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2011 Canadian High Arctic Seismic Expedition: CCGS Louis S. St-Laurent expedition report

D.C. Mosher

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Edited by D.C. Mosher

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Publications in this series have not been edited; they are released as submitted by the author.

2011 Canadian High Arctic Seismic Expedition: CCGS Louis S. St-Laurent expedition report August 18 – September 29, 2011 Kugluktuk to Cambridge Bay, Nunavut

CCGS Louis S. St-Laurent

Photo by Don Glencross

Captain Marc Rothwell, Commanding Officer

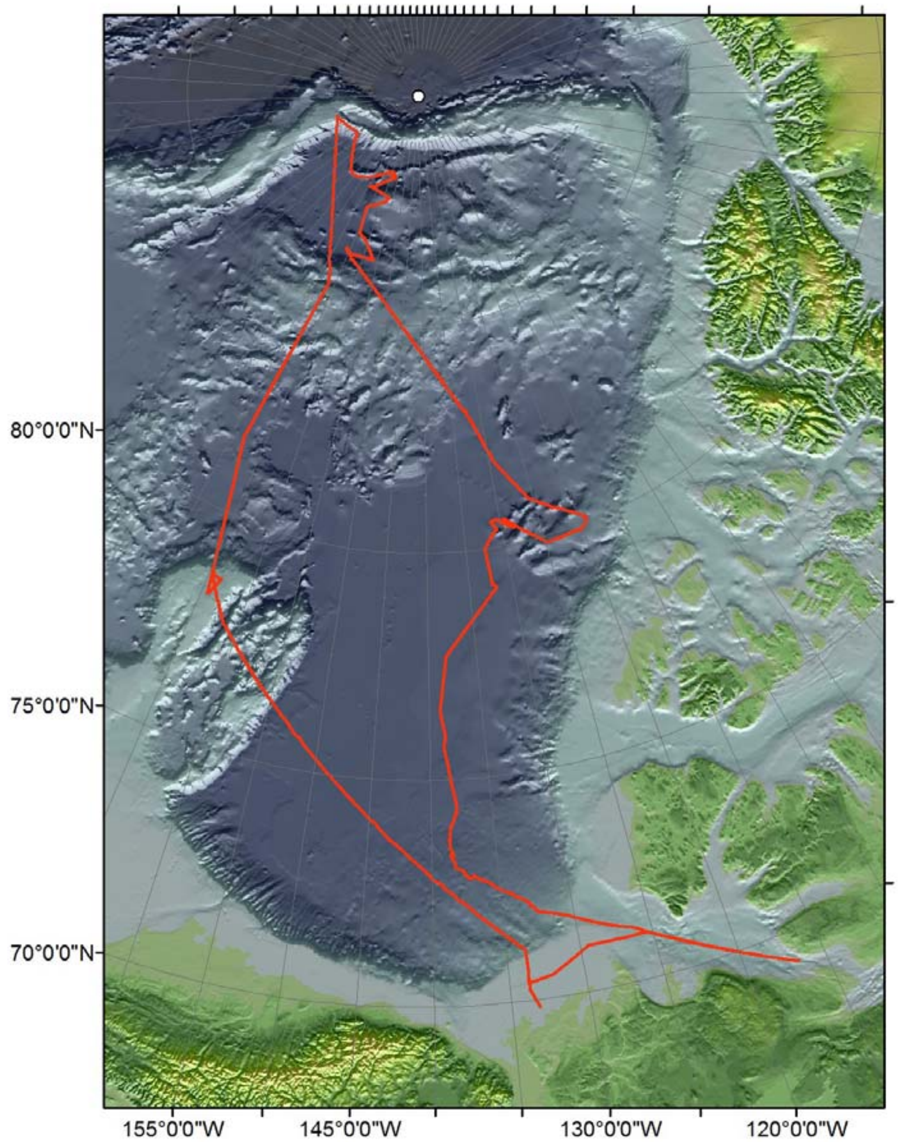
Dr. David C. Mosher, Chief Scientist

Executive Summary

The principal objectives of the 2011 Canadian High Arctic Seismic Expedition were to acquire multichannel seismic reflection, refraction and bathymetric data along positions that serve to establish sediment thicknesses, structural and morphologic criteria along Canadian and US western Arctic continental margins. Strategic ship track lines were established to complement existing data to meet UNCLOS Extended Continental Shelf (ECS) sediment thickness, bathymetric and scientific objectives. In addition, the first Autonomous Underwater Vehicle deployment from an icebreaker in the high Arctic was achieved, permitting acquisition of additional bathymetric data in areas of perennial sea ice cover. Ancillary programs included ice observations to groundtruth remotely sensed data, physical oceanographic data were acquired on an opportunistic basis and an Environment Canada O-buoy was deployed. 1437 line-km of high quality multichannel seismic reflection data were acquired in addition to seismic refraction data recorded from 21 sonobuoy deployments. 7848 line-km of single beam bathymetry, subbottom profiler and shipborne gravity data were obtained from the Louis S. St-Laurent over the course of the entire mission, plus 75 helicopter spot soundings. 110 km of bathymetric data were acquired by the AUV and in excess of 4500 line-km of mulitbeam bathymetric data were acquired from the USCGC Healy.

Dedication

This report is dedicated to our friend, colleague and fellow Arctic researcher, Mr. Steven Solomon. He will be missed.



CCGS LOUIS S. ST-LAURENT
AUGUST 18th - SEPTEMBER 29th, 2011

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Chapter 1: 2011 CHASE Summary

D.C. Mosher

Introduction

Canada ratified Article 76 of the International Convention on the Law of the Sea (UNCLOS) in 2003. This Article specifies a legal mechanism for defining the extended continental shelf (ECS) beyond the 200 nautical mile limit. To assert sovereign rights beyond 200 nautical miles, a country has ten years to collect the appropriate information and submit a case to the United Nations Commission on the Limits of the Continental Shelf (CLCS). Canada can exercise specified sovereign rights out to a distance of 350 nautical miles or further as a natural prolongation of Canadian territory. Rights include jurisdiction in matters related to environment and conservation and powers over mineral and biological resources on and below the seabed.

In order to extend boundaries beyond the 200 nMi limit, Canada must acquire geophysical and geological data to define the limit of Canada's continental shelf as stipulated under Article 76. To this end, Canada has undertaken a program of data acquisition along its frontier regions. Specific to this expedition, Natural Resources Canada and Fisheries Ocean Canada, acting on behalf of the Government of Canada, is operating a project in the western Arctic Ocean (Canada Basin) to acquire necessary marine geophysical and geological data. This 2011 expedition represents the sixth consecutive year of such activities in this region.

Although not yet a signatory of UNCLOS, the United States of America requires similar data along its continental margin for eventual ratification; thus, a collaborative program between Canada and the United States was established in 2008. This collaboration included each country contributing an ice breaker to operate in the ice- covered waters of the western Arctic. The vessels operated in tandem to ensure maximum data quality and each acquired independent but complimentary data sets. For 2011, the US contributed the US Coast Guard Cutter Healy (Healy) and Canada, the Canadian Coast Guard Ship Louis S. St-Laurent (LSSL). For the Healy's part, the principal data acquired were multibeam bathymetry and high resolution subbottom reflection profiles (Chirp). LSSL collected seismic reflection and refraction data in addition to single beam bathymetry, high resolution subbottom profiles (3.5 kHz) and spot sounding data. Both vessels had gravimeters on board to measure the gravitational potential on a continuous basis.

Objectives

The principal objectives of the LSSL2011 program were to, 1) acquire multichannel seismic reflection and refraction data to establish offshore geological and structural affinities with Canadian and US western Arctic continental margins, 2) to acquire bathymetric sounding data at specific locations along these margins in order to validate existing bathymetric data and to establish baseline information such as the 2500 m contour and foot of slope positions, 3) deploy an autonomous underwater vehicle from the icebreaker to test the feasibility of such operations in ice covered seas, and to have that instrument run a mission of multibeam data acquisition in support of the scientific objectives of the expedition, 4) acquire shipborne gravity data over the course of the mission that will be used to groundtruth satellite and airborne gravity data and integrated with existing free-air and bouguer gravity grids, 5) deploy an O-buoy on the ice for ozone and other atmospheric gas measurements for Environment Canada, and 6) conduct physical and chemical oceanographic measurements/sampling on an opportunity basis.

Personnel

Scientific Personnel

Seismic Operations (shipborne)

1.	David Mosher, NRCan	Chief Scientist
2.	Borden Chapman, NRCan	Chief Technician
3.	Deborah Hutchinson-Gove	US Liaison Scientist
4.	Paul Girouard, Geoforce	navigation and data curation
5.	Ken Asprey, Geoforce	Compressor Tech
6.	Michael Gorveatt, Geoforce	Mechanical/ Watch keep
7.	Ryan Pike, Geoforce	Mechanic/Elect Tech
8.	Dwight Reimer, Geoforce	Electronics Tech watch keeping
9.	Rodger Oulton, Geoforce	Compressor Tech
10.	Peter Vass, Geoforce	Machinist and Welder
11.	Nelson Ruben, Geoforce	Mammal Observation and Mechanic
12.	Dale Ruben DFO	MMO
13.	John Ruben DFO	MMO
14.	Jon Evangelatos, NRCan	Data processor / GIS

Hydrographic Operations

15.	Jon Biggar, CHS	Lead Hydrographer
16.	Jim Weedon, CHS	hydrographic watch keeping
17.	Andrew Forbes, CHS	hydrographic watch keeping
18.	David Street, CHS	CHS rep on Healy

AUV Operations

19.	Richard Pederson, DRDC Atlantic	Project Lead
20.	Val Shepeta, DRDC Atlantic	
21.	Chris Brannan, DRDC Atlantic	
22.	Don Mosher, DRDC Atlantic	
23.	Mark Rowsome, DRDC Atlantic	
24.	Sean Spears, DRDC Atlantic	
25.	Owen Shuttleworth, DRDC Atlantic	

26. Brett Pickrill, DRDC Atlantic
27. Don Glencross, DRDC Atlantic - Videographer
28. Chris Kaminski, ISE/contract
29. Stephen Nishio, ISE/contract
30. Gina Miller, ISE/contract

Miscellaneous

32. Hans Böggild, Artist at Sea; author/playwrite/script writer
33. Stoyka Netcheva, Environment Canada - Buoy Deployment
34. Jane Eert, DFO – Physical Oceanography
36. Alice Orlich, US Ice Observer (To Healy)
37. Cpt. Steve Wachowski, US Air Force – UAV (unmanned airborne vehicle)

CCGS Louis S. St-Laurent Personnel

Commanding Officer	Marc Rothwell
C/O	Duane Barron (HEALY)
Chief Officer	Roy Lockyer
Chief Engineer	Mia Hicks
Logistics Officer	Nathan Whiffen
First mate	Neil Casey
Second mate	Glen Fitzgerald
Third mate	Amy Tuck
Fourth mate	Jeremy Wagg
Senior Engineer	Dave Baur
First Engineer	Freeman Stevens
Second Eng.	Kevin Oake
Third Engineer	Scott Curry
VMMR Eng.	Matt Klebert
Electrical Ofc	Phil Seaboyer
Electrical Ofc	Jordan Stagg
Boatswain	Derrick Walsh
Carpenter	Eugene Jones
Winchman	Harold Martin
Leading Seaman	Stanley Fleet
Leading Seaman	Bill Savory
Leading Seaman	Neil Jollymore
Seaman	Lindsay Bartlett
Seaman	Wayne Austin
Seaman	Justin Dalley
Seaman	Lewis Hann
Seaman	Jean-Marc Cormier
E/R Tech	Jamie Richardson
E/R Tech	Justin Ropson
E/R Tech	Travis Tibbo
E/R Mechanic	Rodney Young
E/R Mechanic	Kody Critch
E/R Mechanic	Sheldon Collins
E/R Mechanic	Jonathon Hanlon
E/R Mechanic	Dean Kavanagh
E/R Mechanic	Mitchell Cutler
Chief Cook	Blair Walsh
Storekeeper	Chris Allison
Storekeeper	Mike Goodwin
Second Cook	Craig Byrne
Second Cook	Cheryl Benger

Second Cook	Vicki Howell
Steward	Mark Lewis
Steward	Donna Kennedy
Steward	Deborah Hibbs
Steward	Allison Pyke
Steward	Alphie Haynes
Helicopter Pilot	Christopher Swannell
Helicopter Engin	Stephen Lloyd
Electronics Tech	Stephen Wheeler
Ice Observer	Barbara Molyneaux
Ice Observer	Jacques Collins (Healy)
Medical Doctor	Vincent Demers
Medical Officer	Claude Morency
Cadet	Alex Beaulieu
Cadet	Andrew Barnett
Cadet	Mallory Eddie
Cadet	Jordan Forrest
Cadet	Charlotte Girouard-Ares
Cadet	Brian Salisbury

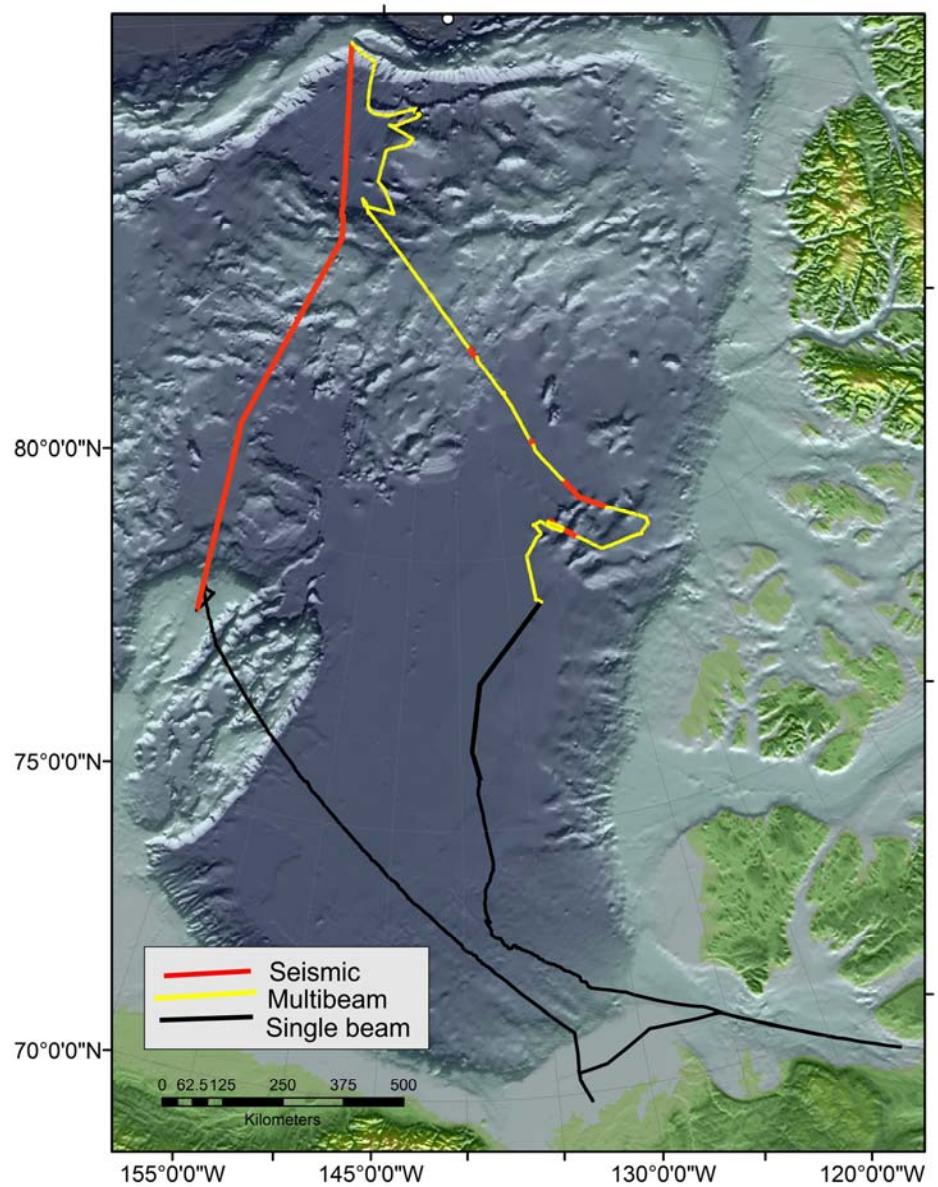


Figure 1-1. Total ship's track with parameters. Multibeam and single beam bathymetry data are acquired constantly, but the coloured tracks represent the principal data component. For "Seismic", Healy led while Louis acquired seismic reflection data. For "Multibeam", Louis led Healy while multibeam data were acquired. "Single Beam" represents the period when Louis was alone.

Navigation, Record Keeping and Networking

Navigation data streams required by the various systems in operation in the seismic lab were provided through dedicated fibre connections from the bridge and the forward lab (Fig. 1-2). Differential GPS navigation was provided by the science Novatel receiver. NMEA sentences from this system were multiplexed to the ship's speed log and gyro NMEA sentences and distributed to the seismic lab at 9600 baud via a dedicated fiber connection. The bathymetry data were distributed to the lab at 4800 baud via a dedicated fiber connection from the Knudsen 12 Khz sounder located in the forward scientific lab. The information received from the bridge was again multiplexed in the seismic lab with the bathymetry and distributed at 19200 baud to the Regulus navigation system and the seismic logger. The 9600 baud navigation stream was also distributed to the sonobuoy GSCDIG logging system from a data line splitter located in the seismic lab. The Regulus navigation system, running Build 4.8.21 of the software, was used to view and log the scientific navigation. The Regulus system was also used to view and update the electronic log. A GPS network time server was installed in the seismic lab and provided a standardized time to all the systems in the lab. Their clocks were updated every hour.

The navigation data were cleaned and merged using a text editor and the standard GSCA programs ETOA, INTA and APLOT. Raw E-format, raw A-format and cleaned and edited 10 second A-format files were saved on a daily basis and transferred to CD for archiving. Shape files for ArcMap were generated from the A-files using the GSC Navigation tools suite in ArcMap. All seismic, gravity, sonobuoy, and Knudsen bathymetric and chirp data, as well as their related logfiles, were also backed up to harddrive for archiving. The compressor watchkeepers and mammal observers maintained paper records of their observations. These were reviewed on a daily basis and transferred to digital spreadsheets and archived. A digital log of the daily scientific activities was maintained around the clock by the watchkeepers and archived. A computer located in the radio room was used to control the sonobuoys. The GSCADIG4 system was used for digitizing and recording the analog sonobuoy signals as well as maintaining the Sonobuoy log sheets . The sonobuoy control was managed from the seismic lab over the network using VNC Viewer, a remote desktop management application. This software was also used for remote observation of, and communication with, the compressor control computers. The navigation data were sent to the GSCDIG computer via dedicated fiber connection and two single port serial to fiber converters.

Computer networking proved more difficult this expedition than in previous years because of computers operating Windows 7; integration with Windows XP machines was non-trivial and it was found that FileZilla ftp software offered the only solution for file transfers between machines of different OS. In addition, there were issues with installing software on Windows 7 machines that formerly were set up on the NRCan network in the office. It seems security issues prevent certain installations, even if the user is considered an "Administrator".

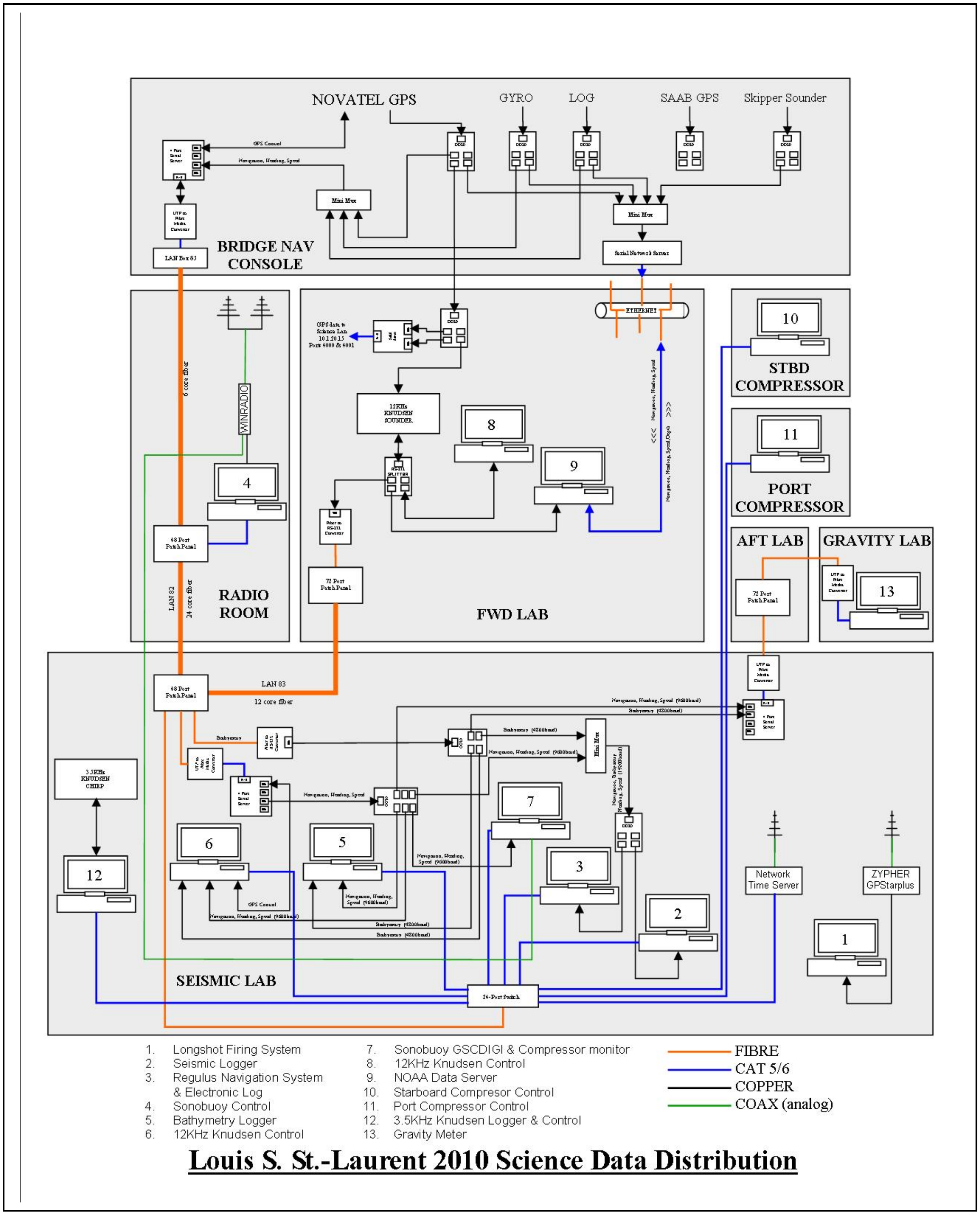


Figure 1-2 Science program wiring schematic, CCGS Louis S. St-Laurent 2011

UNCLOS LSL 2011 Data Archive Summary

Seismics

DVD No.	Line No.	Start	End	Shotpoint Start	Shotpoint End
S1	lsl11_01	236/100058	237/232040	1	8404
	lsl11_02	237/232040	238/135334	8405	11161
S2	lsl11_03a	238/135334	239/075528	11171	14581
S3	lsl11_03b	239/194636	241/122006	14606	23788
S4	lsl11_04a	241/122006	242/005745	23789	26447
S5	lsl11_04b	242/162223	244/212827	26481	36928
S6	lsl11_05	253/172041	254/002121	36931	38740
	lsl11_06	255/030325	255/064743	38741	39484
	lsl11_07	255/185635	256/134705	1	3767
	lsl11_08	258/163745	259/044300	39486	41863

All other data

A	All Sonobuoys
	All SVP, XCTD, XBT
	Seastar DVD CTD
	Navigation
	DRDC AUV
	Electonic Log & Mammal Observers Log
	Data and archive summaries

Gravity

DVD No.	File Type	Start Day	End Day
GG1	GEF	179	219
GG2	GEF	220	264
GG3	GEF	265	269
	RGS, SDE	All Days	
	Log and summary		

Knudsen

DVD No.	Source	Start Day	End Day
B1	3.5Khz SGY	234	251
B2	3.5Khz SGY	252	260
B3	3.5Khz SGY	261	269
B4	12Khz KEB & KEB	234	269

Table 1-1. Summary of data archives

A network radio link was installed by the technicians from the USCGC Healy to provide communication between the two ships over an IP phone connection for the benefit of the science program. The installation went smoothly having the benefit of previous experience. In order to isolate this network from the ship and science networks, the network connection to the phone in the Conference Room was accomplished by patching the radio link installed in the radio room directly to a network receptacle in the conference room via the Forward Lab and After Lab patch panels.

Seismic Reflection and Refraction

The LSSL acquired multichannel seismic reflection and sonobuoy refraction data. The four major equipment categories for seismic data acquisition are:

- Tow sled and G-gun equipment
- Compressor and air distribution system
- GeoEel streamer system
- Sonobuoy system

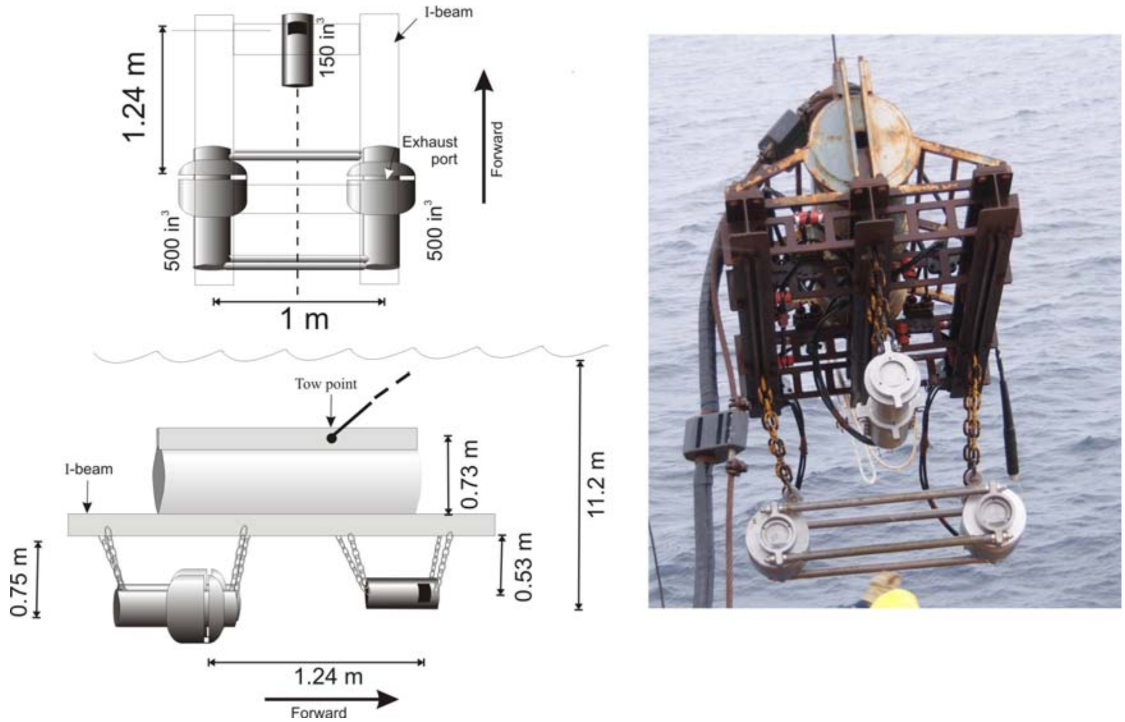


Figure 1-3. Deep tow G-gun array design and photo of it being deployed.

Full technical details of the systems can be read in Chapter 4 of the 2009 cruise report (Mosher et al., 2009). Seismic acquisition required a watchkeeper in the seismic lab and another in the compressor container. The seismic lab watchkeepers (Gorveatt and Reimer) were responsible for data acquisition/recording, watching over-the-side equipment, gun firing and log keeping. As well, a remote screen permitted monitoring compressor pressures and alerts as well as communicating with the compressor watch-stander. Compressor watchkeepers (Roger Oulton and Ken Asprey) were required to watch over the compressor for any failures for emergency shut down and provide general maintenance that might be required during operations.

Seismic Source

The seismic source was an 1150 in^3 pneumatically charged array (Fig. 1-3) of three Sercel G-guns configured for ice operations (Fig. 1-3). Two separate arrays were constructed for redundancy. A square wave trigger signal was supplied to the firing system hardware by a FEI-Zyfer GPStarplus Clock model 565, based on GPS time (typically about 19.5 seconds). Gun firing and synchronization was controlled by a RealTime Systems LongShot fire controller, which sent a voltage to the gun solenoid to trigger firing. There was a 56.8 ms delay between trigger and fire point.

Compressors

Pressurized air for the pneumatic G-guns was supplied by two Hurricane compressors, model 6T-276-44SB/2500. No configuration changes were made for the 2011 Louis program over the 2009 program (Mosher et al., 2009). These are air cooled, containerized compressor systems. Each compressor was powered by a C13 Caterpillar engine which turns a rotary screw first stage compressor and a three stage piston compressor capable of developing a total air volume of 600 SCFM @ 2500 PSI. The seismic system was operated at 1950 PSI and one compressor could easily supply sufficient volume of air under appropriate pressure.

A total of 238.6 operational hours were added to the two Hurricane compressors in 2011. HC #1 ran a total of 18.0 hours while HC #2 ran a total of 220.6 hours. Final hour counts on HC #1, 1675.8 hours, and HC #2, 878.6 hours.

The final installed version of the Hurricane Compressor monitoring software worked correctly and no changes are required.

Issues arising with operation of the Hurricane Compressors in 2011:

HC #1 Compressor had no operational issues in 2011.

HC #2 Compressor repair issues corrected during the 2011 program:

(1) Discharge air pipe coupling at top of air/ oil separator tank cracked and was replaced. This was a repeat issue from previous years. A triangular clamp system was fabricated to reduce the vibrations on this pipe. This proved a satisfactory repair and a second system was also fabricated and installed on HC#1
(2) The pipe on the air/ oil separator tank which supports the safety pop valve leaked. This was removed and the safety valve was installed directly onto the tank without the additional elbows
(3) The welds around the pipe fitting on the side of the air/ oil separator tank, where the site glass fitting affixes, cracked. The original welds were removed and re-welding was done to complete the repair.
(4) The belt guard was removed and repaired after one of the attaching steel lugs broke in half. New steel was used to replace the old steel. At that time an opening between the belt guard and the 1st stage screw was cut into the belt guard to reduce chaffing on the belt guard.
(5) Repairs to loose stanchion post attaching bolts, which support the #3 stage separator, thermostatic valve and screw oil filters helped reduce machine vibration in this area
(6) J-D cooling fan replacement following fan blade failure. Spare removed from NRCan inventory

Conclusions:

Generally the Hurricane compressors performed well in 2011. The flexible high pressure braided hoses, which had been installed on both machines before the 2011 program, greatly reduced machine failures caused by vibration.

The air/ oil separator tanks should be removed from the two compressors for service. It is recommended that doubler plates be welded to the tank sides where the existing piping is attached. The doubler plates would strengthen the area around the openings on the tanks to prevent future cracks which have occurred in the welds around the pipe fittings. The tanks should be pressure tested to 300 PSI.

Both HC #1 and #2 will be removed from the vessel following the 2011 field season.

Routine painting of the exterior of the containers should be planned prior to redeployment.

Seismic Reflection

Full details of the seismic reflection acquisition and processing component of the program are provided in Chapter 2 of the 2009 Expedition report (see Mosher et al., 2009). The towing configuration is shown in Figure 1-7.

Geometrics GeoEel Digital Streamer

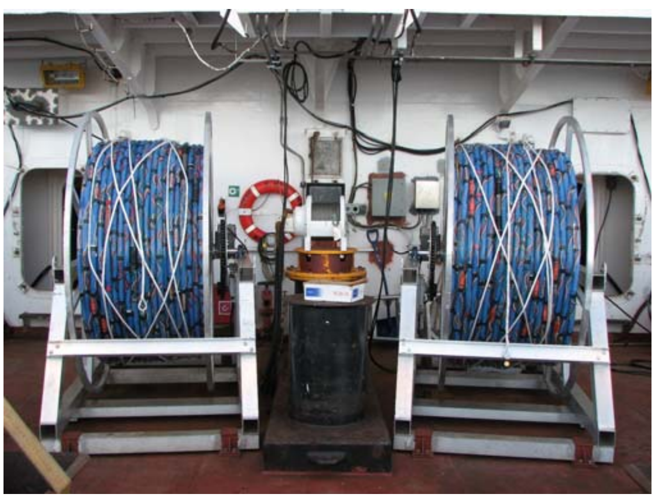


Figure 1-4. Two Geometrics GeoEEL Streamers on the quarter deck of the LSSL.

Two identical Geometric GeoEel streamers were utilised for seismic operations (Fig. 1-5). The active elements in the GeoEel streamer were Benthos Geopoint hydrophones. There were eight groups of four Geopoint hydrophone cartridges in each active section. Thus, with two active sections, the streamer had a total of 16 active channels, each with four Geopoint cartridges. Seismic signals received by the hydrophone elements in the streamer were digitized by 24 bit A/D modules which form part of the streamer system. Digitized seismic signals were sent up the cable as USP data packets to the recording system. The Geometrics software program Stratavisor Version 5.31 provided streamer control, logging and display of the data

For all deployments and recoveries, the streamer was hand hauled and flaked on the deck. This technique allowed preparation of the streamer before deployment (attaching it to the sled and preparing the floats and CTDs). Also, it was faster than deploying and hauling in with the winches, thus preventing the streamer from getting caught in the ice. No configuration changes were made to the streamer for the 2011 Louis program. Please refer to the 2009 technical report (Mosher, 2009) for streamer “component placement”. Two identical Geometrics Inc. GeoEel streamers were assembled in July 2011 while the vessel was along side in Dartmouth, NS.

No configuration changes were made to the GeoEel system for the 2011 Louis program. Please refer to the 2009 technical report for streamer “component placement”.

Operational Issues:

The first equipment deployment occurred 2300 hours on August 23, 2011. The port streamer was deployed at that time.

Immediately following the power up of the GeoEel deck unit, the high leakage alarm activated.

The equipment was recovered and the port streamer was disconnected from the tow cable bundle. The starboard streamer was connected to the bundle and the equipment was redeployed.

On August 24 the port streamer was laid out onto the hangar deck. Each section was separated and checked for leakage. During the inspection, a repeater was found to be missing an “O” ring seal. A small amount of sea water was inside the connector. This repeater was serviced and a new “O” ring was installed. The repeater was reinstalled and the system was checked and judged as operational. The streamer was reinstalled onto the port streamer winch and remained as the back up “spare” throughout the entire program.

At midnight on August 27 the air supply line on the 150 cubic inch air gun failed and then shortly after, the port 500 cubic inch gun air supply line failed. On recovery it was clear that the sled had rotated at least 4 times during the tow operation. This resulted in the damage of two air lines and the streamer bundle cable at the top of the tow sled. As the streamer was being recovered the outer sections were caught in ice. On recovery it was observed that the aft active section jacket was punctured and oil was leaking. The defective section was removed and a replacement active section was installed.

The multiple twists damaged the streamer TC01087 bundle cable. The bundle was rebuilt using six new electrical gun control cables and a new streamer DC01063 cable. Air hoses were swapped end for end and the defective sections were cut and the hoses re-terminated. The system was redeployed and surveying resumed at noon on the 27th.

On September 19, 09:00, gear was deployed. The starboard streamer immediately showed high leakage. The system was recovered and a small amount of sea water was located in the connector of the repeater at the rear of the tow sled. The "O" ring was replaced but the survey was terminated at that time due to shaft and propeller problems. The equipment was never returned to service.

At the termination of the survey, both port and starboard streamers were fully functional with the starboard streamer having been used throughout the entire survey.

A new streamer deployment and recovery method for 2011:

Following the damage to the active streamer section on August 27, 2011, a revised streamer deployment methodology was devised.

Deployment:

In past years, allowing the streamer to sink vertically to excessive depths would have destroyed the depth sensors inside the GeoEel active sections. During the last service procedure at Geometrics Inc., the defective depth sensors were replaced with new sensors which had a much higher pressure rating. This permitted the streamer to be deployed vertically without depth sensor damage.

Before deployment, and on recovery, the streamer was "figure eight-ed" onto the quarterdeck. This operation required most of the crew and technical staff.

A ten pound steel weight, with a small "eye" welded to one end, was fabricated. An approximate 1 foot length of nylon twine and a salvaged sonobuoy parachute were then attached to the eye of the weight (Fig. 1-5).

The weight and parachute were affixed to the outboard end of the streamer drag rope using the free end of the nylon twine, semi-secured with 6- 8 small cable ties. The idea was to secure the nylon twine to the drag rope so that the nylon twine would not slip out from under the cable ties during deployment.

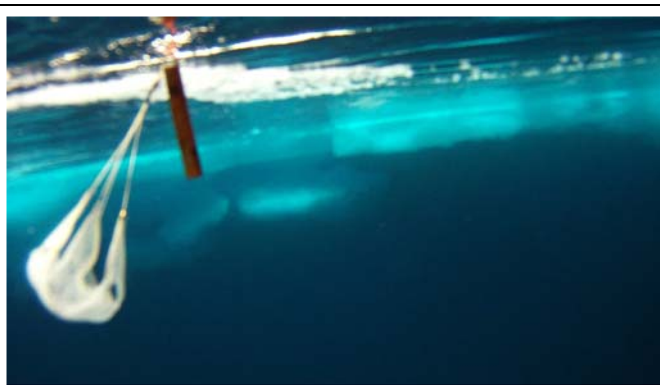


Figure 1-5. Underwater photo of the weight and droag on the end of the streamer.

Before deployment of the streamer began the vessel was brought to a full stop. A small unrestricted pool of open water immediately astern of the vessel was all that was necessary.

The weight, parachute, drag rope and streamer were then lowered over the aft roller off the stern. The boson controlled the speed of deployment, ensuring that the streamer was allowed to sink vertically while maintaining some tension on the free falling streamer.

After deployment, the vessel speed was increased to 3- 4 knots. The parachute then opened in the water and added significant drag to the tail of the streamer, pulling the nylon twine through the cable ties on the end of the drag rope and thus releasing the 10 pound weight and the parachute. The streamer then floated to the proper survey attitude after approximately 5 minutes.

The only issue with this deployment method was the repeated loss of the weight during deployment due to insufficient tension between the drag rope, nylon twine, and cable ties holding the weight. On a number of occasions the weight slipped away before the streamer was deployed and thus recovery was necessary to replace the lost weight and chute.

This was a simple “fix” to a potential damaging situation. Almost all streamer damage that has occurred in past years has resulted from ice contact during streamer deployment. This was due mainly to the fact that the streamer remained virtually on the surface until the sled was deployed, pulling the streamer down to tow depth. It will become a recommended deployment method for surveying in ice covered waters.

No further damage to the streamer occurred during the 2011 program.

Recovery:

Prior to the seismic system recovery, the vessel was allowed to coast to a full stop. The streamer would slowly sink. This took approximately 10 minutes following the full stop. Once the streamer had sunk to a near vertical state, the crew and staff hand- hauled the streamer onto the vessel.

By allowing the streamer to come up from the vertical position ensured that there was little chance of the streamer coming into contact and tangling with sea ice.

Using this method prevented any damage to the streamer during recovery.

Figure 1-6. SeaStar mini CTD, About 2.5 cm in length.

Depth recording CTD’s

Following the damage to the streamer on August 27, it was decided not to use the banana floats on the streamer. Lines 2-4 have no CTD information, therefore, as the depth sensors on the streamer seemed to be functioning appropriately. The depth monitoring CTD’s were re-attached to the streamer jacket using black electrical tape after Line 4. These were removed during the recovery operation and the data were downloaded from each sensor.

The CTD’s were positioned as follows:

(1) At the front of the first A to D Converter
(2) At the front of the second A to D Converter
(3) At the outboard end of the second (tail) active streamer section

No operational issues or CTD sensor losses occurred during the 2011 program.

Data logging and storage:

The data collected from the GeoEel system were logged on the hard drives in the logging computer in SEG-D format using the GeoMetrics StrataVisor software version 5.31. All data were recorded with a 12 second window and a sample rate of 2 ms. A delay of 500 ms was implemented on all recordings. Shot interval varied between 14 and 18 seconds. Data copies were made from the C drive every half hour and stored onto a second hard drive on the same machine. Additional back up was done daily from the C drive. Data remained on the D drive as a second backup.

Some issues arose during the seismic program with missed files being copied from Drive C to Drive D. The issue was typically operator error but no files were actually lost. Another issue arose from operator inexperience in how the setup of the logging files occurred in the GeoEel software. This error caused the numbering sequence for the gun data files to be reset to zero from approx 34,000, thus throwing out the planned orderly logging of file numbers. This can be fixed by software and is clearly noted in the comments section of the Excel watch keeper’s log file.

Conclusions:

The overall performance of the Geometrics GeoEel system in 2011 was judged to be “acceptable”. A considerable portion of the 2011 program involved towing the seismic sled system in fairly old ice, thus reducing the wear and tear on both the sled and the streamer.

The new deployment and recovery methods ensured minimal ice contact during these operations and thus little damage to the wet end system occurred.

The removal of the banana floats allowed the streamer to be deployed vertically but still allowed the CTD’s to be attached to the streamer jacket to record streamer tow depths.

There are only several streamer components which will require Geometrics “factory service” before the next deployment. These components will be grouped and inventoried before being sent to the manufacturer for repairs.

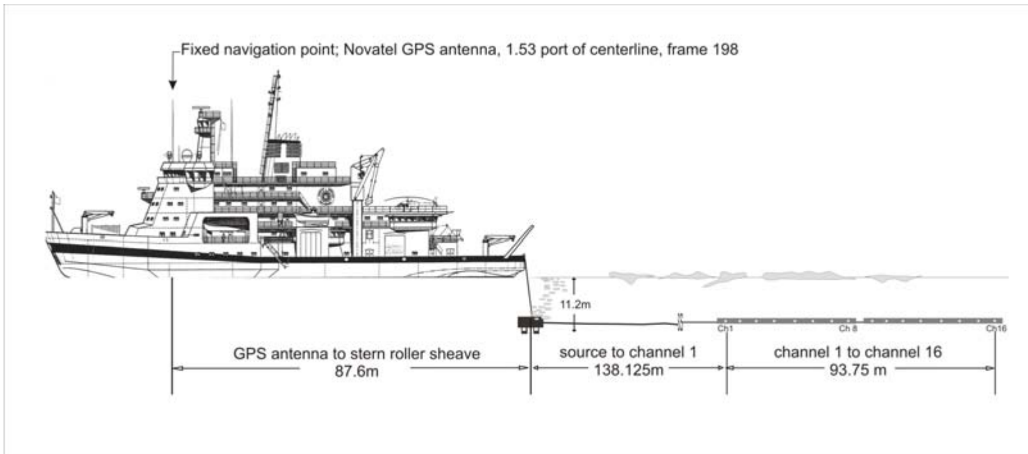


Figure 1-7. Geometries of the seismic reflection equipment.

Reflection Results

Eight seismic reflection lines totalling 1437 line-km of seismic reflection data were acquired (Figure 1-10; Table 1-3). Lines 1-4 were acquired in a transect from Chukchi Plateau to Lomonosov Ridge, across the Chukchi Basin, Alpha-Mendeleev Ridge and Makarov Basin (Fig. 1-11).

Lines 5 and 6 were attempts at getting data within and across Stefansson Basin, east of Nautilus Spur across to Sever Spur. Unfortunately, ice conditions did not permit seismic operations. There were strong winds and too much pressure on the ice to allow the Louis to make forward progress while towing the seismic equipment.

Line 7 crossed from Canada Basin to Sever Spur, transecting the outer three ridges of Sever Spur (Fig. 1-12). It was terminated when ice conditions prevented further forward progress. Line 8 transected the outer two ridges of Sever Spur (Fig. 1-12). Ice impact sheared the Omni wrap on the air hose bundle and punctured one of the air hoses…thus we were down to 1 large gun and one small. We continued to survey until no further forward progress could be made, which was just beyond the outermost ridge.

UNCLOS LSL 2011 Seismic Summary

Line No.	Shotpoint		Line Start						Line End					
			Seismic Data			Watchkeeping Log			Seismic Data			Watchkeeping Log		
	Start	End	Time	Latitude	Longitude	Time	Latitude	Longitude	Time	Latitude	Longitude	Time	Latitude	Longitude
lsl11_01	1	8404	236/100058	78.20044	-164.30862	236/100058	78.200895	-164.290196	237/232026	80.65706	-166.81619	237/232040	80.658293	-166.775837
lsl11_02	8405	11161	237/232045	80.65752	-166.81711	237/232040	80.658293	-166.775837	238/135332	81.65529	-168.34494	238/135334	81.656609	-168.281260
lsl11_03a	11171	14581	238/135351	81.6587	-168.35516	238/135334	81.656609	-168.281260	239/075529	82.90833	-168.02391	239/075528	82.908739	-167.964488
lsl11_03b	14606	23788	239/195328	82.93344	-168.0716	239/194636	82.925962	-168.022503	241/121920	85.52604	-166.79343	241/122006	85.522027	-166.748243
lsl11_04a	23789	26447	241/121934	85.52092	-166.79253	241/122006	85.522027	-166.748243	242/004038	85.87258	-169.91684	242/005745	85.896452	-169.176435
lsl11_04b	26481	36928	242/160813	85.9431	-169.67392	242/162223	85.948067	-169.784773	244/212827	88.19225	143.33814	244/212827	88.192254	143.334824
lsl11_05	36931	38740	253/171914	83.93798	-137.27528	253/172041	83.937417	-137.264381	254/002122	83.76542	-136.14661	254/002121	83.765355	-136.145902
lsl11_06	38741	39484	255/030502	82.08694	-129.84769	255/030325	82.087360	-129.849243	255/064750	82.01497	-129.64043	255/064743	82.014856	-129.640262
lsl11_07	1	3767	255/185650	81.23813	-126.77706	255/185635	81.238121	-126.776949	256/134639	80.5701	-122.94429	256/134705	80.570046	-122.943626
lsl11_08	39486	41863	258/163756	80.1978	-127.05947	258/163745	80.197729	-127.058945	259/044338	80.56597	-129.66303	259/044300	80.565916	-129.663804

Table 1-2. Line numbers and associated start and end times, locations and shot numbers.

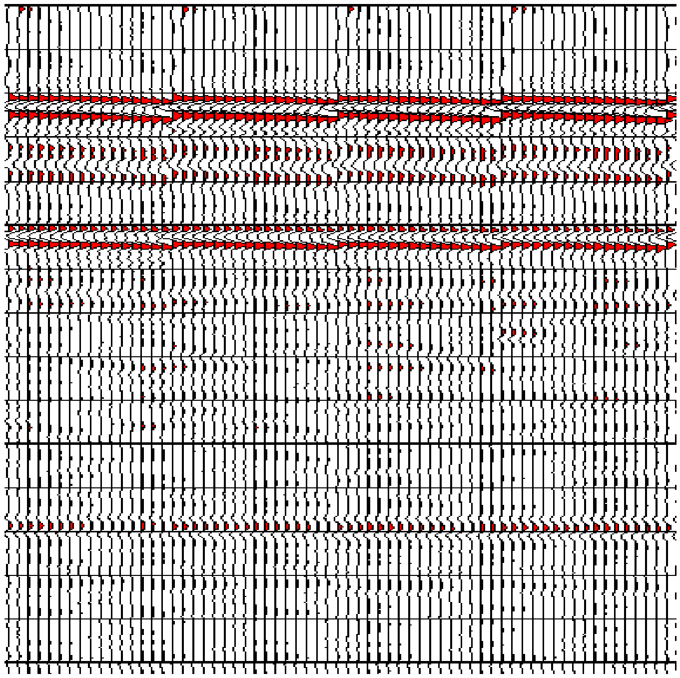


Figure 1-8. An example of shot point data with 16 traces (channels) per shot..

Data Processing

Seismic reflection data were post-processed using GEDCO Vista seismic processing software, version 10. Original SEG-D files were assembled into line segments and converted to SEG-Y format. Seismic processing consisted of debias, bandpass filtering between 12 and 60 Hz, pre-stack surface consistent predictive deconvolution for signature removal, pre-stack surface consistent deconvolution for signature spiking, shot gather stacking, followed by post-stack time varying gain amplification from the seafloor and finite-difference time migration on water velocity only. Figure 1-8 shows 16 channel raw data for each shot-point. Figure 1-9 compares the near channel trace of a section with the post-stack processed result. Final post-processing has not been completed at sea.

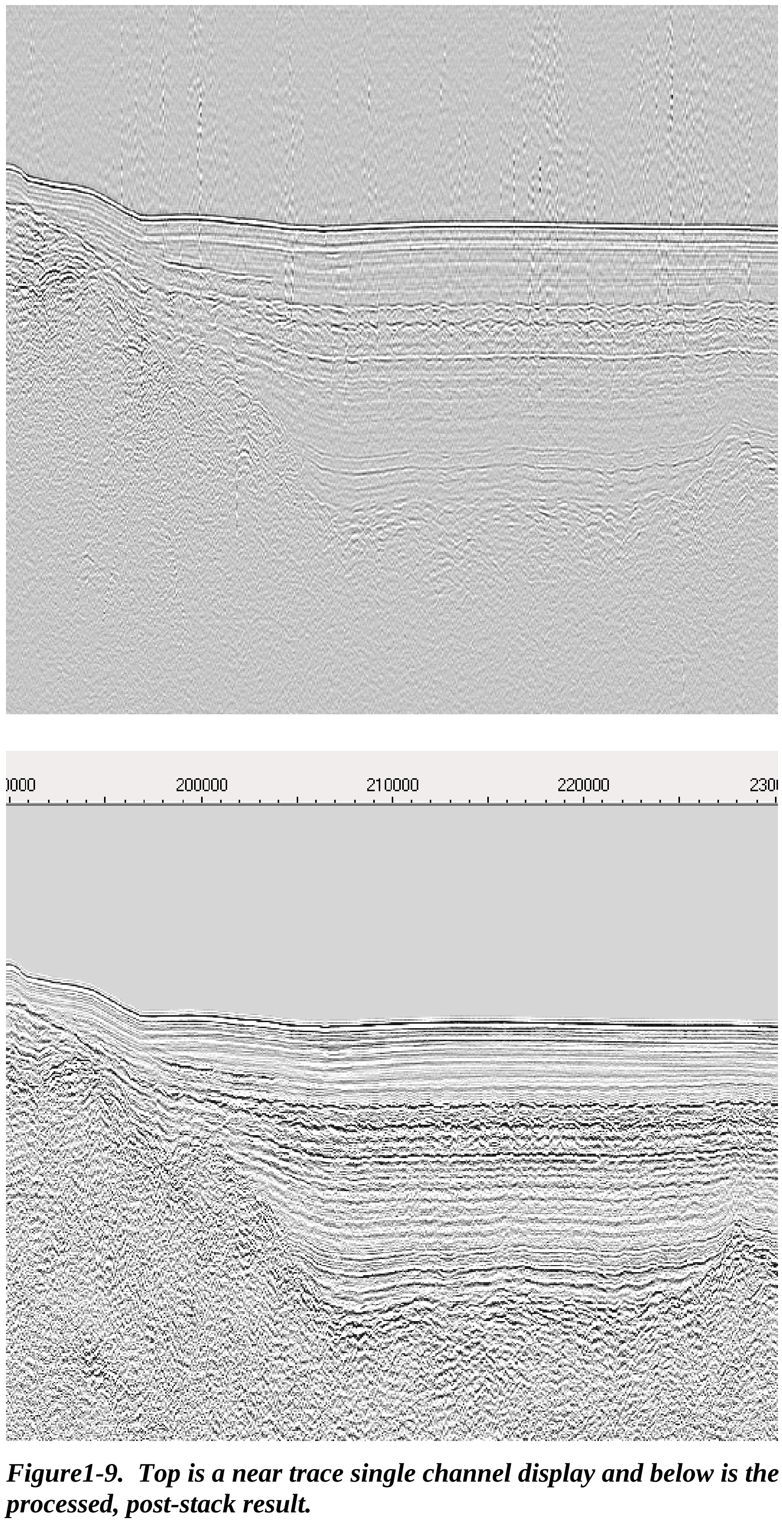


Figure1-9. Top is a near trace single channel display and below is the processed, post-stack result.

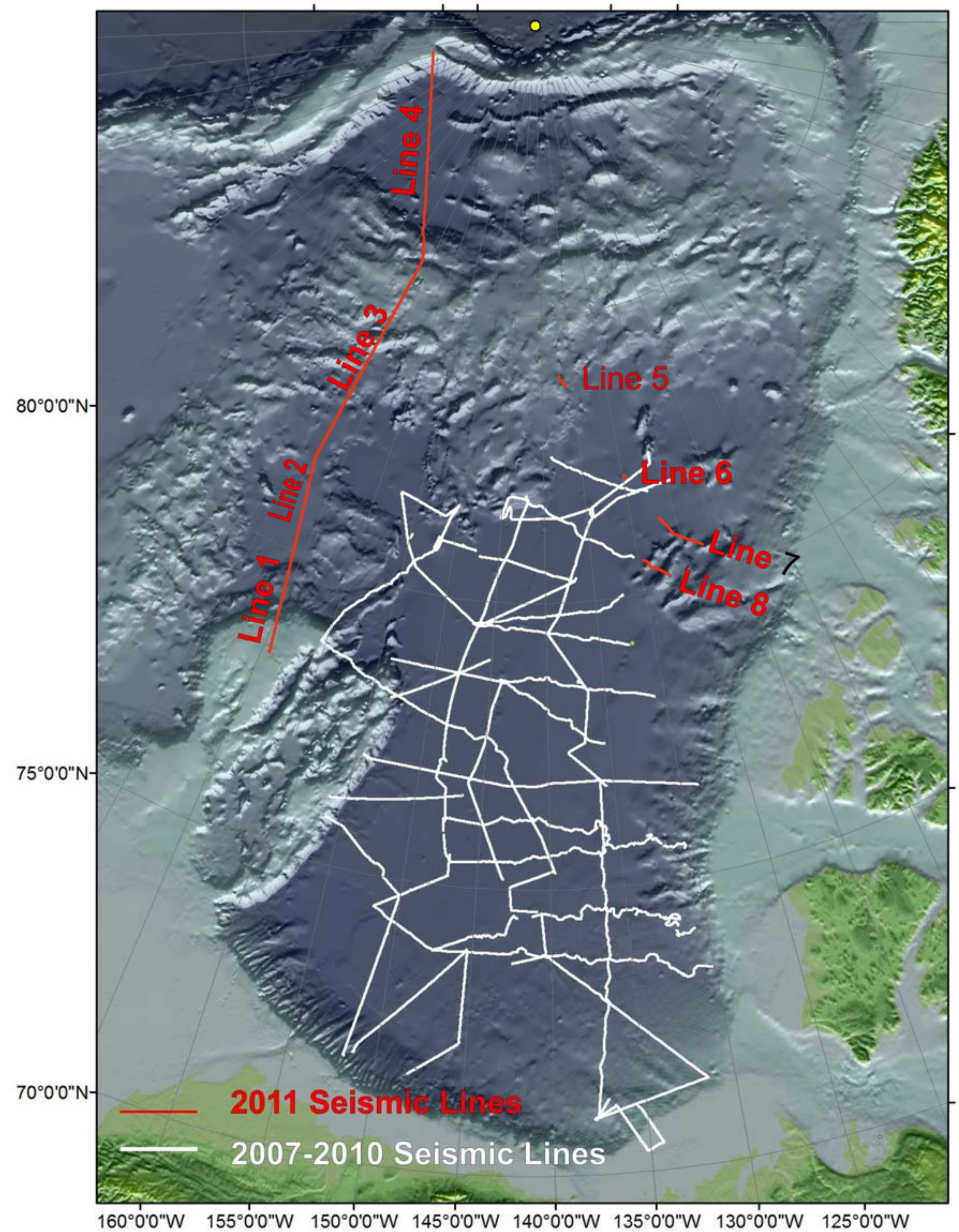


Figure 1-10. Map showing cruise track and line numbers.

