless steel parts of the CART releases
- Only two of the CART releases recovered this year had appreciable damage from corrosion. These two were deployed before we rebuilt our inventory, with a generous application of “blue goop” to all components of stainless steel in close contact
- Both the seawater pump and the seawater drain for the thermo-salinograph operation freeze up when surface water reaches freezing temperature. We did have to shut down the system for several days when in ice on this expedition, for the first time in several years. This issue has yet to be addressed.
- Better results might be obtained by cementing the engine room sea-water temperature sensor with thermal-joint compound to the inside of the hull plating. The backside of the sensor should be heavily insulated with polystyrene foam from the warmth of engine room.

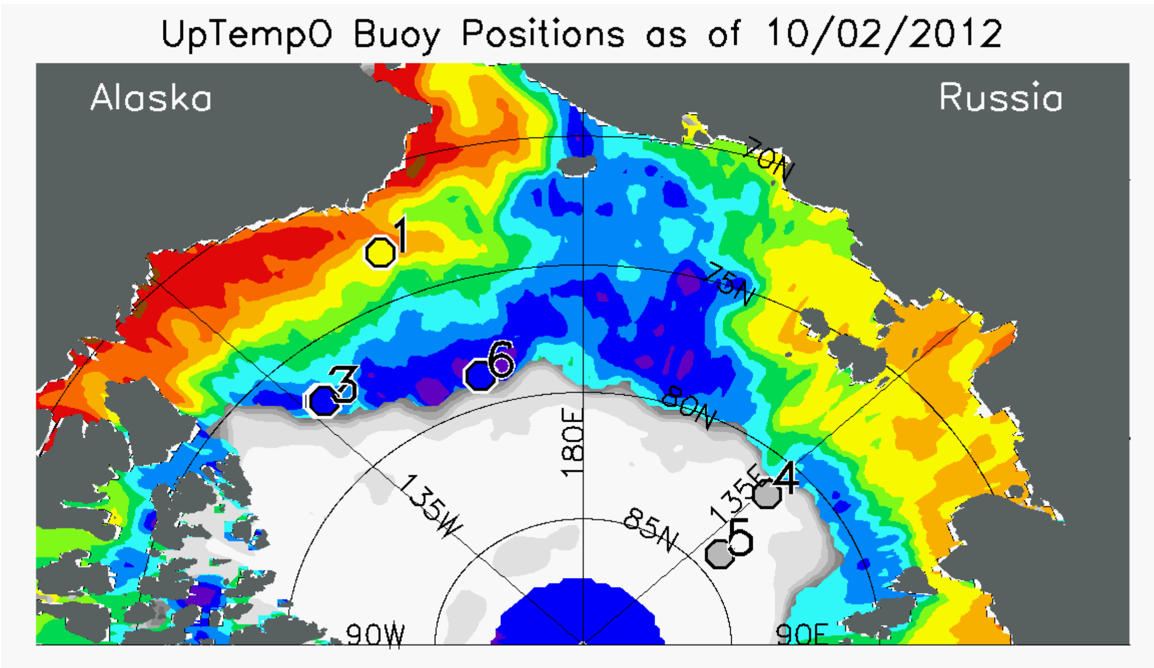
Thanks to CCGS Sir Wilfrid Laurier

I thank Captain Stu Aldridge and the Laurier’s White Crew for their commitment to and roles in completing our work. As usual, Sir Wilfrid Laurier has played a critical and effective role in maintaining an Arctic marine science research programme within Fisheries and Oceans.

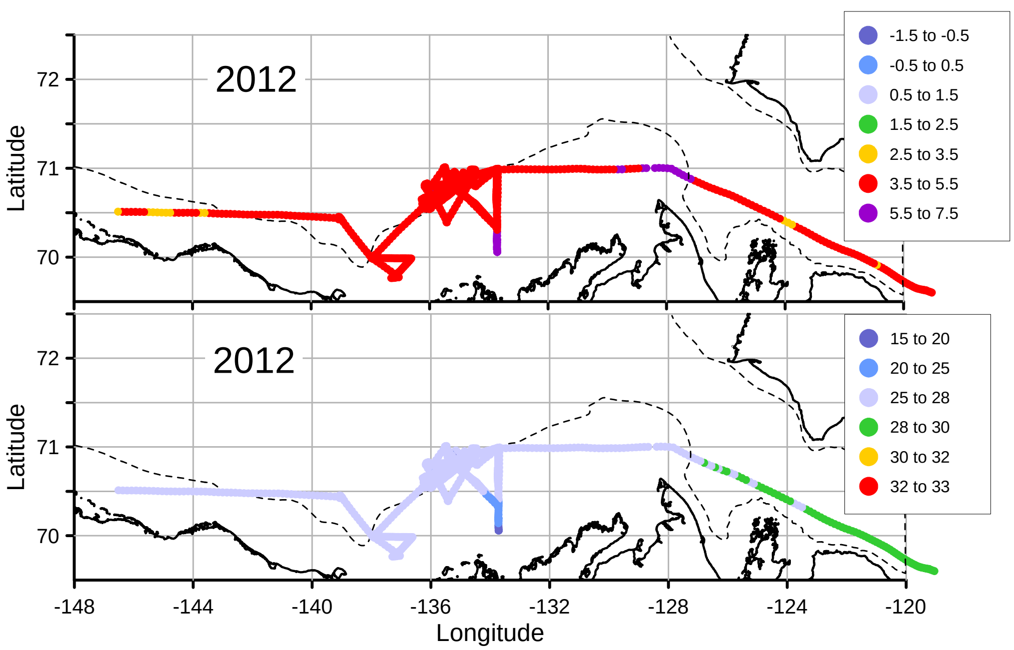
Inter-annual variation in the marine environment