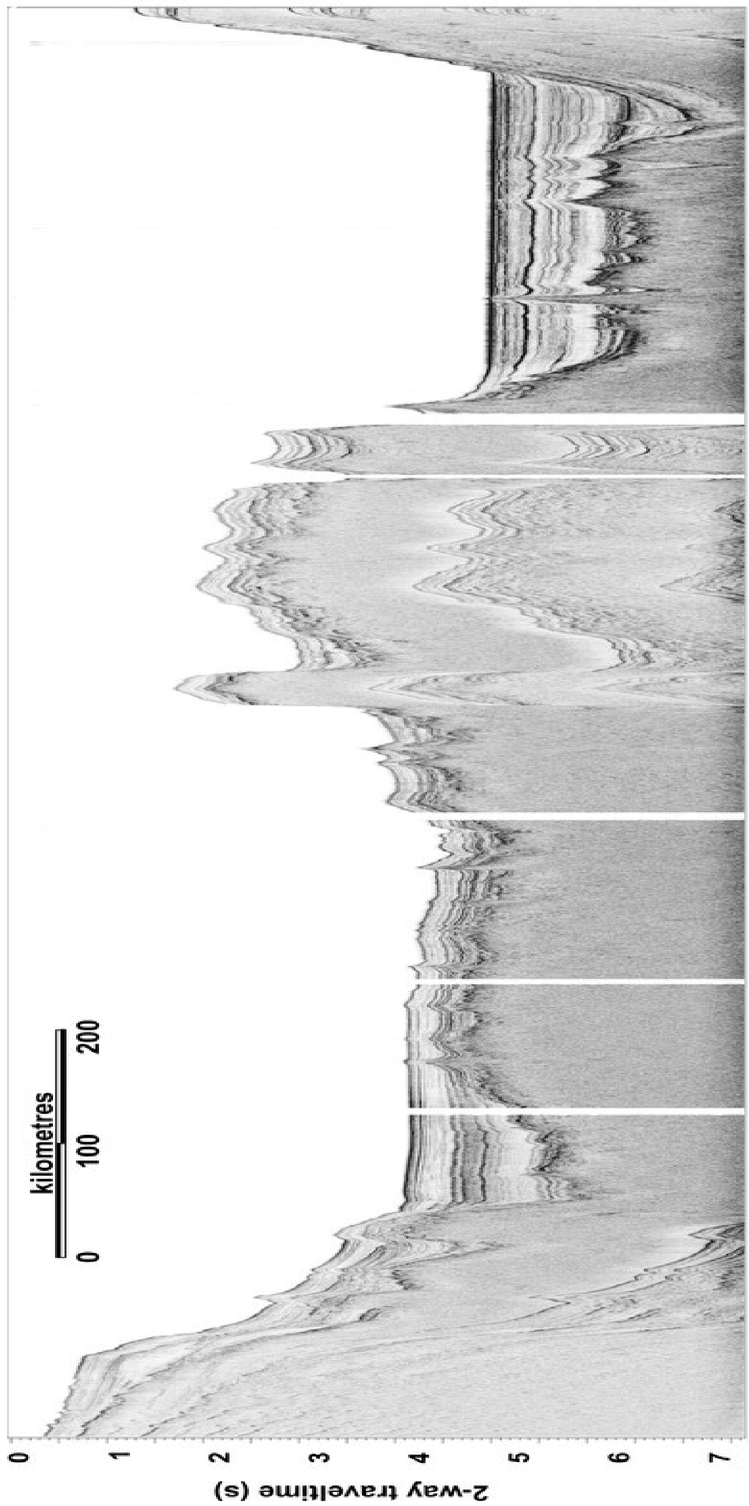


Figure 1-11. Lines 1-4 From Chukchi to Lomonosov Ridge

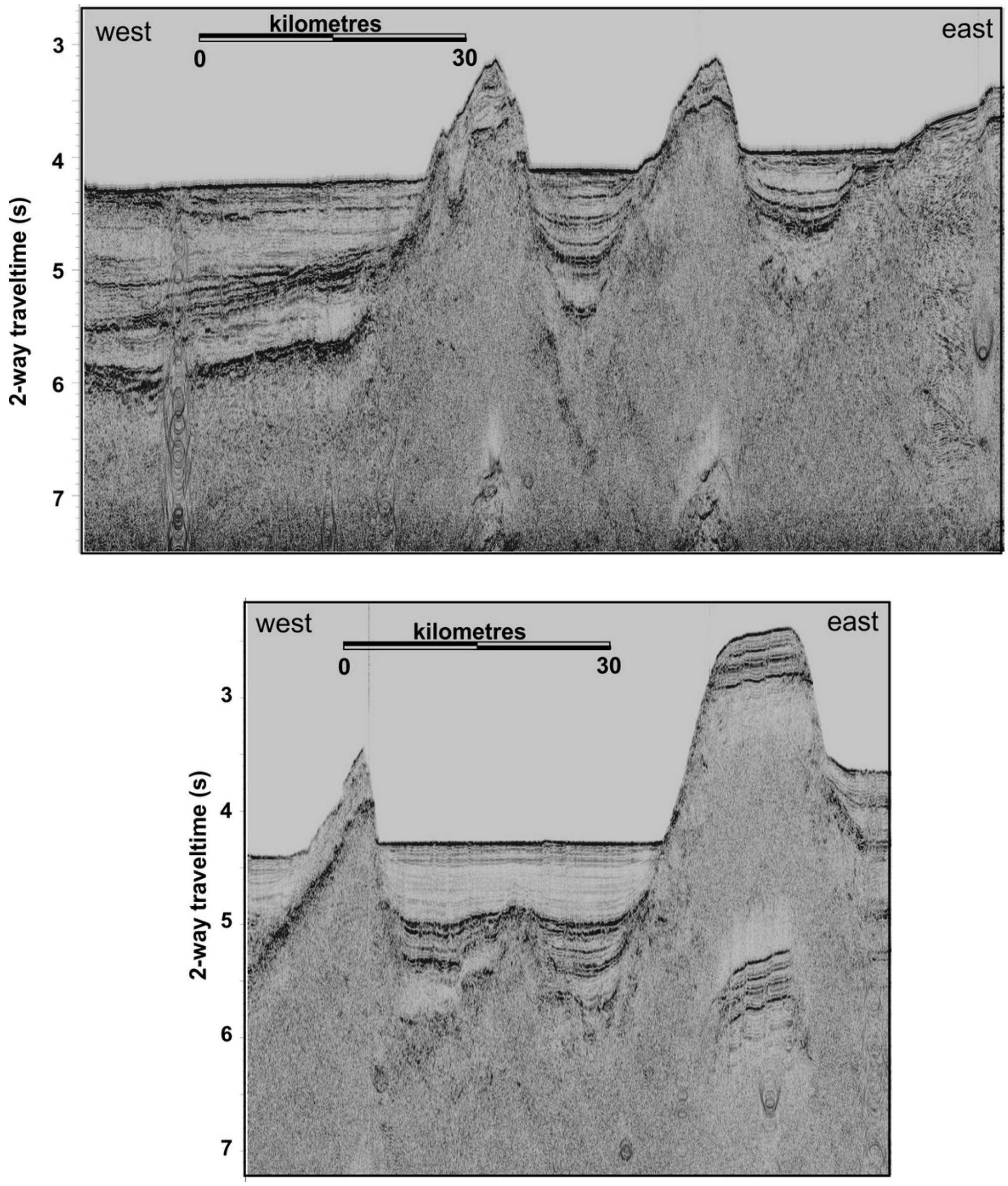


Figure 1-12. Seismic lines transecting Sever Spur. Top is Line 7 and bottom is Line 8.

Seismic Refraction

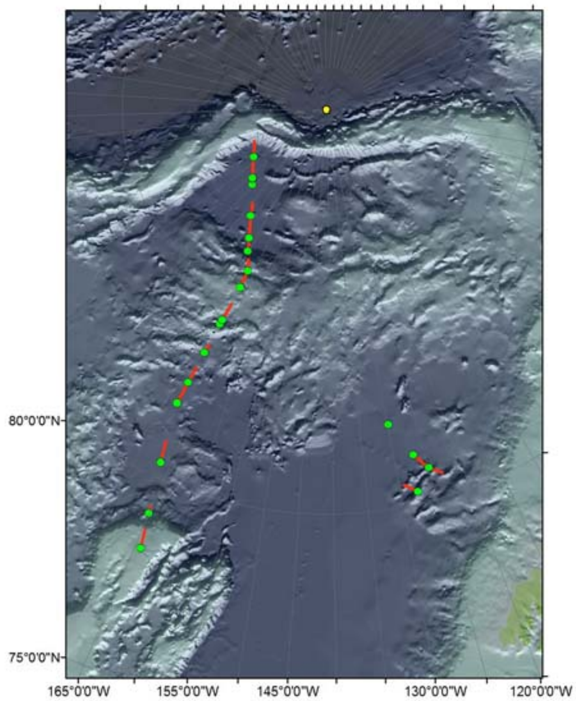


Figure 1-13. Location of sonobuoy deployments along track.

Ultra-Electronics marine sonobuoys (Model 53C) were deployed to acquire wide angle reflection and refraction data for velocity determination, required to convert seismic reflection traveltime to depth. Sonobuoys were deployed at irregular but frequent periods, particularly over line segments meant to be greater than 35 km in length (see Fig. 1-13, Table 1-4). The sonobuoy hydrophone was activated at 60 m water depth. Sonobuoy-received seismic signals were radio-telemetered to two Winradio Model WR-G39WSBe VHF sonobuoy receivers. A stacked Yaggi array of two Andrews DB292-C VHF antennas, cut to respond to frequencies between 150 and 160 MHz were fitted to the aft railing, port side of the "crow's nest". This array has a 15° beam width pattern focussed astern of the vessel. A high pass RF filter prevented damage to the sonobuoy receivers from the strong signal of the Helicopter DF beacon. Signal reception was excellent, often received beyond 35 km. A second set of Andrews yaggi antennas were mounted to the forward facing side of the crow's nest railing; providing an identical forward looking antenna array to the aft array. An RF antenna selector relay was installed between the two arrays, the output of the relay fed to the WinRadio receiver. Control of this relay was via a switch in the seismic lab where the operator could select the forward or aft looking array via the switch. This forward array permitted receiving signals from sonobuoys deployed in front of the ship at distances up to 20 miles. Then, as the ship passed the sonobuoy, the RF relay was switched to the aft array. This allowed satisfactory signal reception form the sonobuoy for the full 8 hour life of the buoy.

Figure 1-14. Sonobuoy being deployed off the quarter deck

Sonobuoy radio signals were recorded on GSCDIG #4 as standard SEG-Y files.

They were also recorded on the prototype Pledge digitizer in SEG-Y format. The seismic trigger pulse from the Zyfer clock was supplied to the digitizer to initiate recording. For the GSCDIG, the record window length was only slightly shorter than the fire period. For the Pledge digitizer, the sample window was set at 25 to 30 seconds. This system can synchronize multiple shots without a delayed write period.

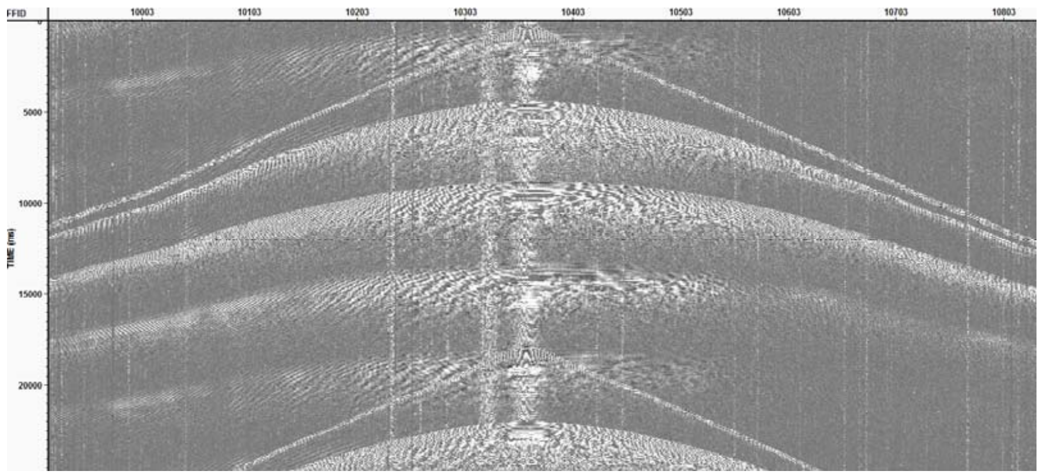


Figure 1-15. Top: an example of a reversed sonobuoy record (sonobuoy 6), with a 25 second record window, recorded on the prototype "Pledge" digitizer.

Refraction Results

21 sonobuoys were deployed with only a few failures (Figs. 1-13 and 1-14 and Table 1-4), either due to ice impact or duds. High quality records were obtained for the majority (Fig. 1-15), although ship to sonobuoy offsets will be irregular due to erratic forward progress during ice breaking. In addition, the complex geology over ridge features, such as Alpha-Mendeleev Ridge and Sever Spur will make it difficult to interpret records. Helicopter and ship-to-ship communications resulted in HF interference on digitized records, but this interference was not fatal. In addition, periodic bursts of noise of unknown source appear on the records.

SB	Line	Deployment Location		Start			End		
		Latitude	Longitude	Time	Latitude	Longitude	Time	Latitude	Longitude
1	lsl11_01	78.226195	-164.295455	236/102257	78.226195	-164.295455	236/182200	78.736006	-164.722964
2		79.084383	-165.016217	236/190000	78.769463	-164.751753	237/031400	79.512290	-165.424210
3		80.375172	-166.425908	237/191716	80.375172	-166.425908	238/030200	80.937275	-167.169311
4	lsl11_03a	81.875360	-168.238017	238/165700	81.875360	-168.238017	239/000109	82.444244	-168.097775
5		82.452876	-168.100183	239/000117	82.452876	-168.100183	239/075528	82.908739	-167.964488
6	lsl11_3b	83.303833	-167.850617	239/211500	83.034892	-167.928142	240/053000	83.554094	-167.764263
7		84.108476	-167.543759	240/141656	84.108476	-167.543759	240/155041	84.209431	-167.506326
8		84.213190	-167.501920	240/155407	84.209431	-167.506326	240/225501	84.692021	-167.248454
9		85.134000	-166.977333	240/231249	84.7121210	-167.245936	241/050920	85.127101	-167.011349
10		85.134126	-167.011347	241/051549	85.134126	-167.011347	241/131617	85.572834	-167.045679
11	lsl11_4a	85.579687	-167.073423	241/132413	85.579687	-167.073423	241/220600	85.870250	-168.820598
12	lsl11_4b	86.020188	-170.155473	242/173608	86.020188	-170.155473	243/020000	86.302851	172.013282
13		86.318365	-172.130396	243/021420	86.318365	-172.130396	243/101500	86.779229	176.568259
14		86.788964	-176.673660	243/102429	86.788964	-176.673660	243/153831	87.093385	179.483928
15		87.410238	174.161650	243/160000	87.103437	179.284051	244/000200	87.512267	171.924802
16		87.517094	171.834839	244/000651	87.517094	171.834839	244/002800	87.532015	171.473506
16a		87.532715	171.473506	244/002824	87.532715	171.473506	244/081000	87.850842	162.450545
17		87.855475	162.316929	244/081724	87.855475	162.316929	244/082302	87.859590	162.222623
17a		87.863534	162.120513	244/083011	87.863534	162.120513	244/165148	88.079093	151.911058
18a	lsl11_06	82.084264	-129.785098	255/042144	82.084264	-129.785098	255/064743	82.014856	-129.640262
19	lsl11_07	81.208876	-126.711611	255/194350	81.208876	-126.711611	256/033900	80.823034	-124.968682
20		80.811852	-124.888348	256/035138	80.811852	-124.888348	256/114130	80.581964	-122.982108
21	lsl11_08	80.292694	-127.374814	258/182342	80.292694	-127.374814	258/022311	80.557366	-129.355254

Table 1-3. Summary of sonobuoy deployments

To aid and accelerate the production of results for the seismic refraction program, preliminary processing of the sonobuoy data was undertaken during the cruise. For this purpose, a C-based program called SeisWide, developed by Deping Chian, was used. The raw sonobuoy data were converted to small-endian and loaded into SeisWide. Data first-breaks were picked in order to calculate trace offset. The program assigns offset values in metres to traces relative to the coordinates of the first trace of the SEG-Y file by using the first-break traveltime to calculate the offset. The offset distances are calculated using the formula developed by Lebedeva-Ivanova's X = a + bT + cT2, where X is offset in km, T represents the pick traveltime, and a, b and c are derived coefficients whose values are -0.006, 1.441 and 0.00075, respectively. These values are based on ray-trace models given the 'typical' water column structure of the Arctic.

Bathymetry and Subbottom Profiling

As in the past five years of this program, the Canadian Hydrographic Service (CHS) performed bathymetric survey operations in conjunction with the NRCan seismic operations (see Chapter 2). This year, however, the operation included the ship's 12 kHz sounder and a newly installed Knudsen 3.5 kHz sounder. In addition, a number of helicopter spot soundings were acquired (Fig. 1-16). The ship navigated along pre-determined transects and the helicopter was deployed to collect spot sounding data between the survey lines. The ship logged 7350 line kilometres of bathymetry data and 74 spot soundings were acquired via helicopter. Virtually the same equipment was used for both platforms.

LSSL collected soundings using a Knudsen 320B/R Plus sounder attached to a hull-mounted 12 KHz transducer. The system used Chirp pulse generation technology. As is common when sounding in ice, bottom detection was sometimes lost due to interference from ice. Watchstanders (Weedon and Forbes) processed data in near real-time to eliminate outliers and maintain bottom tracking. The sounder was active for the entire expedition. Knudsen Echo Control Client V1.47 and Echo Control Server V1.44 software were used for acquisition and PostSurvey V2.24 software was used for viewing during post processing of the data. Data were recorded in Knudsen native KEB format. Attempts to also record in SEG-Y format resulted in software crashes. CARIS (Computer Assisted Resource Information System) GIS v4.4 was used for managing, compiling, and visualizing results of the processed bathymetric data. CARIS HIPS/SIPS v6.1 (Hydrographic Information Processing System/Sonar Information Processing System) was used for survey data processing of positions and depths.

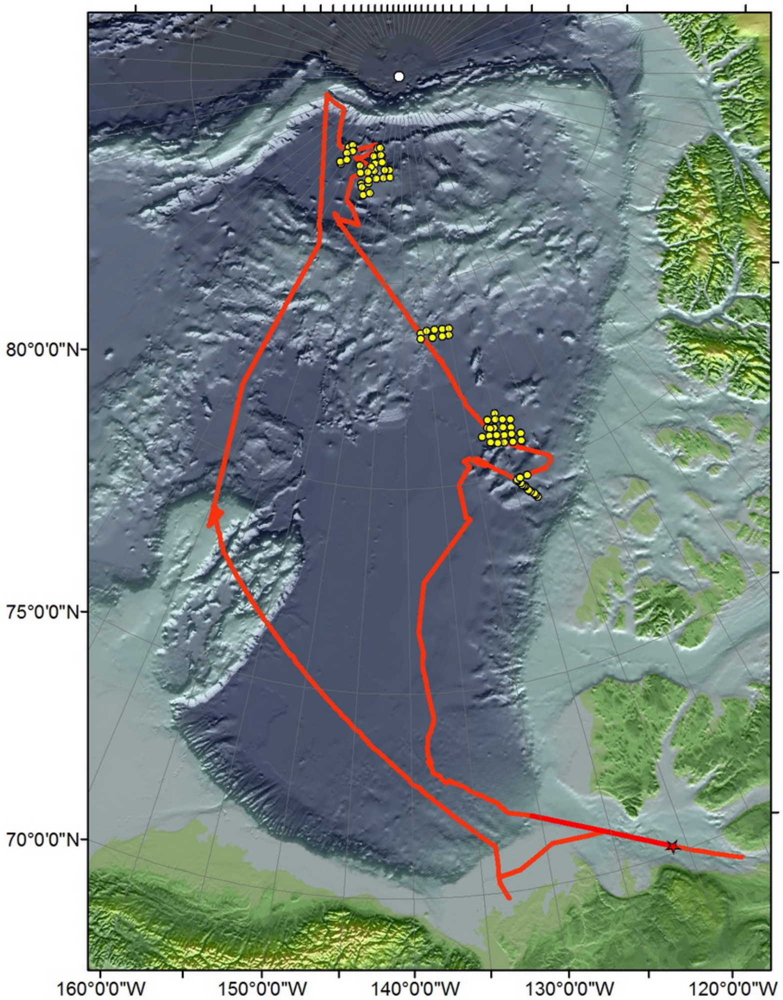
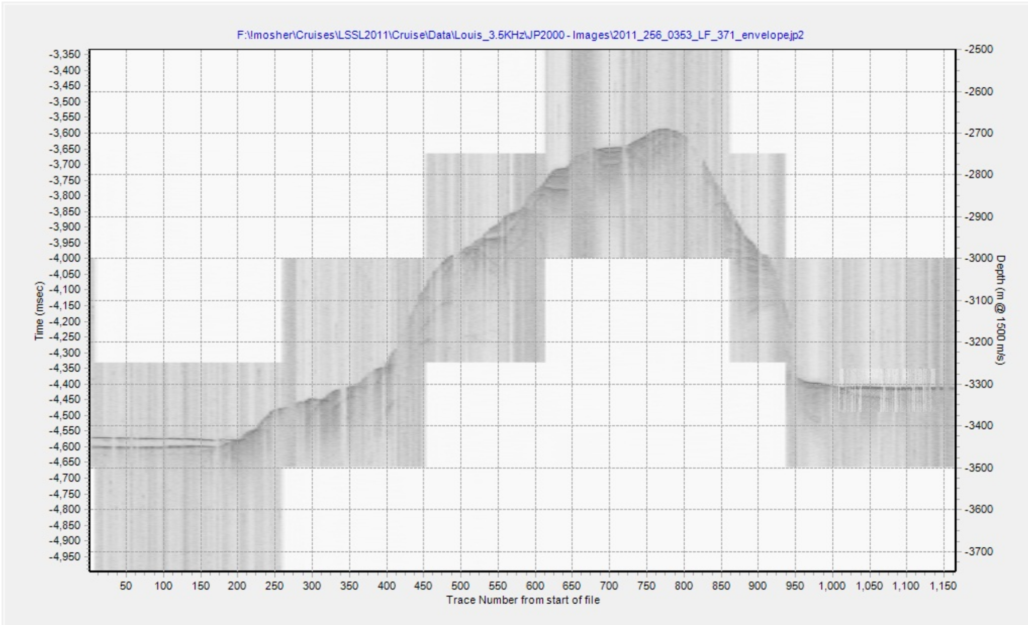


Figure 1-16. CHS spot soundings via helicopter

During drydock, the Louis S. St-Laurent had a 12 element Knusden 3260 Chirp subbottom profiler installed in its drop-keel. The system was operated by CHS during the expedition and was run for the entire expedition. Records are of mixed quality, depending on ice breaking conditions. Fig. 1-19 shows some examples of these data. All data were recorded in SEGY format and converted to JP2000 post-acquisition. The USCGC HEALY joined the LOUIS S. ST-LAURENT on August 23rd and departed September 22nd, during which time additional hydrographic data were collected with their EM122 deep water multibeam and Knudsen Chirp profiler systems (Fig. 1-20). Total track length of the Healy while engaged on this program was 4,485 line-km.



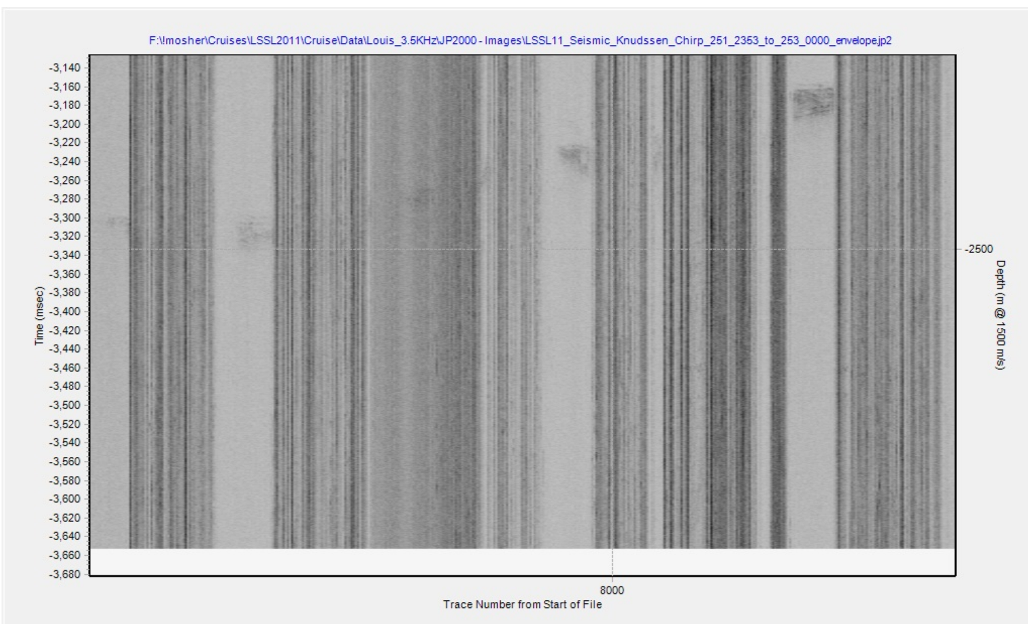


Figure 1-17. Chirp data acquired from the Louis S. St-Laurent. Top is a profile across one of the Sever Spur Ridges during which Healy broke ice ahead of the Louis. Below is a typical example of chirp data during heavy ice breaking operations.

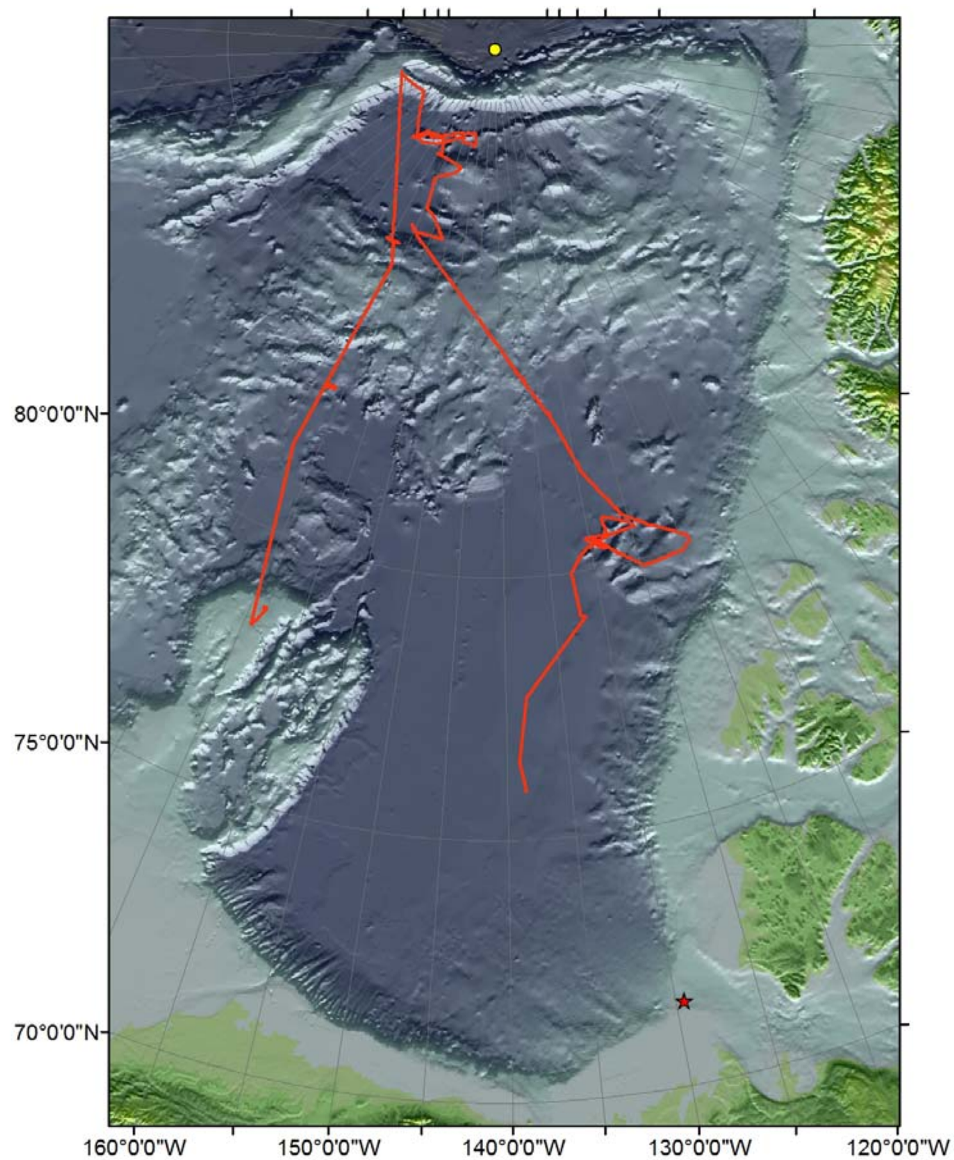


Figure 1-18. US Coast Guard Cutter Healy ship track during which multibeam bathymetric sonar and concurrent chirp subbottom profile data were acquired while working with Louis S. St-Laurent.

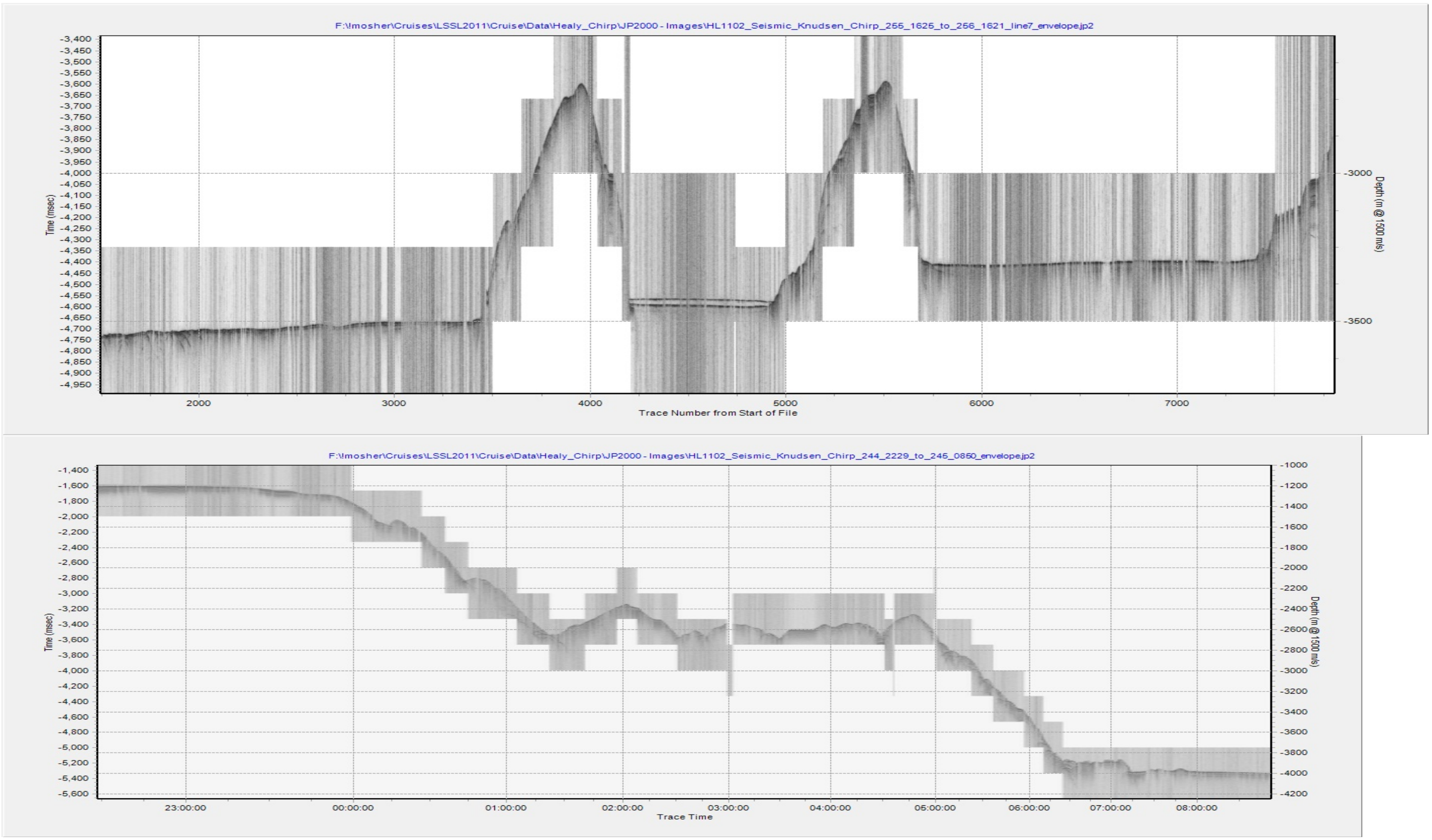


Figure 1-19. Chirp subbottom profiles from the USCGC HEALY. Top is from Sever Spur (Line 7) and is an example of data acquired during ice breaking. The lower profile is from Lomonosov Ridge down to Makarov Basin, and was acquired while LSSL broke ice for Healy.

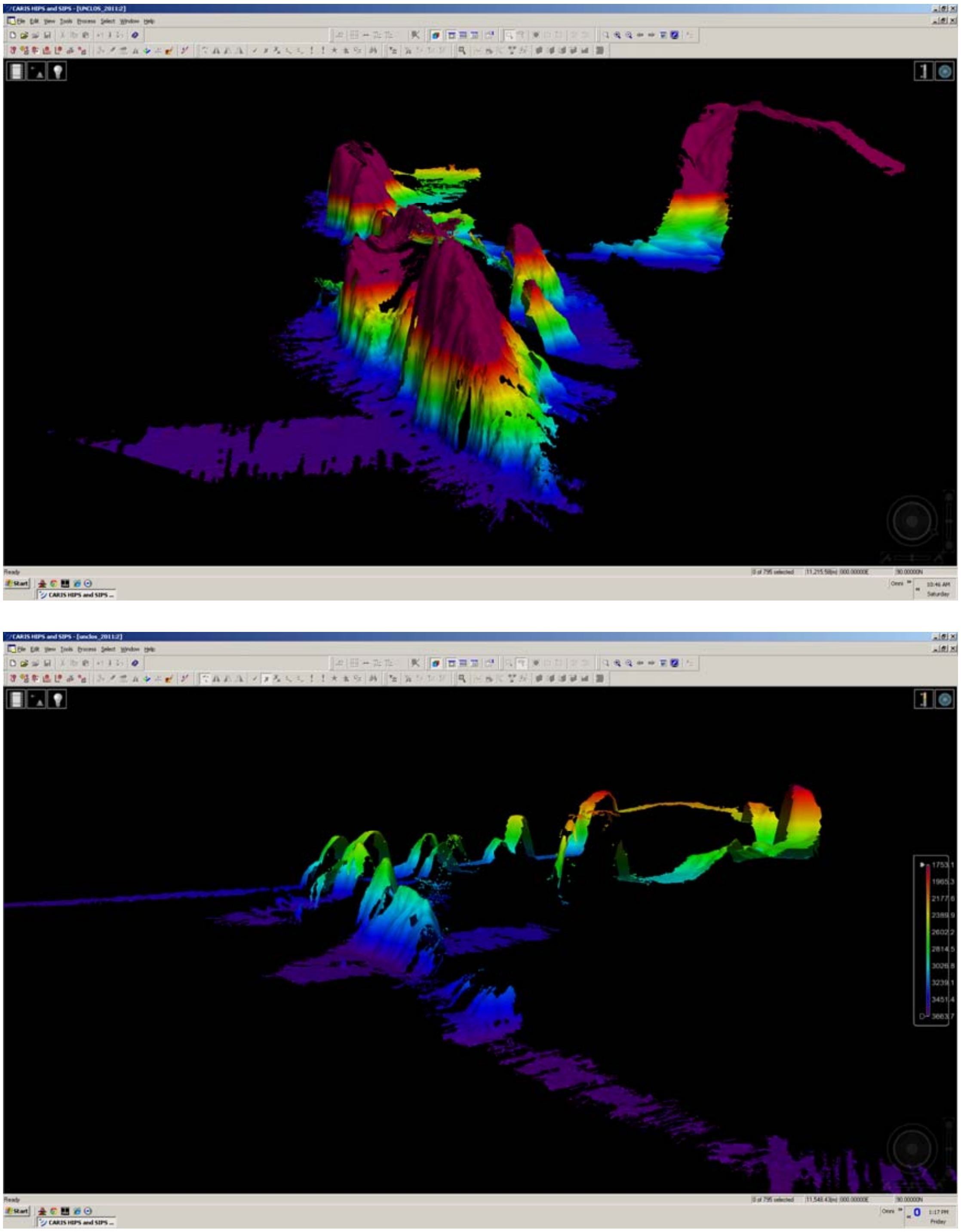


Figure 1-20. Multibeam images from the USCGC HEALY. Top is Marvin Spur looking from the SW towards NE. Bottom is Sever Spur looking from S to N.

AUV Operations

Full details of AUV operations are provided in Chapter 3. As part of the 2011 UNCLOS Arctic Survey Mission conducted aboard the Canadian Coast Guard icebreaker Louis S. St. Laurent (LSSL), two autonomous underwater vehicles (AUV) were brought aboard to acquire multibeam bathymetric data under the ice. These AUV were successfully used last year from an ice camp west of Borden Island and were trialed from the LSSL this year, in May. Each AUV is configured with multiple systems for ballasting, navigation and communication; thus mitigating the risk inherent in conducting under-ice AUV missions. Systems include a variable ballast system, Benthos acoustic modems for telemetry, the GPS Acoustic Positioning System (GAPS) positioning system, Long Range Acoustic Bearing (LRAB) for homing, and Acoustic Tracking System (ATS) for localization. They travel approximately 100 to 200 m above the seafloor, down to abyssal water depths (>3000 m), acquiring multibeam bathymetric data along pre-programmed tracks. They each have about 48 hours of mission capability and travel at approximately 3 knots.

AUV Configuration.
The main AUV payload for the LSSL Expedition was:

- One EM2000 multi-beam sonar (operating at 200kHz)
- One Knudsen single beam sonar (operating at 118kHz)
- One Teledyne Benthos telesonar modem with two selectable transducers (operating between 9-14 kHz; source level of 186 dB)
- ITC Transducer (operating between 6-7 kHz; source level of 181 dB)
  - A hyperbolic chirp or Hyperbolic Frequency Modulated (HFM) chirp signal in the frequency range 6-7 kHz at maximum 181 dB.
- Two selectable GAPS transducers (operating at 26 kHz +/- 4 kHz MFSK ; source level of 192 dB).

Ship-based AUV Systems/ Acoustic Sources & Modems.

- The LRAB SSMMPP operates at frequencies between 800-2000 Hz. During the LSSL Expedition, it operated at 1400±40 Hz with a maximum source level of 190dB.
- Teledyne Benthos Modems operate at frequencies between 9-14kHz with maximum 186 dB source level.

These modems have a maximum source level of 186 dB, but will be operating typically at 800 baud. Since they have a relatively low duty cycle, they will generally transmit only for a few seconds at a time and then remain silent for long periods. In addition, the duty cycles cease when the AUVs are not in-service.

AUV Activities.
During the LSSL Expedition, the AUVs were expected to:

- Operate on subsurface missions in support of the UNCLOS Survey
- Utilize on board Knudsen single beam sonar
- Operate the EM2000 multi-beam sonar, as needed
- Launch and recover an AUV from the CCGS Louis St-Laurent

Homing and Tracking Related Activities.
DRDC Atlantic developed specialised homing and tracking capabilities, used to address AUV issues such as long range tracking, homing to moving platforms and an alternative, limited one way communications system between surface control to the AUV.

AUV Objectives:
The objectives of the AUV program are two-fold.
1) provide proof-of-concept of under ice AUV operations from an ice breaker.
2) Using the AUVs, measure bathymetry of the Marvin Spur, a sliver of the Lomonsov Ridge.
3) Using AUV's, measure bathymetry of the Sever Spur.

AUV Operations:
Deployment 1
On September 3rd, LSSL negotiated to an open water lead to begin AUV operations to survey the eastern portion of Marvin Spur. The AUV "Qaujisaqti" serial number B06 was used for the first operation. First deployment proved that ballasting was inadequate to dive below the surface fresh layer of the Arctic. The vehicle was recovered and adjustments made over night. During the night, the shipped steered a 360º box pattern to align the inertial navigation unit (INU). The following day, the AUV was deployed again. After system and dive tests, the vehicle was sent on its mission. The descent to the sea floor took approx. 4 hours. As the AUV neared the sea floor and during the initial loiter at ~3400-3500 metres, the AUV experienced a suspected obstacle avoidance sonar failure and the AUV bottom avoidance system caused the vehicle to carry out obstacle avoidance measures. The mission was aborted, the vehicle rose to surface and subsequently surfaced beneath the ice nearby to the hole. Repeated efforts to retrieve the vehicle with the ROV were unsuccessful.

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Figure 1-21. Recovery of the AUV in ice.

The following day (Aug. 5), the AUV was precisely located by triangulation with a modem deployed over the side and manoeuvring the vessel repeatedly. The ship was then used to break ice around the AUV until it was visually located. It was then recovered to deck and the mission at this location was aborted. Upon inspection, the only visible damage was a loose modem possibly due to a small chuck of ice pressing on the modem. The forward control planes (#1 and 2) and one aft plane (#3) suffered slight damage, i.e. crinkling and de-lamination of the fiberglass outer-shell. These were replaced with spare planes from B05. Suspect impact with ice being the most likely cause. Only three planes were affected so it cannot be attributed to a pressure at depth effect. The failed CTD sensor was replaced.

Deployment 2

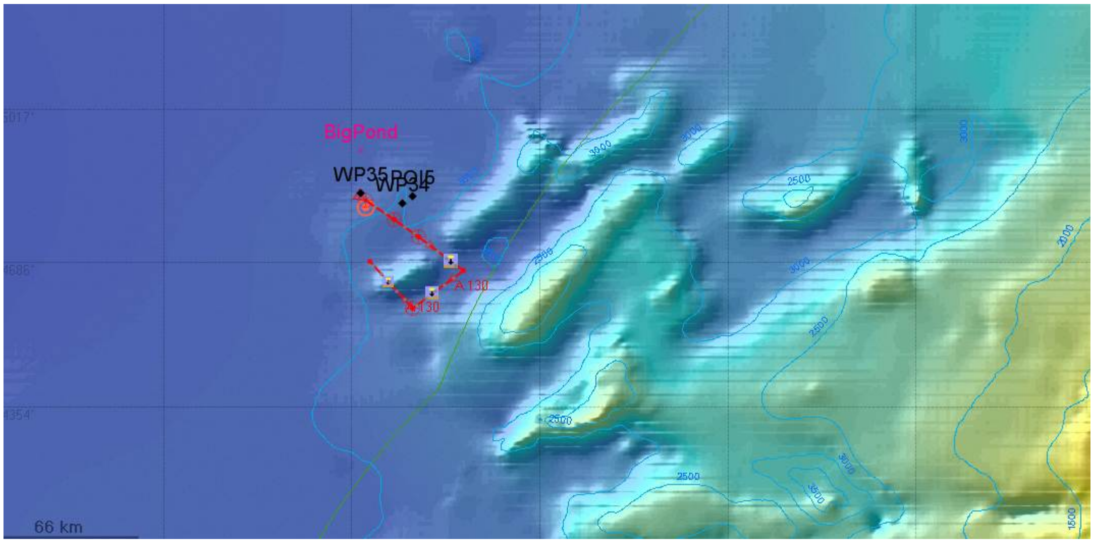


Figure 1-22. AUV mission plan at Sever Spur.

"Qaujisaqti" (B06) was used in the second deployment as well. September 16th, an open water pool was found close to the outboard edge of Sever Spur. A mission was planned to cross the outer (western) ridge of Sever Spur through an interpreted gap in the ridge, as shown on the IBCAO chart, to verify its presence and to return over the southernmost portion of the outer ridge.

Launch procedures commenced at 1806h on Sept. 16. B06 carried out a descent to the sea floor of approximately 3600 m depth. The AUV obtained a bottom lock at 210 m altitude and quickly settled into a loiter at 130 m depth. After successfully completing the two hour loiter, B06 commenced the survey portion of the mission at 0741UTC 16 Sep, 2011. Very good telemetry was obtained out to a distance of approx 15 km at which time the vehicle telemetry was automatically shut off as per the mission plan to conserve AUV power. Intermittent modem telemetry was obtained at a distance of 10.8 km. (0209UTC 17 Sep, 2011). Surface currents were observed to be strong and opposite to ship drift direction at this site, as wire angles on the acoustic modems hanging over the side were severe.

For the return, B06 homed to the LSSL and by 0341UTC was in a homing pattern beneath the ship. By 0600UTC, the GAPS system picked up the AUV position at 1900 m depth. It homed to the ship, but due to strong currents, ended up parking itself beneath heavy ice a hundred metres from the vessel. Even with the ship breaking ice around the vehicle, slop ice kept the AUV submerged. It was decided to command release of the AUV 40 kg drop weight to increase the AUV buoyancy. Eventually the vehicle was observed and lines were attached to bring it aboard.

Figure 1-23. AUV recovery.

Despite close proximity of ice breaking activities by the LSSL to free the AUV, the only damage incurred was some cracking to the fiberglass nose cone and two damaged planes.

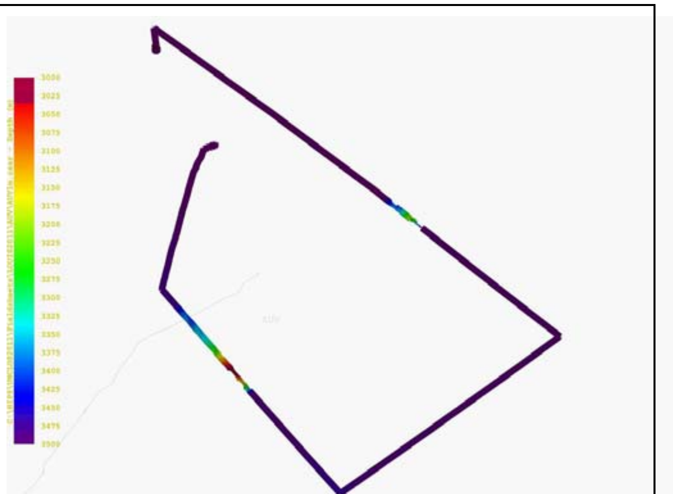


Figure 1-24. AUV multibeam data

The mission was highly successful with acquisition of 110 km of multibeam and single beam bathymetric data. The vehicle was able to home-in on the ship despite significant drift of the ship between deployment and recovery. Inspection of the data showed high quality but with obvious artefacts, likely caused by interference with the Doppler speed log. In addition, comparison with ship-borne data shows the INU track positioning is approximately 500 m off. This error was confirmed with measured difference between the GAPS AUV positioning system and the vehicle's INU; due to positional error incurred during the descent and ascent phase of the mission in which the INU is running in free inertial mode without a bottom lock and corresponding lack of along and cross track velocity.

AUV Science Results Summary

- *110km mission track length*
- *3400m Max depth obtained by the AUV*
- *Collected Knudsen Single Beam Echosounder data*
- *Collected EM2000 Kongsberg Maritime Multibeam Echosounder data*
- *Ability to operate and maintain an AUV from one half of the Hanger aboard the LSSL*
- *Ability to launch AUV from a ship in ice covered arctic waters (3x)*
- *Ability to recover an AUV from under 2.5m thick ice using an ice breaker (2x)*
- *Ability to track an AUV at long range (15km) using ATS tracking system*
- *Ability to localize an AUV using modem ranging*
- *Ability to track an AUV using the GAPS tracking system*
- *Ability to improve INU alignment by rotating the AUV on the flight deck.*
- *Need to synchronize the multibeam and DVL to reduce interference*
- *AUV occasionally loses multibeam bottom coverage after a steep ascent over a sharp rise. This loss of coverage is due to the AUV's lower descent rate. This is a safety feature. Investigate possible higher descent rates?*
- *The CTD sensor on both B06 and B05 failed during this expedition. Further investigation required. Require a new method to clean sensor face to avoid any potential for freezing.*
- *Ships maneuvers can improve or degrade INU alignment. Change in direction better than a long straight track.*
- *Having an experienced AUV handler in man-basket very useful, complete understanding of hook up points in stressful situations.*
- *A through ice audible localization system was useful in maneuvering the ship close to AUV location using forward lookouts. It is difficult to use over the side equipment from an ice breaker and still maneuver. Therefore having an audible system is advantageous.*
- *Ice ponds can be very small, almost impossible to have the AUV surface in an exact position.*
- *Require a very quick response Variable ballast system which would provide quick response to calls for negative or positive buoyancy requests. Thus allowing the AUV to be raised or lowered to/from the under ice surface and jumped to a location of choice more rapidly than the current system provides.*
- *For under ice ROV-AUV recovery. Need an ROV with negative/neutral buoyancy umbilical and real-time tracking system feedback to the ROV pilot.*

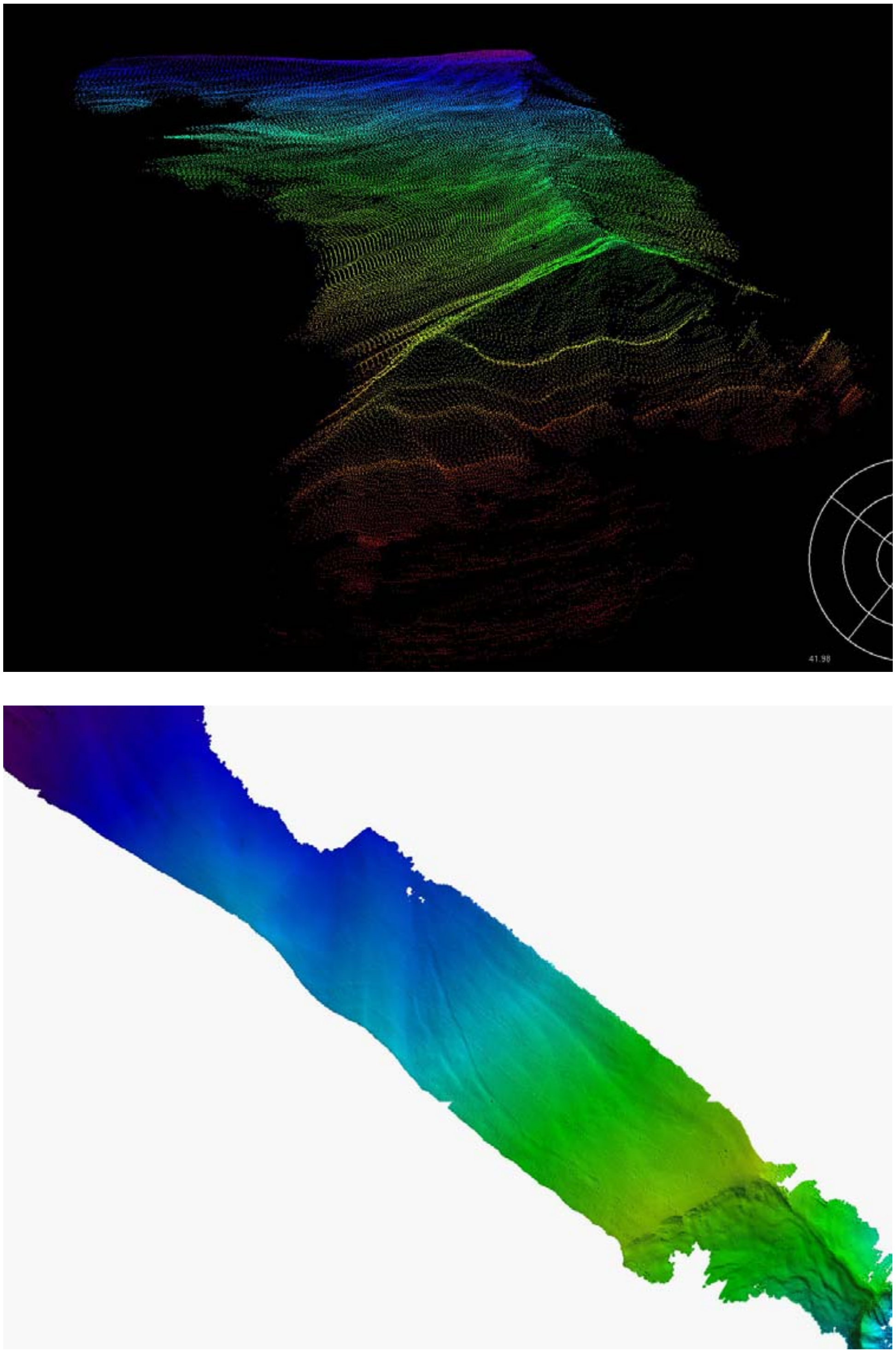


Figure 1-25 Examples of multibeam data acquired by the AUV "Qaujisaqti".

Gravity

Gravity data were recorded continuously during CHASE2011 operations, totalling 7848 km of data, not including the transits to and from Newfoundland. Chapter 4 provides a detailed report of gravity data acquisition on the Louis S. St-Laurent and a final report on installation, ties, instrument operation, drift, and bias values will be provided by the USGS in a follow up report. Daily plots of free air gravity anomaly data, compared with the Arctic Gravity Project model (Kenyon and Forsberg, 2008) are provided in the Appendix.

A Bell Aerospace BGM-3 gravity meter, SN 223, was installed on the vessel in Halifax in July 2011 (Fig. 1-26). The instrument was provided by the Woods Hole Geopotential Instrument Pool under contract to the USGS. The instrument is scheduled to remain on board the vessel until arrival in St. Johns on or about November 20, 2011.

This gravimeter is virtually identical in all respects to the two BGM-3 meters, SN 221 and SN 222, that have been deployed on Healy since 2005. Description of the meters and details of data logging and processing can be found in earlier cruise reports from HLY0503, HLY00805, HLY0806, and HLY0905, for example:
http://ccom.unh.edu/publications/Mayer_08_HEALY_0805_CRUISERPT.pdf (p. 80-83)

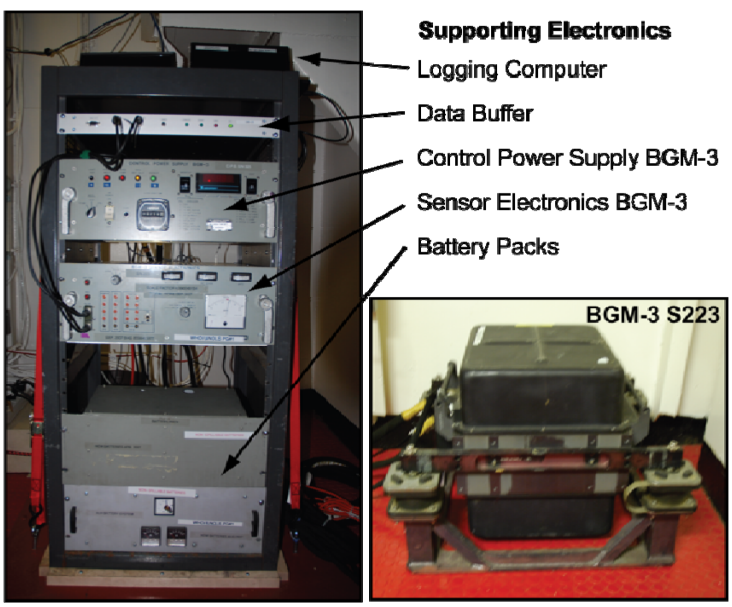


Figure 1-26. BGM-3 Electronics and logging computers installed in Louis Gravimeter Compartment # 615.

Data were logged to a dedicated laptop computer installed with the gravimeter (shown in Fig. 1-26) starting on July 17. Recording will continue continuously until the vessel returns to St. John's and the equipment demobilized. The data recorded while the ship is dockside will be used to correct for the long-term drift of the meter.

The data logging system records three files:

1. *.gef - raw sensor input as received by logger; new file created every hour
2. *.sde - log file reporting the status of sensor inputs
3. *.rgs - composite data file consisting of sensor input from BGM-3, vessel GPS, and Knudsen 12 kHz bathymetry depth.

The logged files files were transferred manually to the Louis shared science drive lsl-regulus daily during the cruise and backed up with the cruise data.

Quality Control at Sea

Three types of quality control of gravity data were completed during the 2011 UNCLOS cruise: (i) a weekly check on hardware values, (ii) a daily check of preliminary smoothed gravity compared to the Arctic gravity grid (Forsberg and Kenyon, 2004) and IBCAO bathymetry, and (iii) a gravity log of hourly GPS navigation positions annotated with comments relevant to the gravity acquisition (kept by D. Hutchinson).

Known Problems

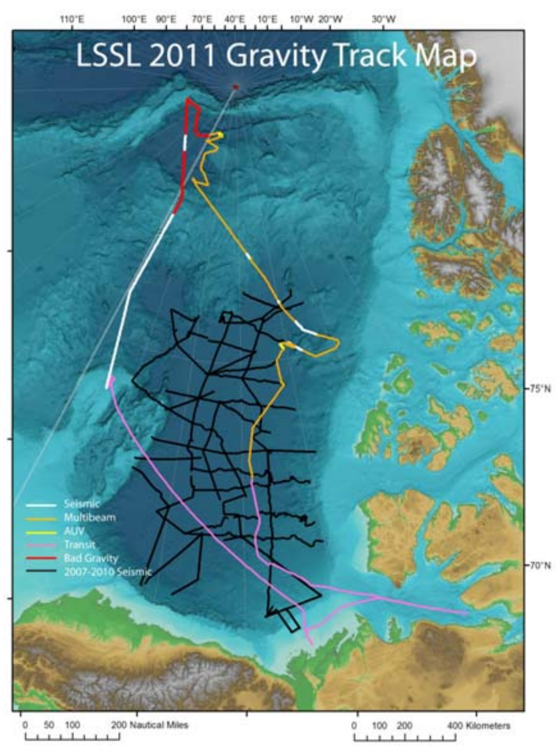


Figure 1-27. Gravity data acquisition from LSSL 2011 keyed to activity. Tracks for seismic data acquisition from 2007-2010 are also shown. Red indicates the locations where gravity data were lost.

Five known problems with the BGM 223 gravity system occurred during the *Louis* cruise and are detailed in Chapter 4: i) Control Power Supply (CPS) / CPU restart with loss of about 61.5 hours of data, ii) Two Simultaneous Gravlog Processes resulting in about 50.5 hours of “confused” noisy data, iii) clock drift on the logging computer was measured to be about 10 sec/day, iv) Performing the recommended sensor tests on the gravimeter (checking the power of the sensor test points with a digital volt/ohm meter) resulted in coincident sensor-only errors in the RGS data records and a loss of data for these times. The down time from these sensor errors is considered negligible, and v) There were problems throughout the cruise with GPS fixes not being recorded every second. An edited depth file was generated at sea and is included with the raw gravity data. These depths need to be merged during final gravity processing.

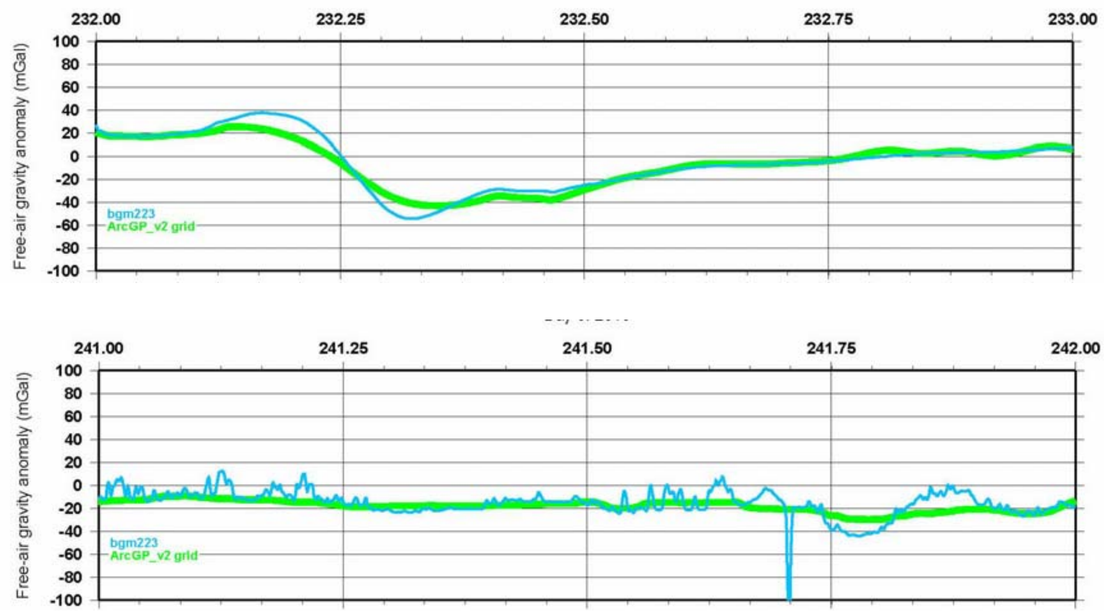


Figure 1-28. Top image shows gravity signal(blue line) with Healy breaking ice ahead of LSSL. Notice the goodness of fit with the ArcGP grid (green line), with some finer detail added. Bottom image shows gravity signal while LSSL breaks ice. Notice the addition high frequency noise due to accelerations of ice contact.

Physical Oceanography

(See Chapter 6 for full details)

Vertical Casts

SVP, XCTD and XBT

Six Rosette casts for water samples with Deep water Sound Velocity Probes and CTD were acquired along with 74 XCTD (eXpendable Conductivity – Temperature – Depth profiler, Tsurumi-Seiki Co., Ltd.). Probes were launched to measure the vertical profiles of water sound velocity, temperature and salinity (Table 1-5 and Fig. 1-29). Sound velocity and temperature data were acquired using an Applied Microsystems SV Plus v2. With the ship stopped, the sensor was deployed from the ship's starboard A-frame. Measurement accuracies from the manufacturer specifications are sound velocity: 0.05m/s with 0.03 m/s precision; temperature: 0.005ºC, pressure: 0.01% full scale (approx 0.5m). The XBT's operated at depths to about 400 and the XCTD's to a depth of 1100 m.

Table 1-4 Physical Oceanographic vertical casts

UNCLOS LSSL 2011 XCTD SUMMARY

Stn.#	Line #	Time	Latitude dd mm.ssss	Longitude dd mm.ssss	Depth metres	Comments
XCTD1	lsl11_1	233/201912	73 17.3800	-141 39.2300	3496	
XCTD2		233/222508	73 37.3800	-142 59.5500	3683	
XCTD3		234/062906	74 52.8000	-148 07.9700	3853	
XCTD4		234/110351	75 37.3700	-151 25.1100	3886	
XCTD5		234/130904	75 54.3200	-152 43.8600	3886	
XCTD6		234/151942	76 14.7000	-154 16.5100	3884	
XCTD7		234/161401	76 22.9600	-154 56.2400	3000	
XCTD8		234/162812	76 24.3700	-155 03.2500	1375	
XCTD9		234/164256	76 25.8100	-155 14.3800	971	
XCTD10		234/190903	76 49.5000	-157 06.4700	455	
XCTD11		234/211743	77 09.9000	-158 46.4300	1849	40%
XCTD12		235/154457	78 36.1700	-164 49.1200	767	60%
XCTD13		236/104016	78 14.4600	-164 18.6300	516	40% Ice - stopped short of bottom
XCTD14		236/192717	78 48.3400	-164 47.3200	1080	60%
XCTD15		236/205814	78 53.7300	-164 52.7500	1742	60% - wire touched ship
XCTD16		236/210426	78 54.0300	-164 52.6400	1794	60%
XCTD17		237/001524	79 06.3600	-165 04.1700	2140	60% - comm error at 224m
XCTD18		237/001917	79 06.9200	-165 04.6900	2145	60% - comm error at 230m
XCTD19		237/043903	79 23.7600	-165 20.4800	2698	80%
XCTD20		237/085237	79 40.0600	-165 37.4000	2850	80%
XCTD21		237/150611	80 04.6300	-166 04.2100	3321	80% - comm error at 267m
XCTD22		237/151005	80 04.9200	-166 04.5400	3320	80%
XCTD23		238/030422	80 54.8900	-167 08.0800	3346	80%
XCTD24	lsl11_3a	238/151126	81 44.4300	-168 15.7600	3380	100%
XCTD25	lsl11_3a	238/151455	81 44.7500	-168 15.7300	3378	100%
XCTD26	lsl11_3a	239/022957	82 31.8800	-168 04.8000	3409	90%
XCTD27	lsl11_3b	239/202916	82 57.9700	-167 57.6700	3283	100%
XCTD28	lsl11_3b	240/022538	83 21.9700	-167 49.7000	3114	100%
XCTD29	lsl11_3b	240/124225	84 00.0800	-167 35.3400	1595	100%
XCTD30	lsl11_3b	241/021913	84 55.9300	-167 07.8300	1898	100% - comm error at 203m
XCTD31	lsl11_3b	241/022145	84 56.1400	-167 07.6900	1897	100%
XCTD32	lsl11_4a	241/155150	85 42.8200	-167 49.9700	2320	100% - ice broke wire at 475m
XCTD33	lsl11_4b	243/023445	86 20.1200	-172 16.0800	3966	100% - ice broke wire at 293m
XCTD34	lsl11_4b	243/023832	86 20.3900	-172 17.7600	3966	100% - ice broke wire at 355m
XCTD35	lsl11_4b	243/150437	87 03.5500	179 56.0200	3984	100% - ice broke wire at 661m
XCTD36	lsl11_4b	244/023943	87 38.1600	168 57.9700	3989	100% - ice broke wire at 267m
XCTD37	lsl11_4b	244/024306	87 38.3600	168 53.8200	3985	100% - ice broke wire at 949m
XCTD38	lsl11_4b	244/152853	88 02.8800	153 40.3600	3700	100% - ice broke wire at 129m
XCTD39	lsl11_4b	244/153127	88 02.9600	153 35.3500	3692	100% - ice broke wire at 151m
XCTD40	lsl11_4b	244/170439	88 04.7200	151 55.0300	3330	100% - ice broke wire at 667m, ship stopped
XCTD41		244/215506	88 11.4600	143 19.6400	1197	100% - stopped
XCTD42		245/034225	88 25.5500	157 12.5700	2561	100% - stopped
XCTD43		245/151710	87 49.5100	177 10.7300	3900	100% - stopped
XCTD44		246/045931	88 05.7800	-166 51.6700	3726	100% - stopped
XCTD45		249/194736	87 39.4700	-157 40.6900	2407	100% - stopped
XCTD46		250/142504	86 46.3300	-164 21.6700	3968	100% - stopped
XCTD47		251/003006	86 25.1800	-158 01.0800	3868	100% - stopped

XCTD48		251/101744	86 15.0900	-165 01.9100	3911	100% - stopped
XCTD49		252/025337	85 46.5500	-155 21.5600	3043	100% - stopped
XCTD50		252/112911	85 21.0400	-149 20.2000	2378	100% - stopped
XCTD51		252/195334	84 54.9063	-144 41.0615		died at 55m - ice
XCTD52		252/195611	84 54.9900	-144 40.5900	2083	100% - stopped
XCTD53		253/034938	84 31.1300	-141 19.3100	1784	100% - stopped
XCTD54		254/033211	83 33.1700	-135 11.7600	2968	100% - ice broke wire at 849?. Hit pan of ice on deployment, then washed off? Conductivity and depths are incorrect - needs some processing.
XCTD55		254/152902	82 58.0800	-132 24.4600	3538	100% - stopped
XCTD56		255/021827	82 05.2100	-129 53.1700	3640	100% - stopped
XCTD57		255/160828	81 20.9200	-127 17.3300	3584	100% - stopped
XCTD58	Isl11_7	255/224044	81 02.6700	-126 03.5600	3515	100% - ice broke wire at 713m
XCTD59	Isl11_7	256/024122	80 52.1200	-125 24.7500	3200(est)	100% - ice broke wire at 155m
XCTD60	Isl11_7	256/024504	80 51.9300	-125 22.6000	3200 (est)	100% - ice broke wire at 223m
XCTD61	Isl11_7	256/134359	80 34.2000	-122 56.6300	3011	100% - stopped
XCTD62		256/204352	80 21.9200	-121 02.2100	2415	100% - stopped - lat/lon entered into 1m file by hand
XCTD63		257/061358	80 05.8100	-119 10.6700	2258	100% - stopped
XCTD64		257/210251	79 53.4600	-121 59.0900	2289	100% - stopped
XCTD65		258/153146	80 12.1400	-127 01.9600	3077	100% - stopped
XCTD66	Isl11_8	259/022039	80 33.4700	-129 21.3400	3598	100% - stopped
XCTD67		262/154103	79 12.0400	-132 21.9600	3627	100% - stopped
XCTD68		264/111854	78 42.5900	-133 58.3000	3703	100% - wire broke at 134m
XCTD69		264/112207	78 42.5200	-133 58.5100	3705	100% - wire broke at 52m
XCT70		264/172718	78 16.1900	-135 57.1200	3736	100% - wire broke at 249m
XCTD71		264/212455	77 59.4000	-137 05.8300	3737	100% - stopped
XCTD72		265/055904	77 16.4700	-138 30.2900	3754	90% - rotten, ice broke wire at 979m
XCTD73		265/111717	76 41.0900	-138 53.2100	3726	90% - rotten
XCTD74		265/214939	75 47.6100	-138 42.8900	3703	90% - rotten
XCTD75		266/071634	74 48.2900	-138 09.2600	3543	60%, 7.5 kts
XCTD76		266/191041	73 52.2700	-138 30.5100	3461	30%, 10 kts
XCTD77		267/024757	73 01.4600	-138 00.7100	2945	25%, 10 kts
XCTD78		267/101147	72 41.7000	-135 52.8000	2591	open water
XCTD79		267/212542	71 51.6000	-131 48.1800	1155	open water

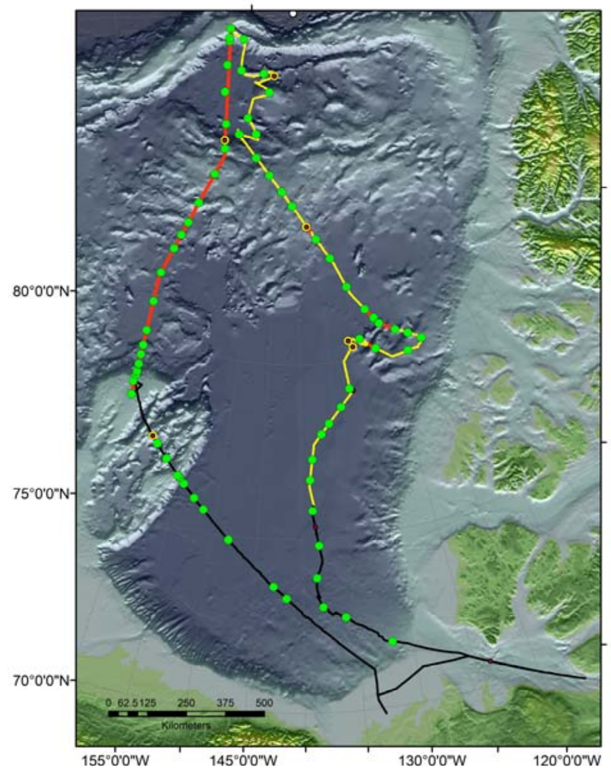


Figure 1-29. Vertical oceanographic profile data. Green dots are XCTD and XBT locations and the Yellow dots are Rosette samples locations with full ocean depth Sound Velocity and CTD Probe data acquired simultaneously..

Underway Systems:
Physical and chemical seawater measurements are taken at frequent regular intervals throughout the cruise via seawater intake valves on the LSSL. These measurements include salinity, temperature (inlet and lab), fluorescence, CDOM (2009-19 only), gas tension, and oxygen saturation.

Instruments in the TSG lab were:

Seabird SBE 21 Thermosalinograph s/n 3297
Seabird SBE-38 Thermometer s/n
WET Labs WETStar fluorometer s/n WS3S-521P
WET Labs CDOM s/n WSCD-1281

Figures 1-30 and 1-31 show a summary of results of salinity and temperature measurements taken through this underway system.

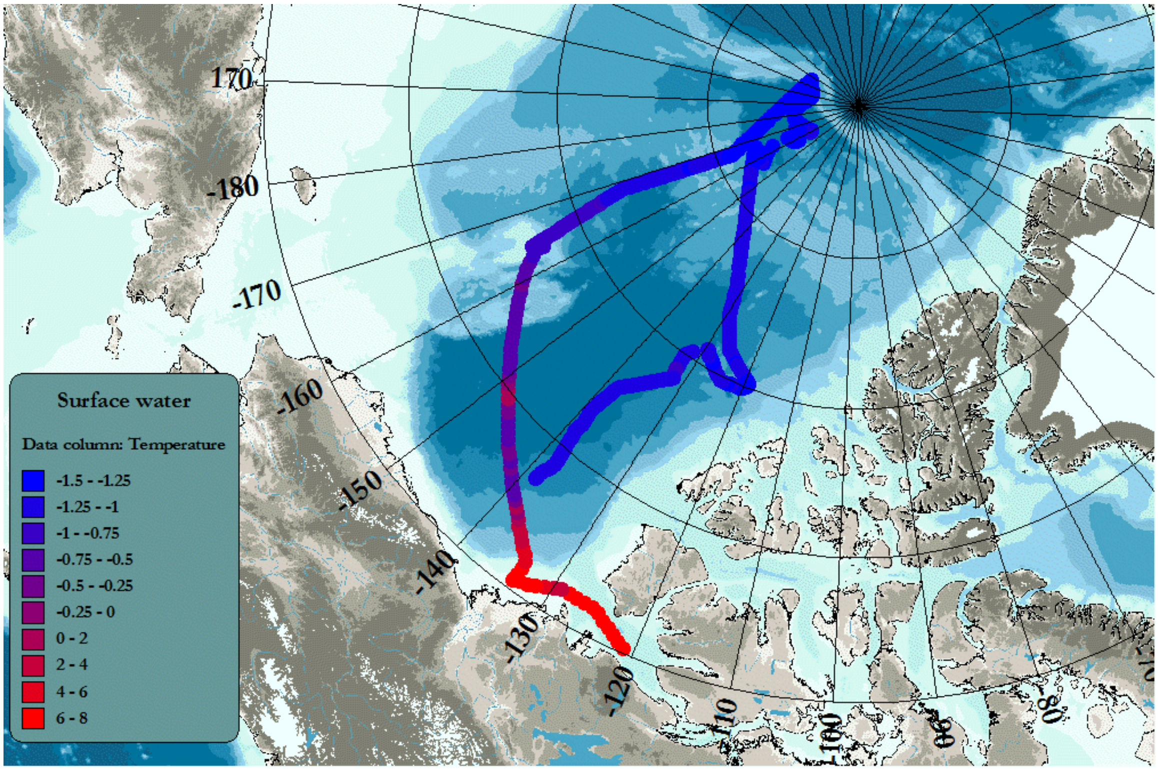


Figure 1-30: TSG inlet temperature

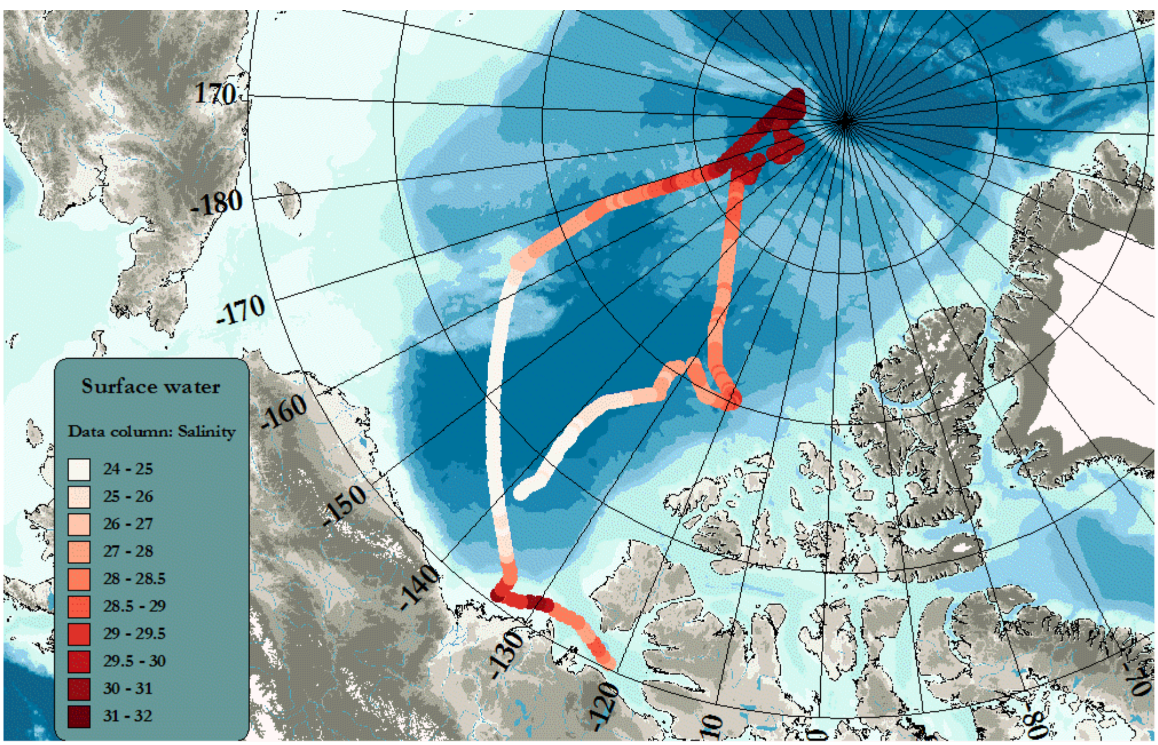


Figure 1-31: TSG salinity

Mammal Interactions and Mitigation

The full environmental assessment report for this expedition is available upon request. Of greatest concern was interaction with marine mammals during seismic survey operations. Appropriate mitigative measures were adopted to address this concern.

Canadian regulations

Details of mitigative requirements for the CHASE2011 program can be seen in the Canadian Environmental Approval Application, provided upon request of the Chief Scientist. In brief, mitigative measures follow the guidelines laid out in the DFO Statement of Canadian Practice (http://www.dfo-mpo.gc.ca/oceans/management-gestion/integratedmanagement-gestionintegree/seismic-sismique/statement-enonce-eng.asp) and include "**ramping-up**" the pneumatic energy source array and 24 hour **observation for marine mammals** by 3 observers to ensure no marine mammals were within **1000 m radius** of the array or otherwise as far as weather conditions permitted. If spotted within this 1000 m radius, the source array was shut down until the ship or animal exceeded the 1000 m radius. It should be noted that during this and the previous four years of seismic exploration in this same region, no cetaceans were seen by observers. 24 hour mammal observation took place only during seismic operations, otherwise observations were noted by the bridge staff. No marine mammals were sighted during seismic operations of the 2011 mission. Table 1-8 summarizes mammals sighted during the mission.

Table 1-5. Mammal sightings

LSSL 2011 Mammal Observations

DAY	TIME	LATITUDE	LONGITUDE	SPECIES	COMMENTS
236	1103	78.270653	-164.332718	ring seal	seal on the ice - starboard
236	1114	78.282005	-164.343787	polar bear	on ice and in good shape - starboard
237	0158	79.223033	-165.17687	bear tracks	polar bear tracks port side
238	0250	80.901462	-167.113646	ring seal	seal in the water - port side
238	1056	81.450777	-167.94667	bear tracks	tracks on ice - stbd side
239	0427	82.678075	-168.03865	ring seal	on the ice - port side
239	0440	82.6939	-168.032124	ring seal	in the water - stbd side
240	1014	83.839607	-167.648236	ring seal	in the water - port side
240	1443	84.138185	-167.530971	ring seal	in the water - stbd side
241	0829	85.344215	-166.880529	ring seal	on the ice - stbd side
241	0900	85.380923	-166.834926	ring seal	in the water in front of ship
241	0942	85.423565	-166.821845	ring seal	in the water - stbd side
241	1143	85.480718	-166.82068	ring seal	on the ice - port side
242	1533	85.93967	-169.618601	ring seal	
243	1152	86.873282	-177.672092	ring seal	in the water - stbd side
262	2002	71.917667	-132.492167	polar bears	Mother and cub in good shape

Weather and Ice

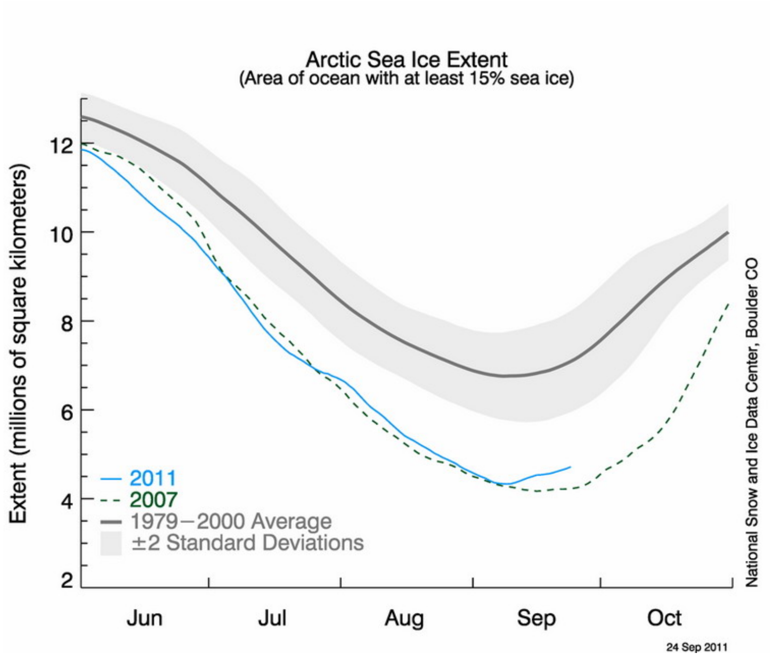
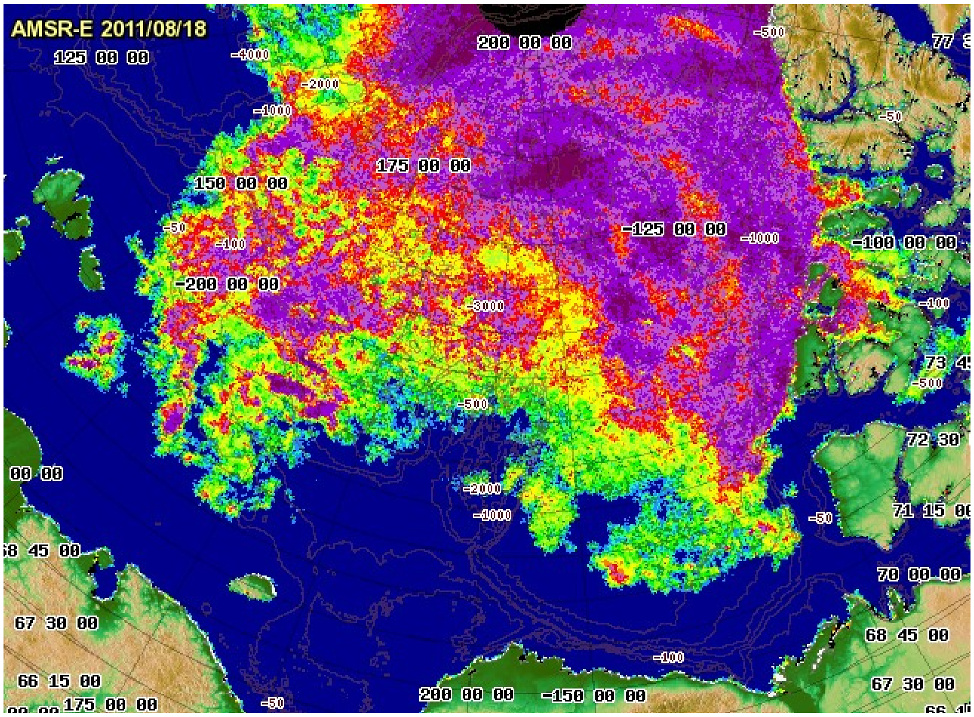


Figure 1-32. Daily Arctic sea ice extent as of September 6, 2010, along with daily ice extents for years with the four lowest minimum extents. The solid light blue line indicates 2010.

A summary of ice conditions along the CHASE2012 track is provided in Chapter 5 and daily weather and ice reports are documented in the Appendix. This season, ice extent was the second lowest in the satellite record, after 2007 (see Figs. 1-32 and 1-33). On September 9, 2011 sea ice extent dropped to 4.33 million square kilometers (1.67 million square miles). This year's minimum was 160,000 square kilometers (61,800 square miles) above the 2007 record minimum extent, and 2.38 million square kilometres (919,000 square miles) below the 1979 to 2000 average minimum. The minimum ice extent this year is close to 2007, and indeed some research groups place 2011 as the lowest on record (http://nsidc.org/arcticseaicenews/, accessed Sept. 26, 2011).

Despite these ice extent conditions, our operational area during the second portion of the program took us to the heaviest sea ice in the Arctic.

Aerial photograph showing ice conditions, taken during the expedition from the helicopter.
Photo by Barbara Molyneaux



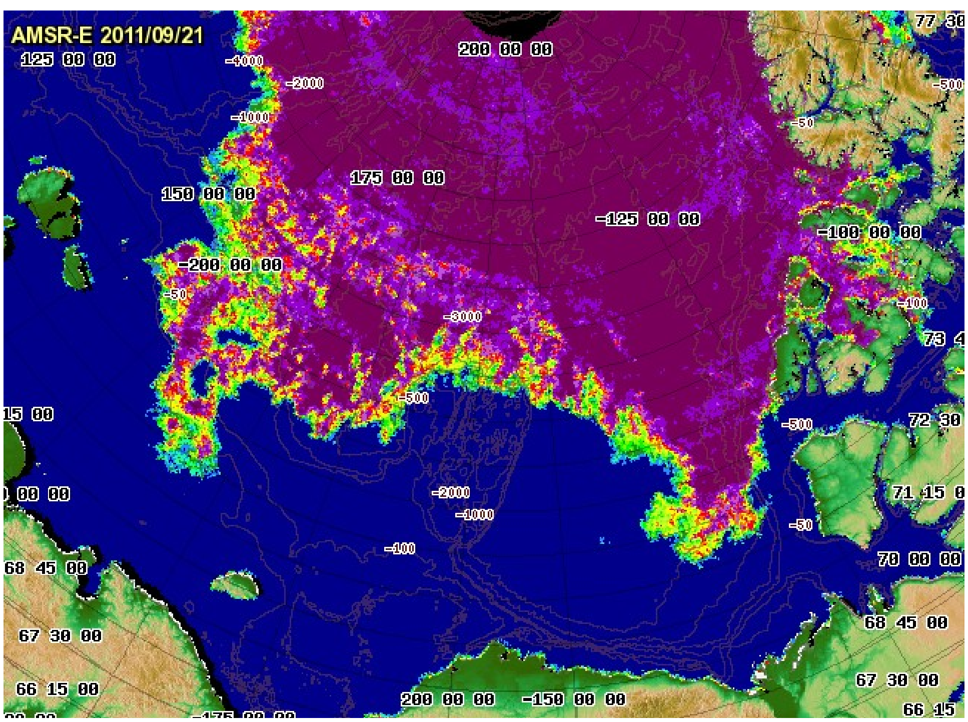


Figure 1-33. Advanced Microwave Scanning Radiometer - Earth Observing System (*AMSR-E*) images: Top is August 18, 2011 and bottom September 21, 2011, showing differences in ice edge positions and approximate percent ice cover, as interpreted from the imagery data.

Weather

Weather conditions were typical of the Beaufort Sea summer season. For a month and a half, Beaufort Sea was under the influence of a stationary high pressure system in anticyclonic flow, with two exceptions: On August 30th and on September 9th, a trough line of low pressure brushed the SW portion of Beaufort Sea which brought decks of clouds at higher altitudes.

This anticyclone drifted with upper levels circulation from west to east and back regularly but never by more than a few hundred NM. This anticyclone signifies that the colder air (cooled by the presence of the ice pack) is trapped under an inversion. With moisture from the surrounding open water and generally light winds, extensive fog resulted from surface to a few hundred feet upward. The result was 25 days of fog, reducing visibility between less than one-half nautical mile and 6 nautical miles. Intermittently, when conditions were favorable, the fog dissipated somewhat from mid-afternoon to early evening. That was when there was enough warming in the lower levels to “burn” the fog from the top down or when the wind was strong enough to lift the foggy layer up a few hundred feet into a stratus layer. The sun shined on only six days on the 17th and 18th of August, on the 22nd and 23rd of August and on the 8th and 9th of September.

Light winds (15 nMi/hr or less) characterized the dominant wind patterns, with a few exceptions: on our transit to Beaufort Sea, winds blew first from the SE at 20 nMi/hr on August 6th and then from the NE at 20-25 nMi/hr with gusts up to 35 nMi/hr on August 7th and 8th. The wind attained gale force on the 8th generating significant waves and swell (up to 4.5 metres). Strong winds occurred again on August 15th, with easterlies at 25 to 30 nMi/hr due to a trough line on the Alaskan North Slope shoreline pushing and tightening the western high pressure-gradient. The same phenomenon repeated itself on the 7th and 8th of September when winds blew from the SE at 25 nMi/hr with gusts up to 35 nMi/hr. There was a steady northwesterly flow at 25 knots in Dolphin and Union Strait during a return transit. Circulation was forced by a low pressure system that developed over Victoria Island and slowly drifted SSE to be 120 NM east of Kugluktuk on the 15th. This brought strong colder northerlies to the region along with rain and snow.

Temperatures remained in a range such that daily minima were near -4ºC and the daily maxima near +4C. The maximum temperature registered in Beaufort Sea was +7.8ºC on September 7th, when the southerly flow described above brought milder air to the region. The minimum temperature was -5ºC recorded on September 5th, near 75N and 135W.

Unmanned Aircraft Systems (UAS)

As part of this Joint Canadian-US mission, Captain Steve Wackowski of the US Air Force participated in the program to test operation of Unmanned Aircraft Systems (UAS) in Arctic conditions. The work was conducted as part of his research for the US Defence Intelligence Agency’s National Intelligence University (NIU). His mission was funded by the National Oceanic and Atmospheric Administration and the National Science Foundations. Captain Wackowski’s full report appears in Appendix 9 of this report.

Figure 1-34. Captain Wackowski launching the UAV 'Raven' from Monkey's Island on the Louis S. St-Laurent.

Objectives: to prove that Small Unmanned Aircraft Systems (SUAS) operations were feasible from moving icebreakers and the products derived from those flights can assist in icebreaking operations, marine mammal detection, and search and rescue operations.

Due to U.S. Coast Guard flight deck certification concerns regarding SUAS operations onboard the HEALY, Captain Wackowski transferred to the LSSL while underway. LSSL Commanding Officer, Capt Marc Rothwell, authorized his accommodation and conduct of his program from the LSSL.

Results: On August 26th, with Cpt. Wackowski as Pilot-in-Command and Flight Engineer Steve Lloyd of Transport Canada as mission commander, the first-ever SUAS flight in the high Arctic from a moving icebreaker was conducted. RQ-11A "RAVEN", serial number 0613, flew for nearly 30 minutes for a distance of 4.7 kilometres from its origination point on the LSSL. It was launched from 'Monkey's Island' (Fig. 1-34) and recovered on the helicopter landing pad. A RAVEN remote video terminal was left onboard the HEALY and the RAVEN's full motion video (FMV) feed was viewed live on her bridge. Flight Engineer Lloyd served as the RAVEN mission commander for the remainder of the deployments, during which they conducted a series of successful day and night flights using both Electro-optical and Infrared cameras (Fig. 1-35), both from the ship and on the sea ice. All flights took place above the 80th parallel north (80º N). These flights demonstrated the benefits of on-demand, airborne FMV for intelligence, surveillance, reconnaissance (ISR) purposes for the crews of Arctic icebreaking vessels. After the initial demonstration of the

Figure 1-35. Infrared image of the LSSL from the UAV.

system's capabilities, it began to receive tasking from the CO/XO of the LSSL. These culminated with requests for an ice reconnaissance mission to scout for a launch point for an autonomous underwater vehicle (AUV) and polar bear watch for a deployed ice buoy team. In total, a dozen successful flights were logged while deployed with the LSSL. Future Arctic missions could benefit from the presence of a UAS similar to the RAVENs used during this deployment.

Conclusions: The success of this year's missions showed unmanned aircraft systems can provide valuable assistance for several aspects of the ship's mission, such as ice reconnaissance and mammal observation. It also has implications for validation of satellite remote sensing date, shipping/vessel identification, search & rescue, personnel recovery, and oil spill response. While the RAVEN has now proven capable, a larger UAS with longer endurance, variable zoom/pan cameras, and a higher ceiling would be more effective for Arctic operations. Deployment of a micro SAR or multispectral camera would also prove effective in verifying the satellite remote sensing data integrated into mission planning systems. Utilization of UAS' has the potential to revolutionize icebreaking mission planning and navigation, with the potential for significant cost savings (i.e. reduced fuel consumption) and reduced risk through elimination or at least reduction in the need for human flight.

Recommendations

- Compressor failures remain an issue, requiring significant maintenance and repair and constant watchkeeping during operation. Experienced staff must be employed for this purpose
- The working environment within the compressor container is extremely uncomfortable. Wind chill is a real issue and concern. As well, the operator/watchkeeper is exposed to the working parts of the compressor, posing a risk during operation. A cabin or enclosed space within the compressor container needs to be constructed for comfort and safety reasons.
- Sounder/Chirp: the hull mounted sounder did not perform well in ice conditions. Can we carry a towed instrument? No doubt it would increase launch and recovery time, which would not be ideal.
- Staffing: we must carry some younger staff for job-shadowing to ensure cross-over in skills and knowledge.
- Re-evaluate the design of the source array. The cluster of 2x500 in3 G guns plus 1x150 in3 G gun was chosen in previous surveys to limit stresses on the tow sled from firing of the airguns. However the current arrangement for mounting the airguns appears to be robust and it seems possible to revise the number and types of airguns in the cluster. The number could be increased to four using the existing mounts on the tow sled, and perhaps GI-guns could be added in some positions to improve the primary-to-bubble pulse ratio.
- The installation of the SeaStar CTD sensors in floats near receiver groups 1, 9, and 16 provided useful depth, temperature, and salinity data that could be used for rebalancing the streamer. Even if the streamer is not rebalanced, the CTDs are useful tools that should be used to monitor the streamer depths. The service life of the existing set should be

checked, and an additional three CTDs should be purchased as spares and also for rapid deployment on the second streamer.

- Before the start of acquisition, the depth calibration of each CTD should be checked by placing the sensors in a permeable container and lowering the package to a known water depth.
- A few months prior to the seismic program, obtain the latest version of the CNT-2 acquisition software and manuals, install two copies of the software on removable hard drives, and create an installation backup. The new software should be tested prior to the start of acquisition. Version 5.36 proved to be reliable and should therefore be kept as a backup in case there are bugs in a later version of the software.
- Replace the computer hard disks on the seismic data recorder before the next field season in case there has been sector damage due to the vibration of ice-breaking. Bring spare Hard Drives in case of failure.
- Investigate use of UAS' as part of mission operations for the high Arctic.

Acknowledgements:

The scientific party wishes to thank Captain Rothwell and the Officers and Crew of the Canadian Coast Guard Ship Louis S. St-Laurent. Additionally, the Scientific Party would like to express its appreciation to the ice-breaking efforts of the US Coast Guard Cutter HEALY and the Officers, Crew and the Scientific Staff of expedition HLY1102. Their assistance went well above and beyond ice breaking in an effort to ensure success of this mission.

The author would like to express our highest appreciation, respect and admiration for the technical crew of the scientific party of LSSL, particularly Mr. Borden Chapman, Chief Technician during all the years of this program. The program would definitely have not achieved success without the long hours of commitment and his and the entire crew's innovative solutions to unique problems that arise from working in the harsh environment of the Arctic.

And of course, our Mammal Observers, for endlessly keeping watch in the frigid and inhuman climatic conditions on Monkey's Island: Jonah Nakimayak (absent in 2011), John Ruben, Dale Ruben and Nelson Ruben. John Shimeld has our gratitude for reviewing this lengthy manuscript; we missed him greatly on this expedition.

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Chapter 2: 2011 Canadian Hydrographic Service Report

Jon Biggar

Background

The mapping for UNCLOS is a joint responsibility of Natural Resources Canada (NRCan) and the Department of Fisheries and Oceans (DFO). Specifically, the Geological Survey of Canada (GSC/NRCan) is responsible for the seismic surveys, while the Canadian Hydrographic Service (CHS/DFO) is responsible for the bathymetric surveys. CHS responsibilities include mapping baselines from which the extent of the territorial sea is measured, charting the 2500m depth contour and the foot of the slope. CHS will be optimizing the location of survey lines at the calculated distances of60, 100, 200 and 350 nautical miles and provide results in the form of charts, maps and diagrams.

Summary

Over the past five years of this program the CHS component was conducted in conjunction with the NRCan seismic operations. The program again was very successful. The program involved two icebreakers: the CCGS Louis S St Laurent (Canada) and USCGC Healy (USA). The escort duties of each ship depended on the science that was being collected. During seismic operations Healy was lead and during hydrographic operations the Louis S St Laurent was lead. This was done to utilize the best tools of each ship. The bathymetry collected on this program will augment and refine the historical information to establish and support Canada's UNCLOS submission. The Canadian Hydrographic Service team was comprised of Jon Biggar, Jim Weedon and Andrew Forbes (Central and Arctic Region). Dave Street (Newfoundland Region) was the CHS representative onboard the USCGC Healy again this year. As in the past two single beam sounding techniques were employed: conventional ship configuration and helicopter spot soundings. The ship navigated along predetermined transects and the helicopter was deployed to collect spot sounding data between the survey lines. The ship logged over 6823 line kilometers (Figures 2-1, 2-6) and the helicopter collected 75 spot soundings (Figures 2-5, 2-6). The program began August 18th and ended September 29th. The USCGC Healy joined the program on August 23rd and departed September 22nd, during which time additional hydrographic data was collected including deep water multibeam and additional 3.5 kHz single beam by USCGC Healy. As part of the program conducted aboard the Canadian Coast Guard icebreaker Louis S. St. Laurent (LSSL), two autonomous underwater vehicles (AUV) were utilized to acquire multibeam bathymetric data under the ice. The objectives of the AUV program were to provide proof-of-concept of under ice AUV operations from an ice breaker and to survey base-of-slope of the Marvin Spur (Lomonosov Ridge). CHS was responsible for the processing of bathymetry data collected by the AUVs. The program was cut short by 5 days because of mechanical problems with Louis S St Laurent's propulsion system. The success of this year's program can be contributed to the dedication and hard work of the captains and crew of the CCGS Louis S St Laurent and the USCGC Healy and the all the support staff.

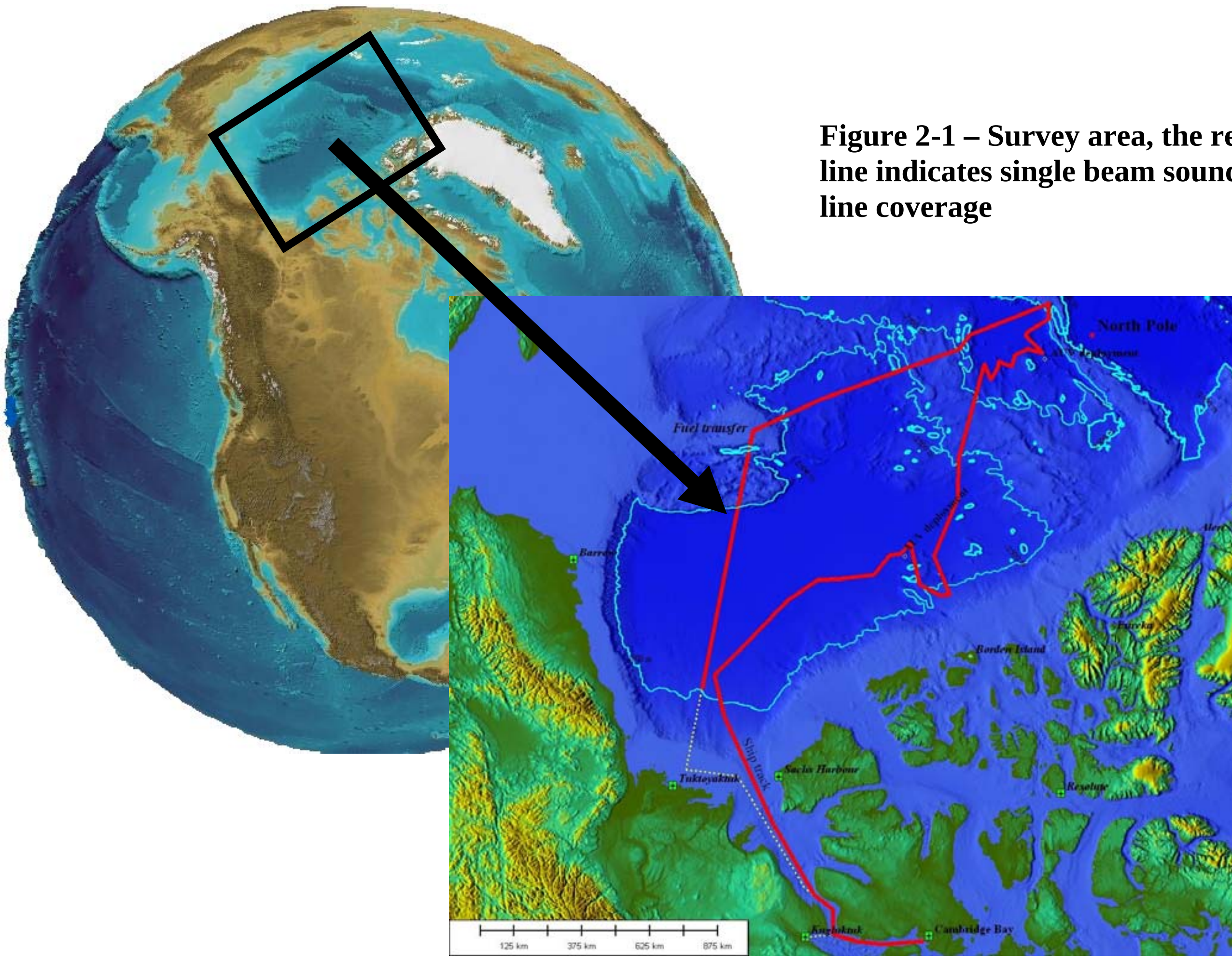


Figure 2-1 – Survey area, the red line indicates single beam sounding line coverage

Sounding Methods

Two single beam sounding methods were employed to collect data on the Louis S St Laurent: conventional ship sounding (Figure 2-3 to 2-6) and helicopter spot sounding (Fig. 2-5, 2-6). The only difference from past years was a 3.5 kHz transducer installed providing the ship the capacity to collect sub –bottom bathymetry data. The helicopter, a Messerschmitt MBB BO105, was used to maximize the area covered and to collect spot sounding data inaccessible to the ship because of ice conditions. AUV collected approximately 110 kms of data.

**Figure 2-2. Rack showing both Echo sounders located in the Oceanographic lab on the 300 level -
Knudsen 320B/R Plus sounder (bottom) and PC interface (above). The sounder is a tri frequency configuration with the frequencies set to 30 kHz, 12 kHz and 3.5 kHz. Knudsen Chirp 3260 Dual Channel Echosounder is a dual frequency set to 3.5 kHz and 12 kHz (top) The Knudsen 3260 was controlled by a laptop computer shown below.**

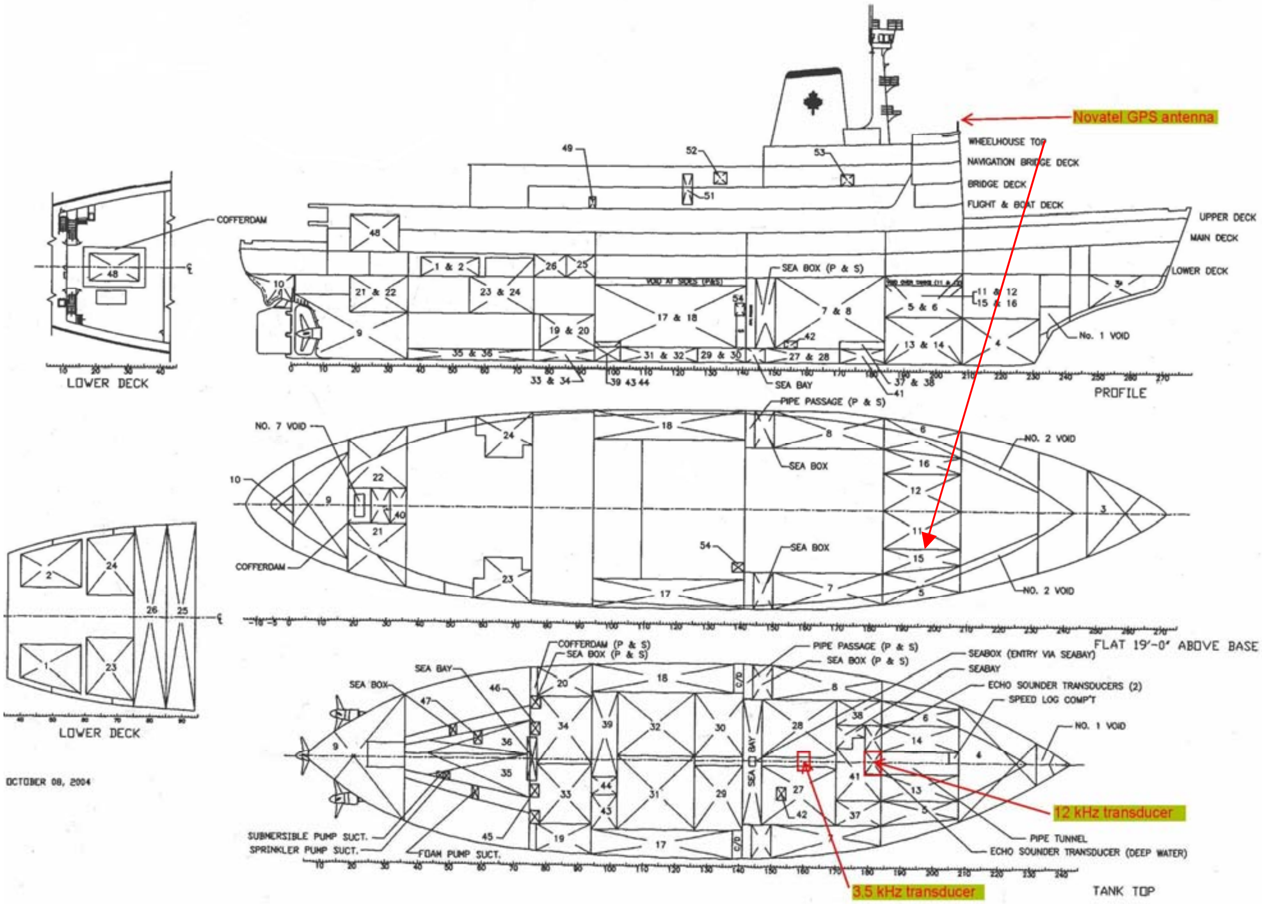


Figure 2-3. Above diagrams of the Louis S St Laurent illustrate the locations of the transducers and the Novatel GPS antenna. 12 kHz transducer 2.03 m port, 10.3 m aft of GPS antenna and 3.5 kHz transducer is 2.03 m port and 18.3 aft of GPS Antenna

The ship collected bathymetry using the Knudsen 320B/R Plus sounder attached to a 12 kHz transducer and a Knudsen 3260 sounder attached to the 3.5 KHz transducer. The 3.5 kHz transducer configuration was installed during dry dock operations this spring.
The systems use Chirp pulse generation technology. The Knudsen 320B/R sounder system was operated remotely using Knudsen Echo Control Client and Echo Control Server software via a network connection in the aft seismic lab. The Knudsen 3260 was operated remotely using a remote connect software. The 3.5 kHz transducer preformed significantly better (quality) with the newer Knudsen 3260 sounder. Both sounders are capable of dual frequency operations but the older Knudsen 320B/R was problematic when coupled to both transducers. The sounder would stop periodically and require a software restart/reboot of the computer. The sounder was disassembled and reassembled with no noticeable issues apparent. A laptop computer with remote desktop software was installed which was networked to the aft seismic lab for control of the Knudsen 3260 sounder. As when sounding with an icebreaker, bottom detection was lost due to interference from ice/ship's bubbler system and sea state. Knudsen Echo Control Client and Echo Control Server software was used for acquisition and PostSurvey software was used for viewing during post processing of the data.

12 kHz transducer well

3.5 kHz transducer with 12 element-transducer well

Figure 2-4 Photos of the 12 kHz and 3.5kHz transducer wells.

As in previous years the Knudsen sounder and computer interface on the ship would periodically lock up and require a system reboot. The spot sounding procedure was done in open water. The open water technique was achieved by slinging the transducer below the helicopter and placing into the water while in a hover. The Knudsen 320M was used which was prone to HF radio transmissions interference (reset sounder) and simply required a ground wire to the aircraft frame to rectify the problem. The sounders were set to a fixed velocity of 1500 ms/sec and then corrected to an averaged true velocity derived from the sound velocity casts. In the open water, marks were placed on the tether to which the pilot would submerge the transducer and this number was applied as a draft value to the sounding. The whole process under ideal conditions was expected to take 2 to 4 minutes per location. The ice conditions were in most cases was lighter than previous years. The data was logged to a laptop and post processed in Excel. The helicopter logged 14.1 hours of flight time to collect 75 spot soundings. As in the previous seasons the weather hampered the operations.

Figure 2-5. Helicopter Spot sounding (12 kHz) setup.

A small chain was added to the sling below the transducer and grounded to the aircraft frame (hook). This elimated most of the static electrical charge that the aircraft built up during flight. A break away electircal connection to the transducer point was also incorporated for emergency use. The laptop was not connectred to helicopter power but ran on its internal batteries to elimate any problems with static electicity.

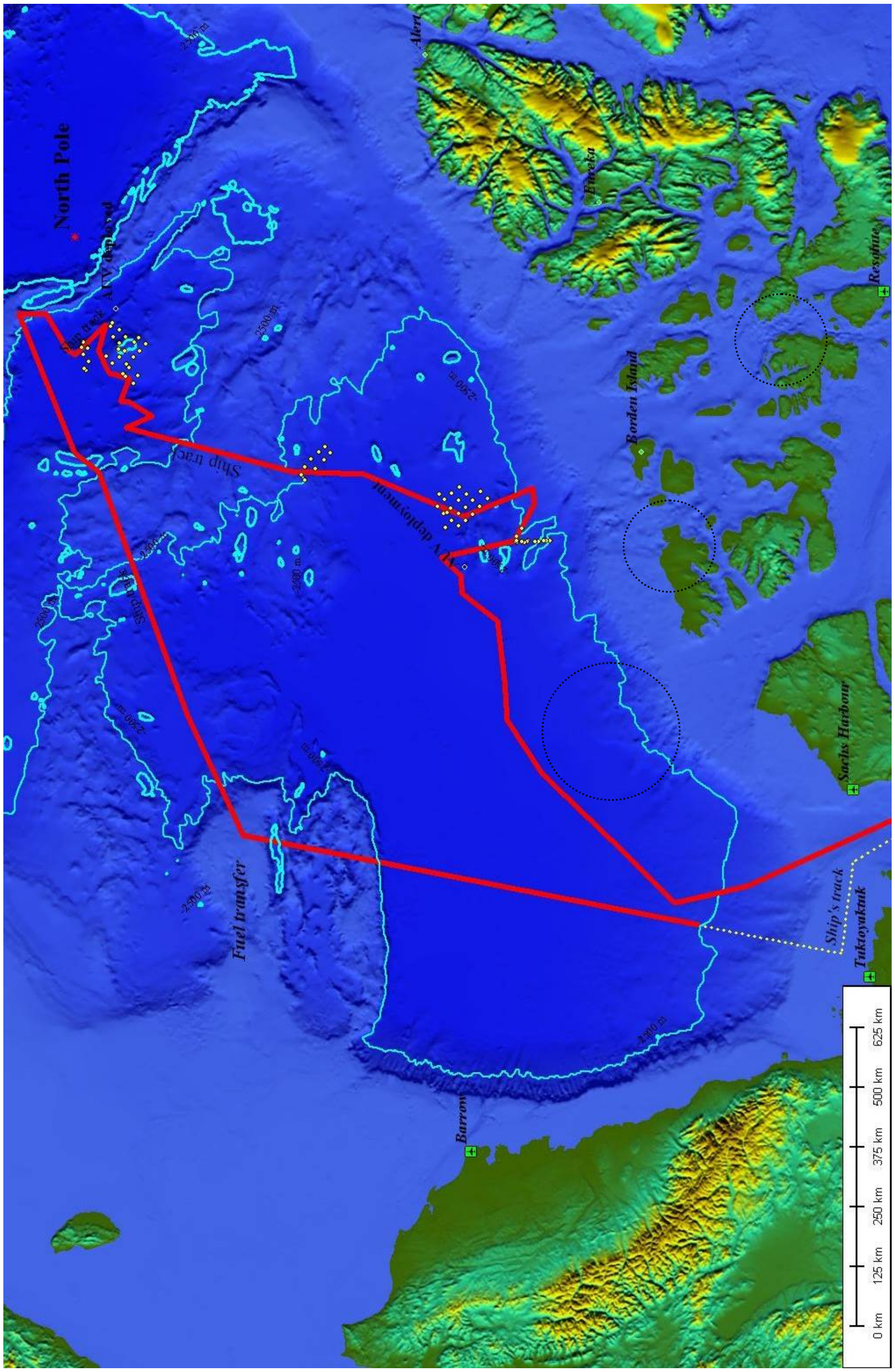


Figure 2-6. Helicopter spot soundings (yellow dots) collected during program.

Positioning Methods

The positioning systems used for both methods of data collection were the NovAtel Propak V3 GPS receivers with L2 antennas. Differential corrections were received from the nation-wide

WAAS service. The Wide Area Augmentation System (WAAS) is an air navigation aid developed by the Federal Aviation Administration to augment the Global Positioning System (GPS). The International Civil Aviation Organization (ICAO) calls this type of system a satellite-based augmentation system (SBAS).
Differential corrections were received below 82 degrees north and above the receiver used a combination of GPS/GLONASS signals. GLONASS is a satellite navigation system operated for the Russian government by the Russian Space Forces. The estimated positional accuracy was less than 5.0 metres in static mode. The ship GPS receiver when above 82 degrees north was prone to position drop outs caused by invalid position solutions. The Novatel receiver and antenna were both changed out with the spare units but the problem still persisted.

NovAtel GPS receiver located on bridge and antenna on monkey’s island above ship’s bridge.

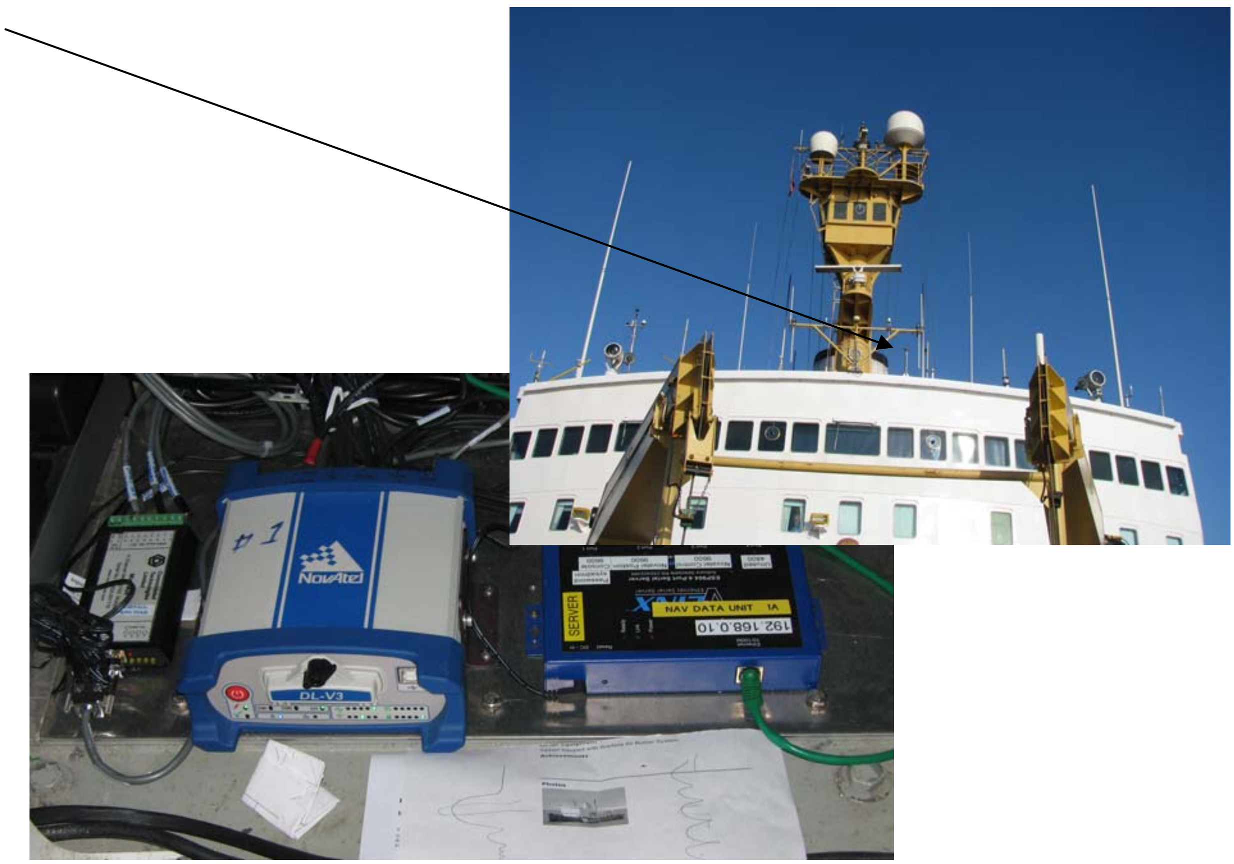


Figure 2-7 NovAtel DL V3 GPS receiver in the equipment rack located on the bridge of the ship.Positional data were fed directly to the seismic lab for distribution to various computers and navigation programs.