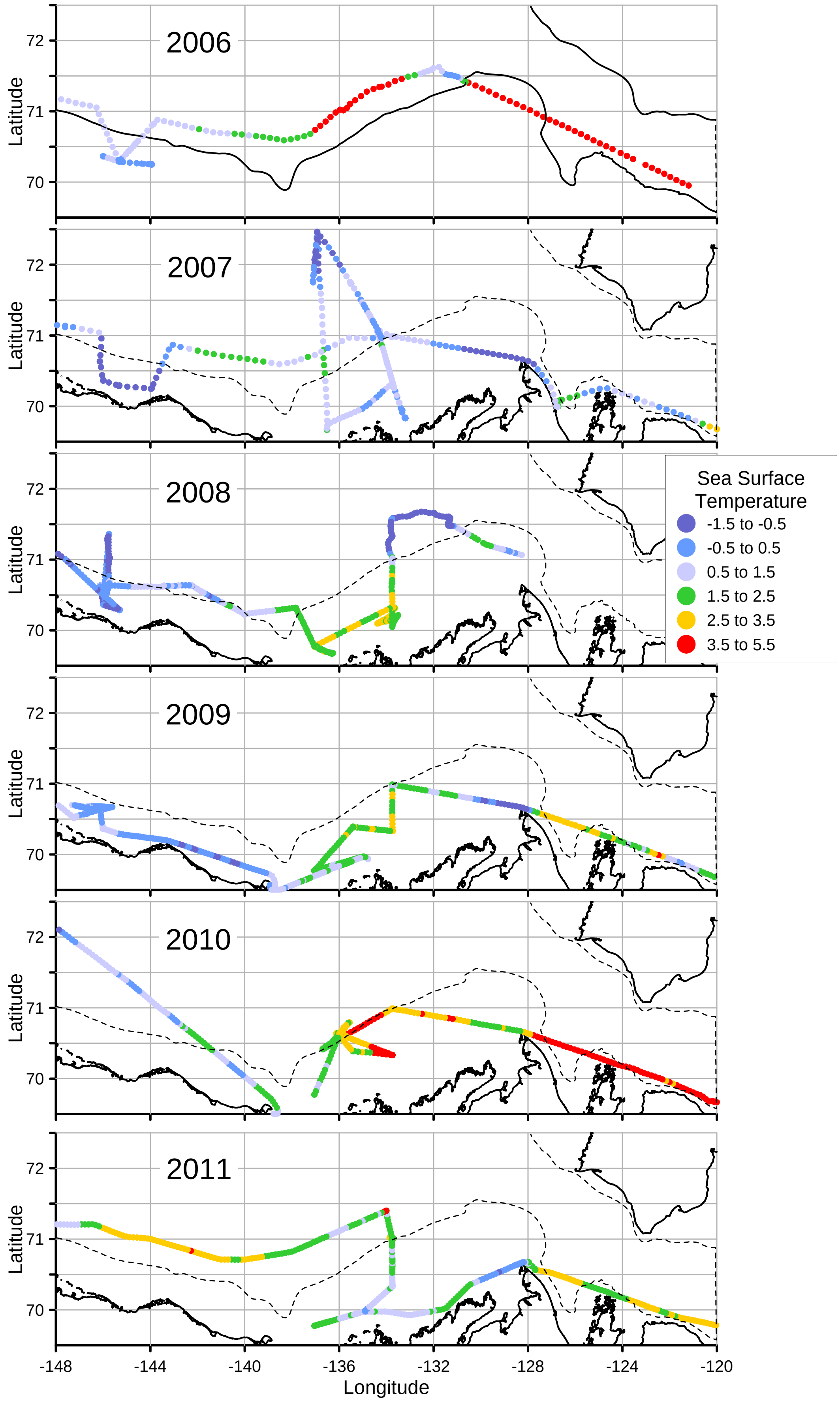
Surface temperature and salinity in the Beaufort (late September)

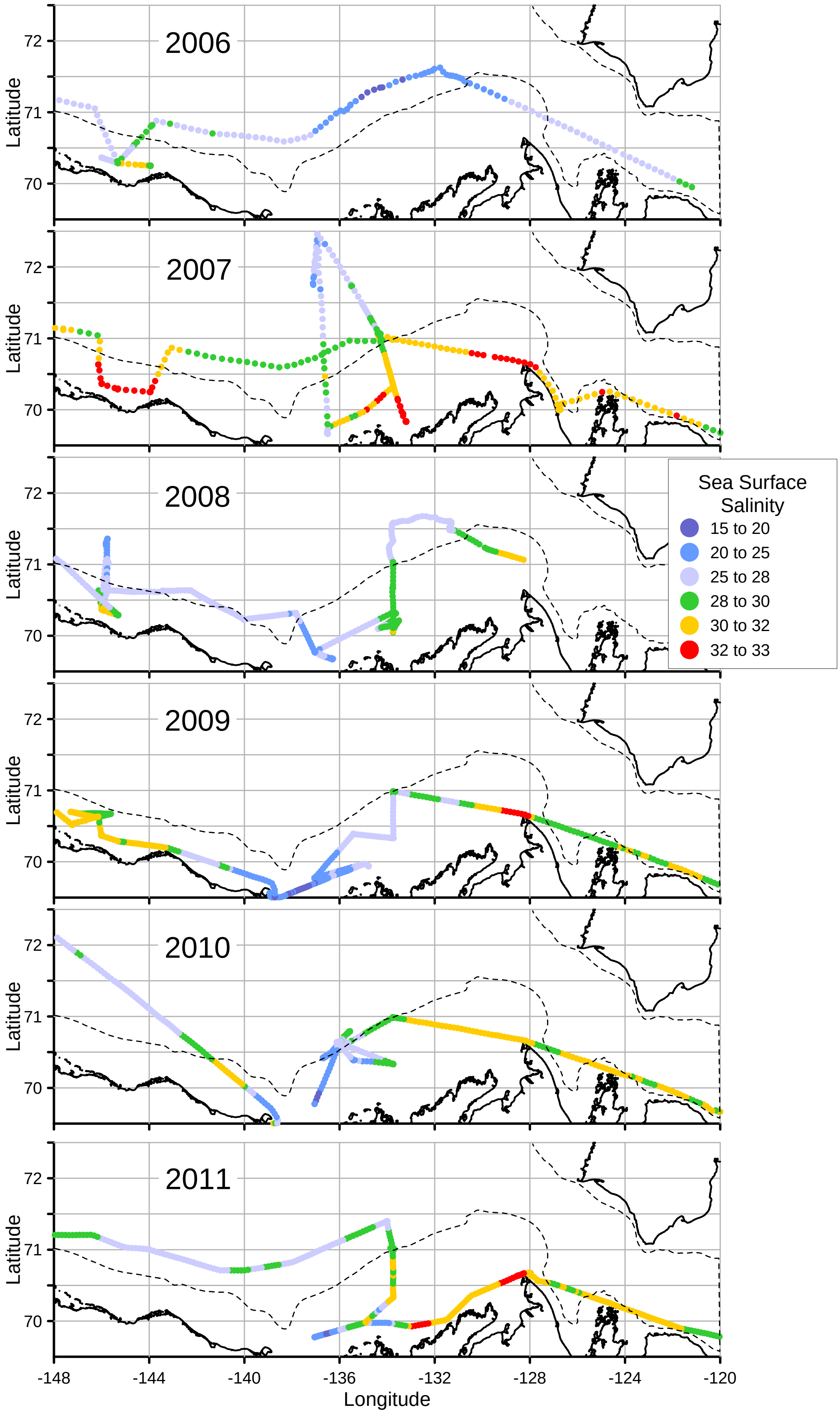
The illustration below displays Arctic sea-surface temperature in early October 2012. Ice is shown in grey and colours change in 1°C increments from 4-5°C (red) down to 0-1°C (greens) and below 0°C (blues). The information was derived from Earth satellite (http://psc.apl.washington.edu/UpTempO/Data.php). The band of 4-5°C water stretching from Amundsen Gulf to the Chukchi Sea is \obvious. Last year at the same time, the entire southern Beaufort was 2°C or cooler.