NovAtel software (CDU – Control and Display Unit) interface was used to configure and monitor the NovAtel GPS receiver. The position was computed using corrections from a Satellite Based Augmentation System (SBAS).   .

Figure 2-8. NovAtel positional display

Data Collection

For navigation and planning, HyPack v9.1 (single beam survey module) was used to monitor and collect the survey data. Sound velocity and temperature were acquired using an Applied Microsystems SV Plus v2. With the ship stopped, the sensor was deployed from the ship's starboard A-frame installed in the water sampling rosette. Measurement accuracies from the manufacturer specifications are sound velocity: 0.05m/s with 0.03 m/s precision; temperature: 0.005ºC, pressure: 0.01% full scale (approx 0.5m). Several profiles casts were taken with a maximum depth of 3800 metres. Additional profiles were obtained and compared with XSV02 expendable probes.

Expendable Deployments
XSV02 (eXpendable sound velocity) probes were launched by a hand launcher LM-3A from the stern of the ship into the ocean to measure the speed of sound to a depth of 2000 m. (maximum range for these probes) The data was communicated back to a digital data converter (MK-21 USB DAQ) and a computer onboard the ship by a fine wire.

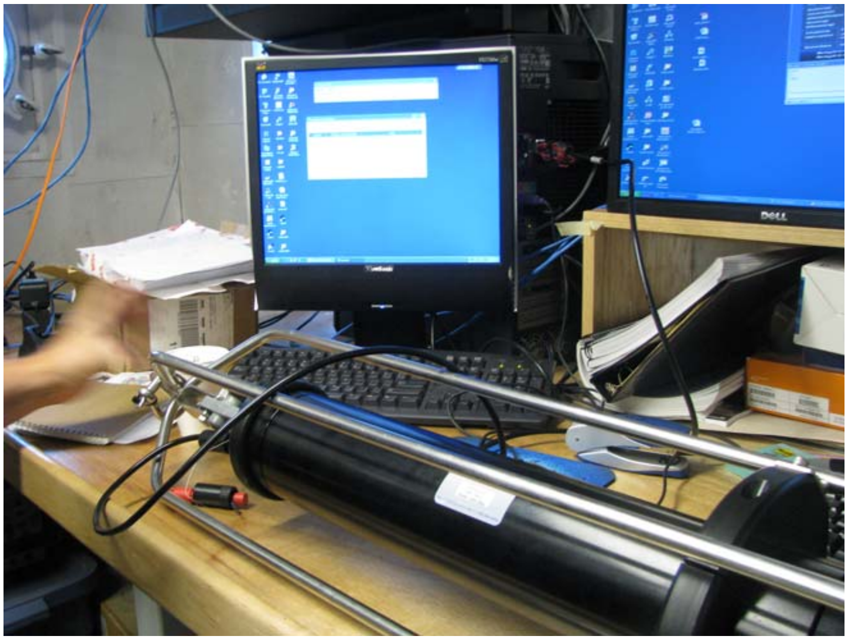


Figure 2-9. SV Plus v2 using Smartalk v2.27 software and Lockheed Martin Sippican hardware. The setup used for downloading XSV02 using the MK21 USB DAQ.

Figure 2.10. Surface ship Bathythermograph Data Acquisition system and LM-3A Hand-Held Launcher (Lockheed Martin Sippican).

Figure 2-11. (right) Science rosette with SV Plus v2 (sound velocity meter) depth range 5000 metres (SVP) mounted.

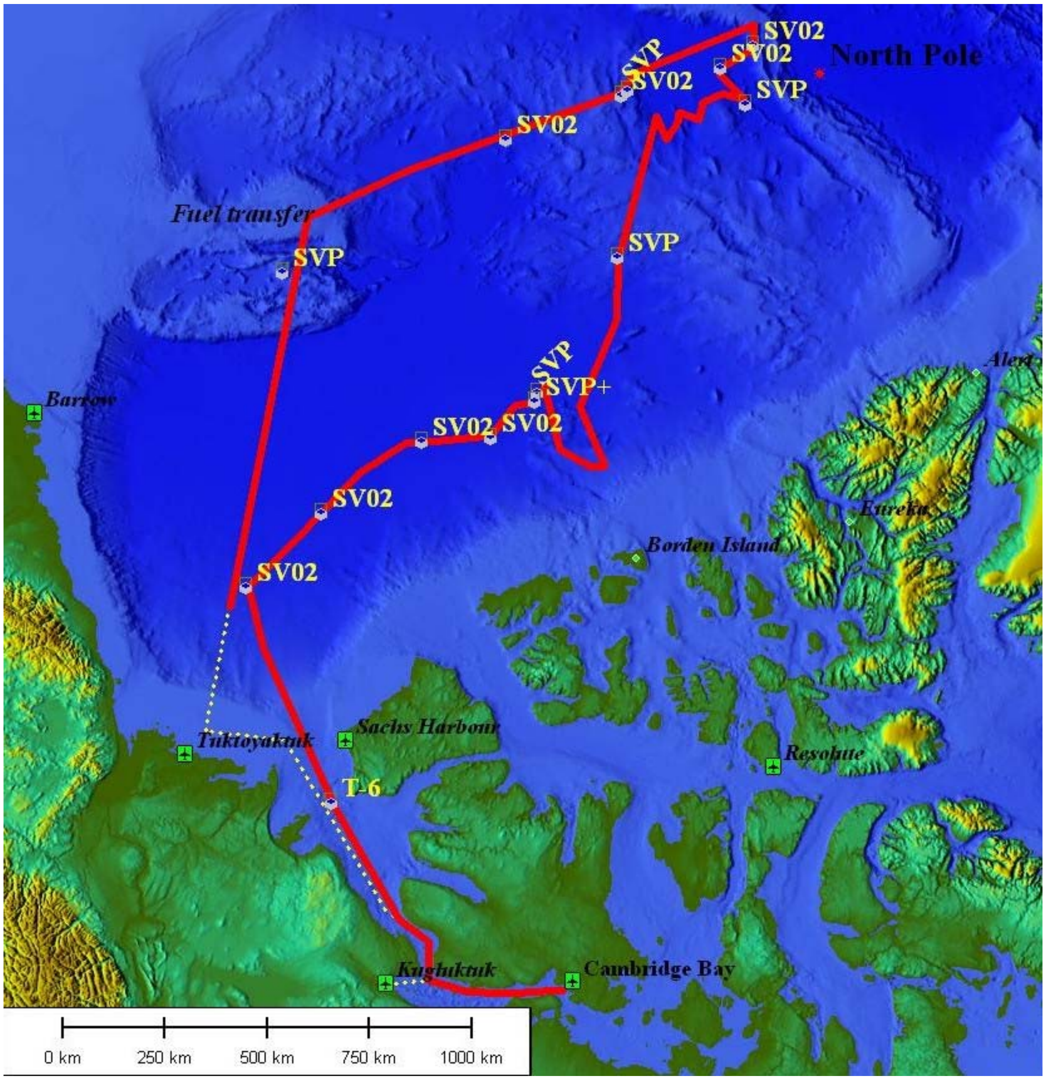
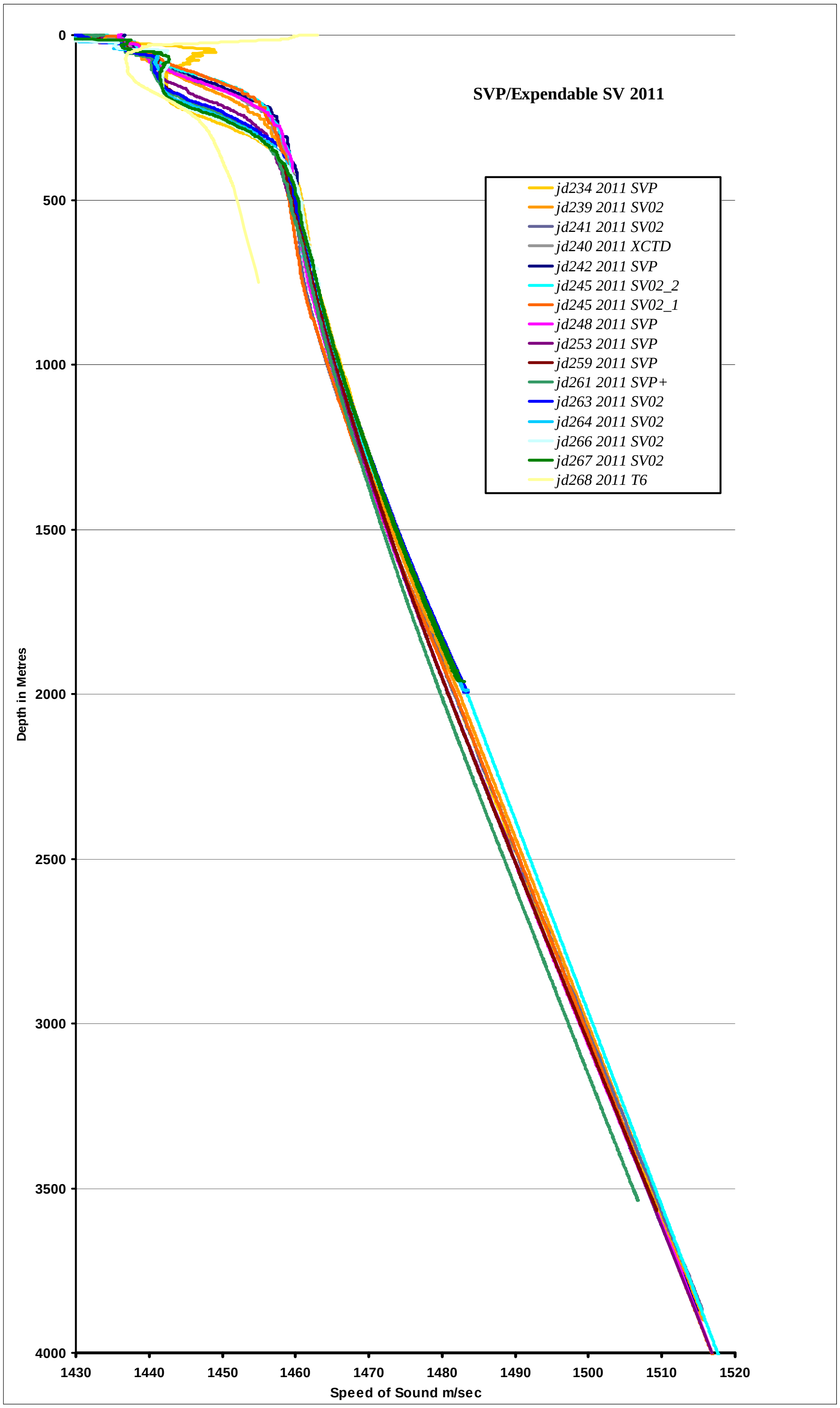


Figure 2-12. Location of sound velocity casts in the survey area.

Figure 2-13. Speed of Sound graph/profiles



Processing Methods

CARIS (Computer Assisted Resource Information System) GIS v4.4 was used for managing, compiling, and visualization of the results of the processed bathymetric data. CARIS HIPS/SIPS v7.0 (Hydrographic Information Processing System/Sonar Information Processing System) was used for survey data processing of positions and depths.
The processing steps consisted of: file conversion from HyPack to the HIPS/SIPS format, navigation editor to clean/edit 'vessel' position, single beam editor to clean/edit depth information and line processing which merges final position and depth files while applying tide reductions and sound velocity corrections. The ship's gyro information was logged and applied to the data to correct for GPS/transducer offsets. The ship's draft was verified weekly and confirming the draft marks from the helicopter. AUV multibeam and single data was processed using the same software. The AUV requires a horizontal position correction for the inertial system.

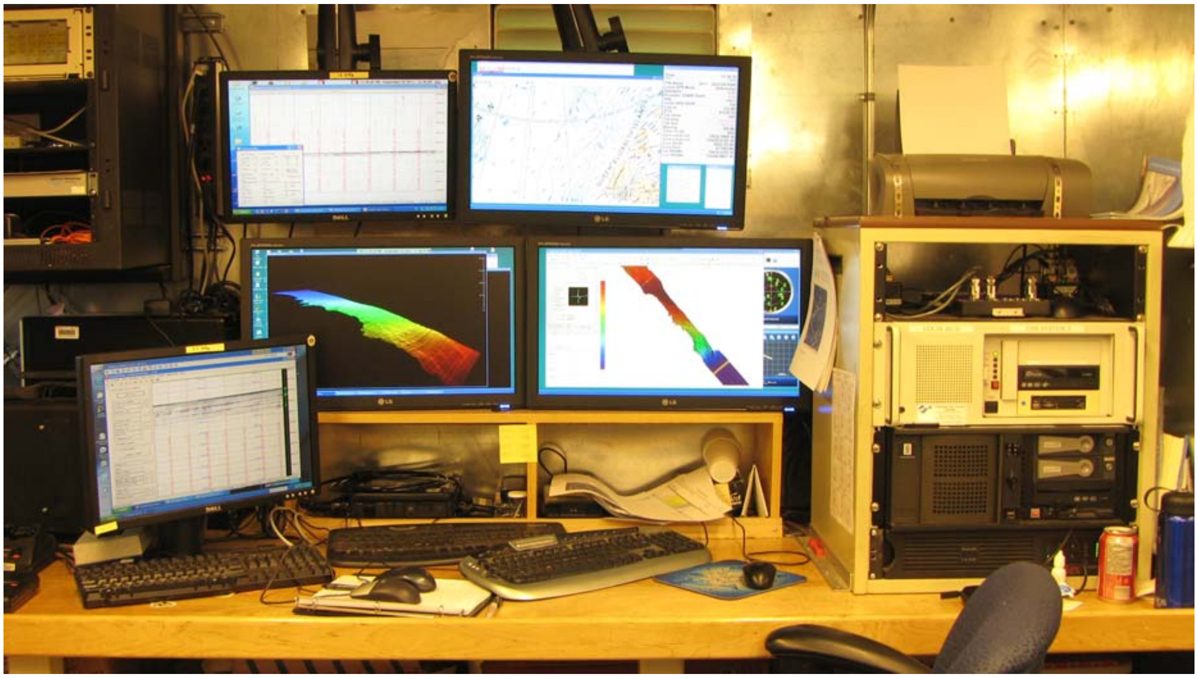


Figure 2-14. NRCan Seismic lab onboard LSSL showing Navigation (collection) and processing station

Software Issues with HIPS/SIPS Processing (J. Weedon comments)
Navigation Editor
- At the start of the survey the Navigation Editor appeared to be working normally when editing the lines in the graphic/line display window. Clicking on the point depicted by the circle would highlight the circle and allow it to be rejected. As the survey continued the display would offset where you had to click in order to highlight the position circle. At first it was a small amount but the offset distance would increase as the survey continued. The offset increased to the point that editing in the graphic/line display window was not possible as you would have to be zoomed out too far to allow for the offset and the detailed required was not possible. At times you were guessing how much the offset was and which direction. Towards the end of the survey the offset would decrease and eventually return to normal editing functionality. Do not know if this was a result of the Latitude/Longitude being surveyed at the time - moving from south to north and back south again.

- Another problem encountered while using the Navigation Editor was the blanking of the computer screen(s) (on the multi display system 2 of the 3 screens would go blank). The screens would go to blank for anywhere from a few seconds to up to a minute and then the display would return. This also appears to affect the operation of the computer as the logging would hang while the screens are blacked out and return to normal when the screens came back. At one point staff said the computer rebooted when the screens blanked out. This blanking happened last year as well. It happens more when the density of sounding along the line is greater (when in shallow waters).

Single Beam Editor
- While editing single beam the program would occasionally freeze and appear to go into some sort of loop. It would do this at times enough to become rather annoying and saving often was required. When this happens if the mouse is positioned within the program window it would rapidly flash as if in a rapid loop. The only way to get out of it was to use Task Manager and terminate the program. This freezing/looping happens while dragging the scroll bar at the bottom of the display window and most often when getting towards the end of the line.

Exporting to Caris Map
- While attempting to export lines (edited/merged) to Caris Map not all of the lines appear to export - even though they have been selected during the export process. I had to export groups of lines in separate export operations in order for all of them to properly appear in the Caris file.

- Another problem with the exporting to Caris Map was having rejected soundings being included in the export even though they were not included in the export process. This appeared to be a problem with the Dual Frequency lines that were collected.

Recommendations and Conclusions

All hydrographic computers hardware functioned without problems. All equipment performed well with the exception of minor software and cabling problems. Three CHS staff is sufficient for sounding operations onboard ship. The program involved two icebreakers; the CCGS Louis S St Laurent (Canada) and USCGC Healy (USA). This proved to be the best arrangement with each ship dependent on one another for ice breaking capabilities and the science collected. During seismic operations Healy was lead and during hydrographic ops Louis S St Laurent was lead. This utilized the best tools of each ship.

Acknowledgements

CHS would like to thank the NRCan group for their help and support and the captains and crew of *CCGS Louis S. St-Laurent and USCGC Healy* for their assistance carrying out the UNCLOS objectives. A special *thank you* note to the CHS staff for their hard work and dedication.

Chapter 3: 2011 AUV Objectives

Richard Pederson

Introduction

Under Project CORNERSTONE two commercial-off-the-shelf (COTS) AUVs were procured from ISE (International Submarine Engineering Ltd.) and modified for operations in the High Arctic. The modification and development work was undertaken by ISE and DRDC Atlantic. The objectives of the 2011 AUV program are two-fold.

- to provide proof-of-concept of under ice AUV operations from an ice breaker
- to measure base-of-slope of the Marvin Spur, a sliver of the Lomonsov Ridge

For the first deployment, the LSSL will be on stand-by during AUV operations. Depending upon the success of the mission, a decision will be taken as to attempt a second deployment and how much time to dedicate to a second deployment.

Overall objectives for Project CORNERSTONE are:

- Provision of support to NRCan/DFO data collection activities in mapping the outer edges of the continental shelf in the Arctic Ocean, for the determination of the 2500 m isobath and the foot of the slope. Through the use of AUVs, areas of the seabed, difficult to access via traditional surface deployed methods will be studied. The AUVs will be used for the collection of high resolution, hydrographic quality bathymetric data in heavily ice-covered waters.
- Providing flexibility in collecting single and bathymetric data, thus augmenting surface spot soundings, seismic, gravity and magnetic data collected to date. All data will aid the substantiation that the surveyed areas and ridges meet UNCLOS requirements for an extension of the Canada's continental shelf.

Internally, DRDC Atlantic and DND will benefit from:

- The development of an AUV based homing and long range tracking capability, thus augmenting the autonomous nature of underwater activities.
- Maturing the Long Range Acoustic Beacon (LRAB) system to the point of operating up to 100km from base. Further, the LRAB system will be configured to listen for a four-tone sequence, which provides both a homing signal and a simple one way message command to the AUV from the surface operator.

AUV Science Summary of Results

- *110km mission track length*
- *3400m Max depth obtained by the AUV*
- *Collected Knudsen Single Beam Echosounder data*
- *Collected EM2000 Kongsberg Maritime Multibeam Echosounder data*
- *Ability to operate and maintain an AUV from one half of the Hanger aboard the LSSL*
- *Ability to launch AUV from a ship in ice covered arctic waters (3x)*
- *Ability to recover an AUV from under 2.5m thick ice using an ice breaker (2x)*
- *Ability to track an AUV at long range (15km) using ATS tracking system*
- *Ability to localize an AUV using modem ranging*
- *Ability to track an AUV using the GAPS tracking system*
- *Ability to improve INU alignment by rotating the AUV on the flight deck.*
- *Need to synchronize the multibeam and DVL to reduce interference*
- *AUV occasionally loses multibeam bottom coverage after a steep ascent over a sharp rise. This loss of coverage is due to the AUV's lower descent rate. This is a safety feature. Investigate possible higher descent rates?*
- *The CTD sensor on both B06 and B05 failed during this expedition. Further investigation required. Require a new method to clean sensor face to avoid any potential for freezing.*
- *Ships maneuvers can improve or degrade INU alignment. Change in direction better than a long straight track.*
- *Having an experienced AUV handler in man-basket very useful, complete understanding of hook up points in stressful situations.*
- *A through ice audible localization system was useful in maneuvering the ship close to AUV location using forward lookouts. It is difficult to use over the side equipment from an ice breaker and still maneuver. Therefore having an audible system is advantageous.*
- *Ice ponds can be very small, almost impossible to have the AUV surface in an exact position.*
- *Require a very quick response Variable ballast system which would provide quick response to calls for negative or positive buoyancy requests. Thus allowing the AUV to be raised or lowered to/from the under ice surface and jumped to a location of choice more rapidly than the current system provides.*
- *For under ice ROV-AUV recovery. Need an ROV with negative/neutral buoyancy umbilical and real-time tracking system feedback to the ROV pilot.*

AUV Science Operations

Note: Local time is 7 hours behind UTC
All times local unless identified as UTC.

Based on the science schedule the first dive for the AUV "Qaujisaqti" serial number B06 will be a dive to survey a portion of the Marvin Spur commencing 3 Sep 2011.
All AUV preps are complete; the Marvin Spur Mission plan and AUV fault response table review is complete. The AUV team will finish up the cabling to the tow-sled and CDHA array once all the seismic operations have been completed. With the ship breaking ice working, any work conducted on the quarterdeck is difficult due to the constant ship heaving and violent movements. So we are waiting for the ship to stop and all seismic gear to be recovered prior to completing that portion of the AUV equipment set-up.

3 Sep
Overnight the ship transited to a small open pond. Due to a number of reasons such as:

- the small area of open water available;
- the 10 m draft of the ship;
- deployed tow sled (22 m depth) with two tracking arrays (GAPS, ATS) and the homing beacon and telemetry modem ;

The AUV must be launched differently that that usually conducted in an open water case.
In open water the AUV is launched on the surface and is driven manually away from the ship on the surface to a dive point well away from the ship. This is done to avoid any collision with the ship. However in ice covered waters, it is impossible to drive the AUV any distance on the surface. The only method available is to deploy the AUV weighted/ballasted heavy and have it sink naturally to a depth greater than the depth of any potential obstacle. i.e. ships keel, tow-sled etc.

The AUV will sink due to internal ballast. At 30 meters depth (well clear of ships keel and sled) the AUV will power up its thruster and proceed under power to 40 meters depth and commence the descent to the sea floor pattern.

At 0600 the AUV team commenced the Pre-dive. By 0745 the ship had maneuvered into the open pond. The pond area was approx 200 m x 200 m and was covered with lots of ice bits both big and small. The ship entered the pond and started to open it up. During the pre-dive it was identified that the AUV CDT sensor was outputting incorrect values. 17 ppm vs. 30 ppm as per current ships calculated values. It was decided to turn off the CDT sensor and rely on the default sound speed value for the PHINS INU speed of sound input.

Prior to any AUV dive the first priority is to check the correct ballast of the AUV in that body of water. Based on observations of the balance of the AUV on the crane in the water it will be necessary to add additional weight. Once the vehicle was removed from the water and recovered back onto the flight deck an additional 25 lbs lead was added internally to the AUV.
A second in water check confirms that the AUV appears to be adequately ballasted. However after releasing the AUV from the crane, there was actually not enough ballast and the vehicle would only nose into the water with the aft antenna sticking out of the water (Fig. 3-1). It is suspected that the top fresh water layer is preventing the vehicle from sinking through into the sea water layer beneath.

Figure 3-1. Too little ballast

The AUV was recovered from the open pond using the 2 person man basket (Fig. 3-2) This technique worked well.

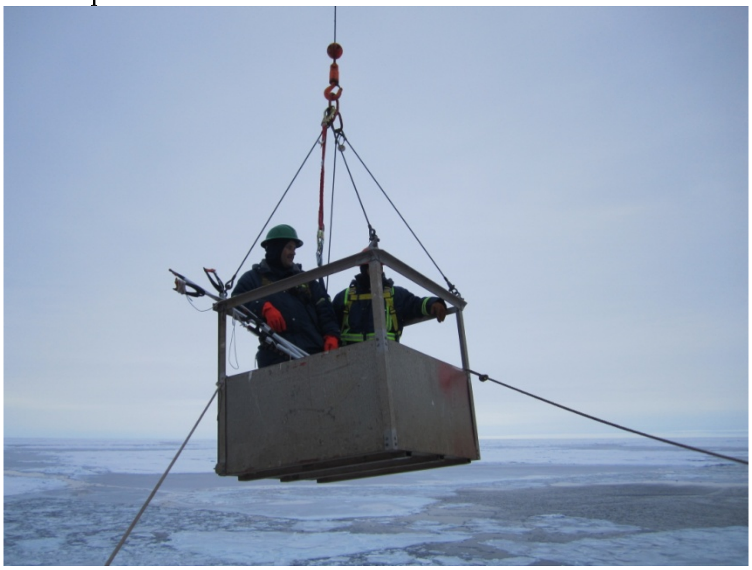


Figure 3-2 Two Person Man-Basket

After the recovery it was too late to launch the AUV today as it would require having the deck crew up well after working hours. Therefore it was decided to commence the dive tomorrow morning. Overnight the team re-ballasted the AUV with an additional 10 lbs forward and 20 lbs weigh aft.
During the night, the ship transited in a box pattern to aid the alignment of the AUV inertial navigation unit.

4 Sep

Overnight the pond decreased yet again in size. The pre-dive commenced at 0500. Sled deployed at 0600. The Deck crew arrived on the flight deck for AUV launch at 0635.
0726 AUV launched.
B06 commenced the initial test dive at 500 m depth. The AUV operators obtained good acoustic communications between the ship and AUV out to a range of 3200 m. The ATS tracking signal is being received by the tow-sled deployed CDHA array. The homing beacon is tuned on to test the latest homing code with LRAB command function enabled. Part of the test mission involves the AUV homing back toward the ship and the vehicle does indeed home correctly back toward the ship as seen by the AUV telemetry status updates. No ATS or GAPS tracking at this time.

At 1104 the survey mission test dive has completed successfully at which time the AUV commenced the survey mission and started the descent to the sea floor. The descent to the sea floor will take approx 4 hours. As the AUV neared the sea floor after the 4 hour dive and during the initial loiter at ~3400-3500 meters the AUV experienced a suspected obstacle avoidance sonar failure.
As the surface AUV operators had continuous acoustic communications with the AUV near the sea floor. It was observed that the AUV bottom avoidance system was operated erroneously which caused the vehicle to carry out obstacle avoidance measures. This resulted in the vehicle continuously ascend in a step wise function. Due to this I authorized a mission abort and to recovery the vehicle to investigate.
It was not prudent to continue the mission with the primary obstacle avoidance capability in an unknown state, when operating in an area with unknown topography.
AUV Homing and a surface stop up initiated by acoustic commands to the AUV.

The vehicle ascended to the surface in homing mode. At 0130 the AUV eventually came to rest under the ice surface in the vicinity of the ship at just under 700 m range. Unfortunately due to the very small lead in which we were situated the AUV came up just under the ice pack edge. Due to the late hour recovery attempts would be conducted the next morning. The AUV remained at rest under the ice and the AUV team commenced a night watch on the AUV using acoustic communications.

5 Sep
It was a rather long recovery in which ship deployed acoustic modem ranges to the AUV were used to triangulate the exact AUV location. The modem range from a set location on the ship to the AUV was plotted on the bridge ECPINS display. The procedure taken is as follows: The ship would stop, a benthos modem was deployed from the quarterdeck by hand to approx 20 m depth, a range from the modem to the AUV was obtained, and this range was plotted on the bridge ECPINS display. The modem would be recovered and the ship would move to another location to repeat the process.
This resulted in an accurate charted location for the AUV. The bridge team used this AUV location to manoeuvre the ship slowly and safely toward the AUV.

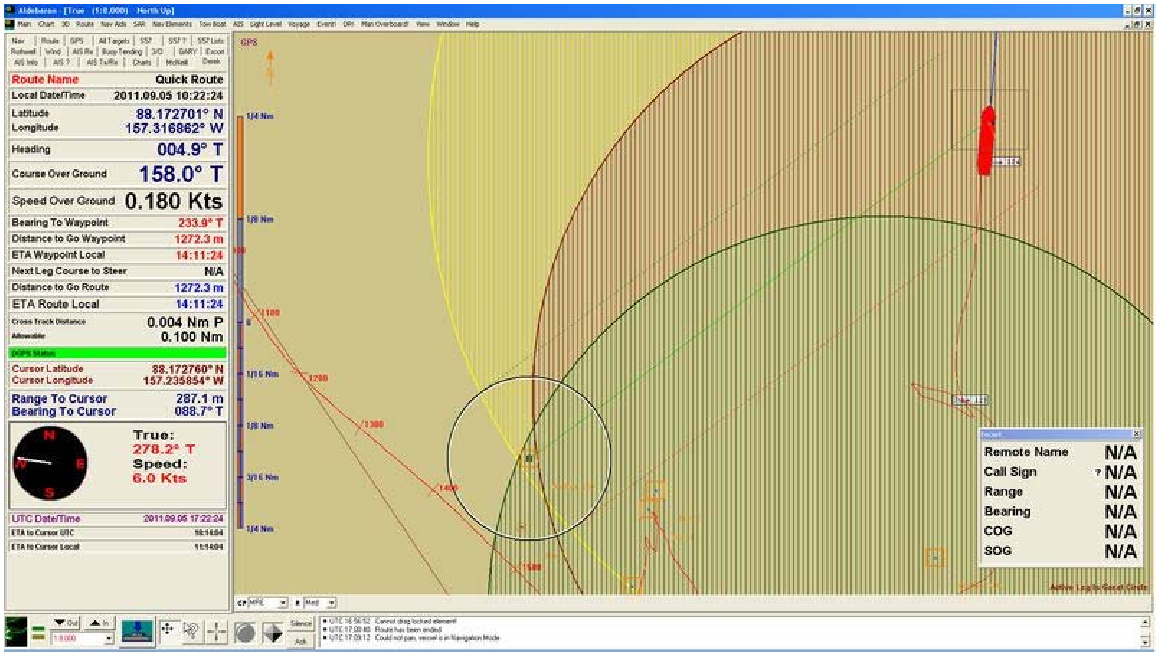


Figure 3-3 ECPINS Bridge Display

The AUV ATS chirp was audible and the forward ship lookouts could use this audible chirp to report the AUV location on the bow as the ship closed the AUV position. With the AUV location known under the ice, the ship maneuvered to precisely carve away the ice near the AUV. This created cracks that would propagate into the ice above the AUV. This resulted in opening up the ice enough for the AUV to be seen (Fig. 3-4)..

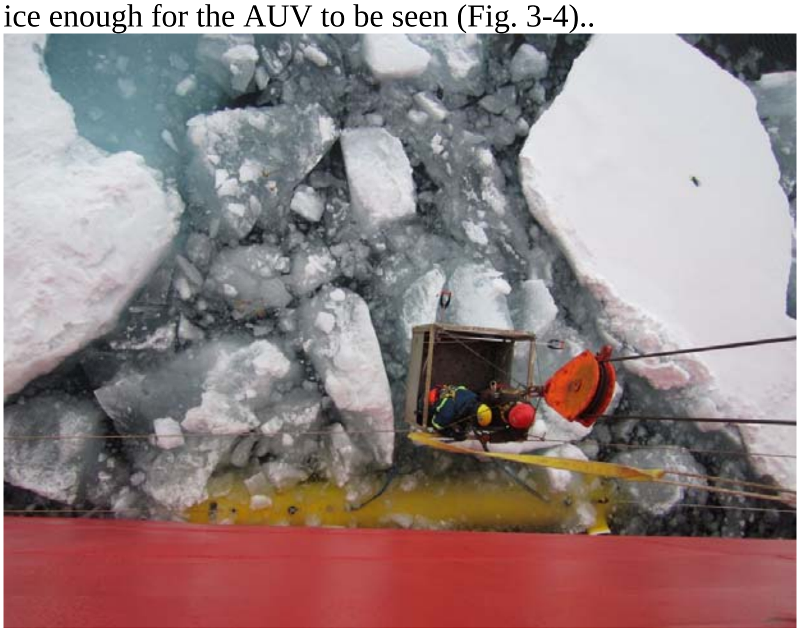


Figure 3-4 AUV in the Ice

Using acoustics communications, the AUV ballast was set to +30 lbs buoyancy, but was still low in the water. The small ice and slop ice immediately covered the AUV resulting in the AUV being pushed down a couple of feet. The ship maneuvered alongside the AUV and using the double man basket successfully secured lines to the AUV and hooked it onto the forward crane. It was not possible to easily maneuver the ship around in the ice to hook onto the AUV using the aft crane. Therefore the AUV was hoisted out of the water and the ship moved out of this area of thicker ice back to the open pond and placed the AUV back into the water with a float line and tag lines attached. The ship maneuvered around and successfully recovered the AUV using the aft crane.

An attempt to use the ROV to capture the AUV was tried. However it proved very difficult to use the Phantom ROV to initially hook on a recovery line to the AUV. The ROV umbilical is buoyant and due to the large amount of floating ice the umbilical would hook up on the ice, necessitating a recover of the ROV for another attempt. With the GAPS system not functioning well no ROV-AUV location feedback was available for the ROV operator. It was a very difficult operational scenario. The ROV operator reports under ice keels on the order of 28 ft depth in that vicinity. He also reports that the smooth circular keels appeared to be a yellow colour from the diffuse late afternoon/evening light. This made it almost impossible to distinguish between a shiny yellow ice keel and a yellow AUV at a distance. Visibility was about 4 -6 m. There was even ice rubble moving around under the ice sheet. With the under ice ridges and keels the AUV could easily get tucked up in an inverted valley when it fetched up under the ice. The ROV has a camera that can swivel up 90 deg to look upward into these valleys, but with the ice rubble floating around, ice sheet movement, and drifting of the ROV all these factors combined to made ROV ops very difficult.

Figure 3-5 ROV attempting AUV search

The decision was made to attempt an AUV recovery using the ship to cleave away the ice from the AUV with the LSSL breaking it free from the ice. The AUV recovered aboard the LSSL at 3:30 pm local time, Monday 5 Sep.

Upon inspection the only visible damage is a loose modem possibly due to a small chuck of ice pressing on the modem. The forward control planes (#1 and 2) and one aft plane (#3) have suffered slight damage, i.e. crinkling and de-lamination of the fiberglass outer-shell. It was decided to replace them with spare planes from B05. Suspect impact with ice being the most likely cause. Only three planes were affected so it cannot be attributed to a pressure at depth effect.
The CDT sensor will be replaced as it failed during the pre-dive for this mission.

12 Sep

All AUV systems are operational. Daily pre-dives were conducted on the AUV in the hanger.

13 Sep
The intention is to conduct seismic operations in the Sever Spur area and when time and conditions permit to try for a second AUV deployment. The AUV mission would be to survey the foot of the slope on Sever Spur. A daily AUV pre-dive will be conducted until launch.

Reset the B06 PHINS INU as it has been running continuously since the vehicle was turned on 3 weeks ago. At this latitude the alignment will not take very long. We have been bench testing the B05 PHINS continuously for about the same period of time and logging its data. The logged data from the spare INU will be useful for analysis at a later date to investigate effects from high latitude operations on the INU system.

14 Sep
The AUV plan is to collect foot of slope data once we get over to the seaward end. The hope is that there is sufficient open water from leads to deploy and recover in that area.

Continuing daily AUV pre-dives without any issues.

15 Sep
It was decided that time permits a second AUV survey mission. The intent is to collect multibeam from both the Healy and AUV along the outer edge of the Spur but from different areas. The Healy will go to the North and the AUV will survey at the Southern end of the Spur. Yesterday the heavy ice made transit very difficult with the seismic gear deployed, so the seismic was recovered late yesterday evening. The LSSL will carry out some breaking for the Healy to conduct multibeam over the spur. Then head for an early morning rendezvous with a nice open pond, as observed by Don Mosher from the helicopter last evening.

The current ships position is approx 50 nm from the last reported position of the open pond. Looks like it will be a late afternoon/early evening AUV deployment vs. a mid morning.

During the last pre-dive, a problem with the AUV Variable Ballast (VB) system priming pump was identified. The failure of the priming pump means the VB system can only pump to 18 lbs negative as opposed to -35 lbs. Full range positive to +90 lbs is not affected. ISE recommends that B06 can still be launched as there is sufficient negative buoyancy to launch and carry out the mission successfully. 18 lbs negative buoyancy will permit the AUV to drop below the ships keel, tow-sled and potential ice keel.

The AUV mission is to collect both multibeam and single beam on the other foot of the slope on Sever Spur. This area is heavy with ice making it difficult to useful collection from the Healy. Current wind speed is 13 knots with a wind chill of -22C.

The AUV obstacle avoidance system has been repaired so do not expect to see the same problem in mission two as occurred in mission one. In mission two the mission plan is being updated to ignore LRAB command functionality and as per the Risk Assessment workshop advice the mission plan will only enable AUV homing in the final phase of the mission plan as the AUV nears the ship.

16 Sep 2011
The weather today is windy at 15 knots plus and a wind chill of -21C. It is snowing and darn cold.
The ship has arrived at the open ice pond. It was important to identify the water environmental conditions so a rosette was conducted to obtain a pressure/salinity profile, which took approx three hours. This data is used to determine the correct ballast setting for B06. After review of the density at depth 5 lbs of ballast was removed from the AUV nose section.

At 1810 B06 is pushed onto the flight deck for in water checks and launch.

Figure 3-6 AUV on flight deck

During the in-water checks the CTD registered an intermittent ground fault. To reduce any potential problem, it was decided to disable the CTD sensor. Thus a default sound speed value for PHINS calculations is required. John Biggar had conducted a SVP earlier and a value of 1504 m/s at 3300 m depth was selected.
At 1902 the AUV is released and gently sank beneath the ice off the starboard side. It descended to 40 meters depth to carry out a 2 hour loiter to ensure all systems check out correctly before descending to the sea floor.

The entire descent and loiter was timed to provide approximately a 22 km duration dive prior to the commencement of the survey portion. This 22 km length was based upon the advice of the AUV risk workshop. In which a Pre-Mission Monitoring Phase is conducted to increase the chance of completing missions to the highest percentage 90.6%. “If a reasonable probability of success is to be enjoyed, such action is a necessary part of the mission plan”
Both GAPS and ATS tracked B06. The calibrated GAPS unit had to be recovered and reset due to a GPS problem and redeployed, did not have time to re-calibrated the GAPS system when redeployed as B06 was being deployed at the same time.
For this AUV mission the GAPS head was removed from the tow-sled. It was thought that the poor performance of GAPS during the first dive was probably due to being in such close

proximity to the mass of the tow sled. Therefore the GAPS head was removed from the sled and deployed off the aft crane.
During the hook up to the crane, the GAPS head was accidently dropped and fell approx 2 ft onto the deck. The hydrophone protective caps were in place and thus protected the hydrophones. No visible damage occurred to the system. During subsequent operations during the AUV mission no damage or degradation to system function was discernable. The system tracked with an offset due to orientation and can be quantified and corrected. Overall the system worked well after deployment. GAPS tracked B06 to 1624 m depth, then lost track and no further track was obtained during the descent.

ATS tracked B06 from the surface to depth continuously. Due to the ATS tracking head being attached to a sometimes swaying tow-sled the ATS bearing occasionally registers an off-set ATS position.

Figure 3-7 ATS array mounted on tow-sled

For this survey the ATS B06 chirp pulse was modified with a 3 dB reduced amplitude, with a pulse repetition rate of 1/min to reduce (suspected - hypothesized) interference to the vehicle homing LRAB array input i.e. *false LRAB commands. Even if they occurred the vehicle control computer (VCC) will ignore them as per the mission plan directions*.
Vehicle telemetry from the sled mounted modem became intermittent at approx 2014 m vehicle depth, we switched to the forward deployed 450 m depth modem and re-obtained telemetry with B06. Then we switched back to the shallow modem which worked to a depth between 2600-2900

m. B06 carried out a descent to the sea floor approximately 3600 m depth. The AUV obtained a bottom lock at 210 m altitude and quickly settled into a loiter at 130 m depth. Very good telemetry was obtained continuously during the loiter. After successfully completing the two hour loiter, B06 commenced the survey portion of the mission at 0741UTC 16 Sep, 2011.

Very good telemetry was obtained out to a distance of approx 15 km at which time the vehicle telemetry was automatically shut off as per the mission plan to conserve AUV power.

The LRAB homing beacon was turned on to transmit a homing source in case the AUV returned early due to a fault condition.

ATS also continued to receive the B06 ATS pulse to a distance of approx 15 km. With the LRAB beacon transmitting, the CDHA systems ability to distinguish the ATS pulse is reduced. The LRAB beacon was to have been deployed on a longer cable and lowered deeper to increase the separation between the CDHA ATS array and the LRAB beacon. However this was not done resulting in the close proximity of the array and source and resultant degradation in system performance.

Estimate that B06 is making good a speed of 1.4 m/s. Based upon this B06 would go into homing mode at approx 6 pm, 17th Sep. Leading to the AUV being under the ship at approx 2130 hrs on 17 Sep, 2011.

The AUV Mission is a 21 hour duration survey mission through the Southern Sever Spur area. The route takes the AUV through the potential gap between the two outer most Southern ridges.

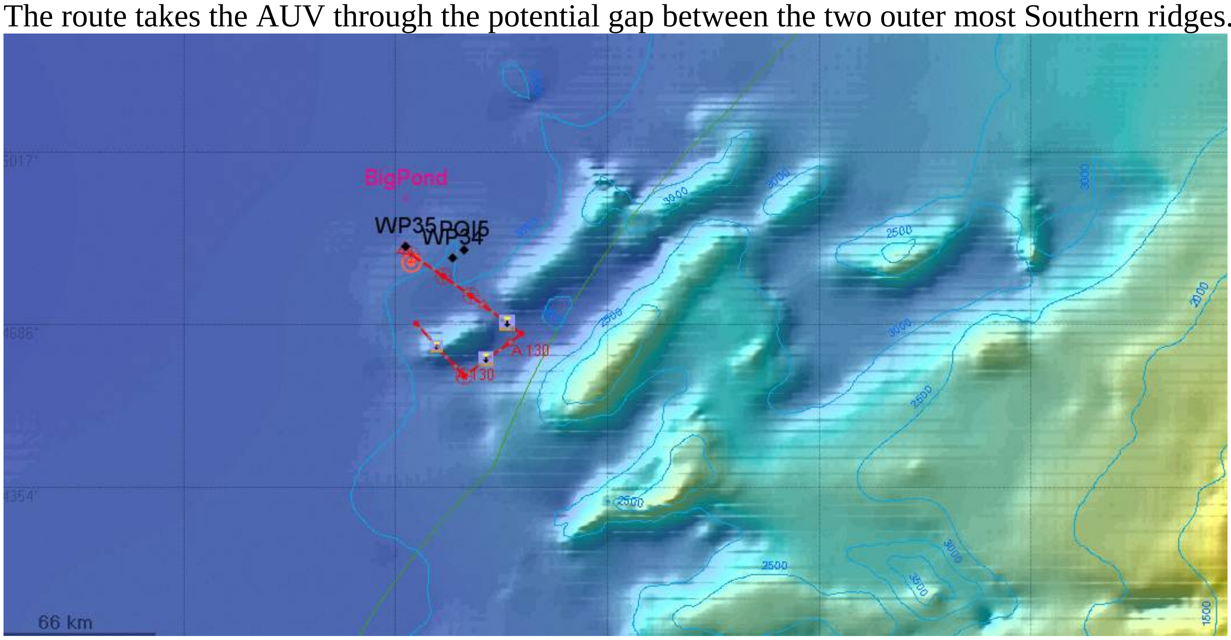


Figure 3-8 AUV Mission track

Recovery:

B06 was first identified as returning using modem communications. The ATS tracking system is limited in range due to the nearby homing source. The homing source was occasionally turned off to remove the adjacent high source level and to effect a long range ATS pulse correlation. The first ATS AUV range was obtained at 10.9 km with the LRAB source turned off.

Intermittent modem telemetry was obtained at a distance of 10.8 km. (0209UTC 17 Sep, 2011) B06 homed to the LSSL and by 0341UTC was in a homing pattern beneath the ship. No GAPS tracking of B06 with B06 at depth. From telemetry position updates the homing pattern appeared different from that observed in 2010 at the remote ice camp. Investigation into this pattern change will be conducted and be included in the final ISE technical report on performance of the AUV during the expedition.

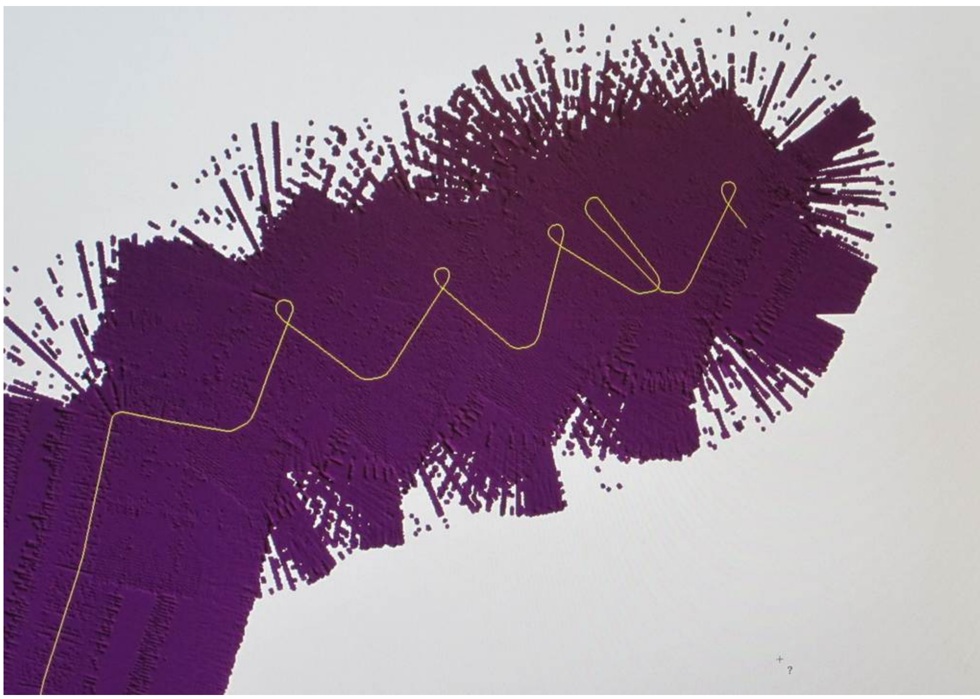


Figure 3-9 Actual AUV Homing track pattern

At 0445 hrs attempts using acoustic communications to command B06 to start ascending were finally acknowledge by the vehicle. It was difficult to establish acoustic comms with B06. Throughout this activity, two modems were deployed. One attached to the sled at a depth of 22 m; one on the foredeck at a depth of 400-450 m. During this recovery the ship was actually drifting at a rate of 0.25 to 0.9 knots continuously. Due to the winds and ripping current the forward modem was pulled upward and tilted, reducing effective modem comms. The sound speed profile indicated a 400 m layer which would reduce effective deep water acoustic comms, considering the modem may have been pulled into the boundary layer.

During the ascent both the aft and forward modems were used to communicate with the vehicle. To avoid any potential of entanglement between the deep modem and the AUV, the forward modem was recovered during the AUV ascent.

By 0600UTC, the GAPS system picked up the AUV position at 1900 m depth. The AUV ascent from 3500 m to 500 m took 1 hr 16 min.

0611UTC - B06 is at 500m depth under the ice approximately 2.3 km Northward of the ship. Both GAPS and ATS tracked the vehicle at 500 m depth as it closed the ship. Good GAPS performance was observed.

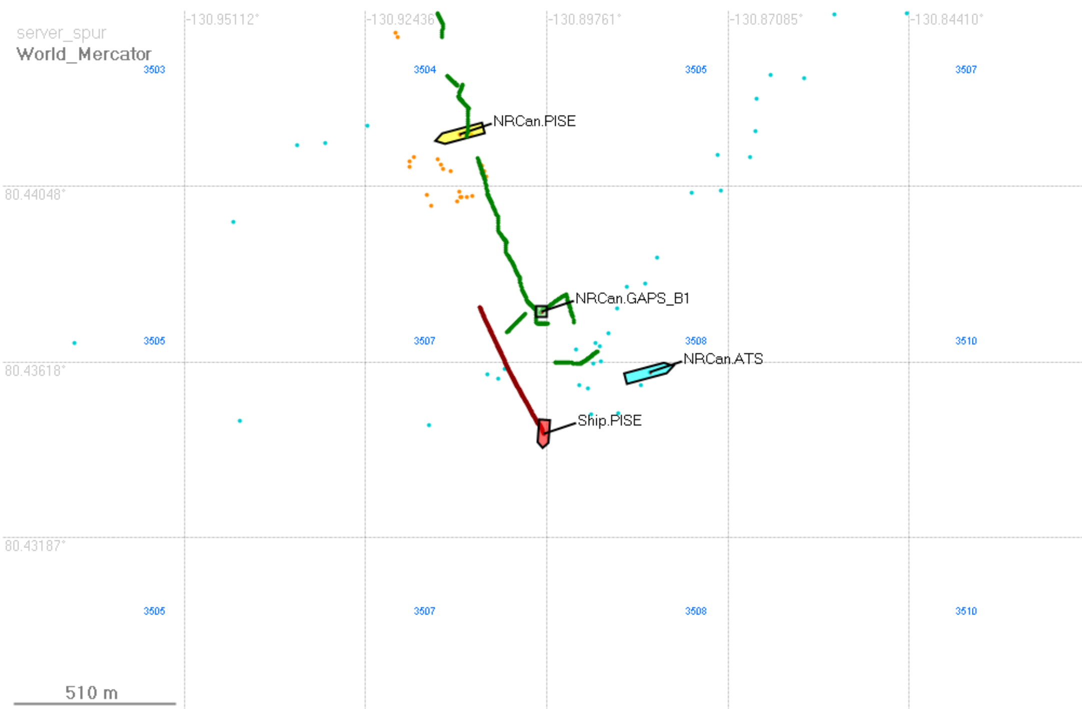


Figure 3-10. GAPS tracking the AUV as it homes to ship

Using telemetry B06 was commanded to start homing (still at 500 m depth) to bring it closer to the ship. B06 turned direction toward the ship. It took approximately 10 minutes to ascend from 500 m to 50 m depth. During the short ascent the vehicle drifted slightly northward in the current while the ship was blown southward by wind action. This resulted in the AUV opening the ship during the ascent to 50 m. Therefore another attempt to get the vehicle closer to the ship was required to minimize the distance between AUV and ship. JUMP commands to move the vehicle closer to the ship with the AUV remaining at 50 m depth were used. Using four small position jumps the AUV was brought closer to the ship.

While B06 was approx 100 m aft of the ship, it was commanded to start a Controlled park up *(In a controlled park up mode, the AUV shuts off the thruster and uses the VB system to ballast light and ascend safely -but slowly, under the ice)* under the ice and the LRAB beacon was turned off. The direction of travel of the vehicle would have had the vehicle come right under the ship based on GAPS tracking. To avoid any potential upward motion into the ship I decided to stop the vehicle aft of the ship and have it rise aft and be moved away from the ship in the current and hopefully come to the surface in the thin ice aft.

Using the AUV control console chart display during this recovery stage (fig 3-11) the error between the AUV INU position (Yellow shape) and GAPS measured AUV position (Green shape) is as follows:.
06:53:40 UTC GAPS RANGE 828.1 meters, INU range 1499.5 m (671 m difference)
06:54:30UTC GAPS POSITION 80.44420N, 130.9123W. INU POSITION 80.44847N, 130.92638W (540 m difference)
The range measured difference is 671 m and the Lat/Long difference is 540 m between the two systems. (*This difference between the Range and Lat/long measurements can be attributed to the slight timings differences when making these calculations manually).*
Overall it can be seen that the AUV INU has a certain positional error on the order of 600 m due to the error incurred during the descent and ascent phase of the mission in which the INU is running in free inertial mode without a bottom lock and corresponding lack of along and cross track velocity.

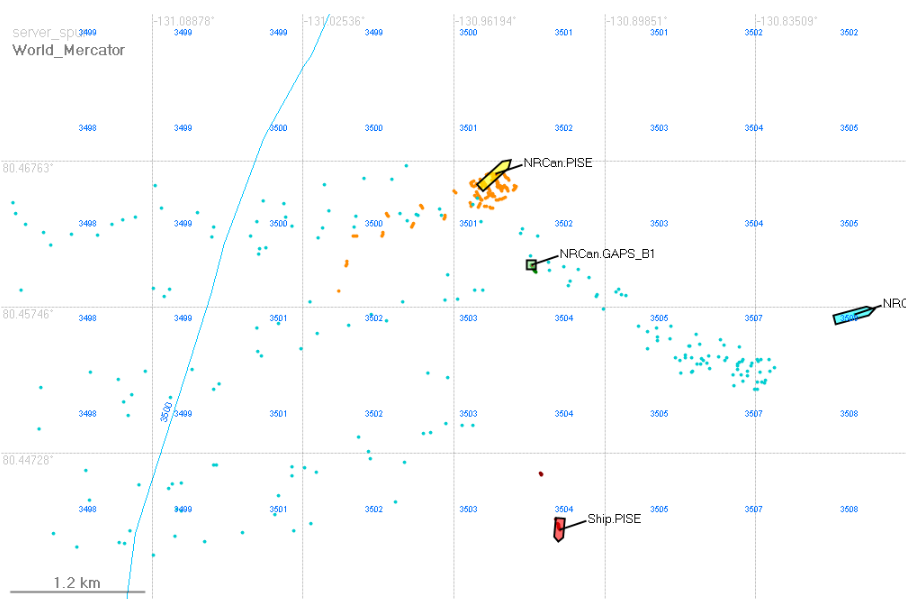


Figure 3-11. Difference in AUV and GAPS AUV position

After completion of the “controlled park up” the AUV is positively buoyant and at rest under the ice at a depth of 2.5 m, at a range of 298 m on the aft-starboard side of the ship. This location is just on the edge of the thin ice/thick ice boundary.

0130 - The vehicle is at rest and safe – not drifting away and stationary relative to the ship. A night watch remained in the hanger monitoring B06 vitals and the GAPS provided AUV position.
The recovery is planned to occur in a few hours on Sunday morning during working hours, the remainder of the team retired until morning.
The Chief Officer indicated that the Deck Dept would be available at 0800 18 Sep.

18 Sep Sunday:
0600L – B06 remained in position overnight. No issues. At 0800 the team was in position to commence recovery activities; however the ship decided to conduct Helicopter ops first.
We commenced AUV recovery Ops at 0900, using the aft modem to triangulate a position and the GAPS position to confirm this accurate position. The same procedure as used during the first recovery was used in which the AUV lead scientist Richard Pederson liaised with the Captain on the bridge. Modem ranges from the ship to AUV are manually plotted on the ECPINS bridge display in addition AUV based GAPS lat/long positions are also entered with an estimated SOG/heading to keep an approximate live updating AUV position.

The vehicle was approx 100 m away in the thicker ice sheet (fig 3-12). The ship broke out a wedge of ice and attempted to push the ice back out into the more open area. This was difficult as the winds keep pushing the ship, but this wind also eventually helped push the ice out of the wedge area and released the pressure of the ice in the area. B06 was wedged just under a large pan (estimate 1.5 the length of B06 and one length wide 2.5 m thick). At one point B06 completely surfaced but as the ice returned. B06 was covered again by small slop/chunk ice and B06 submerged.

Figure 3-12. AUV located in ice wedge

B06 was under thick ice and it was difficult to get it out from under the slop ice. It was decided to command the release the AUV 40 kg drop weight to increase the AUV buoyancy in an effort to keep it above the slop ice. The slop ice keep moving back in and pushing the vehicle down. The aft modem was lowered and the drop weight command was issued. The drop weight released. Some additional ship maneuvering was necessary to remove sufficient ice from the immediate area for B06 to come up from under the ice pan it was stuck under. When the ship moves in and around the slightest movement/bubblers can cause the ice to move about and cause the ice to move over the AUV which has the effect of pushing the AUV down quickly.

Figure 3-13. AUV recovery

The double man-basket method was used to attach all lines to B06. The ISE AUV team member in the man-basket mentioned using rubber gloves this time which kept his hands dry, with no loss of dexterity. By 1317 lift and tag lines had been secured to B06. At 1330 B06 is secured on the cradle on the flight deck. A post dive check of the vehicle was conducted and the sonar data downloaded for analysis. The only damage incurred was some cracking to the fiberglass nose cone and two damaged planes. i.e. stripped stop pin which is sheared off. This should be relatively easy to repair.