The illustrations below display the temperature (top) and salinity (bottom) of surface water drawn during transit. The colour of dots indicates value according to the legend. Corresponding plots for the years 2006-2011 are shown on the pages that follow.




2006
2007
2008
2009
2010
2011
Latitude
72
71
70
Sea Surface Temperature
-1.5 to -0.5
-0.5 to 0.5
0.5 to 1.5
1.5 to 2.5
2.5 to 3.5
3.5 to 5.5
-148
-144
-140
-136
-132
-128
-124
-120
Longitude


2006
2007
2008
2009
2010
2011
Latitude
72
71
70
-148
-144
-140
-136
-132
-128
-124
-120
Longitude
Sea Surface Salinity
15 to 20
20 to 25
25 to 28
28 to 30
30 to 32
32 to 33

Surface conditions in 2012 were the warmest for in October during the 7-year period of routine observation (2006-1012) and the second freshest after 2006. In contrast to other years in the sequence, there was little evidence in 2012 of salinity decrease with increasing distance from the coast. Salinity was higher in Amundsen Gulf, as is typical of most years (except 2006).

The surface salinity typically decreases with distance from the coast, implying that fresh water from the Mackenzie River has during the last 6 summers generally been transported northward to accumulate in the Canada Basin. There also appears to be a westward component to this transport, since the surface waters of the basin north of Alaska are typically fresher than those in the basin within the Canadian sector.

Meteorological insights

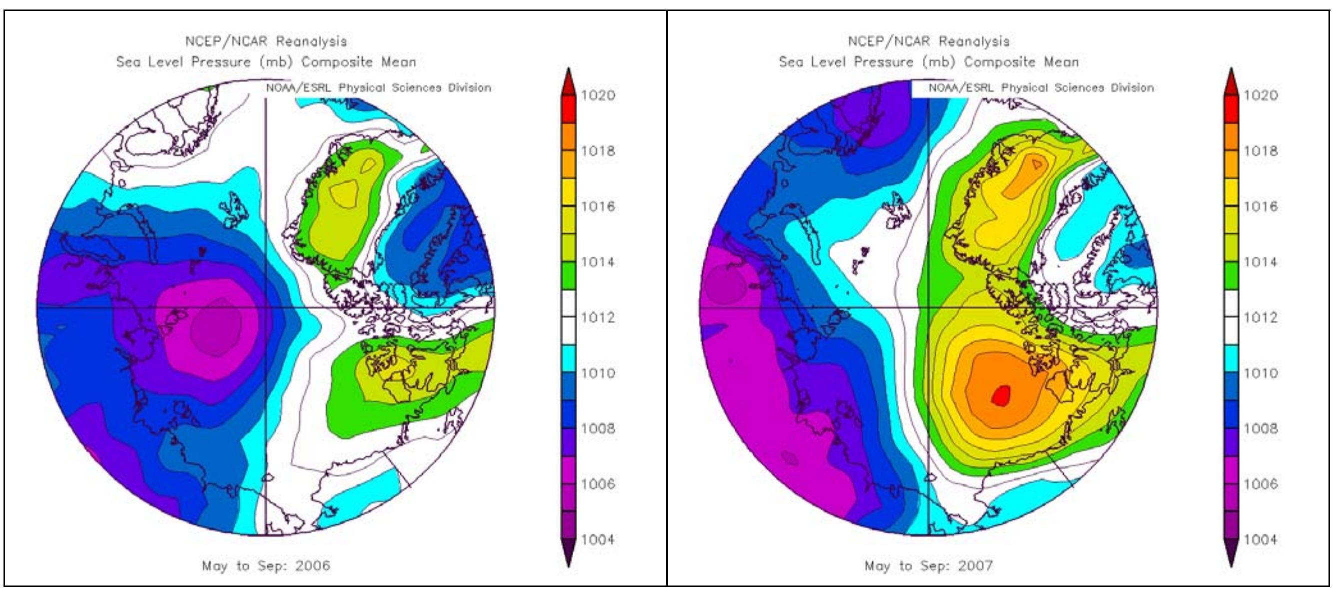
Contoured plots in the eight frames below depict the pattern of average air pressure at sea level during the months of May through September for 2006 through 2012, and the 30-year average over these months at the lower right [data from the NCEP re-analysis project]. On average, a weak cell of high pressure dominates the Beaufort Sea in summer. Winds blow clockwise around this cell, giving easterlies across the Beaufort to Wrangel Island, and southerly winds (white band) across the central Arctic from Siberia towards Fram Strait. The latter drive the trans-polar drift of sea ice