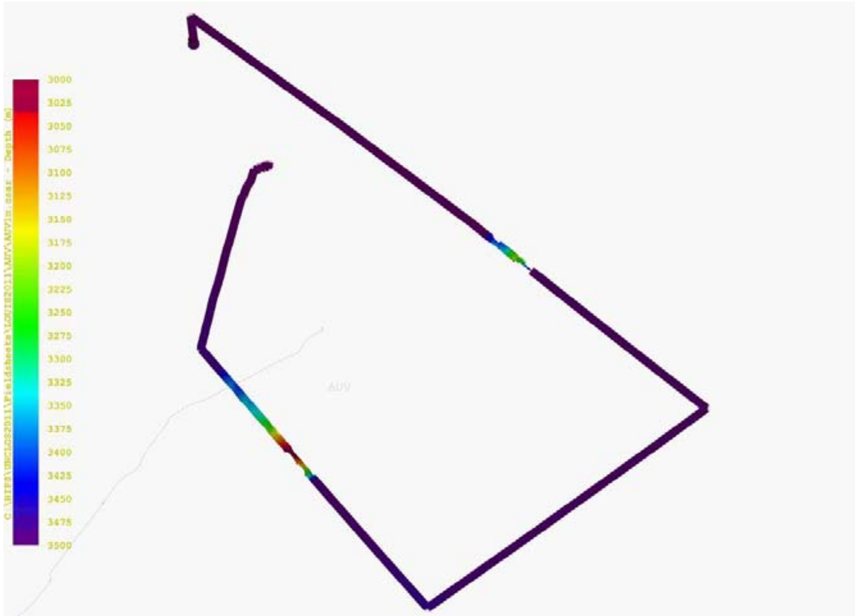


Figure 3-14. Plot of AUV bathymetry data

Post deployment the AUV has been prepped for transit, the AUV batteries have been discharged and put into sleep mode. The AUV has been secured to the Hanger port side for transit back to St. John's NL.

Figure 3-15. AUV moved to hanger- Port side

Chapter 4: Gravity Data Acquisition
Deborah R. Hutchinson

Gravity data were recorded using a Bell Aerospace BGM-3 gravimeter (Bell and Watts, 1986), SN 223 (Fig. 4-1), the same meter used during the 2010 Arctic expedition aboard *CCGS Louis S. St-Laurent* (*Louis*). The meter is one of the instruments from the Potential Fields Pool Equipment operated by the Woods Hole Oceanographic Institution (D. Fornari, P.I.), provided through a contract with the U.S. Geological Survey. The meter is essentially identical to the two gravimeters (SN 221 and SN 222) installed aboard *USCGC Healy* in 2008 (Coakley, 2008). A final report on installation, ties, instrument operation, drift, and bias values will be submitted to USGS in November, 2011, as part of the contract.

Installation

The instrument was shipped from Woods Hole, MA, to Halifax, NS, the week of June 20 and arrived with obvious physical damage to the shipping case. The meter was plugged in upon its arrival. On June 28, James Kinsey and Tom Lanagan set up the system aboard *Louis* in the gravimeter room and conducted system tests and checks, as well as installing the data logging laptop (Fig. 4-1). Despite the external damage, the meter appeared to be working well. The installation report notes that, on 29 June, the pre-cruise bias was reported as 856,112.25 mGal and the scale factor as 4.990049154 mGal/count (calibrated in spring, 2007).

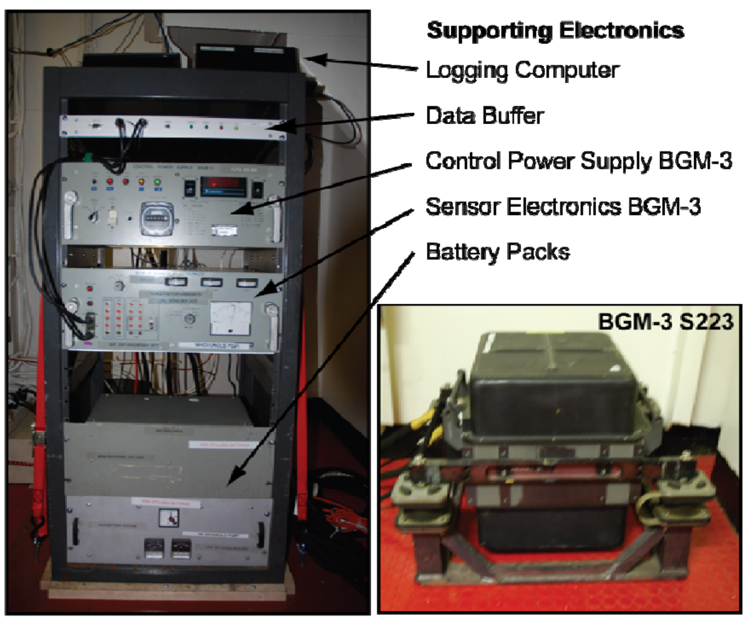


Figure 4-1: Installation of BGM-3 gravimeter S223 in the gravimeter room of CCGS Louis S. St-Laurent.

Gravimeter Location on the Ship

The gravity room is amidships forward on *Louis* (Fig. 4-2). The room is on the port side of the vessel with one wall along the centerline of the ship. The meter was installed along the wall opposite the centerline; the electronics rack was installed adjacent to the meter (Fig. 4-1). GPS Positions were supplied from the GPS antenna mounted on the rail above the bridge, offset

2.03 m port of the centerline of the vessel. This GPS unit supplies positions for all data acquired during the *Louis* 2011 cruise. Depths were supplied from the 12 kHz hull-mounted echosounder utilized and recorded by the Department of Fisheries and Oceans (DFO) hydrographers (immediately port of and adjacent to the centerline at the location shown on Fig. 4-2).

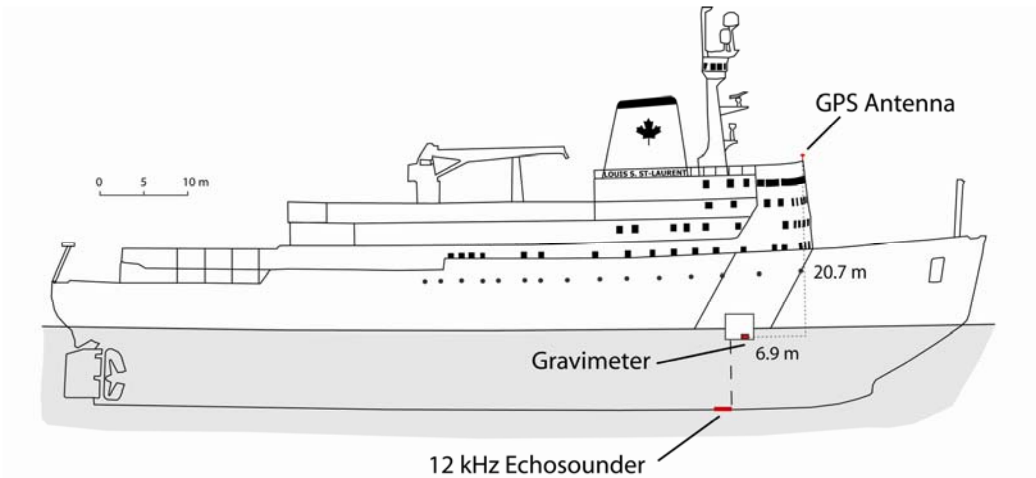


Figure 4-2: Location of the BGM-3 gravimeter in CCGS Louis S. St-Laurent.

The center of the gravimeter is 20.7 m below the GPS antenna, 6.9 m aft of the antenna, and 2.8 m to port from the centerline of the ship. Because the GPS antenna is also located to port of the centerline, the center of the gravimeter is offset to port less than a meter (~ .8 m) from the antenna. The center of the 12 kHz echosounder window is approximately 2.4 m further aft than the center of the gravimeter.

Gravity Ties

During installation of the gravity meter (June 28-29), a land tie was done between the middle of the Bedford Institute of Oceanography (BIO) pier and the dock. According to the installation report, the value at the middle pier was 980,560.97 mGal. The middle of the pier was used rather than the end because of modifications to the pier during the last 15 years. The end-of-cruise tie from which drift can be calculated was made on 15 November, 2011, at the drydock pier in Halifax, Nova Scotia and measured 980,564.89 mgal. After accounting for bias and reducing the measurements to sea level, the calculated drift for the duration of the installation (~4.5 months) was -4.36 mgal. While at sea, the position, heading, and velocity data from the GPS were used to estimate the correction for the earth's oblate spheroid shape and the Eötvos correction (for velocity on a rotating Earth).

Gravimeter Operations

After installation of the gravimeter, gravity data were logged once per second. Recording began on 28 June while the ship was docked at BIO in Dartmouth, NS. Raw data were recorded every second in two formats: Gravity Engineering Format (GEF) files, created once per hour, which logged all gravity sensor and other incoming data (GPS position, depths from Knudsen 12 kHz echosounder, gyro compass heading) as separate strings. Raw Gravity String (RGS) files, containing the 1-s merged data from the GEF data strings, were created once per day (Table 1).

The RGS strings are present in both the GEF and RGS files. In addition, files recording sensor information were also output, although not consistently during the cruise.

Table 4-1: Sample Raw Gravity String (RGS) record

SAMPLE STRING:
RGS 2011/08/25 00:00:00.733 982999.220 25428 1314230400.733 4.990049154 856112.250 BGM3 S223 GPS: 79.104265 -165.067809 1314230399.657 0 0 GPS_GP150 349.453 4.031 DEPTH: 2153.000 1314230399.1810 KNUD035 HDG: 352.700 1314230399.769 UNKNOWN_SRC NO_DNV_ERROR 1314230400.733 -999

Name of Field	Value (from sample string)	Description
string identifier	RGS	identifies record a RGS (Raw Gravity String)
YYYY/MM/DD hh:mm:ss.sss	2011/08/25 00:00:00.733	date and time logging laptop receivedBGM-3 count
raw_gravity	982999.220	unfiltered measured gravity in *mgal*
counts	25428	the counts measured by the gravimeter (e.g., for a BGM3, the value transmitted from the data buffer)
gravity_unixtime	1314230400.733	time the gravity measurement was obtained in seconds since Jan 1 1970
scale_factor	4.990049154	the scale factor for the gravimeter obtained during factory calibration
bias	856112.250	the bias obtained during the last ship to pier tie
gravimeter & seial number	BGM3 S223	gravimeter model and serial number of the gravimeter used to obtain the gravity measurement
position latitude longitude	GPS: 79.104265 -165.067809	GPS_LAT and GPS_LON received by the laptop
GPS_unixtime	1314230399.657	time GPS_LAT and GPS_LON was received by the laptop in seconds since Jan 1 1970
Satellite Information	0 0 GPS_GP150 349.453 4.031	NUM_SATS; GPS_HDOP; GPS_SRC; GPS_COG; GPS_SOG
depth	DEPTH: 2153.000	Depth data received by laptop (m)
depth_unixtime	1314230399.1810	time the logged depth was received by the laptop in seconds since Jan 1 1970
depth_source	KNUD035	source of the depth measurement
heading	HDG: 352.700	GYRO_HDG: heading
heading_unixtime	1314230399.769	Time when the Gyro data was received by the laptop in seconds since Jan 1 1970.
heading source	UNKNOWN_SRC	Unknown source of heading string
dnv_status	NO_DNV_ERROR	On a BGM3 system, the status of the DNV indicator. There are 4 possible values: SENSOR_DNV_ERROR --- Error reported by the SENSOR ELECTRONICS CPS_DNV_ERROR --- Error reported by the CPS SENSOR_AND_CPS_DNV_ERROR --- Errors reported by BOTH the SENSOR ELECTRONICS and CPS NO_DNV_ERROR --- No errors reported; system is running fine
dnv time	1314230400.733	time when the dnv sensor data was received by the laptop in seconds since Jan 1 1970.
magnetometer	-999	reserved for magnetometer string (not used on the 2011 Louis cruise)

Quality Control at Sea

Three types of quality control of gravity data were completed during the 2011 UNCLOS cruise: (i) a weekly check on hardware values, (ii) a daily check of preliminary smoothed gravity compared to the Arctic gravity grid (Forsberg and Kenyon, 2004) and IBCAO bathymetry, and (iii) a gravity log of hourly GPS navigation positions annotated with comments relevant to the gravity acquisition.

(i) **<u>Weekly check</u>: The weekly tests checked the Control Power Supply (CPS) measurements with standard ranges, and Sensor Test Point Measurement, including sensor power and sensor oven voltage values. Voltage measurements were taken with Fluke 777 True RMS Multimeter. These were performed by D. Reimer of the science party.**

(ii) **<u>Daily check</u>: The daily checks involved checking the data buffer lights and downloading 24 hours of RGS values and performing preliminary processing on them to look at various aspects of the gravity, GPS, and depth acquisition strings. The linux shell scripts used to inspect the data were:**

run_smooth: to filter and smooth the 1-s RGS values into a 1-minute format and output plots of cumulative(i.e, from the beginning of the cruise) BGM gravity, predicted gravity, free-air anomaly; speed, course, Eötvos correction, free-air anomaly, Arctic gravity grid, and IBCAO depths. The output from run_smooth is preliminary because there are no corrections for meter or clock drift. Smoothing was applied in the time-domain with a 2-minute standard deviation (half-width) Gaussian filter.

plot_daily_series: to plot, for the last 24 hours, panels comparing (a) the BGM free-air anomaly with the Arctic gravity grid, (b) the depth measurements with IBCAO bathymetry, and (c) the speed, course, and eotvos corrections. These daily plots are included in the addendum at the end of this chapter. The speed can vary significantly during acquisition in the ice, especially when backing and ramming to break ice. The gravity signal not unexpectedly becomes noisy at these times.

plot_map: to plot maps showing cumulative track for the cruise superimposed on the IBCAO bathymetry, the Arctic gravity grid, the magnetic grid, and a blank background.

run_summarize_RGS_errors: to identify various errors in the RGS files (Data Not Valid – DNV – errors; CPS and sensor errors; errors or no-data points for the depth and GPS strings, as well as truncated or extended records that might not be readable). This script was developed during the cruise to quantify errors identified in processing the data.

run_GEF_check: to check clock drift between the laptop clock and GPS clock using the first record of GEF files. This script was developed during the cruise to quantify clock errors identified while processing the data.

The shell scripts were provided by D. Scheirer (USGS) and were updated during the cruise as bugs were identified. The daily checks were performed by D. Hutchinson.

(iii) <u>Gravity log</u>: An excel gravity log (LSSL2011_Gravlog.xlsx) was kept with four worksheets. The first logged GPS times of events affecting gravity acquisition (SOL, EOL, when *Louis* was following *Healy*, *Louis* was breaking ice for *Healy*, *Louis* was hove to or stopped; or when errors occurred); the second worksheet tabulated errors from the run_summarize_RGS_errors; a third worksheet summarized gravity clock drift relative to GPS time (the plot and trendline for the clock drift errors is plotted on a separate worksheet); a fourth worksheet has the hourly and intermediate fixes of the gravity data and was generated for making a map of the times the gravimeter was not working or had excessively noisy data. D. Hutchinson kept the gravity log.

Known Problems

Five known problems with the BGM 223 gravity system occurred during the *Louis* cruise:

(i) <u>Control Power Supply (CPS)</u>

On August 29, 2011 (JD241), ~1:40z, the raw gravity values dropped ~2770 mGal from 983218.8 to 980449.3 indicating a major acquisition problem. The RGS files began logging continuous CPS errors at this change in value. Emails with J. Kinsey and R. Herr (of the WHOI Potential Fields Instrument Group) resulted in the recommendation to restart the CPS unit, which we did on August 31, 2011 (JD243) at 15:05z. The subsequent daily plots looked fine, and the problem was assumed to be fixed. Down time from CPS errors was ~61.5 hours. Throughout the rest of the cruise, CPS errors continued to be logged, though at a much smaller rate. These errors are discussed below in the summary of errors.

(ii) <u>Two Simultaneous Gravlog Processes</u>

After restarting the CPS, the gravity measurements looked good for about 9 hours, after which the Free-Air Anomaly (FAA) on 1 September (JD244) began showing large (20 mgal) excursions from the Arctic gravity grid. At the beginning of 2 September (JD 245), the excursions of the FAA grew to 50-100 mgal. The change in the size of the excursions coincides with the change from *Louis* following *Healy* to *Louis* leading and breaking ice in front of *Healy* (Fig. 4-3). Upon recommendation of J. Kinsey, we checked the status of gravlog on the acquisition computer and discovered that two versions of the gravlog program were running. One of the gravlog processes was therefore stopped on September 3, 2011 (JD 246) ~0230, after which the FAA gravity measurements immediately quieted down (although by this point in the cruise, *Louis* was breaking ice in front of *Healy*, so the gravity was expected to be somewhat noisy (±5 mgal). Because the beginning of two gravlog processes is not known, the down time estimated from the start of the noisy records (Fig. 4-3) is ~50.5 hours.

The RGS files for the two days of erratic values (1-2 September) are not of consistent length, containing both extended and truncated records. Approximately ½ the normal number of records (~43,000 records versus ~86,400 records in a normal day) were recorded, and it remains to be determined if this discrepancy is due to the truncated/extended record lengths and how frequently the missing records are distributed through the file. Random inspection of the GEF logs for those days indicates that some of the RGS records are in the GEF files, but not in the RGS file, suggesting some of the missing records might be recovered (Table 2, compare times 00:00:09-00:00:18). For other times, the RGS records may not have been created in either file (Table 2, compare times 00:00:19-00:00:41). Whether a full set of daily RGS values can be recovered remains to be determined in post-cruise processing.

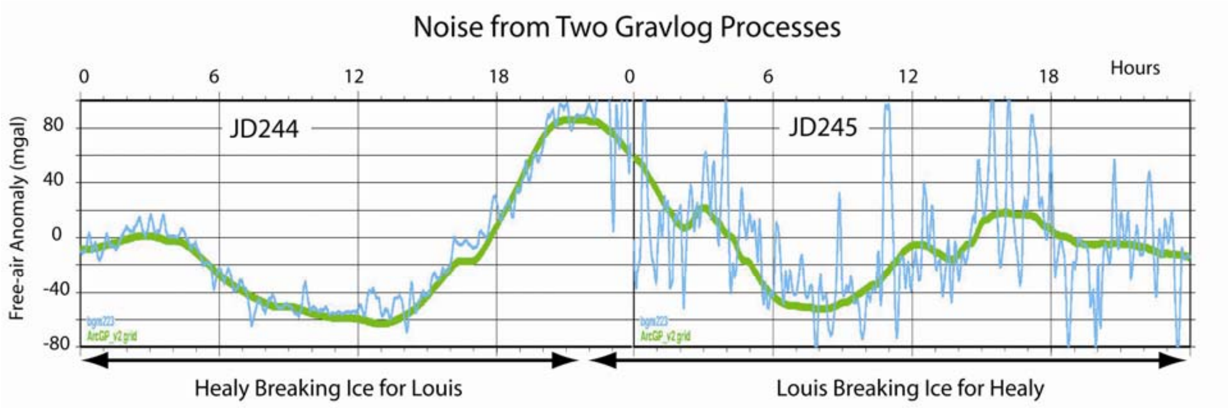


Figure 4-3. Noise in Louis gravity during the time that two gravlog processes were running. The change in the amplitude of the excursions coincides with the change from Louis following Healy to Louis leading and breaking ice in front of Healy.

Table 4-2: Comparison of RGS records logged in the RGS file (left column) versus logged in the GEF file (right column) for September 1, 2011 (JD 244).

File: 20110901_0000.rgs	File: 20110901_0000.GEF
RGS 2011/09/01 00:00:09.857	Missing
Missing	RGS 2011/09/01 00:00:08.857
Missing	RGS 2011/09/01 00:00:10.857
Missing	RGS 2011/09/01 00:00:11.853
Missing	RGS 2011/09/01 00:00:12.853
Missing	Missing
Missing	Missing
Missing	Missing
Missing	Missing
Missing	Missing
RGS 2011/09/01 00:00:18.853	RGS 2011/09/01 00:00:18.853
RGS 2011/09/01 00:00:19.853	RGS 2011/09/01 00:00:19.853
Missing to 00:00:30.853	Missing to 00:00:30.853
RGS 2011/09/01 00:00:30.853	RGS 2011/09/01 00:00:30.853
Missing to 00:00:41.849	Missing to 00:00:41.849
RGS 2011/09/01 00:00:41.849	RGS 2011/09/01 00:00:41.849

(iii) Clock drift

The gravimeter acquisition laptop was installed without having a clock synch to satellite time or a time server, hence the logging program was using the internal laptop clock for time. Quite by serendipity, I noticed a time offset between the gravity clock and the GPS time when checking the navigation at the time of crossing the International Date Line. By looking at the GEF files, which logged both the GPS (GPGGA string) and laptop time, the discrepancy between the laptop clock and GPS clock was ~11 minutes, with the laptop clock losing time (~.2 min or 10 sec) every day. This clock drift results in 86,411 and 86,410 records for each day rather than the usual 86,400 records (i.e., number of seconds in a day). In consultation with J. Kinsey, we decided to maintain laptop time for the gravity meter for the rest of the cruise (rather than synching it to the satellite server). Maintaining a consistent time would avoid confusion; and the linear drift of the meter would be easy to monitor and/or correct post-cruise. A plot of clock drift from the beginning of each day from installation to near the end of the LSSL 2011 cruise (Fig. 4-4) indicates the linear pattern was consistent. This clock drift needs to be accounted for in post-cruise processing of the gravity data.

Note: The file LSSL2011-gravlog.xlsx uses GPS time in all entries, and notes RGS (i.e., laptop) time for relevant events).

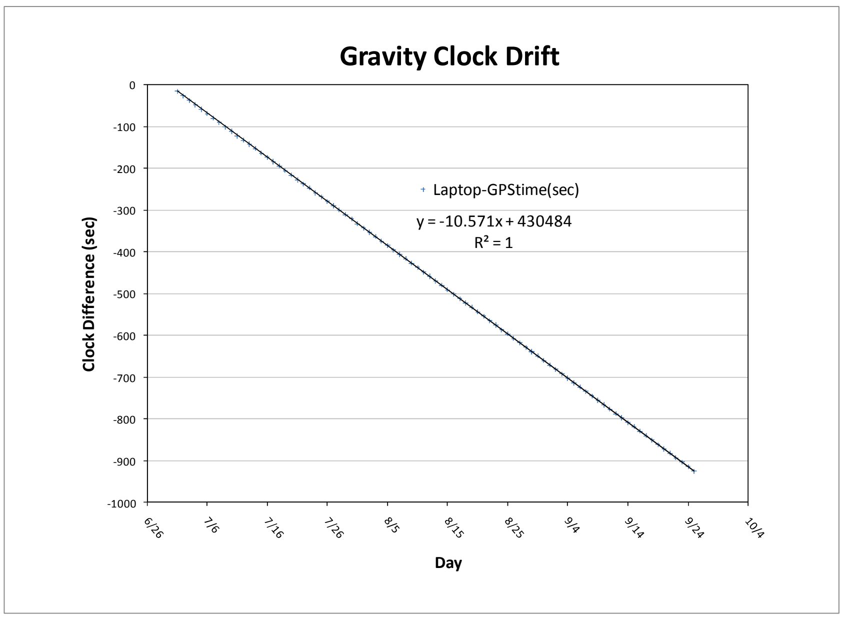


Figure 4-4: Plot showing clock drift between the gravity laptop (logging gravity) and GPS time from time of gravimeter installation (29 June) until near the end of LSSL 2011 cruise (25 September). The laptop lost 10.571 seconds/day and lagged GPS time by ~15 minutes on 25 September. Plotted points are the difference between the two clocks for the first fix of every day. The equation gives the linear trend line and fit of the points.

(iv) <u>Sensor Testing</u>

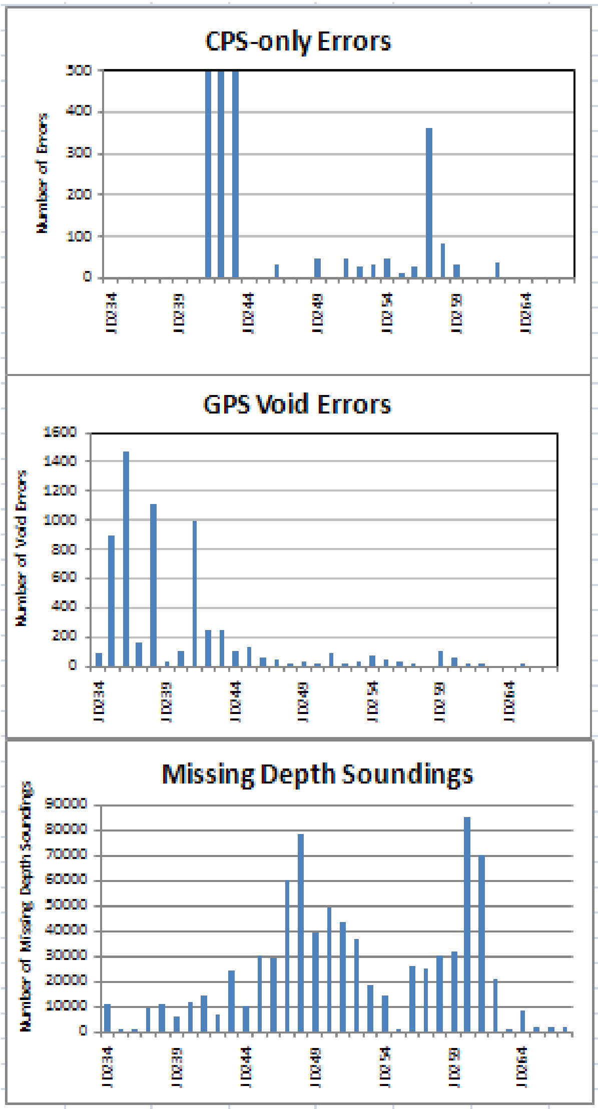
Performing the recommended sensor tests on the gravimeter (checking the power of the sensor test points with a digital volt/ohm meter) resulted in coincident sensor-only errors in the RGS data records and a loss of data for these times. For example, on September, 10, 2011 (JD253), the sensor tests were logged at 17:35z (10:35 local). The RGS files note sensor-only errors at 17:23:56-17:24:30. The time discrepancy (17:35 versus 17:23) is explained by the clock drift (laptop lagging satellite time by ~13 minutes). While this is only a loss of less than a minute of data, it does represent an interruption of data logging. No similar errors were noted when the CPS values were checked. The down time from these sensor errors is considered negligible.

(v) Void values for GPS and/or Depth

There were problems throughout the cruise with GPS fixes not being recorded every second. Early in the cruise, J. Biggar worked to troubleshoot the drop-outs, but no problems with antenna, receiver, or cables proved effective in changing the behavior. The void depth values were particularly common when *Louis* was breaking ice in front of *Healy* or in areas of rough and rapidly changing bathymetry. See the cruise report chapter summarizing hydrographic measurements for a more complete description. An edit depth file was generated at sea and is included with the raw gravity data. These depths need to be merged during final gravity processing.

(vi) Summary of Errors

A summary of the significant errors recorded in the RGS files is shown in Figure 4-5. The CPS errors on JD 241-243 are off scale at >50,000 errors per day (Fig. 4-5A) before the CPS was restarted.



4-

Figure 4-5. Plot of errors and missing data during gravity acquisition aboard Louis. CPS refers to power supply errors; GPS void refers to missing position fixes.

The fixes that were not recorded in the GPS (Figure 4-5B) are greatest during the start of the cruise, when equipment was being tested. GPS errors towards the end of the cruise, when *Louis* is headed south, are minimal.

Depth recordings were the most erratic during the cruise (Fig. 4-5C). The missing values at the start of the cruise JD 233-234) were when testing was done between the 3.5 kHz and 12 kHz echosounders. Other times of major dropouts coincide with times *Louis* was breaking ice ahead of *Healy*, or in areas of rough topography. Most of the missing depth values have been interpolated and hand edited to recover the values.

Gravity Track

Gravity was collected along the entire *Louis* 2011 cruise, excepting the times of CPS errors. Figure 4-6 shows the *Louis* track color coded by seismic data acquisition (*Healy* breaking ice and *Louis* following); multibeam data acquisition (*Louis* breaking ice and *Healy* following), bad gravity values, and *Louis* hove to for AUV operations. Tabulated data are in Table 3.

Table 4-3: Gravity Data Acquisition by Activity[1]

Activity	Total Km
Seismic (*Healy* breaking ice/*Louis* following)	1044
Multibeam (*Louis* breaking ice, *Healy* following)	1894
Hove to/AUV ops	238
Transit, Kugluktuk to Chukchi	2497
Transit, Canada Basin to end JD268	1540
Bad (CPS errors)	272
Noisy (duplicate gravlog processes)	363
Total	7848

[1]Note: These are km of gravity data for each activity, and may differ from other tabulations, particularly because the bad gravity data occurred during both seismic and multibeam data acquisition.

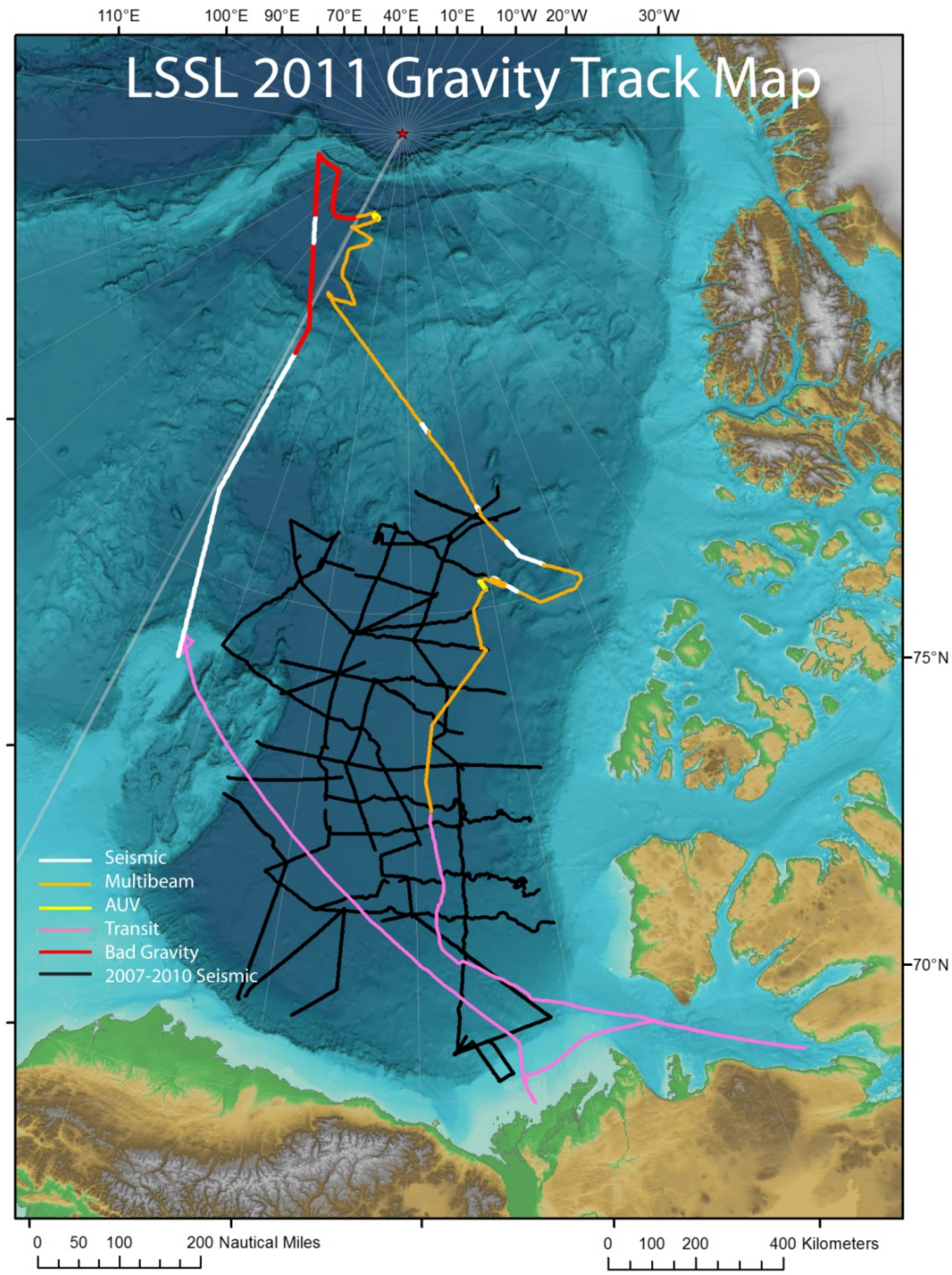


Figure 4-6: Gravity data acquisition from LSSL 2011 keyed to activity. Tracks for seismic data acquisition from 2007-2010 are also shown.

Comparison of *Healy* and *Louis* Gravity Measurements during Icebreaking

The participation of two icebreakers, each with a gravimeter, provides the unique opportunity to compare the effect of icebreaking on gravity measurements. Because of the science requirements, each ice breaker utilized different approaches to ice breaking. During seismic operations, *Healy* maintained *Louis* speed, breaking ice a constant distance in front of *Louis*, in an attempt to keep the track open. Breaking ice at a slower speed (~4-4.5 kts) is less efficient than at higher speeds and can result in more backing and ramming. During multibeam operations, *Louis* would break ice at optimal ice breaking speed (~8-10 knots), then wait 10-15 minutes for *Healy* to catch up.

Figure 4-7 shows a portion of two days during the cruise during multichannel acquisition in very heavy ice, when *Healy* was breaking ice in front of *Louis*. Even with the lead ice breaker, *Louis* was stuck in the ice ~8 times and had to be freed by additional icebreaking around her by *Healy*. The line ended at JD256 1341z after *Louis* became stuck in ice and the conditions were judged unfavorable for continuing seismic operations.

The two meters aboard *Healy* show considerable noise (~5 - 10 mGal) during ice breaking operations (Fig. 4-7A, blue lines). The *Louis* meter does not show the noise (Fig. 4-6B blue line). Bathymetry from Healy (Fig. 4-7C, dark brown line), shows the two outer ridges of Sever Spur are higher and steeper than predicted by IBCAO bathymetry (Fid. 4- 7C, tan line). The FAA gravity anomalies in Fig. 4-7A and B also show that the gravity anomaly is steeper than that taken from the Arctic Gravity Grid (Fig. 4-7A and B, green line).

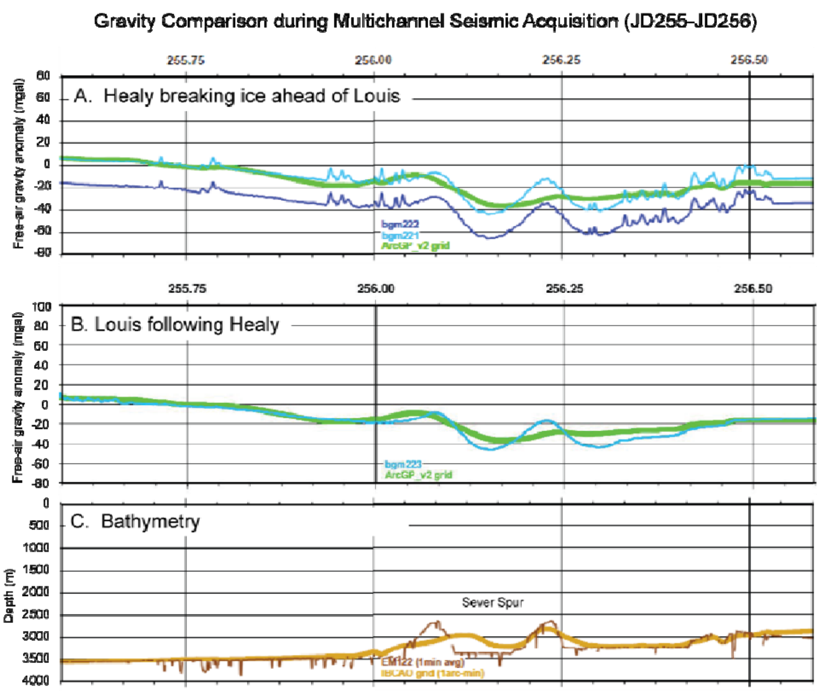


Figure 4-7: Comparison of gravity measurements of Louis and Healy during multichannel seismic profiling (when Healy breaks ice in front of Louis). A. Healy gravity (2 meters with one of the meters offset from the other by ~20 mgal). B. Louis gravity (plotted at a slightly different vertical scale). C. Bathymetry along the track (from Healy). There is a slight offset between Healy and Louis gravity because of the distance Louis was behind Healy.

During multibeam operations, when *Louis* was breaking ice in front of *Healy*, the reverse situation exists (Fig. 4-8). *Louis* gravity shows a noisy record with similar ~5-10 mgal of noise, whereas *Healy* gravity does not. Although the noise on the gravity profiles looks similarly noisy for both *Louis* and *Healy* when they are the lead vessel breaking ice, the difference in their ice breaking provides the opportunity to examine whether one method of ice breaking produces less noisy data than the other. Inspection of both Figures 4-7 and 4-8 suggests that the *Louis* method of breaking ice may result in slightly lower amplitude noise. This observation should be compared against all of the data. At the end of JD250 in Figure 4-8, both ships are stopped for a USCG air drop and separate maneuvering prior to the air drop, which explains the quiet gravity record and spikes for both ships.

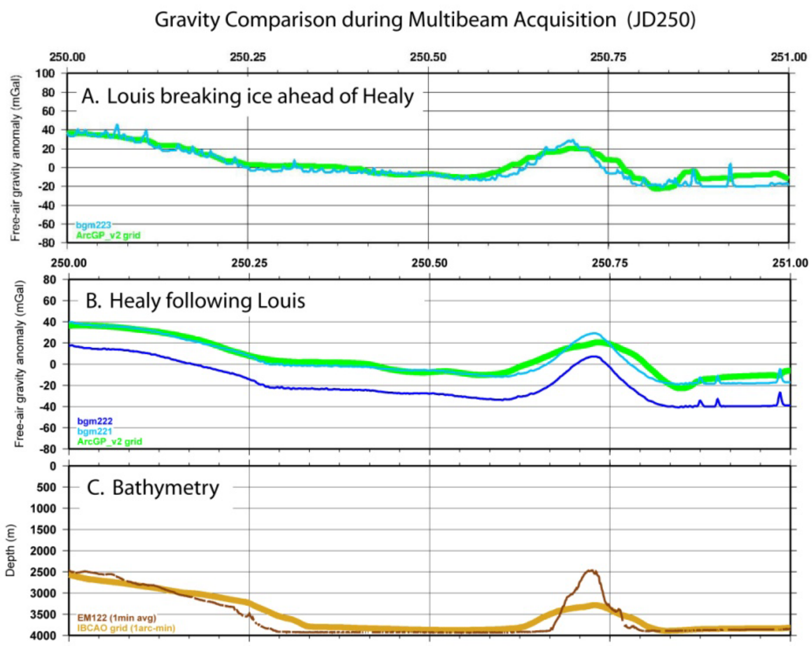


Figure 4-8: Comparison of gravity measurements of Louis and Healy during multibeam bathymetry profiling (when Louis breaks ice in front of Healy). A. Louis gravity (plotted at a slightly different vertical scale). B. Healy gravity (2 meters with one of the meters offset from the other by ~20 mgal) C. Bathymetry along the track (from Healy). There is a slight offset between Healy and Louis gravity because of the distance Healy was behind Louis.

Comparison of *Louis* Gravity for a Repeated Track

During AUV operations, *Louis* was driven in a 7 x 7 km square pattern three times during JD 247 (Fig. 4-9). The first square involved breaking ice, the second and third were in the same track, although offset slightly north and east each pass because of ice drift.

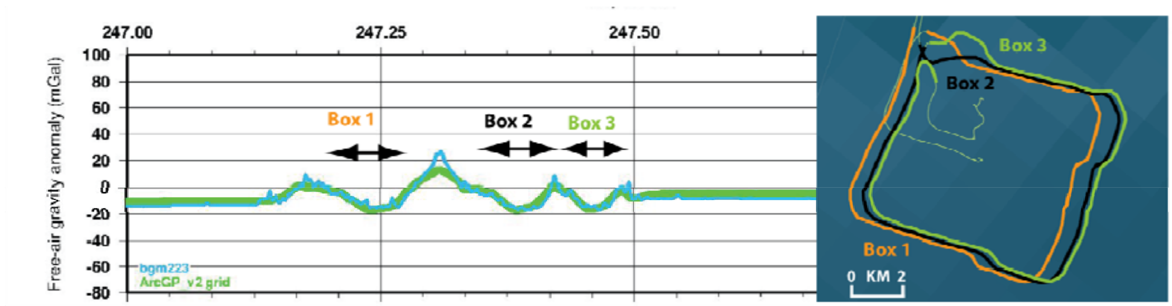


Figure 4-9: Free Air Gravity anomaly profile on JD247 and the geometry of the ship's track for each of three boxes transited during the day. Between boxes 1 and 2, Louis transited north, then south for approximately an hour.

The gravity pattern shows each box is on a gravity gradient, with positive anomalies on the northwest (start of the box) decreasing to the southeast. The length of time the ship took to navigate each box also decreased from slowest (box 1) to most rapid (box 3). This geometry offers the potential to examine the effect of gravity filters on data collected in close proximity with ties where the lines cross and for similar lines acquired at different speeds.

Summary and Recommendations

During the 42 days of gravity data acquisition during the *Louis* 2011 cruise, approximately 3200 km of tracks were covered. Of this, the gravity meter malfunctioned for ~272 km/61.5 hours (CPS errors) and may have unrecoverable data for another 363 km/50.5 hours (duplicate gravlog processes running).

The quality control undertaken during the LSSL 2011 cruise has shown the need for additional post-cruise processing:

1. The raw data need to be corrected for the time discrepancy between the laptop time used to acquire the data and the satellite GPS time. This could be done by either applying a correction to the RGS files to account for the linear drift, or by regenerating the RGS files using GPS time rather than laptop time (JD241-JD243).
2. The raw GEF files should be examined for RGS data that may not have been written to the RGS file during the time that two gravlog processes were running simultaneously (JD244-246).
3. The noisy data during the time of two gravlog processes (JD244-JD246) should be examined for whether the missing RGS records can explain some of the noisiness, and whether any data can be recovered.
4. There should be better documentation of actions to take when problems arise (such as CPS errors) so that poor communications (such as intermittent email aboard *Louis* in the high Arctic) don't extend down time unnecessarily.
5. The raw gravity need to be re-merged with the edited and finalized depth file from the *Louis* 2011 cruise.

In addition, there are several improvements that could be made to the QA/QC approaches:

6. Distance calculation for the minute of time at crossing the international date line showed ~2066 km traveled going from east to west; and another ~1548 km travelled when crossing the date line from west to east. Hence the distances output in the 1-min smoothed gravity files following the crossing of the date line are erroneous by these amounts.
7. The error checking should be a regular part of daily monitoring of the gravity values.
8. A GPS-based time server should be operated from the beginning to end of gravity acquisition and should control the time stamp used for gravity data acquisition, thereby eliminating the need for post-cruise processing to correct position and gravity values. The gravity laptop should be synchronized to the science time server.

The combined *Louis* and *Healy* gravity data offer the opportunity for additional gravity studies:

9. The acquisition of gravity data by the two icebreakers working together, as well as their different styles of icebreaking, provides the opportunity to compare the quality of the data from the different icebreaking approaches.
10. The acquisition of gravity data along a box pattern surveyed three successive times along the same track provides the opportunity to compare Louis gravity on the same track when breaking ice, and when not breaking ice.

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Chapter 5: Along Track Ice Conditions

Deborah R. Hutchinson

Introduction

Similar to the way sea state affects seismic acquisition in open water, ice conditions affect multichannel seismic acquisition from ice-breaker cruises such as the *CCGS Louis S. St-Laruent* (*Louis*) 2011 expedition. In general, lighter ice conditions are amenable to multichannel seismic data acquisition whereas extremely heavy ice conditions – or conditions of ice under pressure – pose too much of a risk for damage to towed seismic gear and are therefore more appropriate for other types of data acquisition. Much of the 2011 two icebreaker program was planned so that multichannel seismic acquisition would be the priority in favorable ice conditions (from *Louis*) and multibeam bathymetric data acquisition would be the priority in the heaviest ice conditions (from *Healy*). Because so much of the cruise was planned north of 80^{o}N, it was expected that ice conditions might preclude multichannel seismic acquisition in some of the areas.

Table 5-1: Source of RADARSAT Imagery in Figures 5-1 to 5-13.

Figure No.	Area	Image[1]
Figure 5-1	Transect North (Chukchi)	2011/08/25 02:51 z (NIC) 2011/08/24 18:33 z (CIS)
Figure 5-2	Transect North (Mendeleev Basin)	2011/08/25 02:51 z (NIC) 2011/08/26 02:22 z (NIC)
Figure 5-3	Transect North (W. Nautilus Basin)	2011/08/26 02:22 z(NIC) 2011/08/27 03:34 z (NIC)
Figure 5-4	Transect North (Alpha Ridge)	2011/08/27 20:24 z (NIC) 2011/08/29 19:25 z (NIC)
Figure 5-5	Transect North (N. Alpha Ridge)	2011/08/30 00:28 z (NIC)
Figure 5-6	Transect North (Makarov Basin)	2011/09/01 02:49 z (NIC)
Figure 5-7	MarvinSpur Survey	2011/09/04 21:32 z (NIC) 2011/09/05 00:53 z (NIC
Figure 5-8	Alpha Ridge	2011/09/07 21:45 z (NIC)
Figure 5-9	Southern Alpha Ridge	2011/09/10 16:55 z (NIC)
Figure 5-10	Stephenson Basin	2011/09/10 16:55 z (NIC)
Figure 5-11	Northern Sever Spur (lower)	2011/09/12 00:45 z (NIC) 2011/09/12 00:46 z (NIC) 2011/09/13 00:16 z (NIC) 2011/09/14 01:27 z (NIC)
Figure 5-12	Southern Sever Spur	2011/09/16 15:40 z (CIS)
Figure 5-13	Northern Canada Basin	2011/09/19 00:41 z (NIC) 2011/09/19 02:22 z (NIC)

[1]All times are zulu (Greenwich mean time), NIC – U.S. National Ice Center; CIS – Canadian Ice Service.

This chapter summarizes the satellite radar images (RADARSAT) available through the Canadian Ice Service (CIS) and the U.S. National Ice Center (NIC) together with visual (photographic) observations about ice conditions. The cruise is divided into 13 segments to show the natural divisions among multichannel seismic lines, multibeam acquisition, and Autonomous Underwater Vehicle (AUV) operations (Table 1). Multibeam acquisition is fully described in the 2011 *Healy* cruise report (http://www.ccom-jhc.unh.edu/publications/Mayer_2011_cruise_report_HEALY1102.pdf). AUV operations are fully described in Chapter 3 of this report, including maps of AUV tracks.

Imagery

The ice imagery shown in Figures 5-1 to 5-13 are screen captures taken from the *Healy* mapserver, which displays the imagery in a web-based Geographic Information System (GIS) format along with ship tracks, ice-buoy locations, and a variety of other observed data from the current and previous cruises. For the 2011 two-icebreaker program , both *Healy* and *Louis* ship tracks could be plotted directly on the imagery in the mapserver, although sometimes with different colors depending on which track was active in the GIS program. Table 5-1 gives the sources and dates/times of imagery used in Figures 5-1 to 5-13 as they were listed in the mapserver legend. Multiple images can be displayed simultaneously as a mosaic, which is why more than one image is listed for some of the figures in Table 5-1.

Transect North: Chukchi Plateau (Line 1)

Science operations began after the rendezvous with *Healy* on the northern edge of Chukchi Plateau when multichannel seismic Line 1 was started (24 August, JD 236). RADARSAT imagery shows that the line begins near the ice edge with abundant open water (Fig. 5-1). Canadian Ice Service (CIS) Analysis Chart for 24 August gives ice conditions for the beginning of the line at 5/10 coverage with 3/10 thin first year ice and 2/10 thick first year ice, both in medium-sized floes. Ice conditions became heavier going north so that by the end of the line (25 August, JD 237), there is 7/10 ice coverage with proportionally more thick first year ice in larger floes. During this line, there were no instances of either *Healy* or *Louis* stopping to break ice.

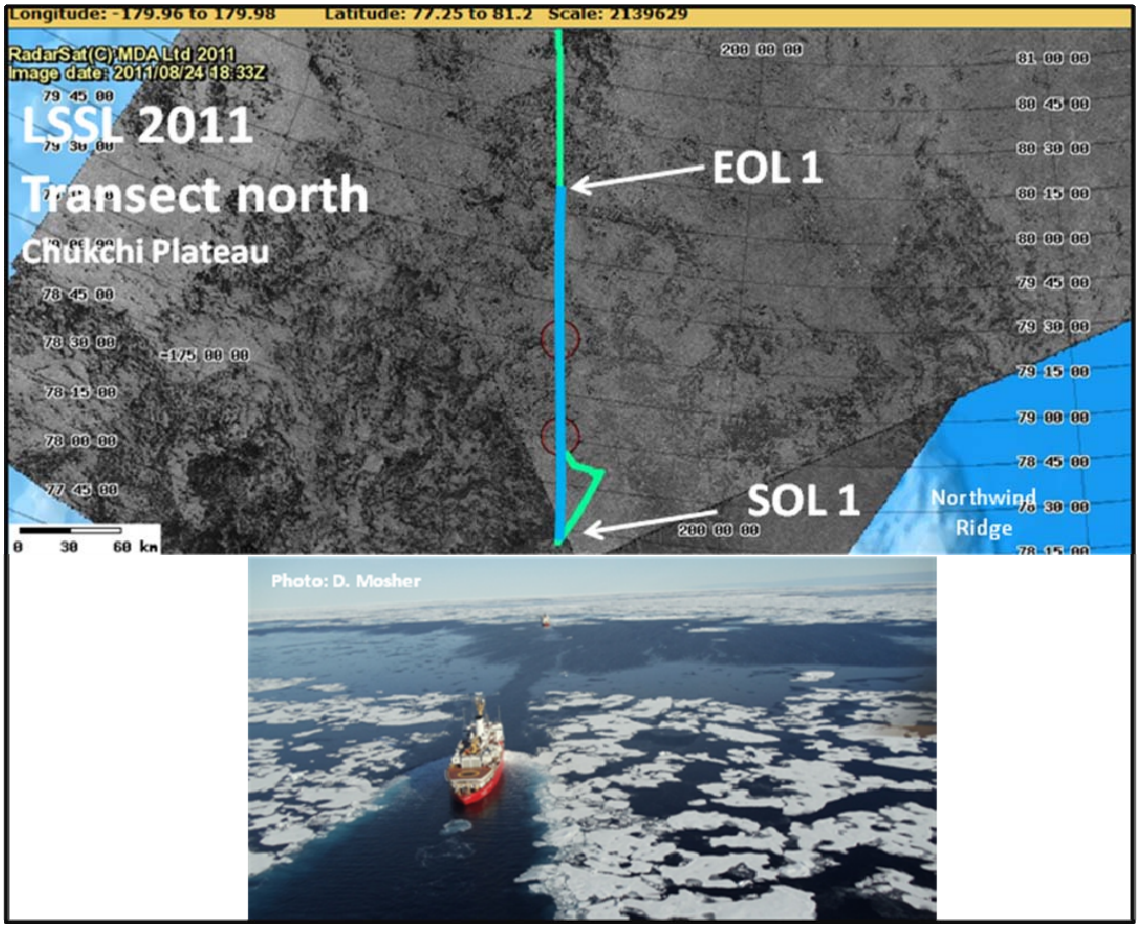

Figure 5-1: Ice conditions at the start of multichannel seismic science operations on the transect north, beginning on the northern edge of the Chukchi Plateau. In the RADARSAT imagery, green line shows the cruise track. Blue portion represents Line 1.

Transect North: Mendeleev Basin (Line 2)

Multichannel line 2 began at the first waypoint along the transect north in the Mendeleev Basin (25 August, JD 237) and is continuous with lines 1 and 3 (i.e., no interruption in shooting at the start or end of line). The RADARSAT imagery shows some open areas at the southern end of the line, but the ice closes up by the end of the line (Fig. 5-2). From the CIS Analysis Charts, the line begins in 7/10 ice coverage and ends in 9/10 ice coverage. The line ends on 26 August (JD 238). Thick first year ice in big floes constitutes the majority of the ice. *Louis* was not stopped by icebreaking on this line .

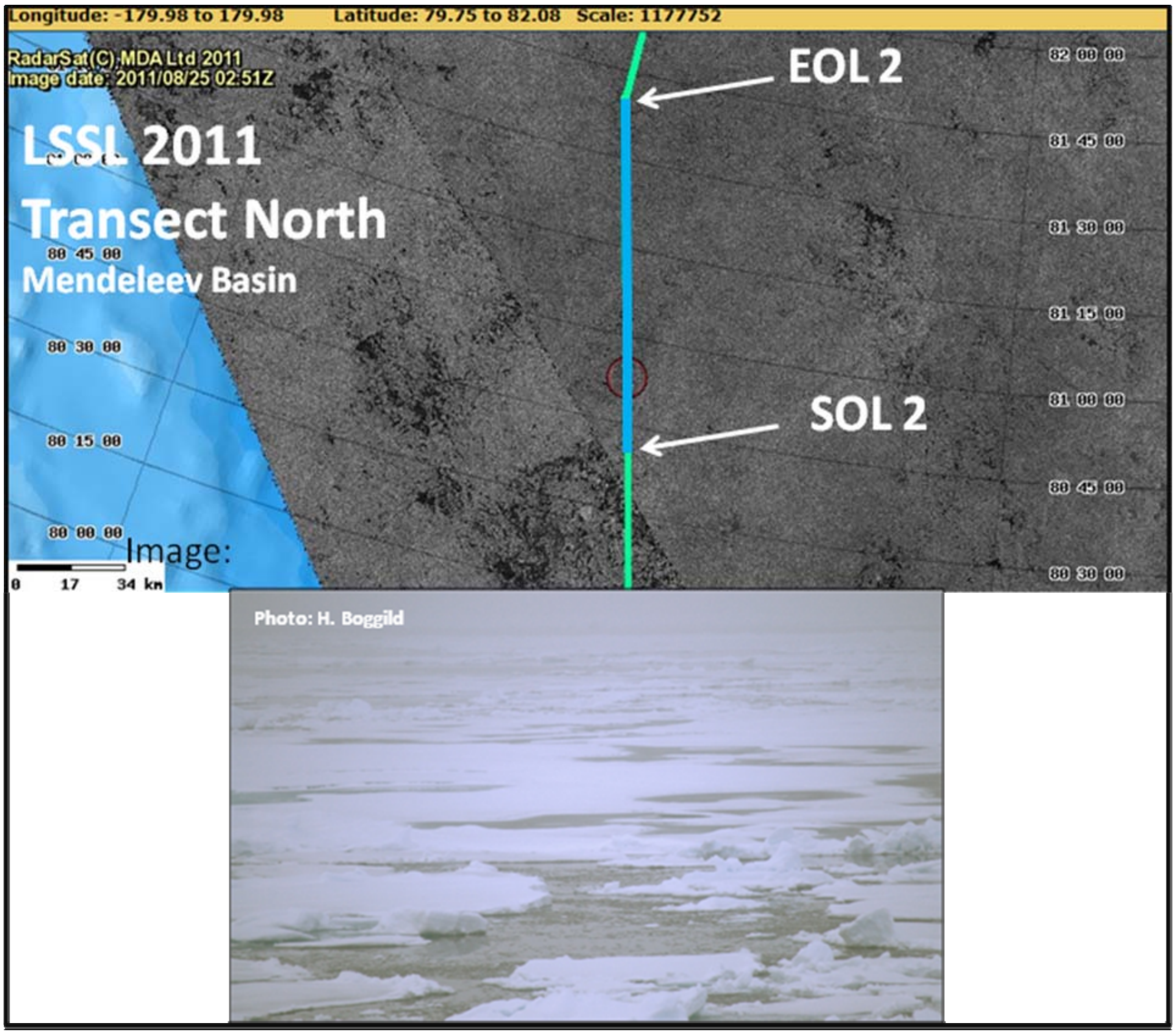

Figure 5-2: Ice conditions along multichannel seismic line 2 of the transect north in the Mendeleev Basin north of Chukchi Plateau. In the RADARSAT imagery, green line shows the cruise track. Blue portion represents Line 2.

Transect North: Western Nautilus Basin (Line 3)

Multichannel seismic line 3 crosses western Nautilus Basin and is continuous with multichannel line 2. RADARSAT shows continuous ice cover (Fig. 5-3). CIS Analysis Charts for the start and end of the line (Aug. 26-27; JD 238-239) show 9/10 ice coverage with up to 8/10 thick first year ice in big floes, and thin first year ice in vast floes. Hence the ice is getting thicker and more expansive. A photograph of ice conditions shows many melt pools atop the ice (Fig. 5-3). Although *Healy* was breaking ice, this did not take enough time so that *Louis* had to stop and wait.   Multichannel line 3 was ended prematurely when the airguns started leaking air. The seismic equipment was pulled out of the water and both *Louis* and *Healy* hove-to during repair.