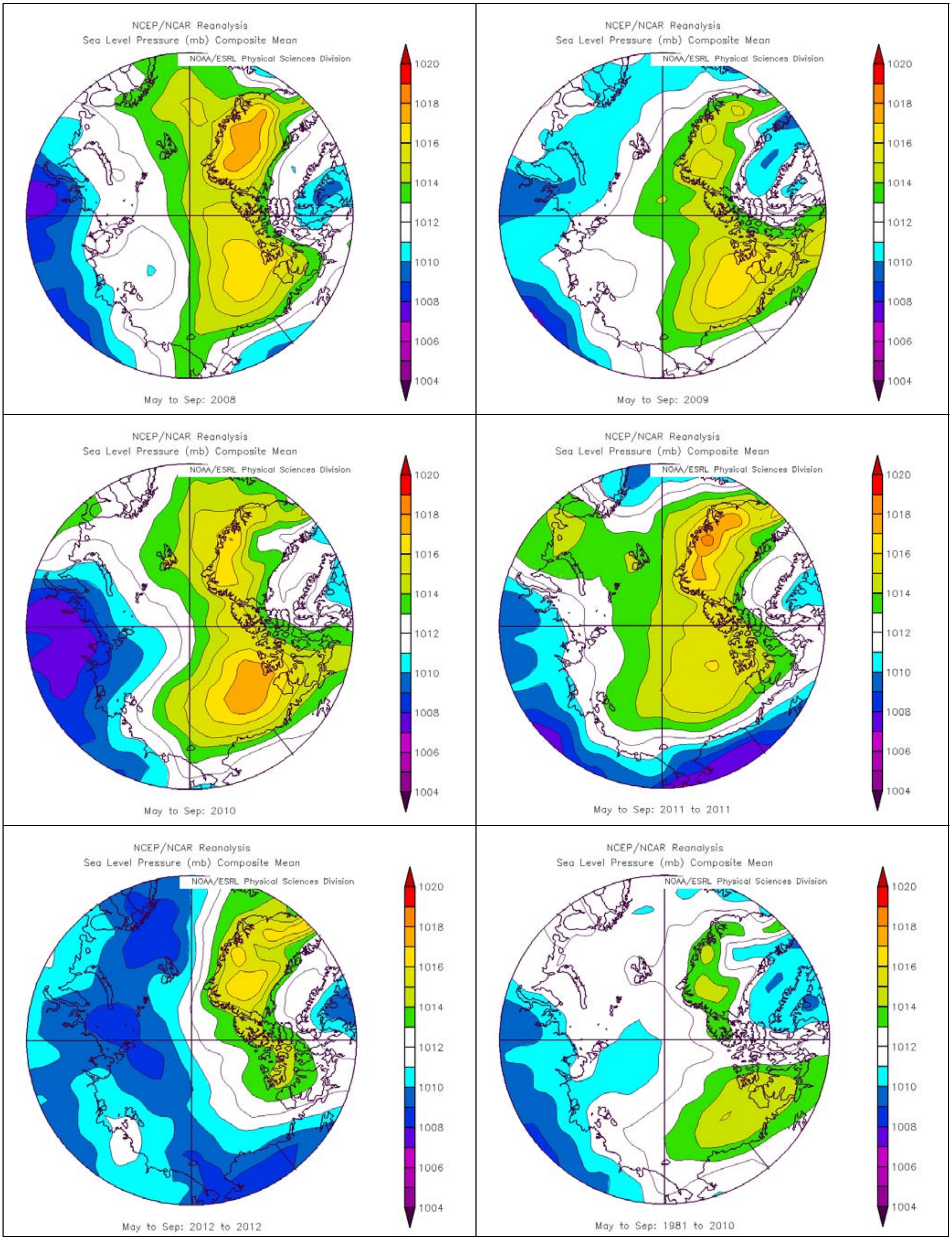
Recent anomalies in atmospheric pressure and winds are important factors underlying present ice and ocean conditions in the southern Beaufort Sea. Each of the seven summers has been different. The pattern in 2009 was most similar to the long-term average, although the high pressure cell in the Beaufort and the winds driven by it were much stronger.

Sea-level pressure was low over the Eurasian Arctic during the summer of 2012 and high pressure was shifted eastward onto the Canadian polar shelf. This pattern maintained moderate southerly winds over the western Beaufort and Chukchi Seas which drove ice northward across the pole to Fram Strait. Lower than normal pressure in the Gulf of Alaska maintained a strong north-south pressure gradient and moderate easterly winds in the southern Beaufort, pushing ice and surface water westward from the Canadian Beaufort. This gradient was stronger than climatology, but not as strong as that in the summers of 2007 through 2010.

The band of easterlies was deflected northward extended much further east this year than in any other of this series, barely reaching 145°W before weakening.

Figure 10 Contoured plots of air pressure at sea level averaged over the months of May through September, individually for 2006 through 2012, and then as an average over 30 years (lower right). Data from the NCEP re-analysis project http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl




NCEP/NCAR Reanalysis
Sea Level Pressure (mb) Composite Mean
NOAA/ESRL Physical Sciences Division
May to Sep: 2008
NCEP/NCAR Reanalysis
Sea Level Pressure (mb) Composite Mean
NOAA/ESRL Physical Sciences Division
May to Sep: 2009
NCEP/NCAR Reanalysis
Sea Level Pressure (mb) Composite Mean
NOAA/ESRL Physical Sciences Division
May to Sep: 2010
NCEP/NCAR Reanalysis
Sea Level Pressure (mb) Composite Mean
NOAA/ESRL Physical Sciences Division
May to Sep: 2011 to 2011
NCEP/NCAR Reanalysis
Sea Level Pressure (mb) Composite Mean
NOAA/ESRL Physical Sciences Division
May to Sep: 2012 to 2012
NCEP/NCAR Reanalysis
Sea Level Pressure (mb) Composite Mean
NOAA/ESRL Physical Sciences Division
May to Sep: 1981 to 2010
1020
1018
1016
1014
1012
1010
1008
1006
1004

Narrative

18 September, Tuesday

Science team of 15 joins Sir Wilfrid Laurier at Cambridge Bay via various means. Temperature on arrival 4°C. Low broken cloud. Occasional sunshine.

Ship operating on Pacific Daylight Time (PDT).

HM tours the ship separately with Golder and with GSC personnel to view spaces available for science, and their possible uses.

Introductory meeting of all scientists, Captain and Chief Officer, at 6 pm for introductions, science programme overview and preliminary discussion of space allocations..

19 September, Wednesday

At anchor in Cambridge Bay. Overcast. Light dusting of snow.

Setup TSG & CTD-rosette system.

Crew thoroughly reorganizes the lower hold and ‘tween decks to provide more stowage for equipment on deck.

R/V Marty Bergmann comes alongside in the evening to transfer 9 bonnets of equipment for transport south.

20 September, Thursday

Broken stratus overcast. -1ºC. Sir Wilfrid Laurier lifts anchor at 8:10 am, westward bound.

21 September, Friday

Beautiful calm clear autumn day. Sir Wilfrid Laurier at Kugluktuk to collect channel marker buoys and anchors formerly used in the Coppermine River.

Sir Wilfrid Laurier underway about noon. Meeting to discuss deployment and operation of the Huntec towed body.

1:30 pm: Start rigging the derrick for a Huntec trial. Some challenge getting the wire far enough outboard. 2 deployments. Trial turns to starboard (preferred) and to port. Complete to everybody’s satisfaction by 4:30 pm.

6:00 pm: Meeting to discuss ROV operation – MBARI, plus Captain, Mate, Scott, Humfrey. 200-lb clump weight. Deploy from derrick, not A-frame. Ship to crab to port on recovery, to minimize possibility of collision. Trial scheduled for 8 am tomorrow.

22 September, Saturday

Sir Wilfrid Laurier is Amundsen Gulf at 118°W. 3-4 kt in 4-m seas and west wind, 45G50 kt. ROV trial not practical.

3:00 pm: Wind down to 25G30 kt. Still slow progress.

23 September, Sunday

7:00 am: Wind now ESE and developing a following sea. ROV trial remains impractical.

5:30 pm: At Site 2, but conditions judged too rough for mooring work here. Continue SW to the starting point for Huntec survey.

7:40 pm: Deploying the Huntec tow in 2-m seas (night #1).

24 September, Monday

7:00 am. Retrieving the Huntec tow. Wind and seas are down.

7:30 am: Meet to discuss the recovery of BREA mooring BR-G.

8:40 am: Hydrophone in water. Recovery completed at 9:48.

Defer the deployment of a replacement mooring because visibility deteriorating in fog and wind forecast to rise.

12:30 pm: Approaching BREA mooring BR-A.

12:50 pm: Hydrophone in water. Recovery completed at 1:43 pm.

3:00 pm: Trail launch and dive of the ROV. Some problem with the sea-catch caused its use to be abandoned. Going down at 3:37 pm, coming out at 4:21 pm. Winch drive belt slipped on recovery and dropped the ROV back into the sea.. Probel fixed by tightening the drive belt.

6:15 pm: Hydrophone in water for the recovery of BREA mooring BR-B. Recoery completed at 6:30 pm.

7:00 pm: Deploying the Huntec tow (night #2) at Coke Cap.

25 September, Tuesday

7:00 am. Wind NW5, light swell, 5°C. Retrieving the Huntec tow.

Overnight problem with the tow – the line streamed well back & pulled in towards the hull. Perhaps too deep?

7:30 am: Meeting to discuss possibilities for keeping the tow line well outboard. Settle on shallower depth (no more than 50 m) & slower speed (no more than 4.5 kt).

8:00 am: Meeting to discuss coring with Captain, Mate, Bosun, GSC people, Humfrey.

8:30 am: ROV dive #1, at Coke Cap. Dive complete at 1 pm.

2:30 pm: Strating deployment of mooring at BREA site BR-A. Complete at 3:30 pm. Triangulation of anchor position, CTD profile.

7:00 pm: Deploying the Huntec tow (night #3) at the 780-m expulsion feature.

26 September, Wednesday

7:00 am. Wind NE4, flat sea, light swell. SAT is 3.6°C. SST is 2°C higher.

7:30 am: Retrieving the Huntec tow.

7:40 am: ROV in water at 780-m feature. Dive complete at 1 pm.

1:30 pm: Start first piston coring operation. Lift at 1:42. Linked to winch wire at 1:48. Start descent at 1:53. Corer back at the surface at 2:44. Back on board at 3 pm. 1 ½ hours in total.

6:16 pm: Gravity coring at GC1

7:30 pm: Deploying the Huntec tow (night #4) on transect towards IOS Mooring Site 2

27 September, Thursday

7:00 am: Wind E24, 3.2°C, SST is 5°C

7:15 At Site 2, with Huntec on board. Captain recommends standby for wind and seas to come down before attempting mooring recovery.

11:30 am: Wind remains at 20G30. Depart for IOS Mooring Site 1, in the hope that seas will come down while in transit.

3:15 pm: At Site 1. Wind 084 at 25 kt. Proceed to Site 9.

5:25 pm: At Site 9. Wind & sea conditions not great, but 2 short moorings dropped here. Finished at 6:30 pm.

28 September, Friday

6:00 am: Approaching Site 2. Wind SW 21 kt. 1m swell. Air temperature is 2.6°C. SST is 5.3°C.

7:30 am: Ranging on SIC11-2 mooring. Recovery completed at 7:53 am.

8:14 am: Start re-deployment. Complete at 8:22 am.

8:45 am: On route to the upper slope near 135° 17’W to complete a gravity-coring transect.

12:14 pm: Start coring.

4:00 pm: Core section complete. ROV dive to 150-m depth during 4:00-6:30 pm, during which an exposure of glacial till was discovered.

6:45 pm: Launch Huntec for overnight survey.

29 September, Saturday

7:10 am: Huntec onboard. Wind N 5 kt. Light swell. SAT is 1.3°C

07:50 am: At site BR-B for deployment of BREA mooring. Complete at 8:40 am, then triangulation plus CTD drop.

10:00 am: Launch ROV at 420-m expulsion feature. Complete at 2:00 pm.

2:15-6:20 pm: Piston & gravity coring at EF-420m

7:00 pm: Huntec deployed for overnight transit to SIC11-1.

30 September, Sunday

7:00 am: Retrieving Huntec 5 miles from SIC11-1.

7:40 am: Enough daylight to start mooring recoveries at SIC11-1. Two recoveries completed at 8:10 am.

8:21 am: Start deployments, both completed by 8:26 am. Transit north-west to the geoscience area.

11:30 am: IKU grab at a linear seabed feature, suspected esker or relict beach. 70° 40.13’N 134° 43.609’W

1:10 pm: ROV dive near the shelf edge at 70° 49.725’N 135° 06.432’W

2:45 pm: Use of IKU grab at till exposure identified by ROV … 3rd drop successful at 3:37 pm.

4:40 pm: At site BR-G for deployment of BREA mooring. Complete at 7:08 pm including break for supper. Triangulate for position of mooring anchor.

Launch Huntec

1 October, Monday

6:30 am: 1.6ºC, NE15. SST is 4.6°C. Recover Huntec

8:40 am: At the Coke Cap expulsion feature, 280-m depth. Piston corer rigged & going down. Core head buried in very soft sediment.

9:20 am: On route south-west to the landslip area for an ROV dive to climb up the slump and for coring.

5:30 pm: Complete coring activity.

7:00 pm: Launch the Huntec for a box-like survey ending at Coke Cap.

2 October, Tuesday

7:00 am: At Coke Cap recovering Huntec. Wind south-east at 25 kt, developing sea. Air 3ºC & SST 4.6°C.

9:05 am: Recovering the ROV after a frustrating hour trying to tame the ship’s drift so as to traverse to the north-west across Coke Cap. Proceed to the shelf edge & then to Kopanoar for gravity coring & possibly an ROV dive.

3:30 pm: 3 cores collected at Kopanoar, but still to rough to launch the ROV. Proceed to the Huntec starting point at 70° 54.247’N 131° 50.756’W.

3 October, Wednesday

6:00 am: 11 miles from Coke Cap. Wind SSW at 6 kt. Air 3.6°C.

8:00 am: ROV in water at Coke Cap. Complete at 10:55 am.

12:20 pm: Start pull-out of the mooring at Coke Cap. Complete at 1:11 pm. Proceed to BR-2.

6:25 pm: Start mooring recovery at BR-2, in perfect conditions. Complete at 6:40 pm.

6:45 pm: Deploy Huntec for overnight traverse eastward onto the shelf and then south-west to SIC11-11.