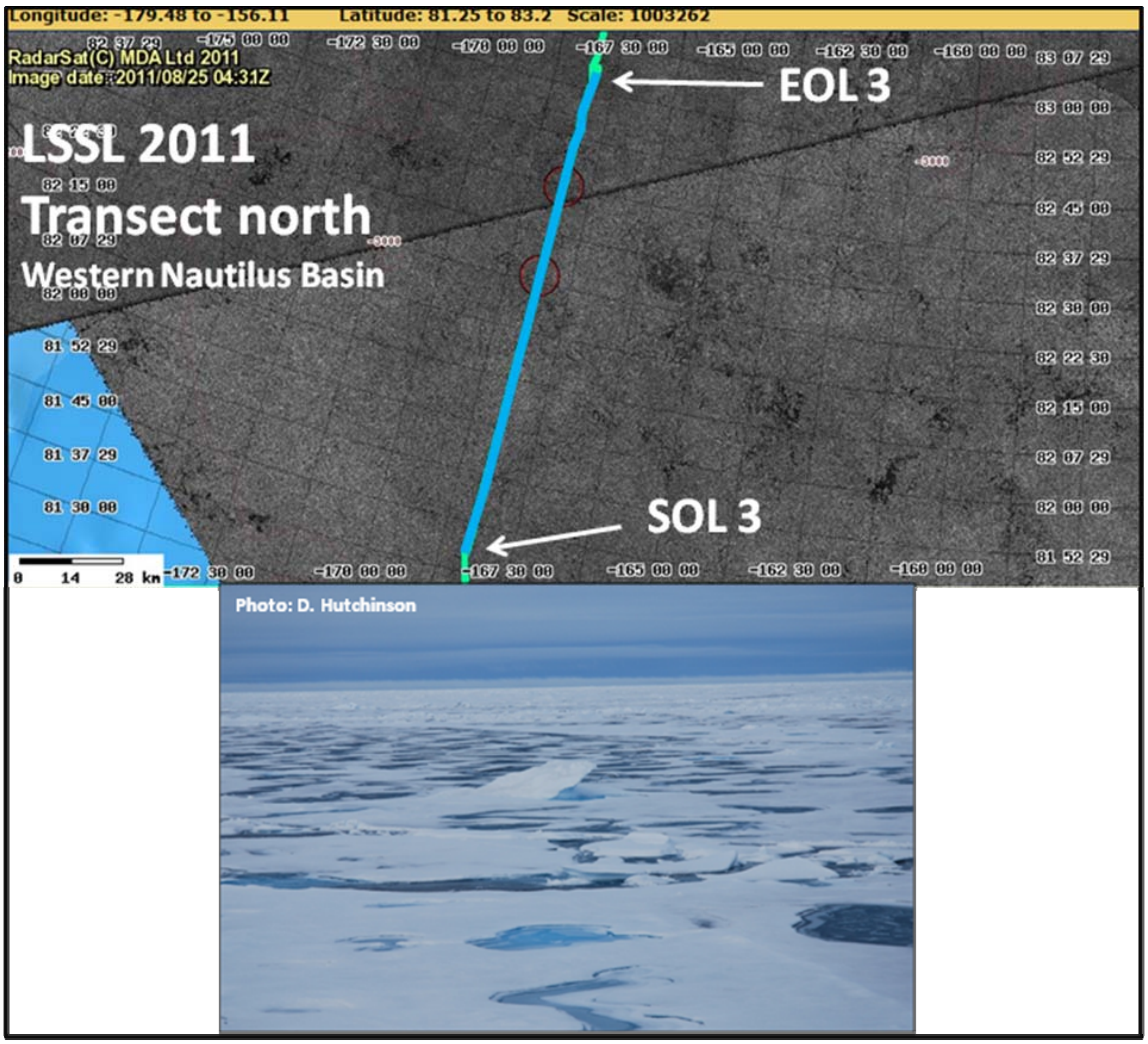

Figure 5-3: Ice conditions along multichannel seismic line 3 of the transect north along the western side of Nautilus Basin. n the RADARSAT imagery, green line shows the cruise track. Blue portion represents Line 3.

Transect North: Alpha Ridge (Line 3B)

After repair of the seismic equipment, multichannel line 3B was resumed later on 27 August (JD 239). Line 3B runs parallel to and just east of the U.S. – Russian border. RADARSAT imagery shows near continuous ice coverage (Fig. 5-4). CIS Analysis Charts for the region show 9/10+ ice coverage with thick first year ice in big floes dominating the area. Although numerous melt pools are evident (photograph in Fig. 5-4), the ice was not noticeably under pressure, with light winds and little ridging. *Healy* was breaking ice throughout this line, and for the first time near the end of the line *Louis* was stopped by the ice and had to be broken free by *Healy* circling around. A change in course direction marks the end of Line 3B (29 August, JD 241).

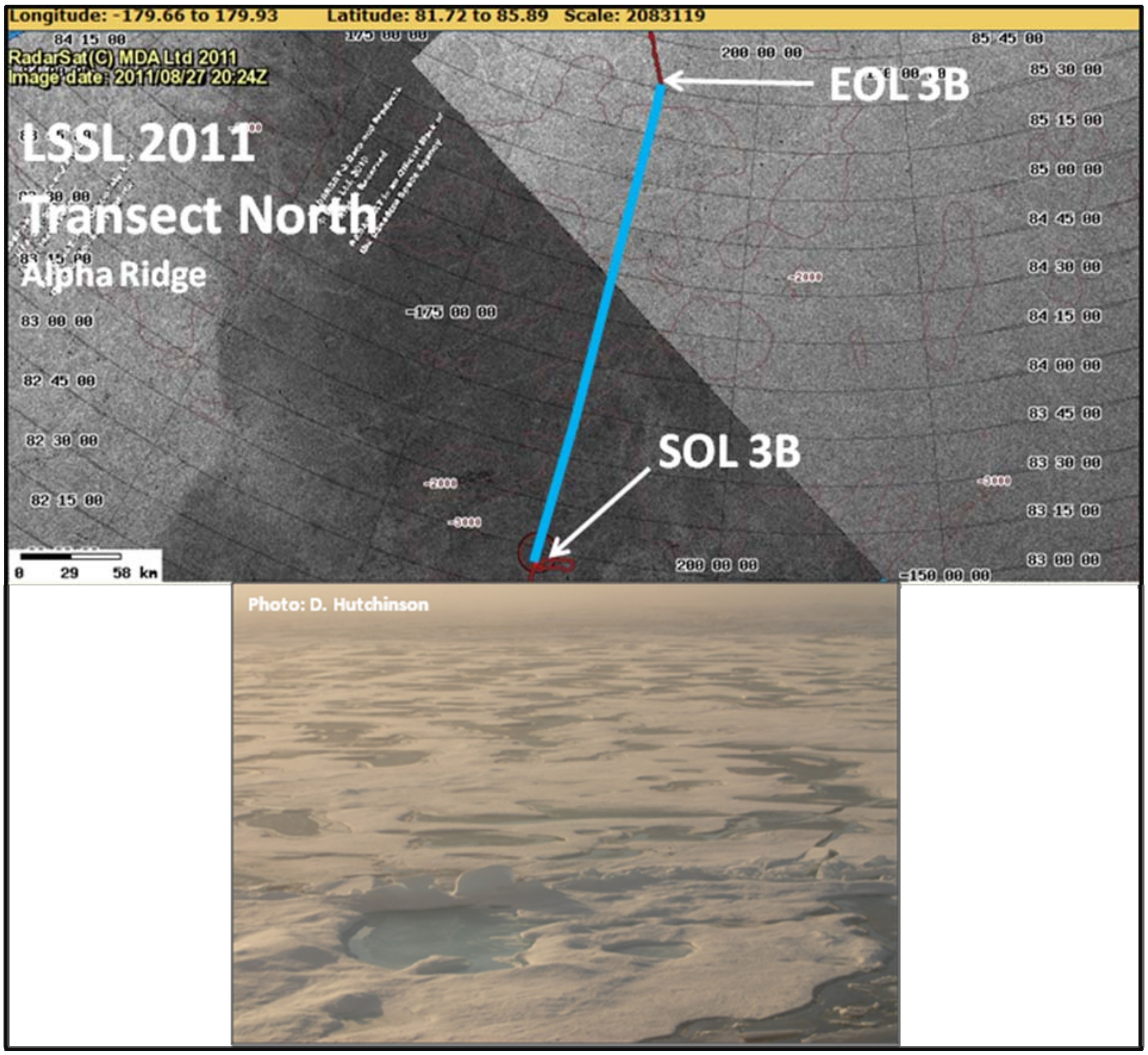

Figure 5-4: Ice conditions along multichannel seismic line 3B of the transect north along Alpha Ridge. In the RADARSAT imagery, red line shows the cruise track. Blue portion represents Line 3B.

Transect north: Northern Alpha Ridge (Line 4)

Multichannel seismic line 4 was shot continuously with line 3B, beginning at the course change on northern Alpha Ridge. RADARSAT imagery (Fig. 5-5) shows continuous ice coverage. CIS Analysis Charts for 29-30 August (JD241-242) show that the ice conditions are still 9+ with thick first year ice in vast floes as the dominant ice type.   Numerous melt pools are evident on the photograph of ice conditions (see photograph in Fig. 5-5). During Line 4, *Louis* was stopped multiple times, either because of waiting for *Healy* to break ice, or because heavy ice was stopping her forward progress and *Healy* had to circle to break *Louis* out. Line 4 was terminated early when the streamer stopped recording and the seismic equipment was recovered on deck for testing.

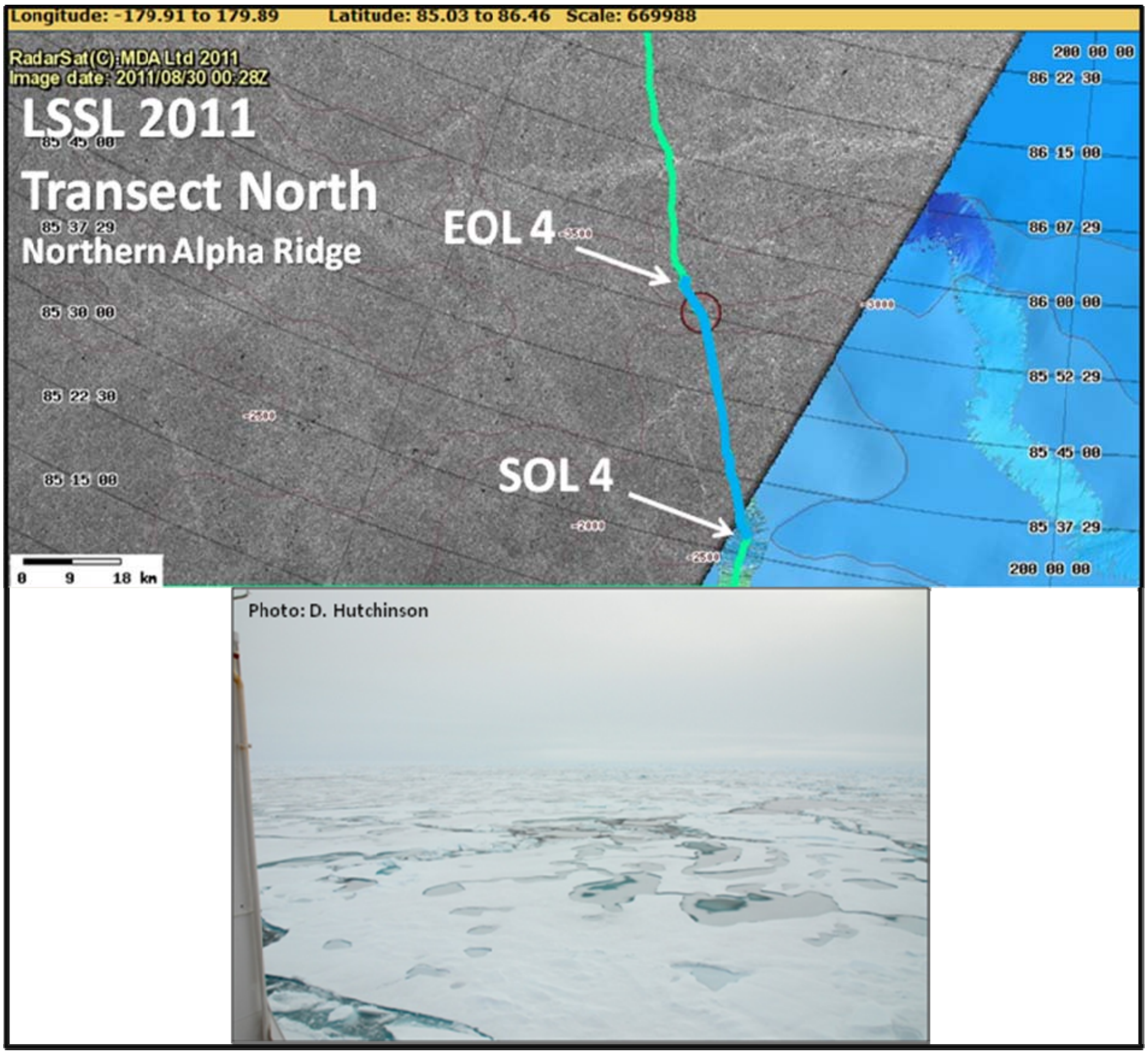

Figure 5-5: Ice conditions along multichannel seismic line 4 of the transect north along northern Alpha Ridge. In the RADARSAT imagery, green line shows the cruise track. Blue portion represents Line 4.

Transect North: Makarov Basin (Line 4B)

After about 16 hours of repair work on the streamer while *Louis* and *Healy* were hove to, multichannel seismic line 4B was begun for the last portion of the transect across Makarov Basin to Lomonosov Ridge on August 30 (JD 242). RADARSAT imagery shows that the conditions are complete ice coverage (Fig. 5-6). CIS Analysis Charts indicate conditions are essentially identical to line 4, i.e, 9+ ice coverage with vast floes of thick first year ice. Ice conditions were more challenging on this line in that several times *Healy* got stuck (for which *Louis* had to wait); *Louis* more frequently put on higher revs to prevent getting stuck; and on multiple occasions *Healy* had to return to break *Louis* out of ice when *Louis* became stuck. Line 4B ended atop Lomonosov Ridge on 1 September (JD 244).

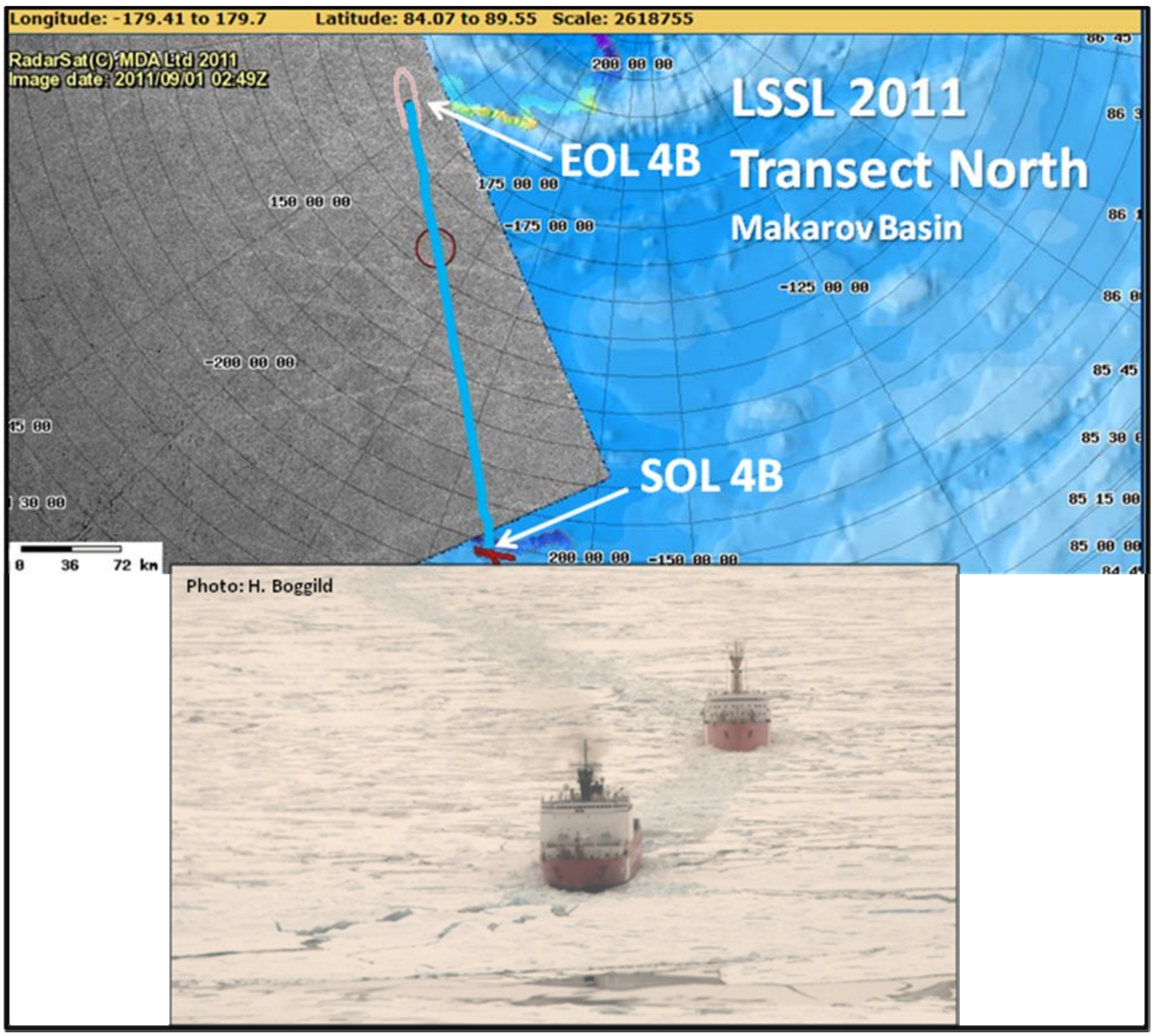

Figure 5-6: Ice conditions along multichannel seismic line 4B of the transect north crossing Makarov Basin. In the RADARSAT imagery, red line shows the cruise track. Blue portion represents Line 5.

Marvin Spur Survey (Multibeam and AUV)

At the end of line 4B, the seismic gear was pulled and multibeam operations began, with Louis breaking ice ahead of Healy (green and white dashed line in Fig. 5-7). In order to maximize efficiency of breaking ice, Louis would increase speed in front of Healy while breaking ice, then wait while Healy caught up. Nowhere during multibeam operations was it necessary for Louis to return to break Healy out. Both ships separated during AUV operations. Louis remained with the AUV (Louis track during AUV operations is shown in yellow in Fig. 5-7); Healy proceeded on an independent multibeam survey (red track in Fig. 5-7). RADARSAT imagery shows complete ice coverage; CIS Analysis charts for this time period (1-6 September, JD 244-249) also show 9+ ice coverage with thick first year ice dominant. Ice around Marvin Spur had much rubble debris and small ridges (see photograph, Fig. 5-7).

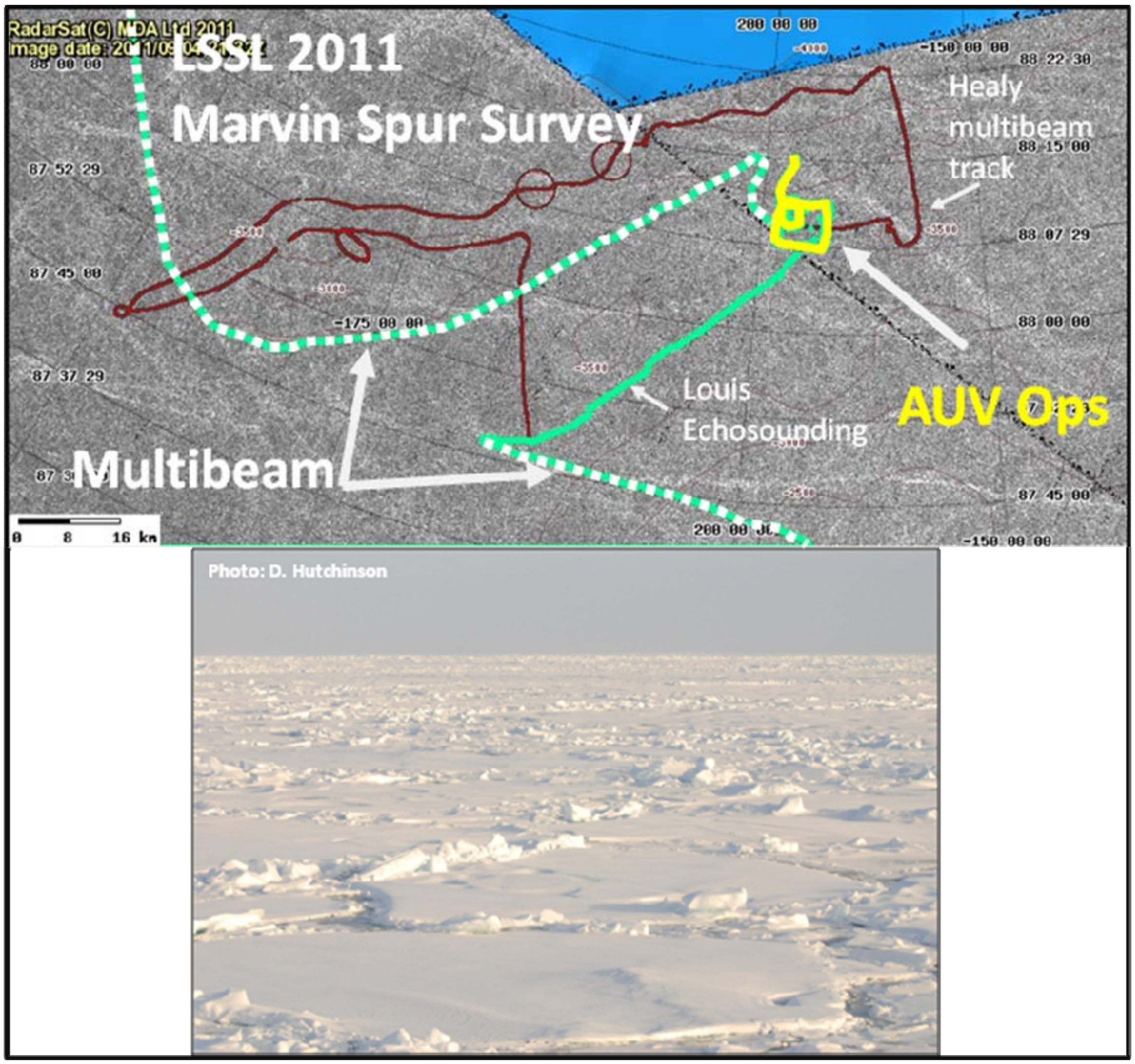

Figure 5-7: Ice conditions during the Marvin Spur Survey. Track colors in the RADARSAT imagery are: red – Healy independent multibeam survey; green dashed – Louis breaking ice for Healy multibeam data acquisition; yellow – Louis track during AUV operations; solid green – Louis transiting to meet Healy.

Alpha Ridge (Multibeam)

Following the Marvin Spur survey, the two ships progressed south with *Louis* leading *Healy* along the track. RADARSAT imagery shows full ice coverage; and CIS ice Analysis Charts show 9+ coverage. During the multibeam survey south across Alpha Ridge, ice conditions noticeably slowed ship speed, with many large ridges requiring multiple passes at backing and ramming to get through (see photographs, Fig. 5-8). Crossing Alpha Ridge took place on 6-10 September (JD 249-JD 253).

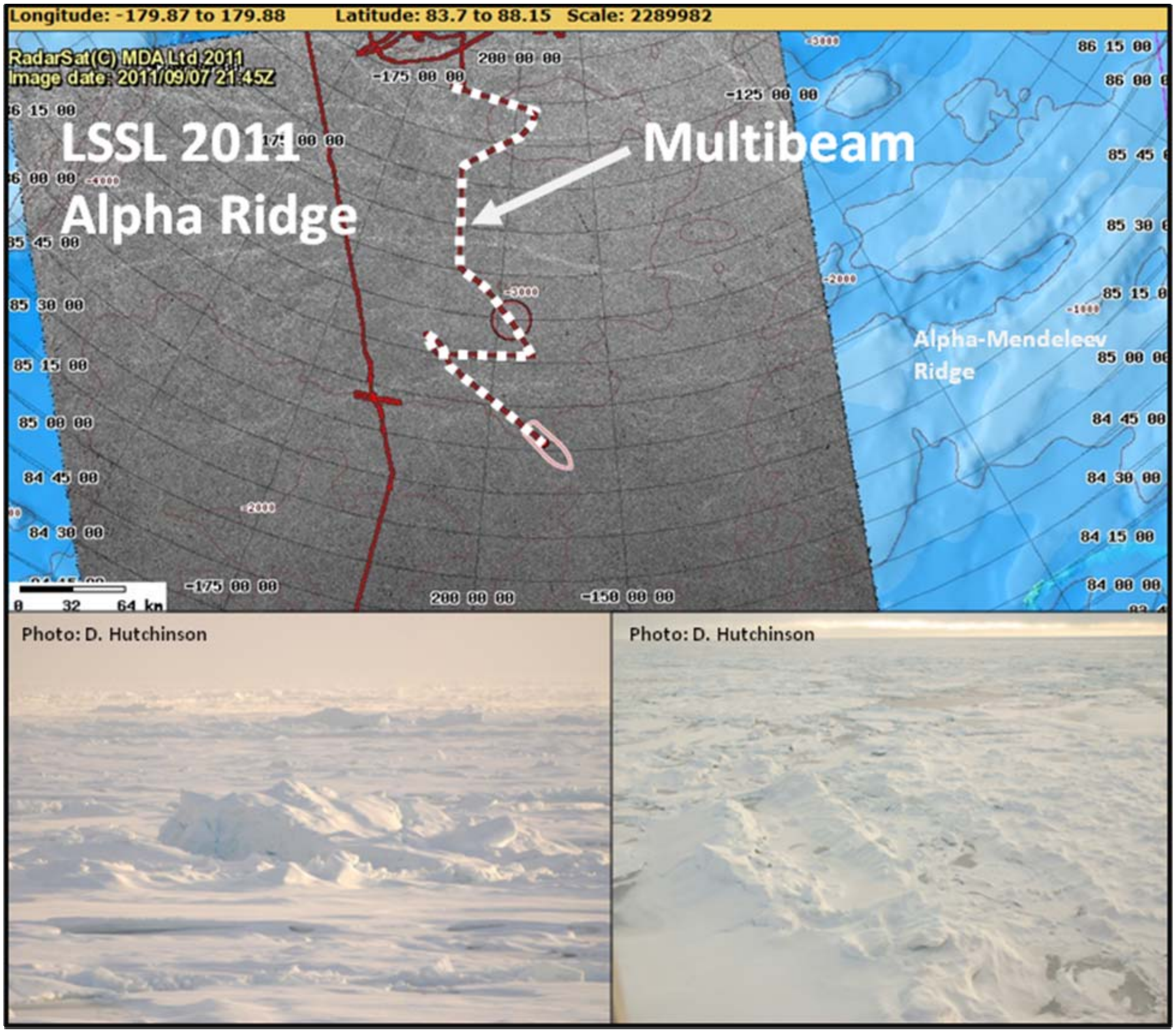

Figure 5-8: Ice conditions during the multibeam survey south across Alpha Ridge. In the RADARSAT imagery, red line shows the cruise track. Red dashed portion represents multibeam data acquisition.

Southern Alpha Ridge (Line 5)

One of the cruise objectives was to collect a seismic transect across Stephenson Basin towards Sever Spur. Despite the heavy and slow ice conditions, the seismic gear were deployed on 10 September (JD 253) to attempt a transect. RADARSAT imagery showed complete coverage (Fig. 5-9), with CIS Analysis Charts also showing 9+ conditions and proximity to old ice. The ice did not appear to be under significant pressure, so the gear was deployed on Line 5 to collect data where Stephenson Basin and Alpha Ridge meet. Progress was extremely slow, with *Louis* becoming stuck early on and requiring *Healy* assistance to be broken out. The line was terminated after 7 hours after judging progress through the ice to be too slow, and the gear was at risk. The gear was recovered early on September 11 (JD 254).

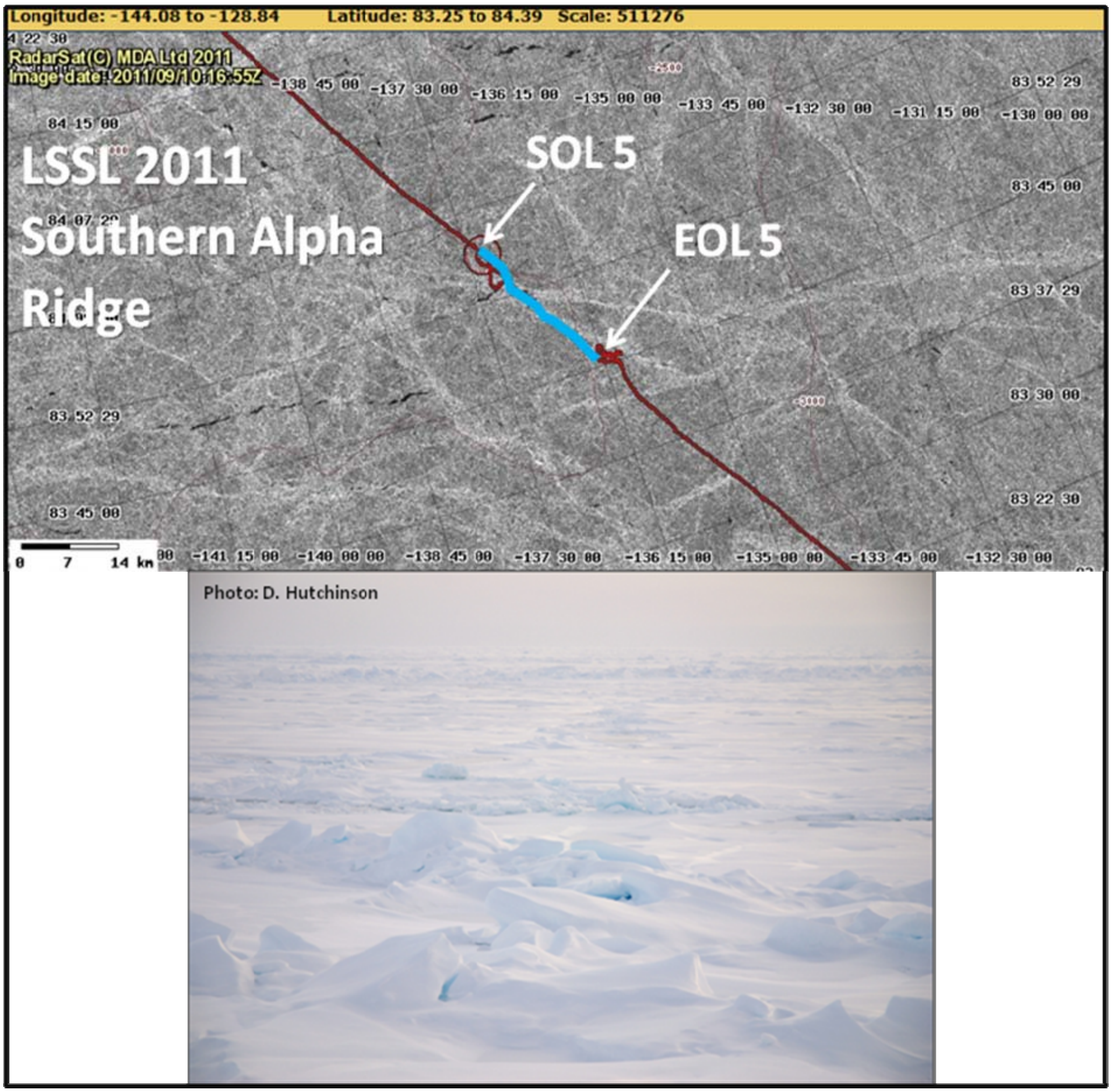

Figure 5-9: Ice conditions along southern across Alpha Ridge for multichannel seismic line 5. In the RADARSAT imagery, red line shows the cruise track. Blue portion represents Line 5.

Stephenson Basin (Multibeam and Line 6)

After terminating line 5, *Louis* continued to break ice and lead *Healy* across Stephenson Basin toward Sever Spur. Ice conditions were essentially the same as those on southern Alpha Ridge (see Fig. 5-9) with 9+ ice comprised mostly of vast first year floes (Fig. 5-10). The ice consisted of rubble fields and ridges (see photograph, Fig. 5-10). Multichannel seismic operations were attempted again on September 12 (JD 255), with *Healy* leading *Louis*, but were terminated when *Louis* became continuously stuck and *Healy* would have to make multiple passes before *Louis* broke free. Therefore, Line 6 ended less than four hours after it began. *Louis* proceeded to break ice ahead of *Healy* for multibeam data acquisition.

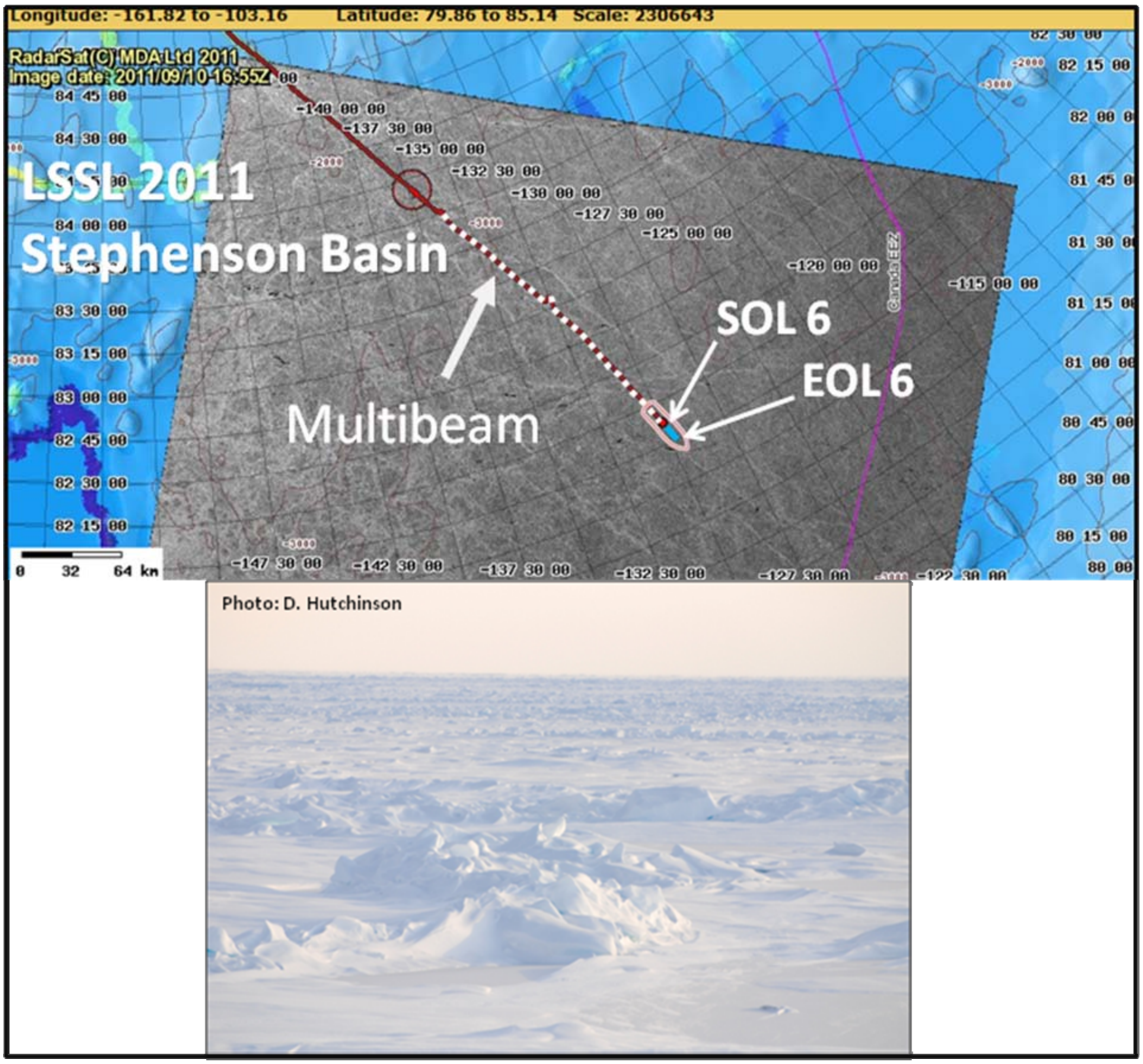

Figure 5-10: Ice conditions in Stephenson Basin for multibeam data and multichannel seismic line 6. In the RADARSAT imagery, red line shows the cruise track. Red dashed portion represents multibeam data acquisition; short blue line represents Line 6.

Northern Sever Spur (multibeam and Line 7)

Multichannel seismic data were again attempted coming up on northern Sever Spur with the acquisition of line 7, starting on 12 September (JD 255). Although *Louis* stopped multiple times and required being broken out by *Healy*, conditions were deemed okay until towards the end of the line, when multiple attempts by *Healy* to free Louis were unsuccessful. The gear were hauled on 13 September (JD 256), and *Louis* proceeded to lead *Healy*, breaking ice for multibeam data acquisition. Similar to Stephenson Basin, the RADARSAT imagery showed continuous ice cover (Fig. 5-11). The ice field was a mixture of rubble and ridges, some very large (see photograph, Fig. 5-11). Multibeam operations continued to the southern side of Sever Spur on 15 September (JD 258).

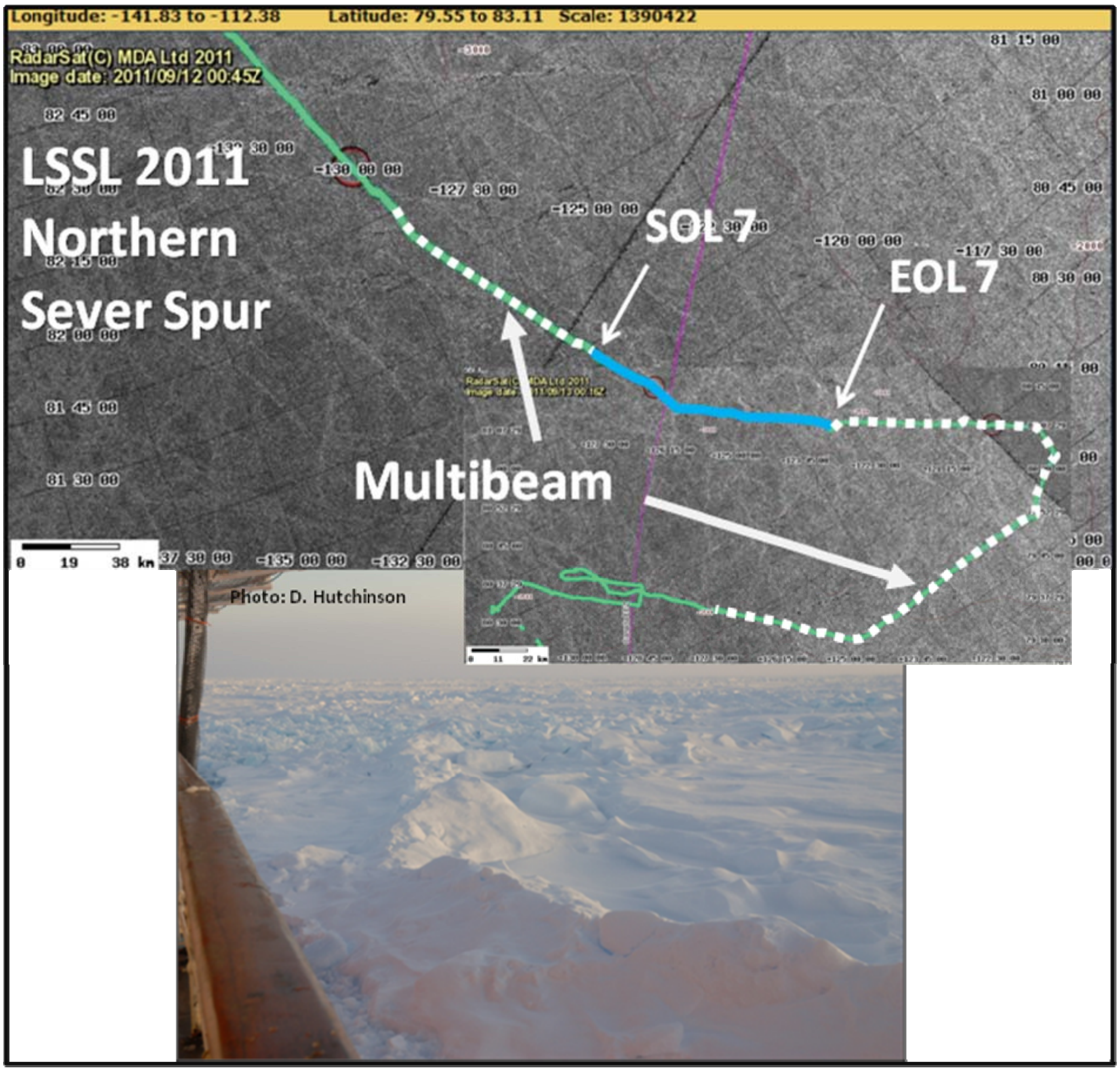

Figure 5-11: Ice conditions in northern Sever Spur for multichannel seismic line 7 and multibeam data.I n the RADARSAT imagery, green line shows the cruise track. Green dashed portion represents multibeam data acquisition; blue line represents Line 7.

Southern Sever Spur (seismic, multibeam, and AUV)

Sever Spur was a high priority objective for gathering both seismic and multibeam data. Multichannel seismic line 8 was collected while the two ice breakers headed west off the spur. Ice conditions were lighter than further east on Sever Spur, but still had continuous ice cover (9+) with big floes and large ridges, although some fractures in the ice were evident (Fig. 5-12). After line 8 was shot (September 15-16, JD 258-259), two additional multibeam crossings of the outermost ridge of Sever Spur were acquired. *Louis* and *Healy* then separated with *Louis* stopping in an open pool of water for AUV ops, while *Healy* continued on a multibeam survey of Sever Spur. The linear path of AUV ops shown on Fig. 5-12 reflects the *Louis* position in ice drift for the three days of AUV operations (16-19 September, JD 259-JD 262), not the AUV track.

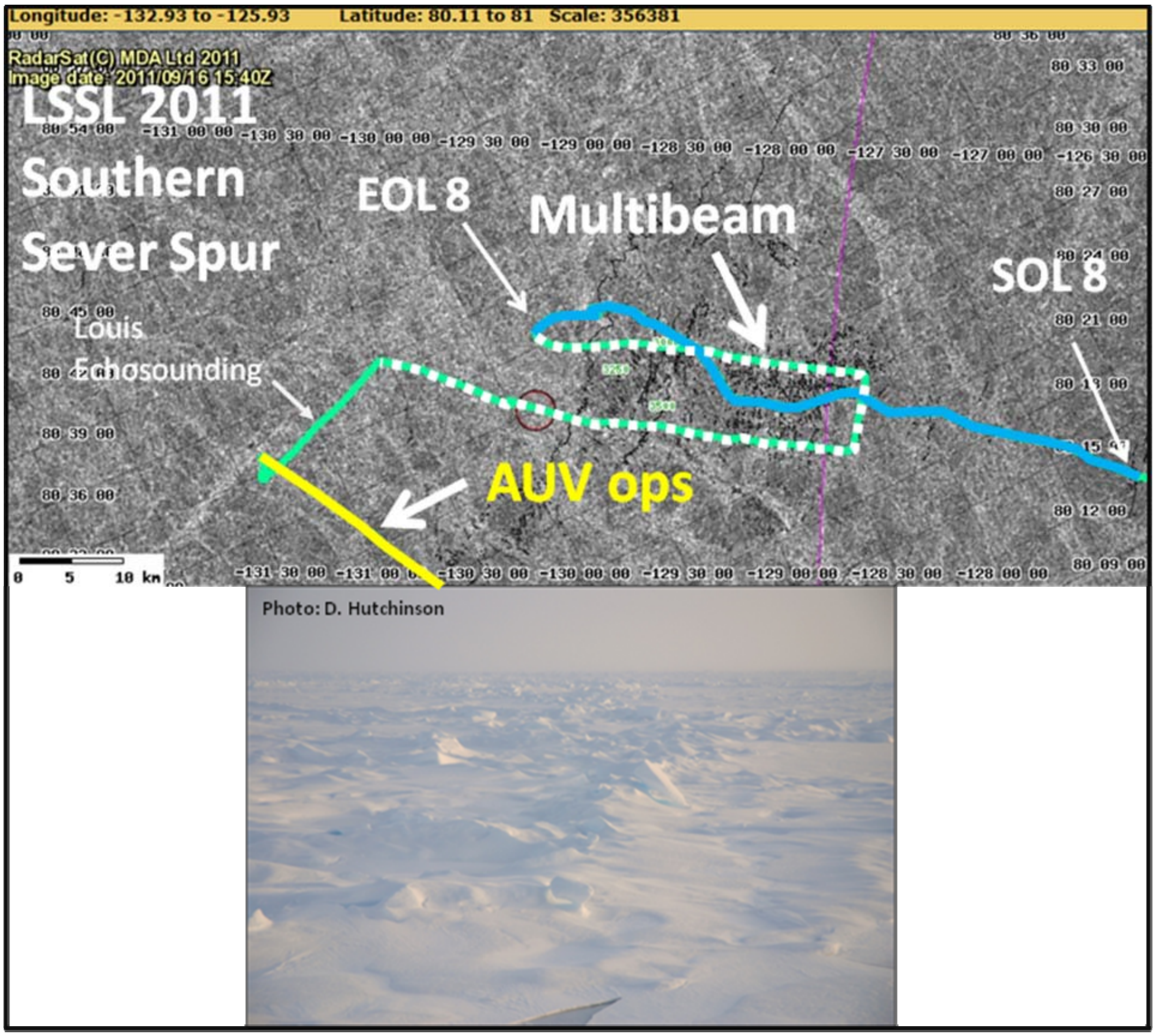

Figure 5-12: Ice conditions in northern Sever Spur for multichannel seismic line 8 (blue line), multibeam data acquisition (green dashed line), Louis transit to the open pool to commence AUV operations (green line). and Louis track during AUV operations (yellow line).

Northern Canada Basin (multibeam)

While the intention was to collect seismic data going south from Sever Spur, and then across northern Canada Basin, ice conditions were not amenable to seismic acquisition. Ice conditions were similar to those found on southern Sever Spur (Fig. 5-12) with old ice interpreted on the CIS Analysis charts to be nearby just to the east, and extensive rubble and ridging around (Fig. 5-13). On several occasions, *Healy* and *Louis* did trial runs with *Healy* leading *Louis* to see if *Louis* could proceed without being stuck, without success. When a place was found where seismic might be resumed, a ship's propulsion problem was discovered aboard *Louis*, and all science seismic operations were terminated for the trip (September 19, JD 262). *Healy* then proceeded to lead *Louis* directly out to lighter ice conditions. On 22 September (JD 264), *Louis* and *Healy* parted company for their respective port calls.

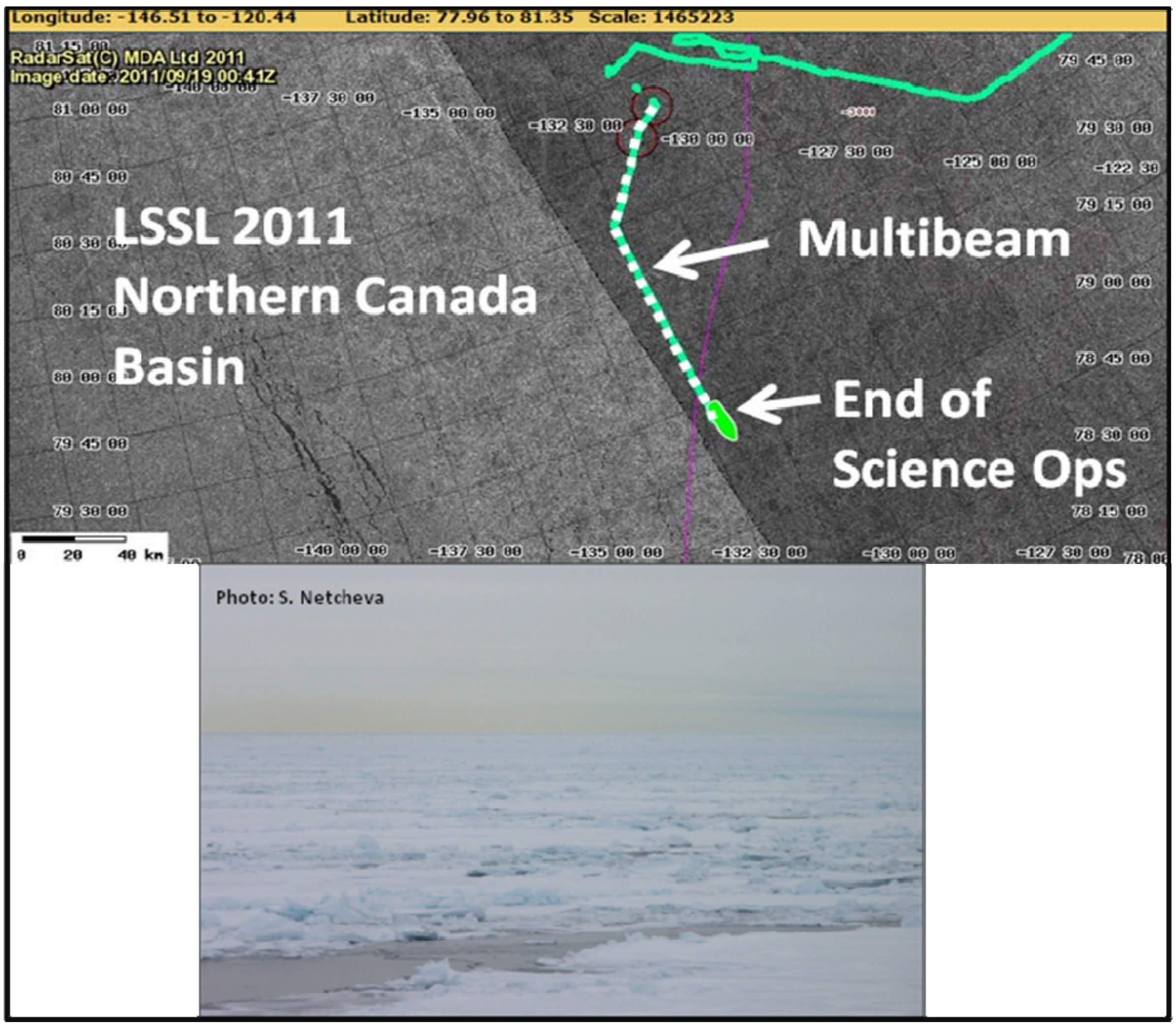

Figure 5-13: Ice conditions on the final leg of science operations, collecting multibeam data. Louis and Healy traded positions several times during this line to test for favourable conditions for collecting multichannel seismic data. In the RADARSAT imagery, green line shows the cruise track and green dashed portion represents multibeam data acquisition.

Chapter 6: Physical Oceanography

Report on the Oceanographic Research *CCGS Louis S. St-Laurent,* August 18 to September 29, 2011

Jane Eert
Fisheries and Oceans Canada
Institute of Ocean Sciences, Sidney, B.C.

Introduction

Since 2002, IOS has collaborated with international colleagues and institutions in the study of the oceanography of the Beaufort Gyre and Canada Basin. In 2011, following the inclusion of oceanography programs during 2008 and 2009, Jane Eert of IOS participated in the UNCLOS survey aboard the CCGS Louis S. St-Laurent to conduct physical and chemical oceanographic measurements along the ship's track.

Objectives:

This oceanography program onboard the *CCGS Louis S St-Laurent* took place between August 18th and September 29th on an opportunity basis during seismic and bathymetric surveying for UNCLOS. The purpose was to take measurements of seawater properties in the Arctic Ocean to better understand water mass distributions and the ocean circulation. These results contribute to the basic knowledge of sea-ice distribution, heat and freshwater transports, biogeochemical cycles, and their temporal variations in the changing Arctic climate system.
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The shipboard data collection included physical and geochemical sampling:

- Profiles of water temperature and salinity were obtained with the main CTD, and with expendable CTD (XCTD) probes,
- Additional sensors on the CTD profiler collected in situ data on phytoplankton concentrations (fluorometer), optical clarity (transmissometer), dissolved oxygen, and Chromophoric Dissolved Organic Material (CDOM)
- A rosette was used with the CTD to obtain water samples from discrete depths to be analyzed for dissolved oxygen, salinity, nutrients, oxygen isotope ratio, CDOM, bacteria, radionuclide tracers and barium. Dissolved oxygen and salinity analyses were performed on board.
- continuous underway sampling of near-surface seawater temperature, salinity and phytoplankton (fluorescence), CDOM, and dissolved gases,

- continuous recording of meteorological data (wind speed, air temperature, etc), navigation data, and soundings.

SCIENTIFIC PERSONNEL: Jane Eert of DFO's Institute of Ocean Sciences joined the UNCLOS group to do the oceanographic work during this cruise.

Voyage overview:

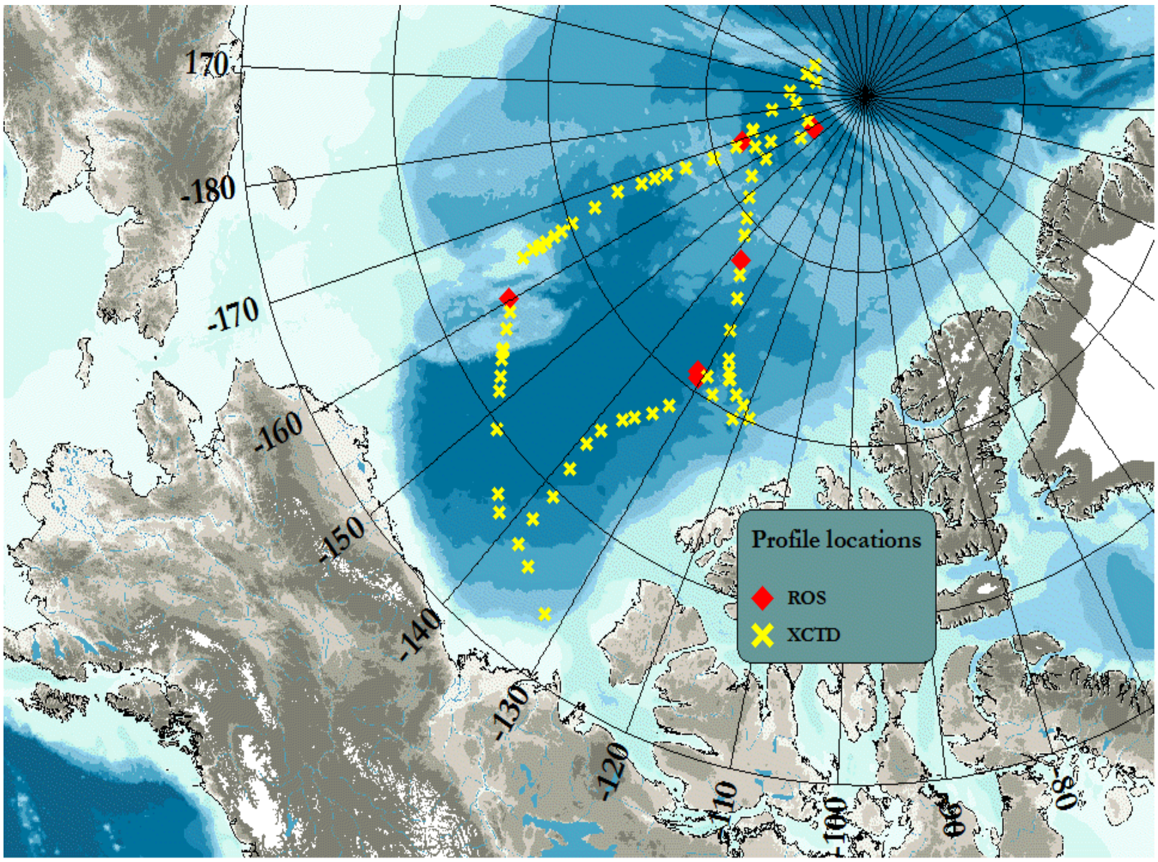


Figure 6-1. The stations where physical and geochemical measurements were taken during 2011-21

.

PROGRAM COMPONENTS

Measurements:

- 6 CTD/Rosette Casts at 6 Stations
- 111 Water Samples, to be analyzed for: Salinity, Oxygen, Nutrients, CDOM, Bacteria, Barium, and O-18
- A subset of water samples to be analyzed for radioactive isotopes of iodine, cesium, thorium and protactinium
- Underway data collection of ship's meteorological, depth, sea surface, and navigation sensors.
- 78 XCTD (expendable temperature, salinity and depth profiler) casts typically to 1100m depth
- 24 Drift Bottles deployed at 87 53.89N, 164 51.54W

CTD/Rosette

The primary CTD system used on board was a Seabird SBE9+ CTD s/n 0756, configured with a 24- position SBE-32 pylon with 10L Niskin bottles fitted with internal stainless steel springs in an ice-strengthened rosette frame. The data were collected real-time using the SBE 11+ deck unit and computer running Seasave V7 acquisition software. The CTD was set up with two temperature sensors, two conductivity sensors, one oxygen sensor, fluorometer, transmissometer, CDOM fluorometer and altimeter. All these sensors have 0-5v analogue output which is included in the CTD data string. In addition CHS mounted their sound velocimeter in place of Niskin bottle 24, leaving 23 Niskins for water samples.

During a typical deployment:
The transmissometer and CDOM sensor windows were sprayed with deionised water and wiped with a DI water-soaked lens cloth prior to each deployment.
The package was lowered to 5m to cool the system to ambient sea water temperature and remove bubbles from the sensors. The pumps turned on automatically after 1 minute and the system soaked for 2 minutes. The package was then brought up to just below the surface to begin a clean cast, and lowered to within 8-10m of the bottom at 60m/min. Niskin bottles were closed during the upcast without a stop. The instrumented sheave (Brook Ocean Technology) reads to the winch operator, CTD operator and bridge, allowing all three to monitor cable out, wire angle and CTD depth.

Data/Performance notes:
The SBE9+ CTD overall performance was good. Editing and calibration have not yet been done, but the data will likely meet or exceed the SBE9+ performance specifications given by Seabird. Header information of position, station name, and depth has not been quality controlled yet. Salinity and oxygen were sampled from the water and can be used to calibrate the sensors.

Figure 6.2. The 24-bottle rosette with the SBE9+ CTD is deployed from the mid-ships A-frame (photo 2008).

XCTD

Overview

Profiles of temperature and salinity were measured on board the *CCGS Louis S. St. Laurent* (LSSL) from August 18 to September 29, 2011 using expendable probes capable of being deployed while the ship was underway. Profiles were collected at 65 stations along the ship's track.

Procedure

XCTD (eXpendable Conductivity – Temperature – Depth profiler, Tsurumi-Seiki Co., Ltd.) probes were launched by a hand launcher LM-3A (Tsurumi-Seiki Co., Ltd.) from the stern of the ship into the ocean to measure the vertical profiles of water temperature and salinity to a depth of 1000 m (or the bottom in case where the bottom depth is less than 1000 m). The data is communicated back to a digital data converter MK-130 (Tsurumi-Seiki Co., Ltd.) and a computer onboard the ship by a fine wire which breaks when the probe reaches its maximum depth.