4 October, Thursday

7:00 am: Recovering Huntec. Beautiful sunrise. 4.7°C

7:20 am: CTD profile while awaiting daylight.

7:56 am: Ranging on the mooring. Recovery complete at 8:04 am.

8:09 am: Ready to re-deploy. Complete at 8:11 am.

8:19 am: Underway to BR-2.

10:30 am: Start deployment at BR-2. Complete at 10:49 am, except for triangulation.

2:50 pm: Searching for desired depth of water near BR-1. Found at 3:30 pm, measuring ship's drift.

3:50 pm: Start mooring deployment at BR-1. Complete at 4:22 pm, followed by triangulation & CTD profile.

5 October, Friday

10:00 am: Anchored in fog north-east of Cross Island.

1:00 pm: Last of 4 helicopter flights to get people in to Deadhorse. Overnight at the Aurora Hotel.

5 October, Saturday

09:40 am: Return flights via Anchorage and Seattle to Victoria, arriving at about midnight, or elsewhere

Appendix 1: Locations of moorings, Beaufort and Chukchi Seas 2012-13

Site	Latitude			Longitude			Sounding (m)	Depth (m)	Drop time PDT	
SIC12-1	70	19.9470	N	133	44.5150	W	51	55	30-Sep-2012 08:22	IPS
SIC12-1	70	19.9404	N	133	44.6384	W	51	55	30-Sep-2012 08:26	ADCP
SIC12-2	70	59.3421	N	133	44.6340	W	109	111	28-Sep-2012 08:22	
SIC12-9	70	03.5113	N	133	42.8436	W	31	35	27-Sep-2012 17:54	IPS
SIC12-9	70	03.5143	N	133	43.0212	W	31	35	27-Sep-2012 18:12	ADCP
SIC12-11	69	46.4659	N	137	02.7432	W	31	36	04-Oct-2012 08:10	
MGH12	70	39.0156	N	135	56.8047	W	287	283	03-Oct-2012 12:54	

Site	Latitude			Longitude			Sounding (m)	Depth (m)	Drop time PDT
BR-A-12	70	45.3611	N	136	00.8559	W	678	661	25-Sep-2012 15:30
BR-B-12	70	40.2061	N	135	35.1478	W	156	156	29-Sep-2012 08:40
BR-G-12	71	00.3959	N	135	30.0232	W	721	702	30-Sep-2012 19:08
BR-2-12	69	59.4614	N	137	57.6230	W	154	154	04-Oct-2012 10:49
BR-1-12	70	25.9539	N	139	01.5419	W	771	750	04-Oct-2012 16:22

Appendix 2: BREA mooring locations from triangulation

The table above lists the location at which the anchor of each mooring was dropped to fall freely to the seabed, dragging the mooring over and down with it.

The table below lists the positions determined by acoustic triangulation on the transponders at the base of each mooring after it had come to rest at the seabed.

The column labelled "Separation" displays the horizontal distance between the position that the anchor was dropped, and that triangulated.

Site	Latitude			Longitude			Separation (m)	Depth (m)
BR-A-12	70	45.4080	N	136	00.7980	W	94	661
BR-B-12	70	40.2960	N	135	35.1720	W	167	156
BR-G-12	71	00.4680	N	135	29.9100	W	150	702
BR-2-12	69	59.4780	N	137	57.6480	W	35	154
BR-1-12	70	26.0100	N	139	01.3920	W	139	750

Appendix 3: Locations of CTD/rosette profiles

Conseq No	Station	Latitude		Longitude		Depth, m	Date time utc	
2012-21-0001	BR-G	71	00.230	135	31.090	710.5	24-Sep-2012	17:09
2012-21-0002	BR-A	70	45.060	136	01.370	644.8	24-Sep-2012	20:58
2012-21-0003	BR-B	70	39.900	135	35.300	139.0	25-Sep-2012	01:46
2012-21-0004	BR-A	70	45.470	136	01.290	666.0	25-Sep-2012	23:08
2012-21-0005	PC1	70	47.930	136	06.450	767.6	26-Sep-2012	22:07
2012-21-0006	PC1	70	47.810	136	06.350	772.4	26-Sep-2012	22:40
2012-21-0007	SIC12-9	70	03.610	133	42.840	32.6	28-Sep-2012	01:39
2012-21-0008	SIC12-2	70	59.180	133	44.970	110.9	28-Sep-2012	15:36
2012-21-0009	BR-B	70	40.260	135	35.600	174.7	29-Sep-2012	16:12
2012-21-0010	SIC12-1	70	19.910	133	44.680	54.8	30-Sep-2012	15:37
2012-21-0011	BR-G	71	00.500	135	30.030	709.6	01-Oct-2012	00:36
2012-21-0012	MGH12-1	70	38.980	135	56.880	283.1	03-Oct-2012	18:10
2012-21-0013	BR-2	69	59.500	137	57.650	155.4	04-Oct-2012	01:49
2012-21-0014	SIC12-11	69	46.570	137	02.880	36.4	04-Oct-2012	14:21
2012-21-0015	BR-2	69	59.580	137	58.010	158.3	04-Oct-2012	18:27
2012-21-0016	BR-1	70	26.000	139	02.020	743.4	05-Oct-2012	01:00

Appendix 4: Locations of geoscience stations (PGC Cruise 2012-004)

Stn	Type	Ref. No.	Date	Latitude	Longitude	Depth, m	Notes
1	ROV	MBARI #5	269 15:53	70.6495	-135.947	275	Dive on 270m expulsion feature (Coke cap)
2	ROV	MBARI #6	270 15:36	70.8072	-136.099	758	Dive on 750m expulsion feature s
3	Piston	PC 01	270 21:20	70.8010	-136.101	741	Centre of 750m expulsion feature
4	Piston	PC 02	271 00:08	70.7807	-136.082	748	Debris cone south of 750m expulsion feature
5	Gravity	GC 01	271 14:40	70.8120	-136.112	790	Background north of 750m expulsion feature
6	Gravity	GC 02	272 19:28	70.8446	-135.148	240	Michaels shelf edge background
7	Gravity	GC 03	272 20:16	70.8397	-135.133	177	Michaels shelf edge mound
8	Gravity	GC 04	272 20:35	70.8396	-135.133	178	Michaels shelf edge mound
9	Gravity	GC 05	272 21:14	70.8337	-135.112	140	Charlie's Pinnacle
10	Gravity	GC 06	272 21:31	70.8338	-135.113	132	Charlie's Pinnacle
11	Gravity	GC 07	272 22:01	70.8298	-135.113	130	Charlie's Plateau
12	Gravity	GC 08	272 22:15	70.8298	-135.114	131	Charlie's Plateau
13	Gravity	GC 069	272 22:37	70.8288	-135.106	156	Charlie's moat
14	Gravity	GC 10	272 22:55	70.8288	-135.106	156	Charlie's moat
15	ROV	MBARI #7	272 23:36	70.8340	-135.117	156	Dive on depression north of Charlie's moat
16	ROV	MBARI #8	273 17:44	70.7871	-135.550	415	Dive on 420m sea floor expulsion feature
17	Piston	PC 03	273 21:25	70.7913	-135.563	400	Centre of 420m floor expulsion feature
18	Piston	PC04	273 23:14	70.7999	-135.593	460	Debris cone 742m expulsion feature
19	Gravity	GC11	274 00:55	70.7758	-135.671	520	Background 420m expulsion feature
20	IKUGrab	IKU 1	274 18:46	70.6682	-134.726	49	Sinuous ridge feature mid-shelf
21	ROV	MBARI #9	274 20:29	70.8289	-135.108	49	Dive on Charlie's moat
22	IKUGrab	IKU 2	274 22:12	70.8303	-135.108	146	Charlie's moat
23	Piston	PC05	275 15:48	70.6501	-135.948	286	Centre of 270m expulsion feature (coke cap)
24	ROV	MBARI #10	275 17:15	70.5864	-136.075	286	Dive on Charlie's moat
25	Piston	PC06	275 20:20	70.5803	-136.058	138	Top of slope on CL of landslide feature
26	Piston	PC07	275 21:46	70.5693	-136.036	107	Deformation structure at top of slope on CL
27	Piston	PC08	275 22:56	70.5731	-136.044	116	Deformation structure at top of slope on CL
28	Piston	PC09	276 13:10	70.5767	-135.913	75	Shelf edge stratigraphic core
29	ROV	MBARI #11	276 15:06	70.6496	-135.939	75	Dive on 270m expusion feature (Coke cap)
30	Gravity	GC12	276 17:27	70.6183	-135.717	89	Conway shelf edge stratigraphy
31	Gravity	GC13	276 17:52	70.6095	-135.701	72	Conway shelf edge stratigraphy
32	Gravity	GC14	276 18:04	70.6095	-135.700	75	Conway shelf edge stratigraphy
33	Gravity	GC15	276 18:34	70.5879	-135.798	74	Conway shelf edge stratigraphy
34	Gravity	GC 16	276 19:30	70.6031	-135.732	71	Till site cored in 2010
35	Gravity	GC 17	276 19:43	70.6032	-135.732	76	Till site cored in 2010
36	Gravity	GC 18	276 19:51	70.6033	-135.731	78	Till site cored in 2010
37	Gravity	GC19	276 21:59	70.3919	-135.421	69	Beaufort Sea-Kopanoar
38	Gravity	GC 20	276 22:10	70.3919	-135.423	68	Beaufort Sea-Kopanoar
39	ROV	MBARI #12	277 15:23	70.6498	-135.949	289	Dive on 270m expulsion feature (Coke cap)
40	Mooring	IOS	277 19:36	70.6501	-135.947	288	270m sea floor expulsion feature (Coke cap)

Appendix 5: Recovery information for BREA instruments, 2011-2012

TABLE 1 Mooring Recovery Summary 2012 Leg 3

Mooring	Latitude (WGS 84)	Longitude (WGS 84)	Water Depth (m)	2011 Deployment Date	2012 Recovery Date
BR-A-11	70° 45.378'N	136° 00.828'W	660	13 September	24 September
BR-B-11	70° 40.20'N	135° 35.16'W	156	12 September	24 September
BR-G-11	71° 00.402'N	135° 29.994'W	701	19 September	24 September
BR-2-11	69° 59.466'N	137° 57.63'W	157	18 September	03 October

TABLE 2 Summary of data record start and end dates for instruments on Mooring BR-A

Instrument	Start of data logging	End of data logging	Clock Drift hh:mm:ss
IPS5 #51106	12 September 2011 23:00	30 September 2012 01:30	00:12:07 slow
150 kHz QM ADCP #12699	13 September 2011 10:00	11 August 2012 06:32	00:00:31 slow
75 kHz LR ADCP #13079	13 September 2011 10:00	26 September 2012 22:41	00:00:36 slow
Nortek AQD DW 9847	13 September 2011 11:00	27 September 2012 14:00	00:00:51 fast
RBR XR420 CT #15263	13 September 2011 17:00	30 September 2012 22:40	00:00:59 fast
RBR XR420 CT #15269	13 September 2011 17:00	26 September 2012 21:00	N/A
RBR XR420 CT #15274	13 September 2011 17:00	27 September 2012 07:10	00:00:03 slow
RBR XR420 CT #15279	13 September 2011 17:00	26 September 2012 21:40	00:00:35 fast

TABLE 3 Summary of data record start and end dates for instruments on Mooring BR-B

Instrument	Start of data logging	End of data logging	Clock Drift hh:mm:ss
IPS5 #51103	09 September 2011 15:00	29 September 2012 22:30	00:09:48 slow
150 kHz QM ADCP # 8784	12 September 2011 08:00	30 July 2012 22:55:59	00:10:00 slow
LISST # 1445	12 September 2011	29 May 2012	N/A
Nortek 1 MHZ AQD9715	12 September 2011 13:00	26 September 2012 19:00	00:00:45.63 fast
RBR XR420 CT #17112	12 September 2011 08:00	26 September 2012 04:00	00:00:40 fast
RBR XR420 CT #17114	12 September 2011 08:00	26 September 2012 03:00	00:00:22 fast

TABLE 4 Summary of data record start and end dates for instruments on Mooring BR-G

Instrument	Start of data logging	End of data logging	Clock Drift hh:mm:ss
IPS5 # 51108	16 September 2011 23:00	29 September 2012 22:00	00:09:48 slow
150 kHz QM ADCP #12823	17 September 2011 23:00	28 October 2011 07:17:53	00:01:14 slow
75 kHz LR ADCP #12943	17 September 2011 11:00	25 May 2012 20:14:59	00:00:54 fast
Nortek AQD DW # 9839	17 September 2011 00:00	27 September 2012 18:00	00:00:40 fast
Nortek AQD DW #9494	17 September 2011 00:00	27 September 2012 17:30	00:00:44 fast
RBR XR420 CT #15272	17 September 2011 11:00	27 September 2012 7:30	00:00:36 slow
RBR XR420 CT #15270	17 September 2011 11:00	30 September 2012 22:30	00:00:50 slow
RBR XR420 CT #15258	17 September 2011 11:00	30 September 2012 22:40	00:00:15 slow
RBR XR420 CT #15264	17 September 2011 11:00	30 September 2012 22:30	00:00:17 slow