According to the manufacturer's nominal specifications, the range and accuracy of parameters measured by the XCTD are as follows;

Parameter	Range	Accuracy
Conductivity	0 ~ 60 [mS/cm]	+/- 0.03 [mS/cm]
Temperature	-2 ~ 35 [deg-C]	+/- 0.02 [deg-C]
Depth	0 ~ 1000 [m]	5 [m] or 2 [%] (whichever is larger)

In this cruise, 80 XCTDs were launched into the Arctic Ocean, mainly into the Canada Basin. Two XCTDs (the 12th cast and cast No. 51) failed to obtain data because of communication errors. At one station (cast No. 54) the probe hit a pan of ice on deployment and washed off about 10 seconds later; data from this cast may not be usable as it appears the conductivity cell was affected, probably by ice crystals. At 9 of the stations, 2 probes were deployed when the first probe failed to reach the Atlantic subsurface temperature maximum at around 350-400m. Cause of the early failure was heavy ice conditions. In all but 2 cases, the second probe reached the temperature maximum. In general, deployments while the ship was stopped were successful, even in very heavy ice, however this was not always possible within the requirement not to interfere with seismic operations. A list of deployments can be found in Table 6.1.

XCTD Data Management Policy

The XCTD observations are conducted as part of the PACI (PAN-ARCTIC CLIMATE INVESTIGATION), a collaboration between JAMSTEC and DFO. Data will be shared among the participants of this cruise (2011-21). Sharing the data with third party for the purposes of physical oceanography shall be by mutual consent between JAMSTEC and IOS/DFO.

Science coordinators:
JAMSTEC: Motoyo Itoh (motoyo@jamstec.go.jp)
IOS/DFO: Bill Williams (Bill.Williams@dfo-mpo.gc.ca

Table 6-1. XCTD Deployment details

Drop #	Date-Time	Lat	Long	Water depth (m)	Max. probe depth (m)
1	21/08/2011 20:19	73.290	-141.654	3496	1100
2	21/08/2011 22:25	73.623	-142.993	3683	1100
3	22/08/2011 6:29	74.880	-148.133	3853	1100
4	22/08/2011 11:03	75.623	-151.419	3886	1100
5	22/08/2011 13:09	75.905	-152.731	3886	1100
6	22/08/2011 15:19	76.245	-154.275	3884	1100
7	22/08/2011 16:14	76.383	-154.937	3000	1100
8	22/08/2011 16:28	76.406	-155.054	1375	1100
9	22/08/2011 16:42	76.430	-155.240	971	1100
10	22/08/2011 19:09	76.825	-157.108	455	1100
11	22/08/2011 21:17	77.165	-158.774	1849	1100
12	23/08/2011 15:40	78.603	-164.819	767	1100
13	24/08/2011 10:40	78.241	-164.311	516	740
14	24/08/2011 19:27	78.806	-164.789	1080	1100
15	24/08/2011 20:58	78.896	-164.879	1742	230
16	24/08/2011 21:04	78.901	-164.877	1794	1100
17	25/08/2011 0:15	79.106	-165.070	2140	224
18	25/08/2011 0:19	79.115	-165.078	2145	230
19	25/08/2011 4:39	79.396	-165.341	2698	1100
20	25/08/2011 8:52	79.668	-165.623	2850	1100
21	25/08/2011 15:06	80.077	-166.070	3321	267
22	25/08/2011 15:10	80.082	-166.076	3320	1100
23	26/08/2011 3:04	80.915	-167.135	3346	1100
24	26/08/2011 15:11	81.741	-168.263	3380	1100
25	26/08/2011 15:14	81.746	-168.262	3378	1100
26	27/08/2011 2:29	82.531	-168.080	3409	1100
27	27/08/2011 20:29	82.966	-167.961	3283	1100
28	28/08/2011 2:25	83.366	-167.828	3114	1100
29	28/08/2011 12:42	84.001	-167.589	1595	1100
30	29/08/2011 2:19	84.932	-167.131	1898	203
31	29/08/2011 2:21	84.936	-167.128	1897	1100
32	29/08/2011 15:51	85.714	-167.833	2320	475
33	31/08/2011 2:34	86.335	-172.268	3966	293
34	31/08/2011 2:38	86.340	-172.296	3966	355
35	31/08/2011 15:04	87.059	179.934	3984	661
36	01/09/2011 2:39	87.636	168.966	3989	267
37	01/09/2011 2:43	87.639	168.897	3985	949
38	01/09/2011 15:28	88.048	153.673	3700	129
39	01/09/2011 15:31	88.049	153.589	3692	151
40	01/09/2011 17:04	88.079	151.917	3330	667
41	01/09/2011 21:55	88.191	143.327	1197	1100
42	02/09/2011 3:42	88.426	157.210	2561	1100
43	02/09/2011 15:17	87.825	177.179	3900	1100
44	03/09/2011 4:59	88.096	-166.861	3726	1100
45	06/09/2011 19:47	87.658	-157.678	2407	1100
46	07/09/2011 14:25	86.772	-164.361	3968	1100
47	08/09/2011 0:30	86.420	-158.018	3868	1100

48	08/09/2011 10:17	86.252	-165.032	3911	1100
49	09/09/2011 2:53	85.776	-155.359	3043	1100
50	09/09/2011 11:29	85.351	-149.337	2378	1100
52	09/09/2011 19:56	84.917	-144.677	2083	1100
53	10/09/2011 3:49	84.519	-141.322	1784	1100
54	11/09/2011 3:32	83.553	-135.196	2968	849
55	11/09/2011 15:29	82.968	-132.408	3538	1100
56	12/09/2011 2:18	82.087	-129.886	3640	1100
57	12/09/2011 16:08	81.349	-127.289	3584	1100
58	12/09/2011 22:40	81.045	-126.059	3515	713
59	13/09/2011 2:41	80.869	-125.413	3200(est)	155
60	13/09/2011 2:45	80.866	-125.377	3200 (est)	223
61	13/09/2011 13:43	80.570	-122.944	3011	1100
62	13/09/2011 20:43	80.365	-121.037	2415	1100
63	14/09/2011 6:13	80.097	-119.178	2258	1100
64	14/09/2011 21:02	79.891	-121.985	2289	1100

65	15/09/2011 15:31	80.202	-127.033	3077	1100
66	16/09/2011 2:20	80.558	-129.356	3598	1100
67	19/09/2011 15:41	79.201	-132.366	3627	1100
68	21/09/2011 11:18	78.710	-133.972	3703	134
69	21/09/2011 11:22	78.709	-133.975	3705	52
70	21/09/2011 17:27	78.270	-135.952	3736	249
71	21/09/2011 21:24	77.990	-137.097	3737	1100
72	22/09/2011 5:59	77.275	-138.505	3754	979
73	22/09/2011 11:17	76.685	-138.887	3726	1100
74	22/09/2011 21:49	75.794	-138.715	3703	1100
75	23/09/2011 7:16	74.805	-138.154	3543	1100
76	23/09/2011 19:10	73.871	-138.509	3461	1100
77	24/09/2011 2:47	73.024	-138.012	2945	1100
78	24/09/2011 10:11	72.695	-135.880	2591	1100
79	24/09/2011 21:25	71.860	-131.803	1155	1100

Underway Measurements

This section describes measurements taken at frequent regular intervals throughout the cruise. These measurements include:

- From the seawater loop system: salinity, temperature (inlet and lab), chlorophyll fluorescence and CDOM fluorescence, gas tension, and oxygen saturation.
- Hull temperature
- From the Novatel GPS: all NMEA strings (GPRMC, GPGGA, HEHDT, among others) as well as position, time, speed and total distance
- AVOS weather observations of: air temperature, humidity, wind speed, barometric pressure
- Sounder reported depth

Methods

See section below for technical description of monitoring procedures, data flow and network setup.

The Louis uses a 3" Moyno Progressive Cavity pump Model #2L6SSQ3SAA, driven by a geared motor. The pump rated flow rate is 10 GPM. It supplies seawater to the TSG lab, where a manifold distributes the seawater to instruments and sampling locations. On one of the manifold arms, a vortex debubbler is installed inline to remove bubbles in the supply to the SBE-21 thermosalinograph (TSG) and the blue cooler containing the gas tension device and the oxygen sensing optode. Control of the pump from the lab is via a panel with on/off switch and a Honeywell controller. The Honeywell allows setting a target pressure, feedback parameters and limits on pump output.

During 2011-21, the set point pressure was 15.0 PSI. Flow rates to the gas cooler varied from 3-5 liters/min and to the TSG from 8-10 l/min. Water samples were taken at intervals from the loop to calibrate salinity and CDOM. Additional water samples were taken to map surface distributions of bacteria, nutrients, zooplankton and iodine 129. At 4 northern locations, 40L samples for cesium 137 analyses were taken.

Two remote temperature sensors are installed in the engine room: an SBE-38 inline thermometer, readings from which are integrated into the SBE-21 data stream, and an SBE-48 hull mounted temperature sensor which is logged separately.

GPS is provided to the SBE-21 data stream using the NMEA from PC option rather than the interface box as in past years.

Weather observations are collected by the AVOS system, provided and maintained by Environment Canada.

Depth is provided by the Knudsen 12KHz sounder. Reported values are digitized depth rather than travel time, so it is important to independently log the average sound speed setting on the Knudsen.

Instruments in the TSG were:

Seabird SBE 21 Thermosalinograph s/n 3297
Seabird SBE-38 Thermometer s/n
WET Labs WETStar fluorometer s/n WS3S-367P
WET Labs CDOM s/n WSCD-1281

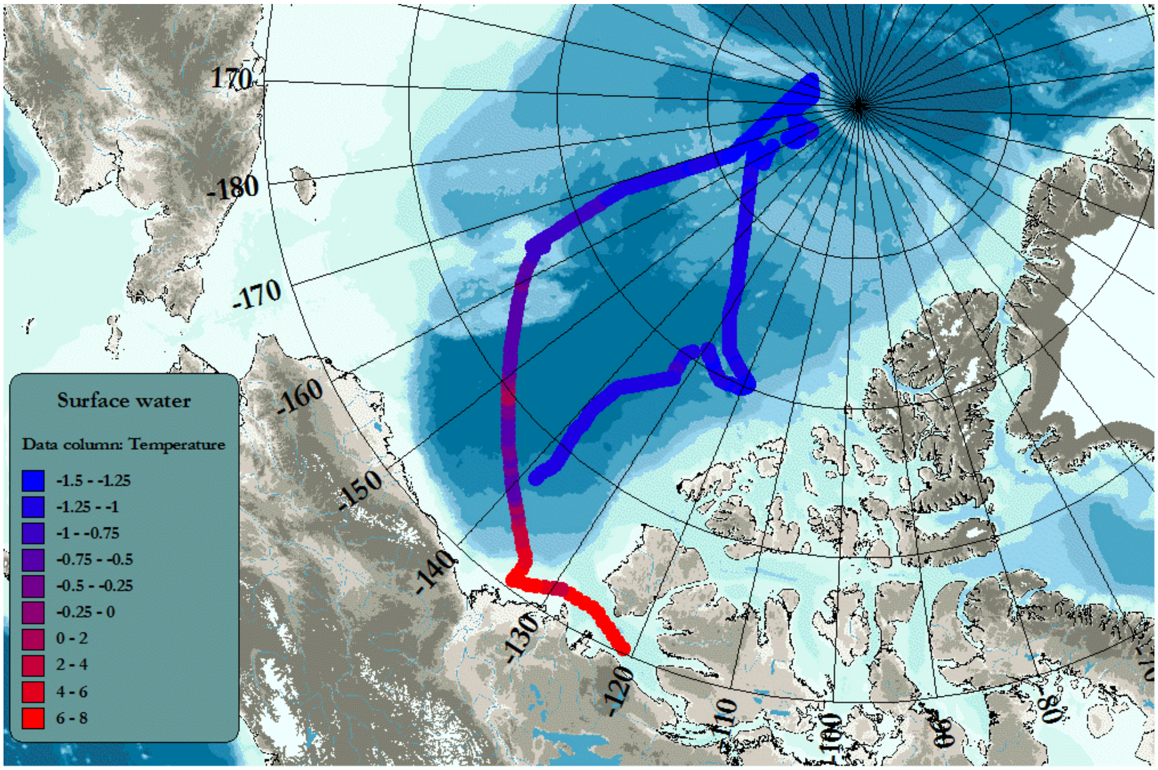


Figure 6.3.: TSG inlet temperature for 2011-21

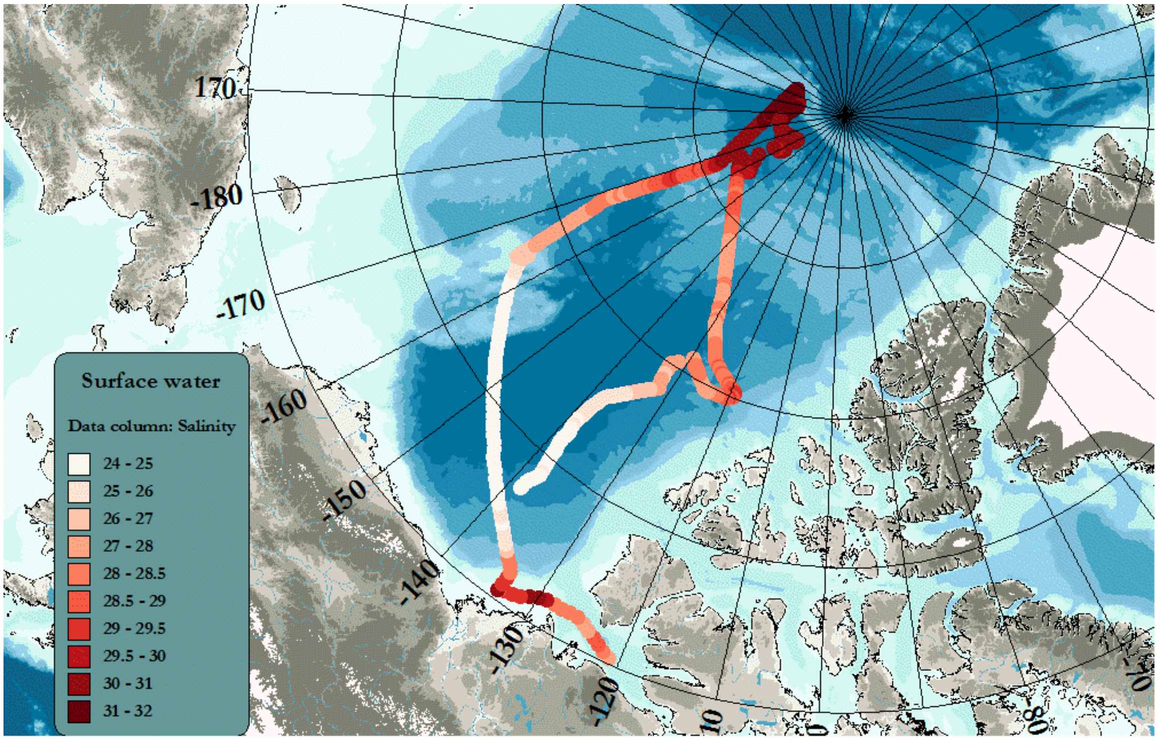


Figure 6.4.: TSG salinity for 2011-21

Logging:

1. **TSG laptop:**
   Via Seasave: Time, latitude, longitude, lab temperature, SBE-38 inlet temperature, conductivity, fluorescence.
   Via Hyperterm: SBE-48 temperature at hull
   Via GTD logging program: Oxygen saturation, gas tension.

2. **Knudsen computer, main lab:**
   Via Fugawi: Ship's track, including GPS time, latitude, longitude, speed and total distance.

3. **SCS Data Collection System:**

The ship uses the Shipboard Computer System (SCS) written by the National Oceanographic and Atmospheric Administration (NOAA), to collect and archive underway measurements. This system takes data arriving via the ship's network (LAN) in variable formats and time intervals and stores it in a uniform ASCII format that includes a time stamp. Data saved in this format can be easily accessed by other programs or displayed using the SCS software.

The SCS system on a shipboard computer called the "NOAA server" collects:

- Location from the ship's GPS (GPGGA and GPRMC sentences)

- Heading from the ship’s gyro (HEHDT sentences)
- Depth sounding from the ship’s Knudsen sounder (SDDBT sentences)
- Air temperature, apparent wind speed, apparent and relative wind direction, barometric pressure, relative humidity, and apparent wind gusts from the ship’s AVOS weather data system (AVRTE sentences). SCS derives true wind speed.
- Sea surface temperature, salinity fluorescence and CDOM from the ship’s SBE 21 and SBE38 thermosalinograph and ancillary instruments
- Sea surface temperature from the SBE48 hull mounted temperature sensor
- SCS derives speed over ground and course over ground

Problems

The Moyno pump and Honeywell controller worked very well again this year. Ice under pressure continues to be a difficult environment for the pump. While it was not turned off for any extended period, it was unable to keep the 15 PSI lab pressure in the heaviest ice areas. As well, the flow to the TSG was often full of bubbles despite the debubbler and careful processing of the time series will be required to remove the affected measurements.

Salinity Sampling and Analysis

Overview

Salinity samples were drawn from the Niskin bottles into 200 mL glass salinity bottles after 3 rinses. The samples were then tightly capped and all casts were analyzed on board the ship. Samples were analyzed on a Guildline Autosal (model 8400b; Serial number 69086). Data are reported in practical salinity units (psu). The salinometer was standardized against IAPSO Standard Sea Water with known salinities (batch P152). About 10% duplicate samples were taken analyzed at the same time as the primary samples.

Methods

Samples were analyzed using the Autosal Model 8400B (SN: 69086) as per standard IOS protocols. Water samples were collected from Niskin bottles immediately following a rosette cast. Salinity bottles and caps were rinsed 3 times before filling. Samples were then transferred to the temperature controlled lab for analysis on the Autosal within two weeks. Samples were allowed acclimatize to ambient temperature for a minimum of 24 hours before analysis. Room temperature was maintained at 23 +/- 1.0 C. Bottles were inverted and mixed prior to analysis. IAPSO standard seawater was measured at the beginning of each day’s run. During the early part of this cruise the standby number drifted downward from 6089 to 6083; this was adjusted to 6098 with the first calibration on September 15. The Salinometer Data Logger program was used to record data and to provide data output in Excel spreadsheet or text format.

Problems

During the run on September 7, the pumps failed to turn back on after being briefly turned off. The problem was traced to the pump switch which was replaced.

Duplicate Analysis

The pooled standard deviation for all duplicated samples was 0.0013 PSU with no outliers removed.

Dissolved Oxygen Sampling and Analysis

Overview

Dissolved oxygen concentrations were measured on board the *CCGS Louis S. St. Laurent* (LSSL) from August 18 to September 29, 2011 at 5 stations. The number of samples analyzed including replicates was 136. Dissolved oxygen concentrations during the surveys ranged from 5.9 to 9.6 ml/l. Greater than 10% of samples were collected in duplicate with a pooled standard deviation of 0.0033 (n = 14).

Sampling Procedure

Once the rosette was recovered and wheeled into the sampling shack, the bottle integrity was checked, and then the samples for oxygen were taken first. The DO samples were drawn with a rubber y-tube in which one of the y-arms had a temperature sensor siliconed into the flow of sample being taken. The samples were drawn into a calibrated glass flask with attached stopper and immediately pickled with 1ml of manganous chloride followed by 1ml of alkaline iodine. The stopper was inserted so that no air was present in the sample and the sample was shaken to mix the contents. After about 20 minutes after all the samples were pickled, they were re-shaken and a squirt of D.I water was placed on top of the stoppers to prevent any sample/air interface and the samples were stored at room temperature or refrigerated until analyzed.

Analysis

Dissolved oxygen samples for 2011-21 were analyzed onboard 16-24 hours after collection using an automated version of the micro Winkler technique as modified by Carpenter (1965). The instrumentation and methodology is from Scripps Institute of Oceanography (SIO). Rather than using visible colour as an indicator of the endpoint, it uses the very strong absorption of ultra- violet light by tri-iodide ion at 350nm wavelength. Because this absorption band is quite wide, and 365nm UV sources and filters are readily available, it is the 365nm wavelength that is actually used in the system. In this system, the process of thiosulfate addition to determine the endpoint is carried out just as an analyst manages this function for a visual endpoint titration. The reagent is added rapidly at first and then as changes in UV absorption are noted the rate of reagent addition changes gears and is slowed in increments and finally stopped. The endpoint is approached by adding ever smaller increments until no further change in absorption indicates the endpoint has been passed. For the analyst, the change in colour of the sample has been replaced with the change of voltage from the photodiode detector circuit.

Instrumentation

The general make up of the titrator is as follows:

-system controller-either a P.C. or laptop with USB to RS232 cable (Keyspan)

-2 Brinkmann 665 dosimats, 1 with a handheld keyboard and a 10ml calibrated burette for KIO_3 standard and 1 with a 1ml calibrated burette for Thiosulfate.

-VWR mini stirrer

-Spectronics pencil lamp UV source and mount

-UV detector with a 365 nm filter mounted (lamp and detector are mounted either side of a water bath that sample is placed in)

- a power supply for UV pencil lamp.

-AtoD device (external digitizer made by B&B #232sda12)

-2 platinum surface temperature sensors (1 each for Thiosulfate bottle dispenser and KIO_3 bottle dispenser).

Standards and Blanks

Standards and blanks were run immediately before analyzing. Standards and blanks were also measured whenever any reagents and/or sodium thiosulfate or potassium iodate were changed and before they were used to run any samples. A dedicated Dosimat was used to accurately dispense either 1 ml (blanks) or 10 ml (standards) of KIO_3. Blanks and standards were run in sets of 4 with the criteria that 3 out of 4 had to agree to within 0.0003 (blank value or THIO titer in ml). Thiosulfate normalities and blank values measured over the course of the cruise are shown in Figure 6.5.

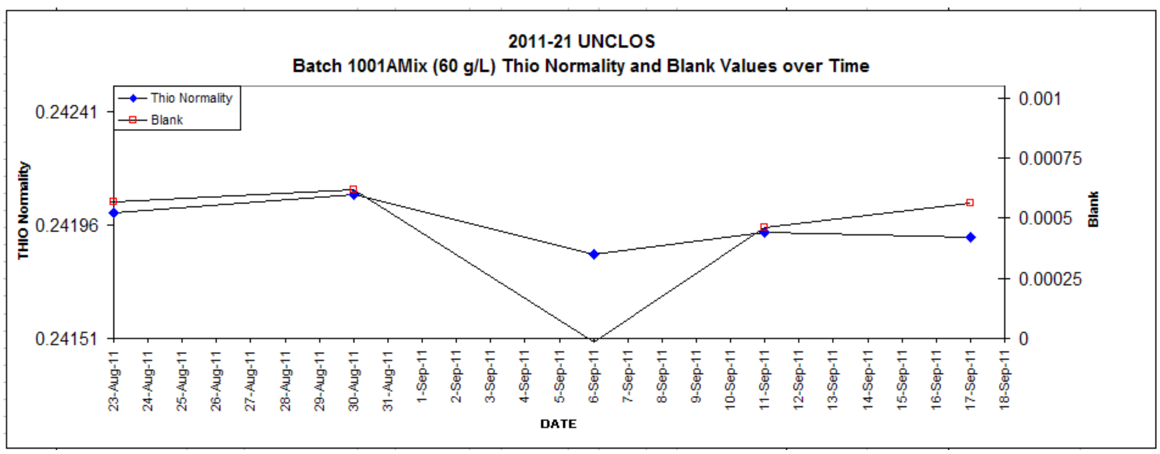


Figure 6.5: Blank and Thiosulphate normality values determined during standardizations

A single bottle of Thiosulfate batch #1001A was used for the entirety of the cruise. The observed normality range was 0.00024 N. A single standard, batch 1104A was used. Normally more than one standard should be used in the course of acruise, but since UNCLOS followed so closely after JOIS and the results were so consistent with the results from JOIS, no second bottle was opened. The low blank value on September 6 occurred just after changing the acid; I am not sure why this changed back to values more in line with previous results on the following runs.

Precision

. For cruise 2011-21, 10 pairs of replicates and 5 sets of triplicates were run. Sample #85 was excluded due to replicates outside for Chavenet's criterion and one of the triplicate set for sample #46 was excluded for a bad titration curve, resulting in a final Sp of 0.0033 based on 30 samples.

Problems Encountered by the Analyst

1) 1 sample was over-titrated, with an unusable titration curves for both titrations for unknown reasons.
3.) On one titration the endpoint plot display failed to show any points because the X axis range was incorrectly set; this did not have any effect on the endpoint calculation, but it made it difficult to judge the accuracy of the endpoint

Conclusions

Dissolved oxygen sampling and analysis on this cruise was about as trouble free as one could hope for; the results from the duplicates and triplicates well within expected values.

ACKNOWLEDGMENTS

Many thanks are due to Dr. David Mosher and his UNCLOS team for generous support during the cruise. Thanks, too, to Jon Biggar and his hydrographers for combining forces between oceanography and sound speed measurements and for help with the CTD/rosette deployments.

I would also like to thank the Coast Guard for their support, particularly Captain Rothwell and the crew of the *CCGS Louis S. St-Laurent*.

And special thanks to Deborah Hutchinson Gove and Claude Monmorency for helping with the long water sampling sessions after each rosettes cast.

Chapter 7: O-Buoy Deployment

O-buoy 4 deployment during UNCLOS Joint Canada-U.S. mission onboard CCGS Louis S. St-Laurent icebreaker August 17 – September 29, 2011

Dr. Stoyka Netcheva, Atmospheric Scientists with Air Quality Research Division, Atmospheric Science and Technology Directorate, Environment Canada

Photographs at the end of this chapter document the O-buoy assembly, testing, and installation.

Instrument Assembly

O-buoy 4 assembly began on August 25, 2011 with clearing work space at the outer corner of the port side of the helicopter hangar and taking the crates with equipment from the upper deck down to the flight deck. With the help of the flight deck crew, the boxes were opened and the equipment was unpacked in few hours. The work space for the O-buoy was limited because the hangar also contained the helicopter and AUV assembly. A wooden frame made by the ship's carpenter Eugene Jones secured the O-buoy body from rolling. The first tests on the O-buoy were conducted without installation of the batteries on August 28th. GPS reception inside the hangar was facilitated by being able to use the AUV team repeater installed on the upper deck railing. An Iridium antenna was installed on the upper deck railing and connected to the O-buoy by a patch cable.

On site multistage calibration was conducted on the ozone instrument. Due to the space and time restrictions the equipment was tested inside the hangar in its semi-assembled stage where the access to each instrument was easier and where troubleshooting would require no additional human power or risk of damage to the lithium (Li) batteries insulation, electrical cables or sampling tubing.

DOAS (BrO measuring) instrument functionality was confirmed by moving entrance optics prisms, turning the ice detecting LED and window heater on. The overall light through output response was tested in two consecutive days by mounting the scanning head in horizontal position and recording solar spectra (this test proved to be essential for the proper assessment performance of the instrument in previous deployments). The hanger door was open and allowed for DOAS scan head to perform multiple scanning cycles of the full range of elevation angles while simulating zenith reception by a luminescent lamp during 2.5 and 4 hours test. Evaluation retrieval confirmed good light through output and unit functionality by relieving the presence of significant amounts of NO_2 in the marine boundary layer as would be expected on the ship's stern coming from its stack. Carbon dioxide flow rate and pressure settings were adjusted and confirmed to be in a good range. After the calibration gas standards concentrations were taken into account, the measured values proved to be within the expected range. GPS, meteorological sensors, and data logger functionality were accessed in the O-buoy supervisory computer in real time during the tests. Iridium communications health was followed through the automated internet postings on daily scheduled communication sessions monitored on the ice observer's computer. 4 AGM batteries were charged by Phil Seaboyer, ship's chief electrical engineer.

Tests conducted by powering the equipment on Li batteries confirmed equipment functionality. Only two Li batteries were found onboard the icebreaker out of a total number of 5 prepared for this deployment. The O-buoy normally operates with 3 Li batteries. Operating the O-buoy on 2 Li batteries decreases the sampling period over the second year of the life of the equipment package at the standard instrument run schedule for the winter period. During the expedition, there was an opportunity to air drop helicopter and icebreaker parts that could possibly also deliver the missing Li battery. However the flight was scheduled for a time later in the cruise when the icebreaker would be past its northern (88^{o}N) position and be further south of 85^{o}N. Information on power consumption by instruments on their standard winter schedule and Li battery capacity was requested and provided by CRREL laboratory and Purdue University engineering group monitoring the power distribution and control of O-buoy. Different options were considered on reducing the sampling time during first winter period to keep the estimated lifetime of O-buoy deployed with 2 Li batteries at 88^{o}N or with 3 batteries deployed near 85^{o}N. Life time and drift patterns at both locations based on existing buoy drift records from International Artic Buoy Program were also evaluated with respect of the scientific value and potential record length. I made the decision to deploy O-buoy 4 at the 88^{o}N location with two available Li batteries with reduced winter schedule in order to take advantage of the exceptional opportunity to get a complex set of the air composition and other parameters from that remote part of the Artic where records do not exist. A request for modifying the winter sampling schedule will be made later at the end of the month of September to maintain data collection through the dark winter season. The 88^{o}N position was the only location on our voyage with scheduled ship stop for AUV deployment where the O-buoy deployment activities would have minimal to no impact on other science operations.

Preparation for Deployment

Due to the icebreaker's helicopter lifting capacity limit of 1000 lb and limited space and time to compare the weight of different O-buoy components, it was impossible to determine if transportation of the floating collar loaded with AGM batteries was possible. The decision was made to repeat what has been done in previous deployments from CCGS *Louis S. St-Laurent* by splitting the buoy into lower and upper parts. A lifting bracket was designed and manufactured by Peter Vass that was tested later on 2500 lb load for transporting the bottom part of the equipment onto the ice. The mast with meteorological sensors and solar panels was already designed with a lifting arm.

Space became available to complete O-buoy assembly and prepare for deployment after deployment of the AUV 16 hours before the beginning of the ice survey. The bottom part assembly was completed; the unit was tested and final deployment preparations were finished. The instrument's tray was placed into the O-buoy hull; both pieces were secured into the floating collar. Wiring and water proof sealing of the lead acid batteries was then done. A test confirmed that no damage was induced to the wiring or plumbing of the unit during that final assembly. The transportation bracket was mounted in place; a tool box was assembled along with testing cables for onsite installation. DOAS scan head and anemometer transportation cases and a laptop were prepared with the equipment for drilling and clearing a hole in the ice; food, drinks and chocolates were ordered to sustain the deployment team on the ice.

O-buoy installation on the ice

Finding a suitable location for the O-buoy was the first requirement. On the morning of September 5, 2011, I and Alice Orlich were taken on survey flight within 1 mile from the ship in search of deployment location by the helicopter pilot Chris Swannell. A set of 2” augers powered by portable generator and a red marking parachute were taken along to test and mark an appropriate site. The surrounding ice was heavily broken in small size floes by the icebreaker manoeuvres during the night. The ice thickness was probed on a few locations across 2 selected floes within the safety limit set for the helicopter by the commanding officer of the icebreaker. There were several thin ice floes but the risk was presumed to be bigger of crushing the instrument by pressure and wind induced movement of the ice, so this option was ruled out for instrument installation. The ice thickness was measured in few spots and was estimated to be more than 3 meters. An exact measurement was taken on one of the locations indicating 4 meters thick ice. I selected the larger ice floe with dimensions of approximately 100m x 200m for deployment.   A few more ice thickness probes were done closer to the edge of the floe. The last measurement indicated 23 cm snow cover over an ice thickness close to 2.8 m that was maximum thickness allowed for O-buoy deployment. This location was marked. The selected location was surrounded by few frozen melt ponds with characteristic multi-year turquoise blue color and old fracture lines in various directions. The ice survey took ~ 2 hours.

The helicopter made 3 flights to move the deployment team and drilling equipment over the marked location. Alice directed the hole drilling activity with her 6” ice core equipment. Extracted ice core samples were inspected for structural integrity and stability of the ice on the deployment spot. Peter Vass, Nelson, Dale and John Ruben led the hole making effort guided by Alice and helped by Steve Wackowski and Neil Jollymore. Final shaping of the hole was done by chipping off of the edge ice pieces and removing remaining underwater ice bridges. Hans Boggild and Don Glencross photographically recorded individual stages of O-buoy deployment on the ice.

Following hole preparation, helicopter pilot Chris Swannell brought the bottom piece slung beneath the helicopter and, guided by Neil, lowered it into the hole. The assembled mast was taken by the helicopter on its second trip. This piece was lowered to the ground and set on its side to allow removal of the protective cover, cables and tubing secured for transportation.

Later, the mast was manually moved over the bottom half of the buoy already in the hole by the team. It was supported on wood blocks and held in place while all electrical connections were done by me and Chris. The optical fibre bundle was pulled through the mast by a guiding rope. DOAS scan head was attached in place and wired. Anemometer was installed and fastened, AGM batteries were connected to the solar panel controller and top and bottom components of the O-buoy were fixed in place. The unit was powered and an external laptop connected to the O-buoy supervisory computer confirmed operation of GPS receiver, meteorological sensors, data logger, AGM and Li batteries. Electrical wiring was confirmed by voltage readings displayed on the computer. The stepper motor scan head rotation was registered confirming proper wiring of the DOAS instrument while the presence of suction on ozone intake confirmed the operation of ozone monitor.

After the instrument installation tests were completed, the deployment party signed their names on the floatation collar and took a group photo at 88.1°N and 157.5°W. Shortly after the last group of the deployment team was onboard the icebreaker, the ship left for its next exploration point.

Post-installation Monitoring
Equipment status was monitored for the rest of the trip by its website data postings at http://obuoy.datatransport.org/monitor under OBuoy # 4.

Additional Atmospheric Measurements aboard CCGS *Louis S. St-Laurent*

An insulated box sheltering two DOAS instruments (targeting BrO and IO presence in the Artic air); a GPS receiver and an ozone monitor run on AC power and controlled by a laptop were installed on Monkey Island, the highest deck on the ship (i.e., above the bridge) on September 9, 2011. These instruments monitored and recorded air composition along the ship's track in parallel with the O-buoy, including coastal locations, as part of this project for characterizing the temporal and spatial extents of the observed processes. The box was taken down and prepared for shipping near the end of the cruise on September 26, 2011.

O-buoy assembly

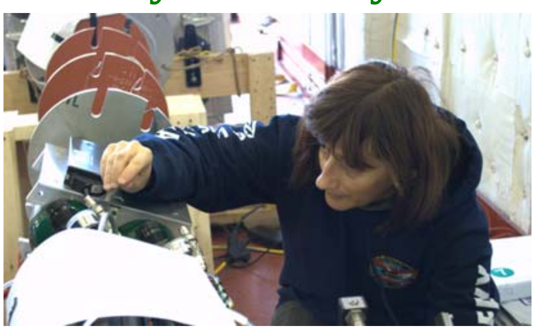
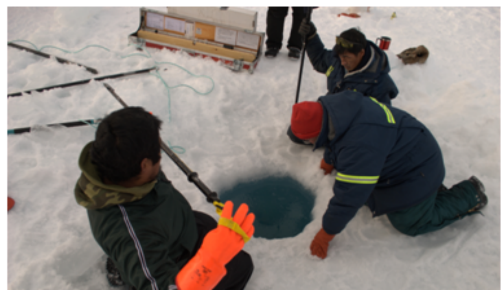


Photo: Hans Boggild

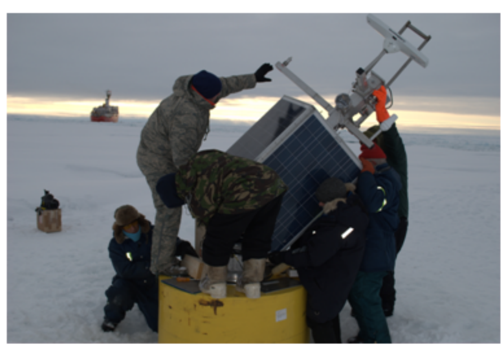
Photo: Harold Martin

September 5, 2011 deployment day: hole preparation



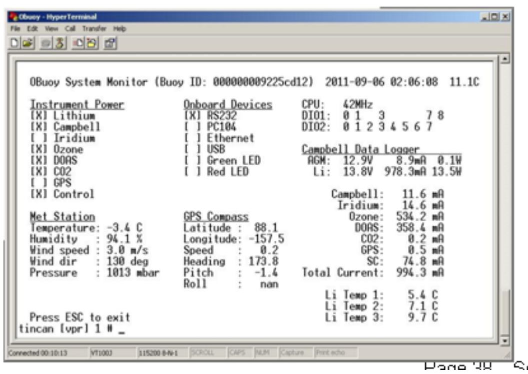
Photos: Hans Boggild

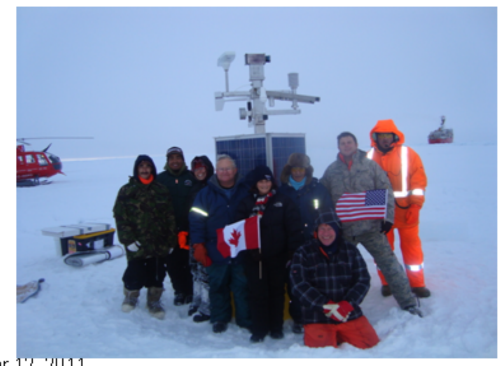
O-buoy 4 deployment September 5, 2011



Photos: Hans Boggild

September 5, 2011 O-buoy test





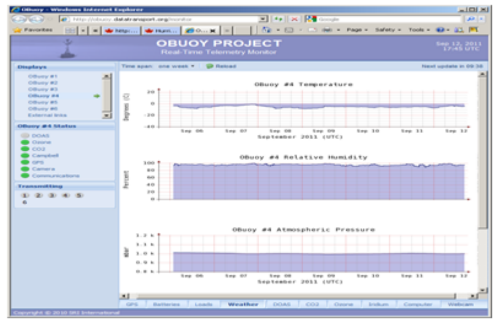
Photos: Hans Boggild and Chris Swannell

O-Buoy 4, the week of September 6 – 12, 2011 data

GPS

O_3

CO_2



Met data

The ice surrounding O-buoy 4 (apr. 88.1° N and 160° W) recorded trough the “eye” of the web camera on September 19, 2011.

Dr. Stoyka Netcheva
September 25, 2011
LSL

Chapter 8: Seismic Operations Technical Report

C.B. Chapman

Compressor Operations for LSSL 2011 Survey Year

A total of 238.6 operational hours were added to the two Hurricane compressors in 2011. HC #1 ran a total of 18.0 hours while HC #2 ran a total of 220.6 hours. Final hour counts on HC #1, 1675.8 hours, and HC #2, 878.6 hours.

The final installed version of the Hurricane Compressor monitoring software worked correctly and no changes are required.

Issues arising with operation of the Hurricane Compressors in 2011:

HC #1 Compressor had no operational issues in 2011.

HC #2 Compressor repair issues corrected during the 2011 program:

(1) Discharge air pipe coupling at top of air/ oil separator tank cracked and was replaced. This was a repeat issue from previous years. A triangular clamp system was fabricated to reduce the vibrations on this pipe. This proved a satisfactory repair and a second system was also fabricated and installed on HC#1
(2) The pipe on the air/ oil separator tank which supports the safety pop valve leaked. This was removed and the safety valve was installed directly onto the tank without the additional elbows
(3) The welds around the pipe fitting on the side of the air/ oil separator tank, where the site glass fitting affixes, cracked. The original welds were removed and re-welding was done to complete the repair.
(4) The belt guard was removed and repaired after one of the attaching steel lugs broke in half. New steel was used to replace the old steel. At that time an opening between the belt guard and the 1st stage screw was cut into the belt guard to reduce chaffing on the belt guard.
(5) Repairs to loose stanchion post attaching bolts, which support the #3 stage separator, thermostatic valve and screw oil filters helped reduce machine vibration in this area
(6) J-D cooling fan replacement following fan blade failure. Spare removed from NRCan inventory

Conclusions:

Generally the Hurricane compressors performed well in 2011. The flexible high pressure braided hoses, which had been installed on both machines before the 2011 program, greatly reduced machine failures caused by vibration.

The air/ oil separator tanks should be removed from the two compressors for service. It is recommended that doubler plates be welded to the tank sides where the existing piping is attached. The doubler plates would strengthen the area around the openings on the tanks to prevent future cracks which have occurred in the welds around the pipe fittings. The tanks should be pressure tested to 300 PSI.

Both HC #1 and #2 will be removed from the vessel following the 2011 field season.

Routine painting of the exterior of the containers should be planned prior to redeployment.

Geometrics GeoEel Digital Streamer

Two identical Geometrics Inc. GeoEel streamers were assembled in July 2011 while the vessel was along side in Dartmouth, NS.

No configuration changes were made to the GeoEel system for the 2011 Louis program. Please refer to the 2009 technical report for streamer "component placement".

Operational Issues:

The first equipment deployment occurred 2300 hours on August 23, 2011. The port streamer was deployed at that time.

Immediately following the power up of the GeoEel deck unit, the high leakage alarm activated.

The equipment was recovered and the port streamer was disconnected from the tow cable bundle. The starboard streamer was connected to the bundle and the equipment was redeployed.

On August 24 the port streamer was laid out onto the hangar deck. Each section was separated and checked for leakage. During the inspection, a repeater was found to be missing an "O" ring seal. A small amount of sea water was inside the connector. This repeater was serviced and a new "O" ring was installed. The repeater was reinstalled and the system was checked and judged as operational. The streamer was reinstalled onto the port streamer winch and remained as the back up "spare" throughout the entire program.

At midnight on August 27 the air supply line on the 150 cubic inch air gun failed and then shortly after, the port 500 cubic inch gun air supply line failed. On recovery it was clear that the sled had rotated at least 4 times during the tow operation. This resulted in the damage of two air lines and the streamer bundle cable at the top of the tow sled. As the streamer was being recovered the outer sections were caught in ice. On recovery it was observed that the aft active section jacket was punctured and oil was leaking. The defective section was removed and a replacement active section was installed.

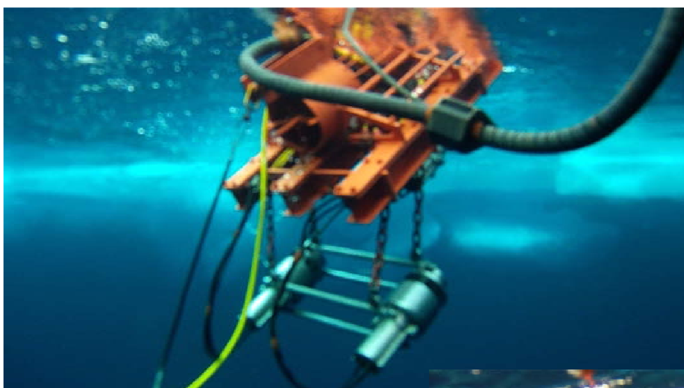
The multiple twists damaged the streamer TC01087 bundle cable. The bundle was rebuilt using six new electrical gun control cables and a new streamer DC01063 cable. Air hoses were swapped end for end and the defective sections were cut and the hoses re-terminated. The system was redeployed and surveying resumed at noon on the 27th.

On September 19, 09:00, gear was deployed. The starboard streamer immediately showed high leakage. The system was recovered and a small amount of sea water was located in the connector of the repeater at the rear of the tow sled. The “O” ring was replaced but the survey was terminated at that time due to shaft and propeller problems. The equipment was never returned to service.

At the termination of the survey, both port and starboard streamers were fully functional with the starboard streamer having been used throughout the entire survey.

A new streamer deployment and recovery method for 2011:

Following the damage to the active streamer section on August 27, 2011, a revised streamer deployment methodology was devised.



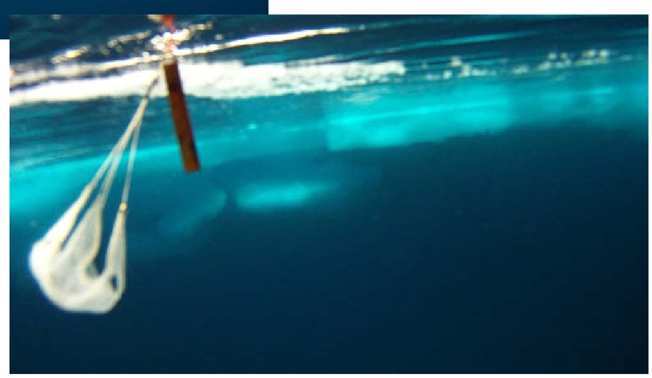


Figure 8-1. Top is an underwater photograph of the seismic sled being deployed. The yellow stretch section can be seen coming from the after section of the sled. Bottom is the chute and weight attached to the after end of the streamer during deployment.

Deployment:

In past years, allowing the streamer to sink vertically to excessive depths would have destroyed the depth sensors inside the GeoEel active sections. During the last service procedure at Geometrics Inc., the defective depth sensors were replaced with new sensors which had a much higher pressure rating. This permitted the streamer to be deployed vertically without depth sensor damage.

Before deployment, and on recovery, the streamer was “figure eight-ed” onto the quarterdeck. This operation required most of the crew and technical staff.

A ten pound steel weight, with a small “eye” welded to one end, was fabricated. An approximate 1 foot length of nylon twine and a salvaged sonobuoy parachute were then attached to the eye of the weight (Figure 8-1).

The weight and parachute were affixed to the outboard end of the streamer drag rope using the free end of the nylon twine, semi-secured with 6- 8 small cable ties. The idea was to secure the nylon twine to the drag rope so that the nylon twine would not slip out from under the cable ties during deployment.

Before deployment of the streamer began the vessel was brought to a full stop. A small unrestricted pool of open water immediately astern of the vessel was all that was necessary.

The weight, parachute, drag rope and streamer were then lowered over the aft roller off the stern. The boson controlled the speed of deployment, ensuring that the streamer was allowed to sink vertically while maintaining some tension on the free falling streamer.

After deployment, the vessel speed was increased to 3- 4 knots. The parachute then opened in the water and added significant drag to the tail of the streamer, pulling the nylon twine through the cable ties on the end of the drag rope and thus releasing the 10 pound weight and the parachute. The streamer then floated to the proper survey attitude after approximately 5 minutes.

The only issue with this deployment method was the repeated loss of the weight during deployment due to insufficient tension between the drag rope, nylon twine, and cable ties holding the weight. On a number of occasions the weight slipped away before the streamer was deployed and thus recovery was necessary to replace the lost weight and chute.

This was a simple “fix” to a potential damaging situation. Almost all streamer damage that has occurred in past years has resulted from ice contact during streamer deployment. This was due mainly to the fact that the streamer remained virtually on the surface until the sled was deployed, pulling the streamer down to tow depth. It will become a recommended deployment method for surveying in ice covered waters.

No further damage to the streamer occurred during the 2011 program.

Recovery:

Prior to the seismic system recovery, the vessel was allowed to coast to a full stop. The streamer would slowly sink. This took approximately 10 minutes following the full stop.
Once the streamer had sunk to a near vertical state, the crew and staff hand- hauled the streamer onto the vessel.

By allowing the streamer to come up from the vertical position ensured that there was little chance of the streamer coming into contact and tangling with sea ice.

Using this method prevented any damage to the streamer during recovery.

Depth recording CTD's

Following the damage to the streamer on August 27, it was decided not to use the banana floats on the streamer. The depth monitoring CTD's were attached to the streamer jacket using black electrical tape. These were removed during the recovery operation and the data was downloaded from each sensor.

The CTD's were positioned as follows:

(1) At the front of the first A to D Converter
(2) At the front of the second A to D Converter
(3) At the outboard end of the second (tail) active streamer section

No operational issues or CTD sensor losses occurred during the 2011 program.

Data logging and storage:

The data collected from the GeoEel system was logged on the hard drives in the logging computer. Data copies were made from the C drive every half hour and stored onto a second hard drive on the same machine. Additional back up was done daily from the C drive. Data remained on the D drive as a second backup.

Some issues arose during the seismic program with missed files being copied from Drive C to Drive D. The issue was typically operator error but no files were actually lost.

Another issue arose from operator inexperience in how the setup of the logging files occurred in the GeoEel software. This error caused the numbering sequence for the gun data files to be reset to zero from approx 34,000, thus throwing out the planned orderly logging of file numbers. This can be fixed by software and is clearly noted in the comments section of the Excel watch keeper's log file.

Conclusions:

The overall performance of the Geometrics GeoEel system in 2011 was judged to be "acceptable". A considerable portion of the 2011 program involved towing the seismic sled system in fairly old ice, thus reducing the wear and tear on both the sled and the streamer.

The new deployment and recovery methods ensured minimal ice contact during these operations and thus little damage to the wet end system occurred.

The removal of the banana floats allowed the streamer to be deployed vertically but still allowed the CTD's to be attached to the streamer jacket to record streamer tow depths.

There are only several streamer components which will require Geometrics "factory service" before the next deployment. These components will be grouped and inventoried before being sent to the manufacturer for repairs.

The entire GeoEel inventory list was attached as an appendix to this report.

Sonobuoy operations for LSSL 2011

The use of modified Ultra Electronics marine sonobuoys continued during the 2011 seismic program with only one significant change. A second set of Andrews yaggi antennas were mounted to the forward facing side of the crow's nest railing. This provided an identical forward looking antenna array to the aft array that has been in use for the past 3 years. An RF antenna selector relay was installed between the two array, the output of the relay fed to the WinRadio receiver. Control of this relay was via a switch in the seismic lab where the operator could select the forward or aft looking array via the switch.

Having the forward array permitted receiving signals from sonobuoys deployed in front of the ship at distances up to 20 miles. Then, as the ship passed the sonobuoy, the RF relay was switched to the aft array. This allowed satisfactory signal reception form the sonobuoy for the full 8 hour life of the buoy.

A single WinRadio receiver was connected to the antenna feed from the RF relay and the audio output from the receiver was delivered to the data logger in the seismic lab.

A total of 21 sonobuoys were deployed throughout the program. Please refer to the operator's log for sonobuoy performance logs.

Conclusions:

The use of the modified marine sonobuoys throughout most years of the UNCLOS program has provided a useful data set for the scientists. The actual hardware costs to put this system together have resulted in good value for money. As little annual maintenance is required for such a system, future GSCA programs could benefit from using the remaining sonobuoys, antennas and receivers on other missions.

There are a total of 39 sonobuoys remaining in inventory (including four with no parachutes) with an expected battery shelf life of 5 years.

The output levels of the four receivers should be factory re- calibrated back at WinRadio. At present the outputs vary from one to another and this offset should be corrected, especially if a multiple receiver operation is planned. The 2- HF filters and a “four receiver combiner” would permit this type of operation and these components are included inside the sonobuoy receiver Pelican case. A disk with the WinRadio receiver software is also inside the case.

Further investigation should be undertaken as to why the three WinRadio receivers which are controlled via a PC USB port are locking up this control PC after several minutes of operation. A possible software update for these receivers may be necessary.

The four Andrews antennas were safely stored inside the Hurricane compressor container at the conclusion of the 2011 UNCLOS program.

APPENDICES 1-8

Appendix 1: Daily Log (Chief Scientist)

August 18.
Departed Edmonton ~09:30 and arrived Kugluktuk at 11:30. Almost immediately started shuffling personnel out to Louis. I was amongst the last of our group, on by about 14:30. Coast Guard charter flight had not yet arrived. Didn't get into Kug until about 16:30, then started shuttling people and supplies. All on board by ~21:30 and weighed anchor at about 22:30. Rain, 4deg and windy all day.

August 19.
Steaming for Tuktoyuktuk to take on fuel. Winds strong and rain continued. Cleared by late afternoon. Gear getting set up. Lots of Beluga off Paulatuk.

August 20th,
Arrived Tuk by about 09:30, but supplier wouldn't deliver fuel. Winds stiff and skies clear. Continuing setting up equipment. Waited through the day but no delivery and no prospect of fuel delivery until Monday. Captain decided to abandon fueling. Departed Tuk that night (18:30) without fuel with expectation of taking fuel from Healy. Heading to rendezvous point. Saw first Polar Bear of the trip. Heard about First Air 737 crash in Resolute and loss of Marty Bergmann – most on board know him. Held first science meeting that evening. Winds heightened and seas rough during the night. Entered ice pack during the night and sea state improved.

August 21 Sunday
Continue transit to rendezvous point through light ice. 5-8 tenths but rotten. Captains meal in evening with a meet and greet that night. Weather overcast, drizzle, fog. Clocks go to Pacific time tonight to synchronize with Healy.

August 22 Transit all day through light ice. Gear set up continued…seismic gear ready by afternoon. Rosette cast by Jane. Arrived Rendezvous point late evening and then moved 26 nMi north to find solid ice to raft against????, Had to stand by for Healy to arrive.

Aug 23
Healy arrived ~0800h. She was very slow in ice because of inexperience of officers and crew in ice operations. We rafted up and began taking on fuel. Officials went to Healy for meeting to discuss logistics, operations and objectives. We then allowed staff to interchange…in order to limit further helo exchanges. Shared lunch on the Healy then supper on the Louis. By 2000h, fueling ops were complete. Our four personnel were sent to Louis and we had one come back to us in exchange (Airforce Captain, to trial his UAVs). 2030, parted company and steamed south west to pick up rendezvous point. 2300 began deployment of seismic equipment

Aug 24.
Seismic deployment a little rough – first time. All gear in the water by 0100h and water egress into streamer on leakage panel display. Pulled all gear and put in second streamer. All operational by 0230. On top of NWind Ridge – 400 m water depth at start. Did sonobuoy

deployment and hit the rack at 0400h. Seismic continued north on line 1 all day. Flew ahead in am to deploy Sonobuoy 2 with Steve Wackowski as safety (US Air Force flying drone plane from Louis). Beautiful day. First sonobuoy did not work so deployed second…it worked. Receivers back in lab locked up and did not get signal until a couple of miles before sonobuoy deployment site, however. Seismic operations continued all day with no issues.

Aug. 25
Seismic operations continued all night and day with no issues. Foggy so no flying for sonobuoy drops. Networks finally getting set up so able to access printers drives etc. As well, now logged in to Healy and accessing Healy mail. Thick fog all day and still relatively light ice conditions, although that should change over night.

August 26
Seismic operations still continue. Finished line 1 and 2 today (Waypoint 10-20 and 20-21). Crossed Nautilus Basin and now climbing Alpha-Mendeleev Ridge. Extracted near trace from these lines and plotted them. Fog Fog Fog…some clearing late morning with overcast allowing Steve Wackowski to fly his drone (UAV) today…pretty cool. Cameras surveyed ice and flew over Healy. Talk about Russian Ice Camp NP38 ahead…should pass it tomorrow by about 9 mi. 23:45 mid gun developed a leak and was shut down after a sharp turn due to Healy turn…and Louis followed

August 27
00:30 port gun developed a leak and gun was shut down, all systems stop and brought gear on board. Streamer tangled in the ice but successfully recovered. Leaks in the array bundle on the sled in lines to both guns. Repaired and back in the water by ~02:30 – high voltage on streamer and recovered gear….puncture hole in streamer section – probably occurred during deployment. Deployed second streamer and high leakage readings!!! Recovered gear. About 06:30 am, stood down until 12:00 to allow guys to get rest. Healy went off to do some mapping. At ~12:00 redeployed and got system in the water and working. Underway and deployed sonobuoy forward of the ships. Passing Russian Ice camp this afternoon. Helicopter recon failed to find any sign of the camp. Operations continued through the evening

August 28 Sunday
Seismic operated throughout the night. Deployed sonobuoy and it worked for a while but must have been crushed, as signal became incoherent – probably flooded. Redeployed a second sonobuoy. Heading up Alpa-Mendelev ridge. Seismics working throughout the day. Ice becoming heavier and more pressure. Deployed another sonobuoy at the same location as the first to shot a reversed profile. Discovered Polarstern is not far away – maybe 100 nMi and heading toward us.

August 29
Ice increasingly heavy and under pressure. Ship got stuck at about 3am. Healy came around and broke us out. Seismic still working though guns 1 and 3 acting up. Finished WP30 and now heading over north side of Mendeleev and into Makarov Basin. Regulus navigation computers acting up this far north and this close to the international date line. Louis continues to get stuck in heavy ice, with no centre shaft and towing the array. Healy continues to help us out by break

ice next to us. Progress slows… At ~ 1630h stuck again…pulled in the sled to untangle the streamer and redeployed by 1700h. Commenced surveying at ~17:30. At 18:30h, lost signal to streamer…probably broken deck cable. Had to pull the sled and streamer in and guys are preparing a new deck cable in the bundle…expected to take all night. No spare as DRDC has our second sled. Worked on replacing the bundle and all airguns until about 12:30.

August 30
Up at 5:00 am to finish airgun and streamer repairs. In the water by 9:00. Used a weight on the end of the streamer to deploy it vertically. On the end of the weight we outfitted a droag. When the ship came up to speed the chute pulled the weight off and the streamer rose to its proper position. Seemed to work well – Kenny's idea! Hard ice conditions meant we made only 14 nMi between 9:00 am and 4:00 pm. Ice conditions improved after that and seem to be making much better progress. Science seminar from Richard Pederson tonight on the AUV operations.

August 31
Seismics worked throughout the night…made some forward progress. Crossed 87N at about 0730 and then crossed the dateline at about 0800. Flew forward to deploy Sonobuoy 15 at about 0900h. Gravimeter reboot seemed to get the program and hardware running again. All systems working well. Only occasionally getting stuck and needing Healy's assistance in getting out. Sent in new set of Hans' blogs tonight. Fine-tuned some of the waypoints with Larry for running the multibeam program.

Sept.1 Thursday
Seismics worked through the night although numerous stoppages due to ice. Crossed 88 deg in the am and made WP40 at 14:30, ending the first phase of the program. At 1500h, Louis took lead and broke ice for the Healy. Conducted multibeam survey across the top and then down Lomonosov making way toward Marvin Spur. Gravity meter still not working well.

Sept 2 Friday
Continued multibeam through the night and day, surveying for the FoS along the southern edge of Marvin Spur. Ice not under pressure and making about 4 knots. Healy getting good data at that speed. Heard from the Polarstern - Ursula Schauer is C/S. Helicopter with Jon Biggar in it was missing for a short time…so we broke off survey to begin a search when he called in. Word from Jacob – no pole!, apparently straight from the PMO. Also, an issue with the Doc and his camera that will have to be addressed. AUV preparations continue. Turns out our forecasted arrival at the deployment location was for this evening and so I've plotted a course to take until tomorrow morning.