TABLE 5 Summary of data record start and end dates for instruments on Mooring BR-2

Instrument	Start of data logging	End of data logging	Clock Drift hh:mm:ss
IPS5 # 51109	17 September 2011 17:00	4 October 2012 14:00	00:12:17 slow
300 kHz WH ADCP # 102	17 September 2011 11:00	05 September 2012 13:20	00:02:08 slow
LISST # 1447	17 September 2011 06:00	04 June 2012	00:03:20 slow
Nortek 1 MHZ AQD 9711	17 September 2011 00:00	04 October 2012 13:30	00:00:45 fast
RBR XR420 CT #15262	17 September 2011 11:00	20 October 2012 11:00	00:00:25 slow
RBR XR420 CT #17113	17 September 2011 11:00	05 October 2012 01:00	

Regional Operations Centre
Canadian Coast Guard – Pacific

PACIFIC REGION CCG VESSEL -POST CRUISE REPORT

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

DATES: 18 September - 5 October 2012

SCIENCE CRUISE NUMBER: 2012-21 **SHIP'S PATROL NUMBER:**

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

AREAS OF OPERATION: Beaufort 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.

The supplementary programme for Sir Wilfrid Laurier's Leg 3 in 2012 had three components:

1) Resumption of study in collaboration with Natural Resources Canada and Monterey Bay Aquarium Research Institute to assess the hazard of gas hydrates for drilling and production;

2) A collaborative effort with ArcticNet to support continued ocean monitoring by instruments on sub-sea moorings in the new deep-water lease blocks in the Canadian Beaufort Sea;

3) A new observatory using recording sonar on sub-sea moorings to obtain detailed data on ice conditions and hazards at the Amauligak site at the 32-m isobath north of Kugmallit Bay.

CRUISE OBJECTIVE/OBJECTIVES:

One primary objective of this expedition was the recovery, servicing and re-deployment of internally recording instruments on sub-sea moorings – "ocean observatories". 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, acoustic back-scatter from plankton and sedimentation. There were 8 moorings for recovery during this leg (2 of about 650-m length; others less than 100 m) and 12 for deployment (including 3 of about 650-m length).

The other primary objective was the investigation of features on the seabed identified through study of a detailed bathymetric map of the outer shelf and slope of the Beaufort Sea acquired by multi-beam sonar. The investigation involved use of a Huntec shallow seismic profiling system, an ROV for visual exploration, piston and gravity corers and bottom grabs for sediment sampling.

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

DAYS ALLOCATED:

10 days primary tasking

DAYS OF OPERATION:

17, including CCG tasking and homebound transit time

DAYS LOST DUE TO WEATHER:

2 days by approximate reckoning, involving slowdown of ship's transit or cancellation of planned activities.

RESULTS:

8 of 8 planned recoveries of oceanographic moorings were completed. There were no inoperable moorings requiring dragging.

12 of 12 planned mooring deployments were completed.

16 profiles were measured with the CTD system, but no water samples were collected.

950 line km of shallow seismic survey were completed using the Huntec towed body.

9 piston core, 20 gravity core and 2 IKU grab samples of seabed sediment were collected.

8 ROV dives were completed in depth between 10 and 780 m, each yielding 2-4 hours of seabed video recording.

RADIOISOTOPE USE:

None.

PROBLEMS [SCIENTIFIC GEAR AND OPERATIONS]:

Erratic logging of thermo-salinograph data

When logging of data from the thermo-salinograph was re-started at Cambridge Bay, the Acer laptop computer crashed repeatedly within a few minutes of initiation. A loss of synchronization with the serial data stream was suspected. The replacement of the KeySpan USB-serial connection by an Easy Sync ES-U-1001-R100 adaptor cured the problem.

A different fault arose when the GPS feed via LAN to the logging computer failed shortly after we left the ship – cause unknown. The ship's position will have to be borrowed from other sources.

Malfunctions of moored instruments

Narrow-band ADCP s/n 506 at SIC11-2: The data in this instrument was recorded in 96 files. Only files numbered 81 and higher were of the expected length (293 kb). This is inconvenient, but no data were lost. Malfunction of the memory card in the first slot is suspected.

Time-variable gain for the 12-kHz sounder

The Simrad hull-mounted 12-kHz transducer was driven via an echo sounder from IOS, with data logged to a laptop computer. Poor documentation of the logging programme and its interplay with controls on the echo sounder made it difficult to adjust the equipment for optimum performance in detecting bubbles. The time-variable gain in particular behaved quite strangely.

SUCCESSES [SCIENTIFIC]:

All moorings deployed from Sir Wilfrid Laurier and from Amundsen in 2011 were recovered. All instruments but one yielded full records of data; one, a temperature-salinity recorder (Site 2), suffered electronic failure and delivered no data. Twelve moorings were re-installed at ten sites. The data from these moorings contribute to the continuing record of sea ice and ocean in this sector of the Arctic Ocean, now 22 years long and supported from CCGS Sir Wilfrid Laurier for 16.

The geology programme provided intriguing new insight into the history of the Beaufort seabed. Glacial till was discovered and sampled in areas thought never to have been glaciated. The shallow underpinnings of seabed expulsion features were delineated using the Huntec seismic system and the existence of similar features beneath the vast landslip on the western part of the continental slope was revealed. Gas samples were acquired from cores and collected from active seeps using a purpose-built pressurized collection system on the ROV.

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

The 50-HP work winch equipped with ½ -inch wire and used for coring leaked oil because of a deformed sealing surface.

SUCCESSES [SHIP]:

The Huntec towed body was deployed over the starboard side of Sir Wilfrid Laurier via the ship's derrick. It was operated in a range of sea conditions for more than 100 hours. The towing depth was typically 50 m and the speed was 4.5 kt. This activity is a first for this ship. The towing wire did come uncomfortably close to the hull in some conditions of wind and sea. Fitting the towed body with trim tabs that could be adjusted so that it pulled out from the ship would make side towing more practical.

The deployment of a 10-m piston corer from Sir Wilfrid Laurier is also a new activity for this ship. The corer was prepared in fore-aft alignment on supports inboard of the A-frame on the foredeck. It was then lifted using two picks from the derrick, lifted over the A-frame and connected to the coring winch once hanging vertically over the side. The high lift of the large, heavy and unbalanced corer makes this work practical only in light seas. The viability of stowing and tending the corer on the outboard side of the A-frame should be investigated.

DELAYS [OTHER THAN WEATHER]:

None

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 thanks go to the captain, officers and crew, whose interest and commitment allowed us to work so productively.