Sept. 3, Sat
Woken at 0400 to find we had only made waypoint 110…none of the course I had plotted to take us through the night. Ice was heavier with ridging and Healy had lost her engines. Started to search for an open pond for AUV deployment. Louis lost her engines. We had found a spot and AUV operations commenced…and, wellllllll, commenced. After an entire day of preparations, AUV was finally dunked and released at 17:00. The trim was off as the nose was hanging low, so it was decided to bring her aboard. No other operations could take place while AUV consumed the hangar, and the flight deck and the starboard side and the engines and the

quarterdeck!. Healy went to survey Marvin Spur and to conduct some ice buoy work while we do the AUV stuff. AUV trim was tested again and found satisfactory but elected to delay launch until tomorrow am. Vessel requested to travel a pattern through the night in order to tune the Inertial Navigation Unit.

Sept. 4 Sun.
0530 h on station and by 0730 AUV is launched. Systems test take numerous hours. It is finally at 3000 m by 1530 and forward-looking altimeter seems to be failing…observing same 'ghosts' as yesterday. Mission aborted… It is to be brought on board. AUV rose and parked itself under the ice adjacent to the fish, but we've been unable to locate it with the AUV…many hours of trying. All hands turned in at 0300 and we'll try again tomorrow.

Sept. 5 Mon (Labour Day)
Continued searching for the AUV in the am…moving the ship to triangulate on it. Finally a visual at 1300h, still under ice. 88º 09' 22"N 157º 26' 29"W. Out of water and alongside at 1420 and recovered at 15:30
At 0830, deployed ice reconnaissance with Helo (Stoyka and Alice Orlich) for the O-buoy deployment in the morning and after lunch, full party went out on the ice. Dale, John and Nelson Ruben, Peter Vass, Stoyka Netcheva, Alice Orlich, and then Don Glencross and Hans Boggild. They were out there until 20:30!
Jane Eert conducted a rosette sample and SVP/CTD.
Set up track plot to join with Healy and continue surveying base of slope. Heading to WP.

Sept. 6
Joined with Healy about 02:15 and commenced surveying…up ridge south of Marvin Spur to pick up the 2500 m bathy and intersect base of slope, then back down to the SW again to get another crossing of the FoS. In afternoon, brought over David Hesilev from the Healy for repair to the wireless system. For some reason it is no longer functioning. Wireless repaired after loosing several hours surveying in order to remain stationary for Crow's nest work. Got wireless working and had our first scheduled call for some time with Healy that evening. Evening activities of Arctic Greenhorn inductions…a bit dramatic in my opinion, including hair cutting – sometimes severe! Continued acquiring bathymetry along the eastern edge of Makarov Basin

Sept. 7
Awoke to realize we were almost out of waypoints…set new points first thing. Continued multibeam work along this eastern margin of the Makarov Basin. Also trying to process seismic data. Air drop in the afternoon – to Healy for parts for her and for helicopter. Talk from Steve Wackowski in the evening. Work around Makarov Basin continued all day and night….Louis still breaking ice for Healy.

Sept. 8
Finished up FoS surveying in Makarov in the late morning and commenced transit across Alpha-Mendeleev with Louis in the lead breaking ice for the Healy. Two more days of this (ouch!).

Sept. 9

Continue with transit across A-M Ridge. Some interesting “cottage cheese” topography appearing on the multibeam imagery. Pub night with Science staff and officers preparing and serving food.

Sept. 10
Arrived WP145 at the south end of AM Ridge at about 0630h and took a Rosette/CTD/Sound velocity profile. Then deployed seismics for transit across Stephanson Basin. Seismics operational by about 1030. No issues on deployment except loss of terminal weight a couple of times, until we got the correct pull restraint on the parachute. Healy now leading Louis through the ice. By 1700h we had made only 12 miles. SW winds are pushing the back to the NE and tightening it up. Pressure ridging and tough multiyear ice is making passage with the seismics impossible. Decided to pull the gear in and break ice for the Healy to gain the 2500 m contour and then transect over to Sever Spur.

Sept. 11, Sunday
Engine and power failure at 3:30 forced shutdown/stop until 7:30…no heat, no lights… Strong (Gale force) westerlies continue, forcing strong ridging and difficult ice conditions. Operational again at 0730. Continue to transit across Stephanson Basin with Louis in the lead…making 6-7 knots. By late afternoon, it appears that ice is not under so much pressure. Early evening, we deploy seismics again and get stuck immediately. Healy backs to within feet of the Louis to attempt to blast away the ice – to no avail. Winds building to 30-35 knots with snow. Strong drift to the NE. 23:00h Borden calls to say compressor one is down (leak)…blown valve in first stage. 11:20, Captain calls to say we’re stuck again – we agree to give it one more try. 11:45, Captain calls to say he can’t make headway, time to pull it in.

Sept. 12
0015h all gear on board and we continue with transit to Sever Spur. 0900h, winds have dropped for now and ice doesn’t appear under much pressure. Gear back in the water by 1200h after a helo flight to check ice conditions ahead. A nice system of leads follows in the direction we want to go…eventually tightens up though. Conduct seismics the rest of the afternoon and night…

Sept 13
Awoken by the bridge at 0510h. We and the Healy are stuck in ice. Healy taking repeated runs at a large ridge. We elect to pull in the Gear at 0700h and gear on board by 07:30h. At 0900h we do a recon flight and ice conditions look heavy but no large pressure ridges and some open water (1-2%). We should be fine to carry on with multibeam and then consider options after for seismics. Should be able to complete the inboard survey of Sever Spur. Winds are light and are to shift to north later today and tomorrow, which may open the pack even more. Ice increasingly heavy as we head to the east.

Sept. 14
Ice very heavy – multiyear flows impossible to get through. We divert from WP152 in the NE and head towards WP153 in the SE. Ice is heavy and we made only 12 miles all night. Plotted a track to cut the corner and head westerly to get into possible easier ice conditions. No seismic

ops…lots of backing and ramming. ~2130, mbeam picked up an 1800 m contour to our stb, near WP 154(2), which was certainly not on any chart.

Sept. 15
In a.m., elected to try Healy in the lead to see if we can maintain way and possibly deploy seismics. Seismics in the water at ~0930…stuck within a few minutes. Healy comes and breaks us out and we're good to go! 1050h time break on center gun fails…operating it manually. By late afternoon, one of the 500 cu.in. guns no longer works (leak in the air hose), so shut it down….running with 1x500 and 1x150 cu.in. Decide to leave it in since sediment is not that thick anyway. Get seriously stuck about 2000h and then by 2130 cannot make further progress…pull in seismics and back track to pick up multibeam and chirp along this same track… 2215h, all gear on board and Louis in the lead again. Called by Larry on the Healy with questions about the waypoint for back-tracking…

Sept. 16
Larry on the Healy called concerning offset for the return track…apparently they wanted to turn north and we wanted to turn south. Somehow, they have an incorrect waypoint, which explains the track offset from yesterday. We headed south on a 4-mile offset parallel track. By the morning, we're still 20 miles from the open pool in which we hoped to deploy the AUV. All stop of 0830 for propeller packing… Helo up at 0830 to look for new pond. Continue line for a short while further and then terminate when it is decided that we've passed any possible foot of slope. Louis heads for an large pond for AUV operations to the southwest and Healy heads northeast to conduct base of slope mapping. Set up after lunch in a pond at 80º 32'N 131º 13'W, First do Rosette and SVP sample, then begin AUV prep. AUV in the water about 18:30 and released about 19:00. Steve Wackowski launched his UAV to get pics of the deployment and crashed on the ice just ahead of our stbd bow…but across the other side of the lead.

Sept. 17
Spent the day waiting for the AUV. No other operations could take place as acoustic gear is hanging in the water. AUV came back in the evening – heard its first ping about 19:30h. Formulated plan to survey to the south with seismics. Communicated that to the Healy. She has completed our survey plan over Sever Spur and will join us by noon today.

Sept. 18 Sun
AUV returned but found a piece of multi-year ice to park under! As it rose to the surface, the current grabbed it and it seems to be located about 150 m away under some ice. Breaking ice around the AUV, finally revealed at 11:10 local time and recovered and on deck at 13:30h. Recovered Steve Wackowski's downed UAV and then a Rosette and SVP while waiting for Healy. Healy breaking some very heavy ice to get to us…some of the worst they have yet encountered. Finally underway by 16:30h. Ice judged too difficult to deploy seismics, so continue in multibeam mode… Several tries with Healy in the lead showed the track closing in too tightly.

Sept. 19
Ice looks better this am…start deploying gear at 0830 at WP 220. Get the gear in the water when notice leakage on the streamer. Bring all the gear in. Number 2 compressor fan blew apart.

That is being replaced. Also, propeller shaft making a strange noise – chief mate suspects she's lost a blade. ROV inspection showed no lost blade but a gap in the propeller mount. Captain determines that this is END OF PROGRAM… Sit in this position awaiting word from Coast Guard ops centre as to what to do to proceed. Healy is standing by as well

Sept. 20
Raft up day… Two ships rafted by noon and personnel were permitted to transfer between vessels soon after. Reception with Dept heads etc in the LSSL forward lounge at 15:00 and food etc on the Healy at 17:00. Present plaque to the Captain Havelick of the Healy and seamount plaque to Larry and Andy. I received a coin from State Dept. and from Healy and a UNH shirt from Larry. After food was a skills competition and then live music. Lines parted at 21:30 and started out of ice with Healy breaking for Louis.

Sept. 21
Transit out of ice to the south continued with Healy in the lead. Ice conditions largely favourable. Stop for ROV inspection of the prop and all is in place still. I gave a science seminar on Seismics and Multibeam this evening.

Sept. 22
Transit out of ice continued. I took a flight on the Helo over to Healy to get the back up drive and exchange gifts for the Captains and then the two ships parted company shortly thereafter.

Sept. 23
Groundhog day continues… still working out of ice. Going very slow because of propeller. Chain block on the propeller broke last night…and prop rotated. Two inspections by ROV today to inspect the prop. Still in 2-4/10 ice, sometimes higher.

Sept. 24
Out of ice edge at 1300h…now getting some swell. Saw mother bear and cub just at the ice edge… at 20:02 UTC, they were at 71º 55.06 and -132º 29.53. Healthy looking pair. Three more spotted off to port but I didn't see them. Held 'awards' ceremony in the evening with presentations of ship's plaque and Borden's retirement gift.

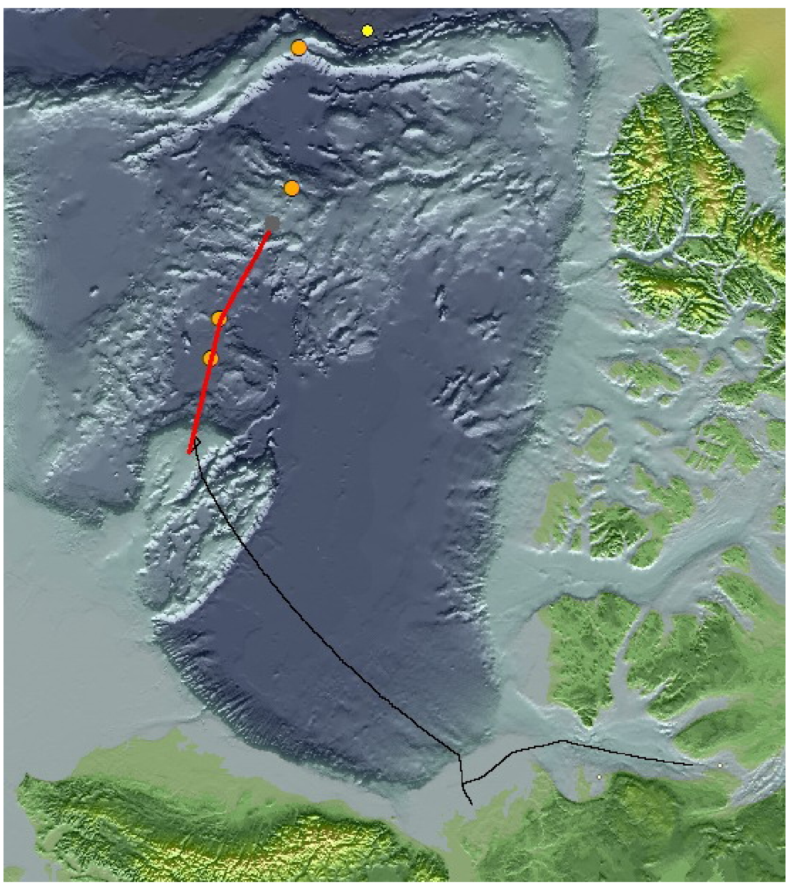
Sept. 25 Sun.
Entering Amundsen Gulf. ETA to Cambridge Bay is Tuesday am.

Appendix 2 Weekly Reports

Weekly Report: August 21-28th

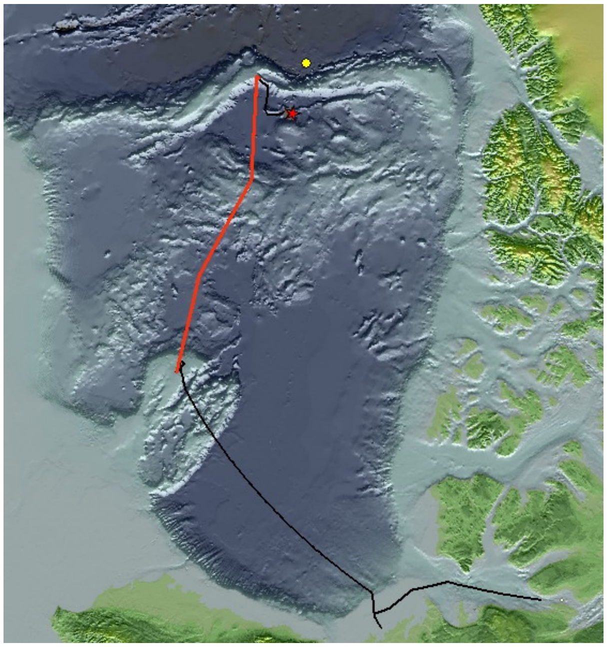
Transited from August 19 to August 22 from Tuktoyaktuk to rendezvous point with USCGC Healy. Healy arrived on the morning of August 23 and we rafted together to commence fuel transfer operations. During rafting ops, crews were able to mingle between ships and we (Chief scientist and senior officers) met with US counterparts to discuss particulars. At 2030h, ships parted company and we steamed to start of Line 1 (WP10) on Chukchi cap. Deployed seismics and were operational at 0100h on Aug 24. Seismic operational with Louis following Healy in relatively light ice conditions. Weather is mostly overcast and fog.

Ice conditions continue to become more difficult as we go north. Seismic continue to operate until August 27 at 0030h when 2 guns went down. Brought gear on board. Some difficult ship maneuvering led to gun sled impact with ice causing two punctures in high pressure hoses on the sled. Repaired and put back in water under very trying conditions (heavy ice cover). A streamer section was pierced – probably against ice on deployment and gear had to be hauled in again. Switched streamers and tried again and streamer had leakage, so hauled gear in AGAIN. Finally, gear in water and operational by 1300h on August 27. On August 28, heading over southern flank of Alpha-Mendeleev Ridge.



Position as of 1745h UTC
August 28, 2011-08-28
84º 20.19N 167º 26.22W
Line km of seismic data: 420 km
8 sonobuoys deployed (2 in advance of ships)
22 XCTD casts
1 Rosette water sample

Weekly Report August 29-September 3, 2011



For the first part of the week, we continued shooting seismics to the north, Nautilus Basin across Alpha Mendeleev Ridge, across Makarov Basin and to terminate on top of Lomonosov Ridge. As we traveled further north, ice was increasingly heavy and under pressure. The Louis got stuck at for the first time on the morning of August 29th with no centre shaft and towing the array and required Healy to come around and break us out. This is the first of many times but Healy under command of Captain Havelick is up to the task – they are doing a great job breaking for us and breaking us out. I have not seen her handled so well in previous years.

Navigation computers were unable to handle positions either this far north or this close to the international dateline…lots of strange route heading values. On August 29th at ~ 1630h we pulled in the gun sled to untangle the streamer and redeployed by 1700h but at 18:30, we lost signal to streamer…probably broken deck cable. We pulled the sled and streamer in and spent all night preparing a new deck cable/bundle. There was no spare as DRDC has occupied our second sled. By 0900 on the 30th, however, we were back in the water and operational. We tested a new way of deploying the streamer, which worked well. We put a weight on the end of the streamer, and hung it vertically. Attached to the weight was a parachute (droag). When the ship came up to speed, the droag pulled the weight off the streamer and the streamer rose to its proper tow depth. The concept of the droag was compliments of Mr. Asprey! Hard ice conditions meant we made only 14 nMi between 9:00 am and 4:00 pm on the 30th, but ice conditions improved after that and we made much better progress.

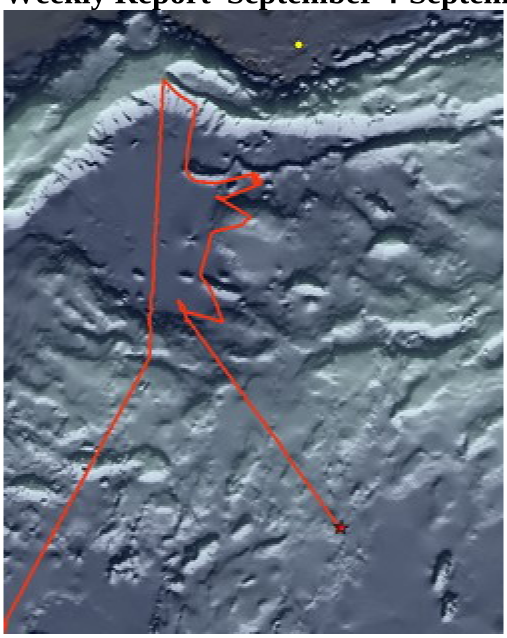
Flew forward to deploy sonobuoys at several opportunities in order to achieve reversed profiles. The gravimeter is acting up and we're not confident of the data. We're trying several things to correct… We crossed 88 deg in the am of Sept 1 and made the end of the seismic line on top of Lomonosov Ridge 14:30, ending the first phase of the program. Bringing the sled and array aboard showed no wear and tear showing that the engineering is finally working out and that the LSSL bridge has done a great job piloting with this gear in the water – despite heavy ice conditions. At 1500h, Sept. 1, Louis took the lead and broke ice for the Healy and we collected multibeam data across the top and then down Lomonosov and surveying for the FoS along the southern edge of Marvin Spur. Ice was not under pressure and we were making about 4 knots, speed dictated by data quality on the Healy. Our northernmost point was about 88º 20' and the crew are heartily disappointed that we cannot go to the pole – but there were never any expectations or indications that we would.

Sept 3 we spent the day getting the AUV prepped for launch. It was released at 1700h, but its trim was found to be unsatisfactory so it was recovered and retrimmed. LSSL crew did a great job on deployment and recovery and clearly the trials back in April were worthwhile. Will try again in the morning. The area is freezing up, so its hard to find an open pond and westerly winds mean the pack is tightening up. While we fool with the ROV, the Healy is attempting to multibeam the western end of Marvin Spur and conducting some ice work.

Statistics to date
Position as of Sept. 4th, 1330 UTC
88º 10.6'N   158º 20.0'W
Line-km seismic data 1232
Sonobuoys 17
XCTDs 42
Rosette Samples 1

David Mosher
Chief Scientist, LSSL2011

Weekly Report September 4-September 10, 2011



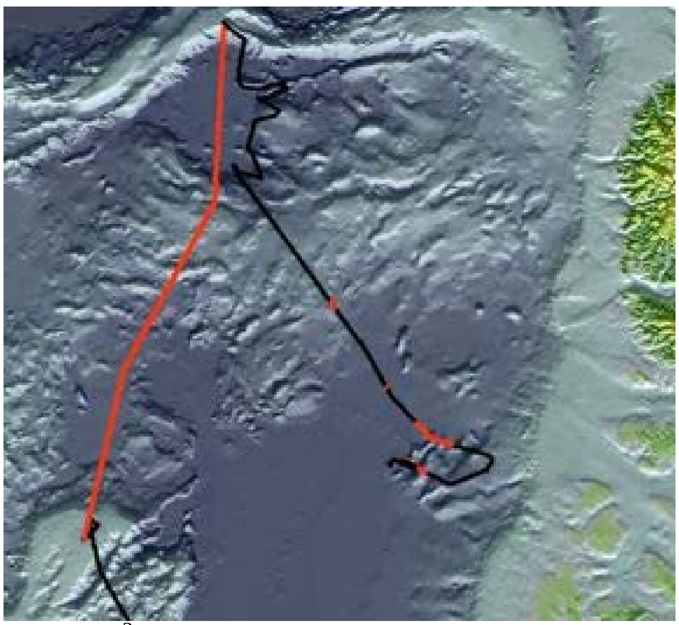
Sept. 4 Sun., launched the AUV by 0730 am. System checks etc take several hours but by 1530h it is at 3500 m. The forward-looking altimeter fails and causes the vehicle to surface. The mission is scrapped and the AUV comes to surface but gets trapped beneath the ice. The ROV is unable to find it for recovery. On Monday, we triangulate on the AUV's location and use the ship to carefully break ice around it (an 11000 tonne scalpel). It is spotted 88º 09' 22"N 157º 26' 29"W and recovered by 1530h. Same day, the Environment Canada O-buoy is launched on an ice flow. It is an all day ordeal with 10 people on the ice but is up and operational and data can be viewed on the web. Multibeam survey around the eastern edge of Makarov Basin continued and highly successful with determination of several 2500 m contour points and FoS identified. On Sept. 7th, received an airdrop of US Coast Guard plane with parts for the Healy and the antenna required for our helicopter. Finished surveying Makarov Basin on Sept. 8th and commenced transit across Alpha-Mendeleev Ridge, with Louis breaking ice for Healy while she continued to acquire multibeam sonar data. Very interesting geomorphology in places on the ridge. At the south end of Alpha Ridge, we elected to deploy the seismic equipment. In 8 hours, we made only 12 nMi due to heavy ice ridging and high ice pressures. Winds are from the west, driving the pack tighter. We elected to pull the seismic gear and proceed with acquisition of multibeam data to continue the transit to Sever Spur. This area of northern Canada Basin remains elusive!

Statistics to date
Position as of Sept. 11th, 0057 UTC 83º 45.2'N   136º 05.9'W
Line-km seismic data 1244
Line-km multibeam data 1350

Sonobuoys 17
XCTDs 53
Rosette Samples 4
Radio-nuclide tracer samples (sea water) 4
O-Buoy Deployment
Spot Soundings 27

David Mosher
Chief Scientist, LSSL2011

Weekly Report September 11-September 18, 2011



We completed the transect across Stefansson Basin, largely unsuccessful in acquiring any seismic data. On September 12, with significant effort we successfully acquired a seismic profile from the western side of the north end of Sever Spur heading east across three of its ridges before ice became too difficult. We switched to multibeam mode.following that, and finished the transect in very heavy ice. We continued south across the landward side of Sever Spur, although we had to divert westward as ice was too heavy in places to make forward progress. Lots of backing and ramming – during the night of Sept. 13-14, we made only 12 miles all night. We're burning between 70 and 80 m^3 of fuel per day (that's about 1.3 feet per gallon).

Picked up a ridge on Sever Spur on the multibeam at about 79º55'N and 124º25.7W that reaches to 1800 m water depth that is not on any chart. On the transit west across the southern portion of Sever Spur, we put the seismics in and got a transit across the two outer ridges of Sever Spur. In the process, ice damaged the umbilical and we lost the timing break for one gun and punctured the air hose on another gun. We completed the survey with one large gun and one small one. We encountered very heavy ice and pulled the gear…it was likely that all guns would have failed soon, since all the airlines were damaged by heavy ice. We backtracked and covered the same ground again with multibeam and chirp in order to have a complete transit.

Sept. 16 we surveyed to ensure that we had passed any possible FoS of Sever Spur and LSSL found a large open water pool in which to deploy the AUV. Healy meanwhile continued north to make several transects of the outer ridge of Sever Spur to find FoS points. The AUV mission was to conduct a transect of the southern portion of the outer ridge of Sever Spur with a return path to determine if a gap in the ridge is real. The AUV returned last night and lodged under some heavy multiyear ice nearby to the open pool. Some careful icebreaking by LSSL allowed retrieval, the AUV was spotted at 11:10h and on deck by 13:30h.

Summary Stats

<u>Seismics</u>

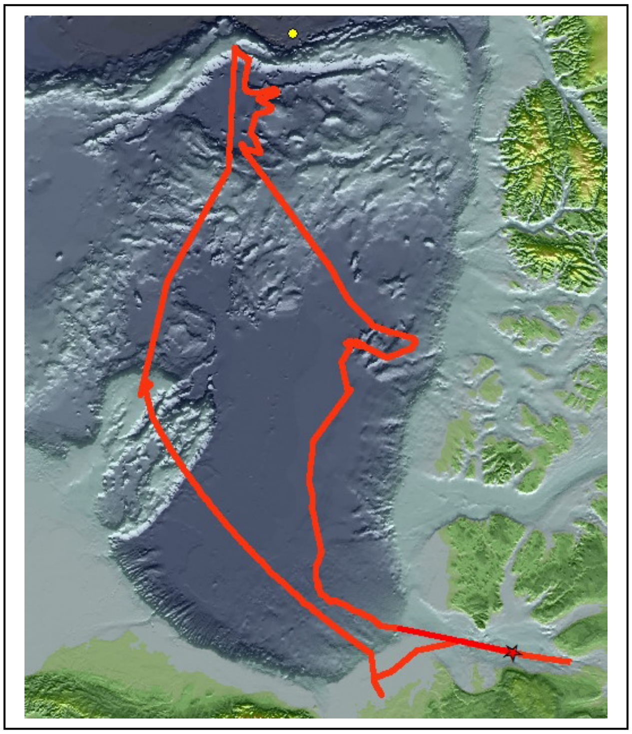
Line 1: 281,754 m
Line 2: 115,381 m
Line 3a: 141,742 m
Line 3b: 279,284 m
Line 4a: 48,645 m
Line 4b: 357,265 m
Line 5: 26,830 m
Line 6: 11,777 m
Line 7: 106,025 m
Line 8: 68,756 m

TOTAL SEISMICS 1,437,459 m

TOTAL MULTIBEAM/CHIRP ~2,220 line-km (additional to seismics)

Sonobuoys 21
Rosette Samples with SVP 5
XCTD's
O-Buoy Deployment
2 AUV deployments

Weekly Report September 18-September 25, 2011



After AUV recovery we were able to get a Rosette sample and SVP while waiting for the Healy to join us. Healy was stuck in a major ridge just 13 miles from us, taking several hours to break out of it. Finally underway by 16:30h. Ice judged too difficult to deploy seismics, so continue in multibeam mode… Several tries with Healy in the lead showed the track closing in too tightly. By morning of the 19th, the ice looked better and seismics was deployed but there was leakage in the streamer, so the gear was recovered. No. 2 compressor fan blew apart as well. While on deck, the Chief Mate noticed a strange noise from the centre shaft propeller. ROV inspection showed that the propeller has backed off of the propeller shaft…suggesting the nut is loose. They claim there is 12 inches of thread and it has backed off 6 inches. We are SHUT DOWN – no more science and we await instructions from Coast Guard Operations on next course of action. We still have port and stbd shafts operational but the rudder is astern of the centre shaft propeller, providing the best steerage. Also, they do not want to loose the centre propeller as it may damage the rudder if it fell off.

Despite the shut down, September 20th is raft up day with the Healy to celebrate the past four years of collaboration between our two countries. We presented our plaque to Captain Havlick of the Healy and other awards were given out before dining on a fantastic meal. Lines were parted by 2100h and we started making our way out of the ice with the Healy in the lead. The remainder of the week was transit out of the ice and making our way to Cambridge Bay. Healy left us on Sept. 22nd and we continued on our own afterwards. Our way out of the ice was slow but once clear of ice, we make 10 knots. Our ETA to Cambridge Bay is Tuesday morning.

Summary Stats

TOTAL SEISMICS 1,437 km
TOTAL MULTIBEAM/CHIRP (Healy) ~4,500 line-km
TOTAL TRACK LENGTH (LSSL) with bathymetry and chirp: 7,350 km
2 AUV DEPLOYMENTS 110 km multibeam

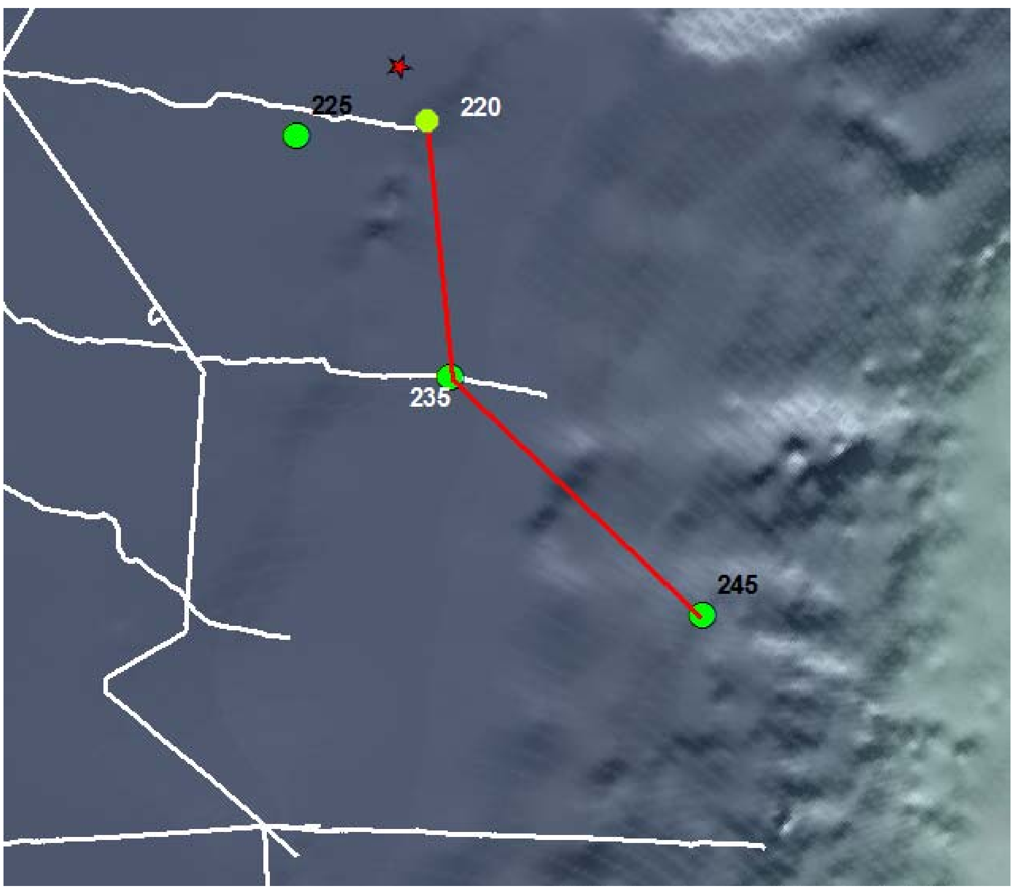
Sonobuoys 21
Rosette Samples with SVP 6
XCTD's 79
O-Buoy Deployment 1
CIS Beacon deploys 2

Appendix 3: Bridge Instructions

Bridge Instructions. Sept. 19, 2011

From WP 220, head towards Waypoint 235 and deploy seismics when feasible. Then to WP 246

LatDD	LongDD	LatDM	LongDM	WP
79.154755	-132.297394	79º 09.285'	-132º 17.844'	220
78.302580	-132.279987	78º 18.1548'	-132º 16.7992'	235
77.358641	-128.927344	77º 21.5185'	-128º 55.6406'	245



David, Chief Scientist

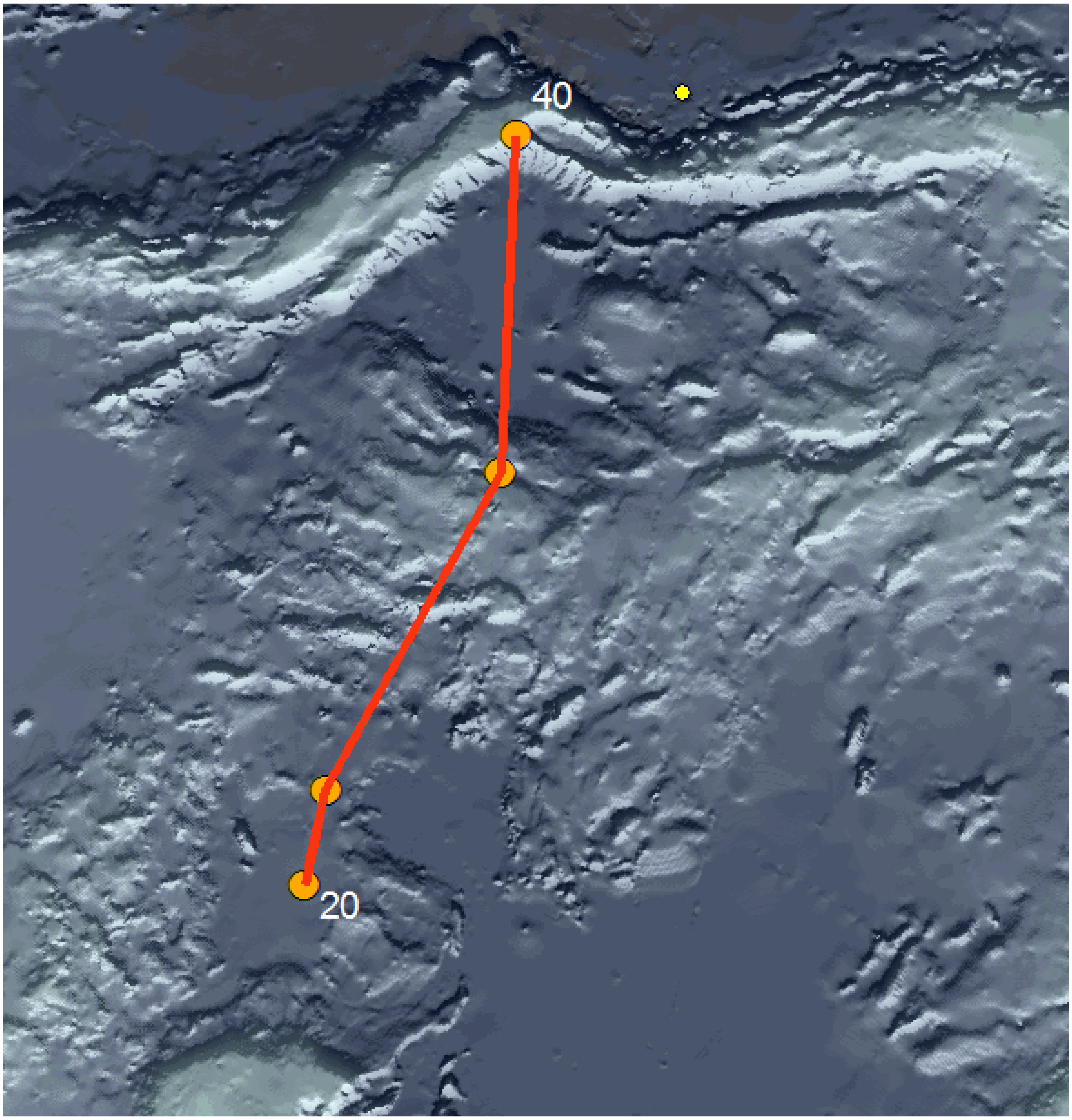
Bridge Instructions. August 25, 2011

Lon	Lat	WP	distance (nMi)
-166º 46.54’	80º 39.49’	20	

-168º 17.08	81º 39.37’	21	63
-166º 44.94’	85º 31.19’	30	240
143º 16.95’	88º 11.61’	40	220

From the rendezvous point, we will deploy the seismic gear and follow in behind the USCGC Healy. The intent will be to deploy south of WP10 and be operational as we cross the site. The entire transect presented above is to acquire seismic reflection data across Alpha Mendeleev Ridge and Lomonosov Ridge. The lines are designed to intersect existing data, so please contact the Chief Scientists if more that 3 nautical miles from the line.

David, Chief Scientist

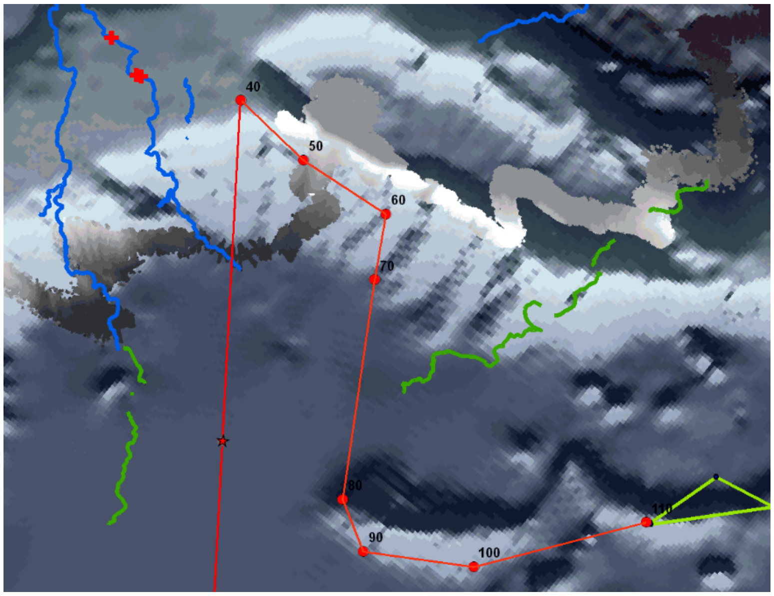


Bridge Instructions. Sept. 1, 2011

At WP40, seismic gear is to be recovered and we will switch to multibeam operations, with the LSSL breaking ice ahead of the Healy. Optimal speeds for surveying will need to be determined based on assessment of data quality with the Healy science personnel. 7 knots, if obtainable in ice, should be feasible without degradation of data quality. The objective of the next component of the survey is to determine the position of base of slope on the eastern side of Makarov Basin at the base of Lomonsov and Alpha-Mendeleev Ridges. We will proceed to Waypoints 50 through to 1100 in sequence, with direction provided by Healy as they assess the data for target depths. At WP110, LSSL will commence AUV operations while Healy continues with surveying and possible sampling.

Lat	Long	WP	Lat DegMin	Long DegMin
88.1945	143.3372	40	88 11.677 N	143 20.230 E
88.31107	150.4776	50	88 18.664 N	150 28.654 E
88.4561	159.04847	60	88 27.368 N	159 02.908 E
88.3282	164.0377	70	88 19.694 N	164 02.263 E
87.8427	176.3105	80	87 50.564 N	176 18.633 E
87.7681	179.9832	90	87 46.084 N	179 58.999 E
87.9141	-172.4667	100	87 54.848 N	172 28.001 W
88.2424	-160.7735	110	88 14.544 N	160 46.412 W

David, Chief Scientist



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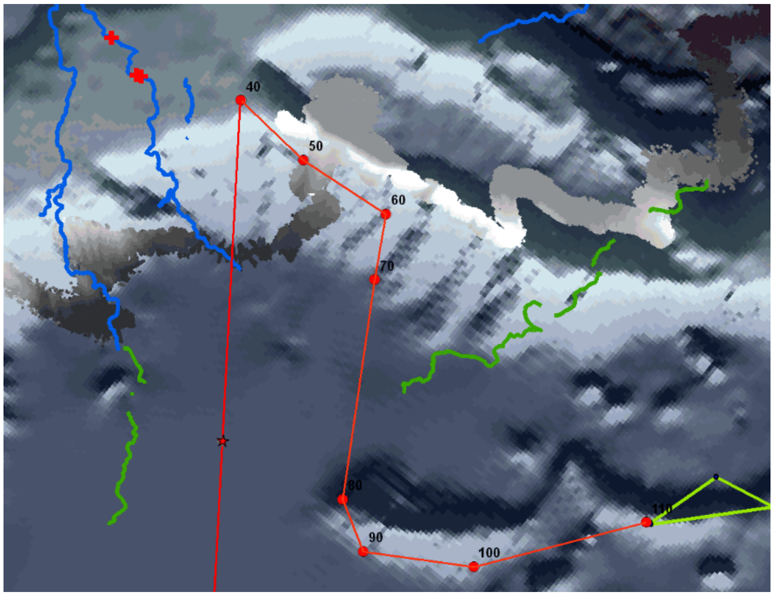
David, Chief Scientist

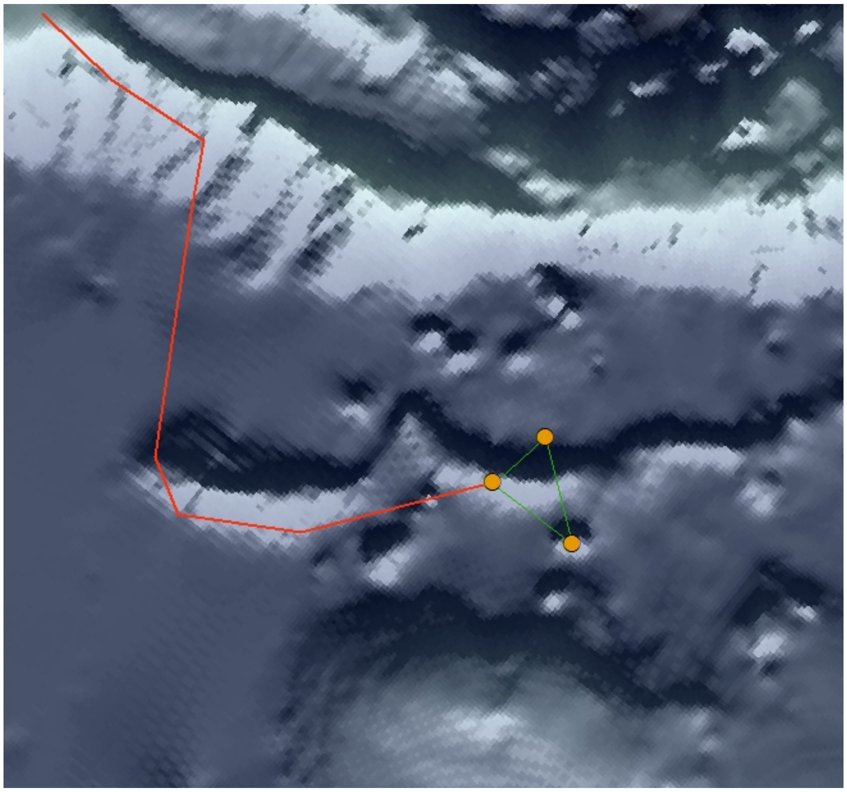


Bridge Instructions. Sept. 1, 2011

From WP110, continue to WP 120, to 130 and return to WP110. These tracks will continue with the LSSL breaking ice for the Healy whilst she aquires multibeam data over Marvin spur. On the return to WP 110, LSSL will begin AUV operations.

Latitude	Longitude	WP	LAT_DEGMIN	LONG_DEGMIN
88.394	-157.590	120	88º 23.64’	-157º 35.40’
88.147	-153.182	130	88º 08.82’	-153º 10.92’
88.2424	-160.773	110	88º 14.63’	-160º 44.65’

David, Chief Scientist

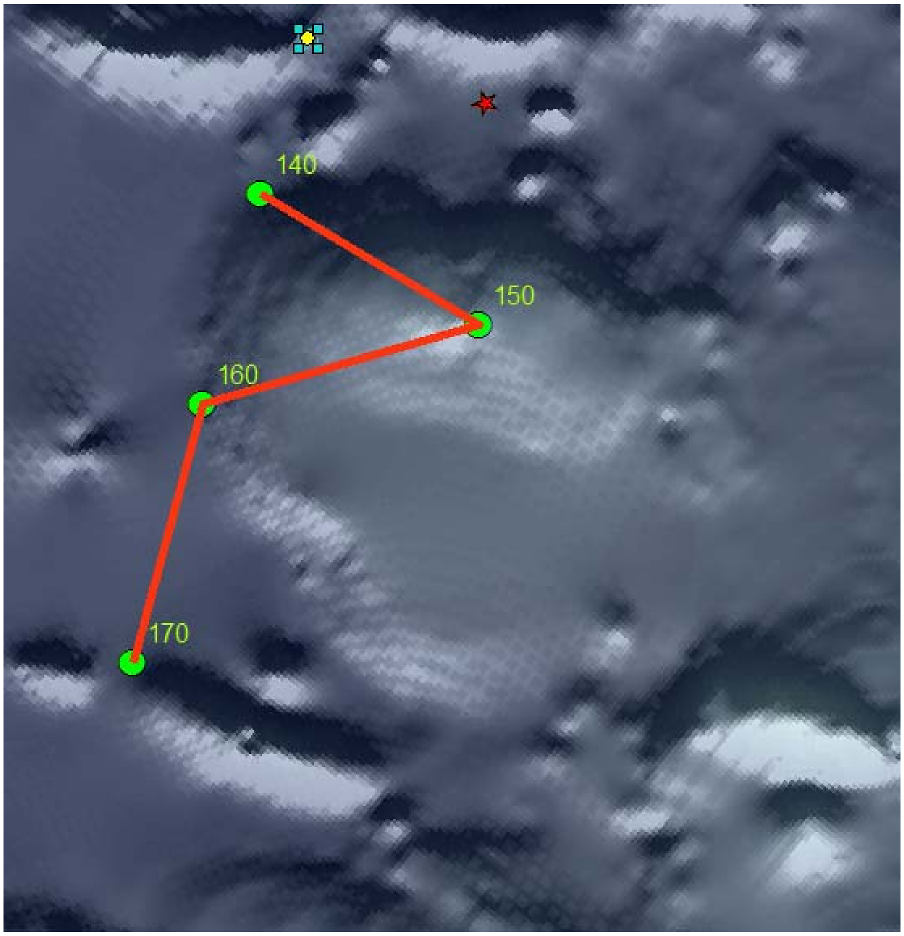


Bridge Instructions. Sept. 5, 2011

Join Healy at WP140, and take the lead as she acquires multibeam in our wake. Proceed through following waypoints and speeds dictated by the Healy for survey quality – probably maximum of 4 knots. It is about 31 nMito WP140 and the survey pattern is a total of 107 nMi.

Lat	**Long**	**LatDeg**	**LatMin**	**LongDeg**	**LongMIn**	**WP**
87.7818 º	-168.1339 º	87º	46.91’	-168 º	08.034’	140
87.6822 º	-154.6427 º	87 º	40.929’	-154 º	38.564’	150
87.3262 º	-166.1572 º	87 º	19.573’	-166 º	09.429’	160
86.7606 º	-164.3988 º	86 º	45.634’	-164 º	23.929’	170

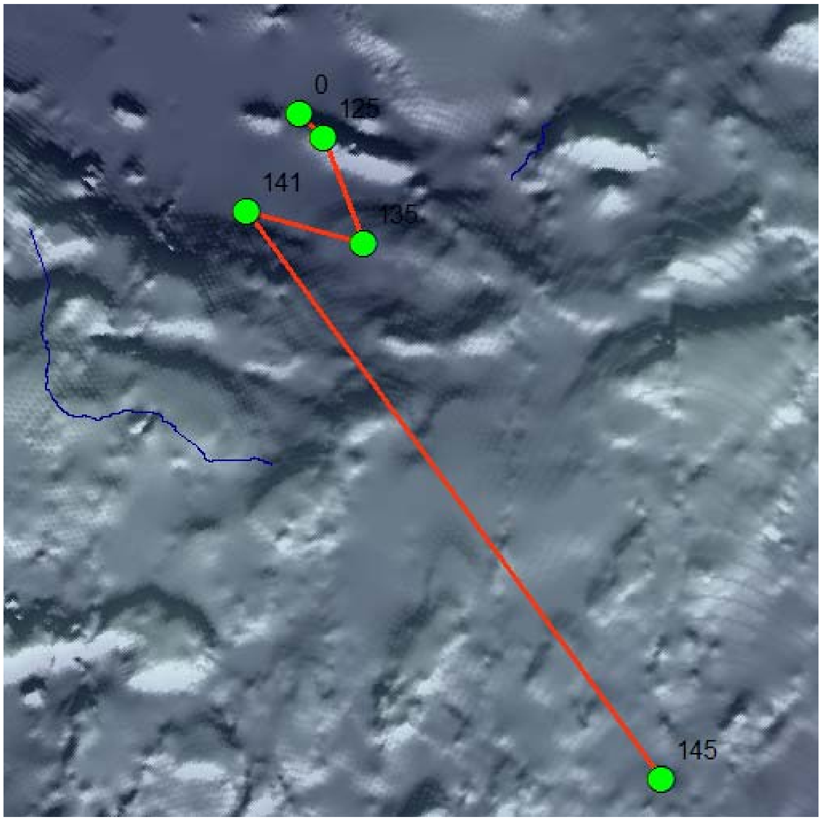
David, Chief Scientist



Bridge Instructions. Sept. 5, 2011

From WP, continue to WP 125, 145 etc. , breaking ice for the Healy as she acquires multibeam. At WP 145, we will likely put in the seismic gear, judging time remaining.

Lat	Long	LatDeg	LatMin	LongDeg	LongMIn	WP
86.7606	-164.399	86	45.634	-164	23.929	0
86.6992	-161.793	86	41.95	-161	47.58	125
86.291	-156.538	86	17.46	-156	32.25	135
86.2508	-165.121	86	15.048	-165	7.23	141
83.9239	-137.296	83	55.432	-137	17.74	145

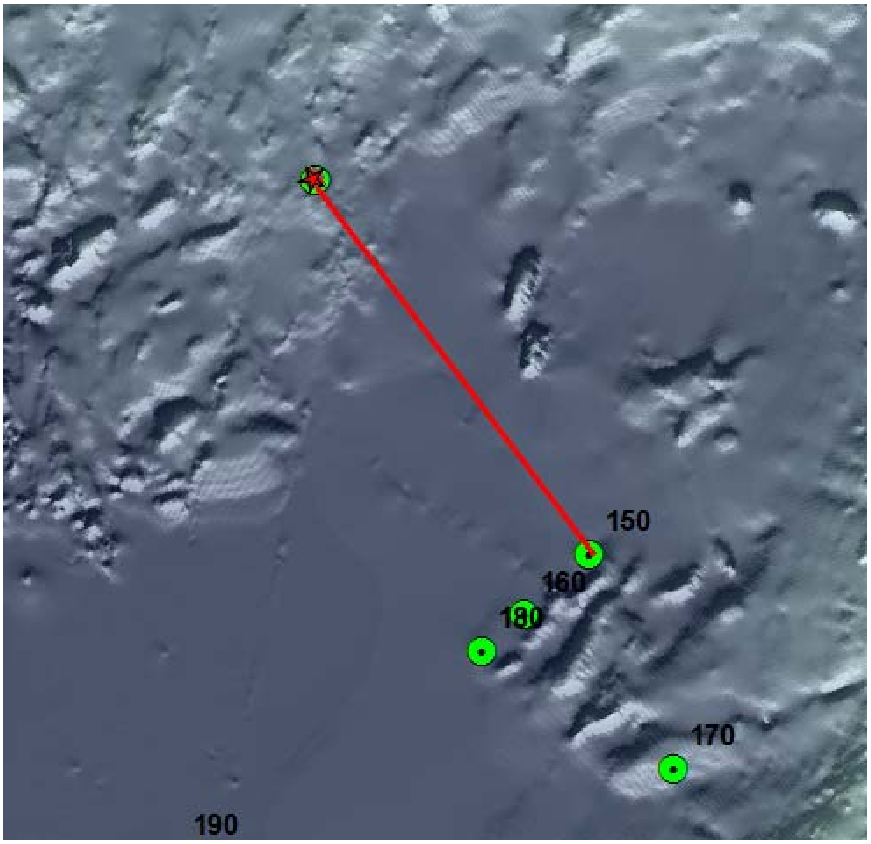


David, Chief Scientist

Bridge Instructions. Sept. 11, 2011

Divert from heading directly to WP 150 and head to WP 146. Considering ice conditions, attempt seismic equipment deployment at WP 146 and shoot seismics to WP 150, potentially proceeding beyond to WP 151, contingent on ice conditions.

Lat	Long	LatDeg	LatMin	LongDeg	LongMIn	WP
83.9239º	-137.296º	83º	55.432	-137º	17.74	145
80.9560º	-125.8725º	80º	57.36’	-125º	52.35’	150

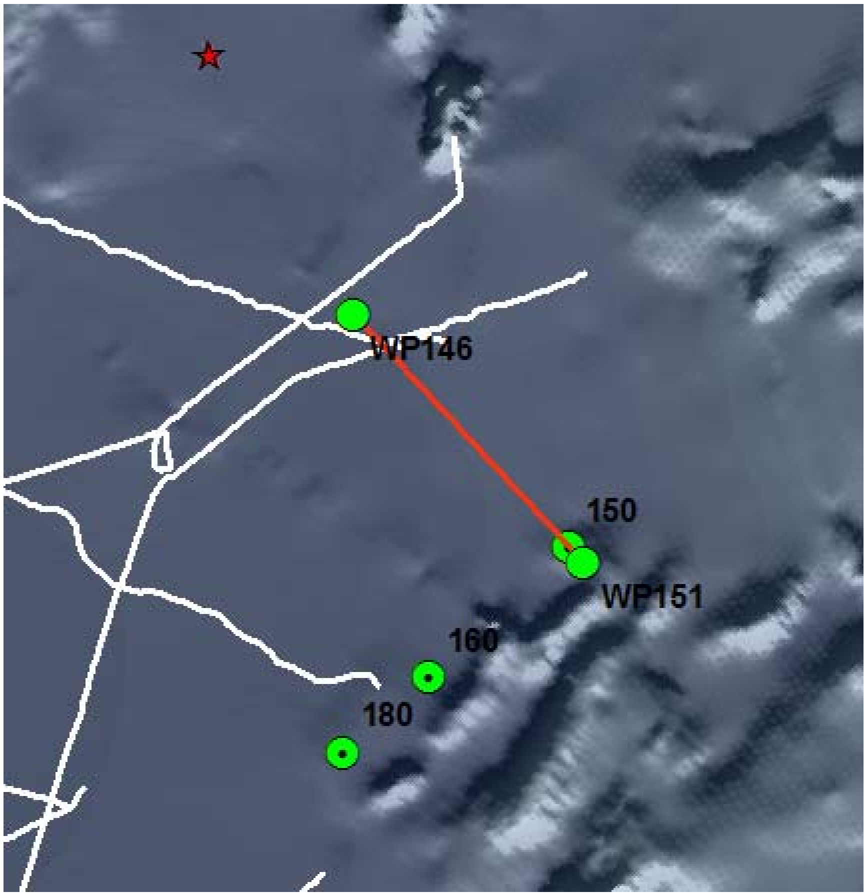


David, Chief Scientist

Bridge Instructions. Sept. 11, 2011

Divert from heading directly to WP 150 and head to WP 146. Considering ice conditions, attempt seismic equipment deployment at WP 146 and shoot seismics to WP 150, potentially proceeding beyond to WP 151, contingent on ice conditions.

Lat	Long	LatDeg	LatMin	LongDeg	LongMIn	WP
81.884º	-129.440º	81º	53.04'	-129º	26.40'	146
80.956º	-125.8725º	80º	57.36’	-125º	52.35’	150
80.893º	-125.653º	80º	53.59'	-125º	39.20'	151



Red line is proposed seismic data, White lines are existing seismic data

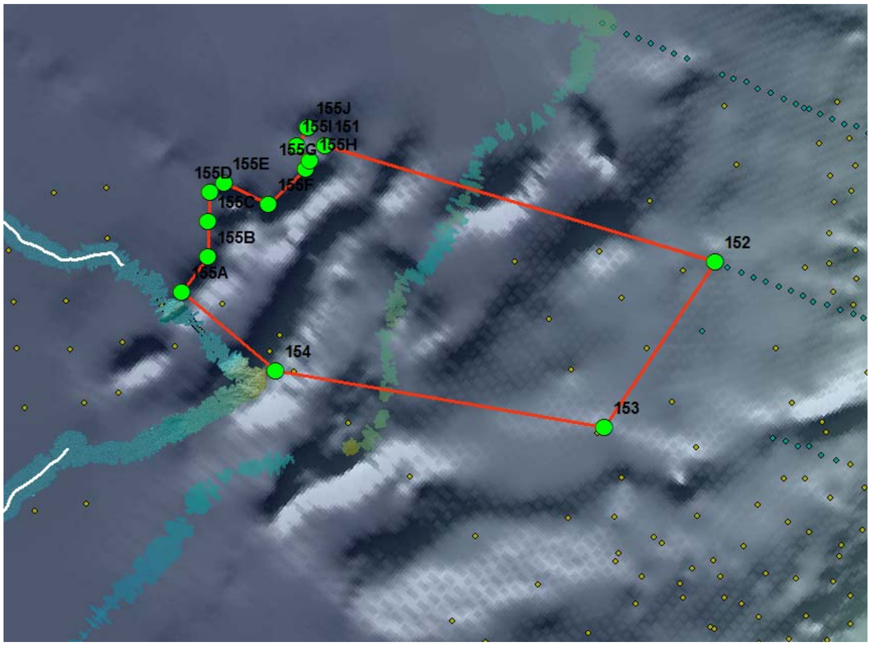
David, Chief Scientist

Bridge Instructions. Sept. 12, 2011

From Waypoint 151 continue through to Waypoint 152. If seismics is still operational at WP151, we'll leave the gear running. If it is not, then we will break ice for the Healy while she acquires multibeam bathymetry. At WP152, recover seismics and continue surveying through successive points with multibeam (Louis breaking ice for Healy). Total survey length is 280 nMi.

LatDD	LongDD	LatDM	LongDM	Waypoint
80.893	-125.653	80º 53.59'	-125º 39.20'	151
80.0854	-118.7516	80º 05.12'	-118º 45.10'	152
79.6856	-121.8904	79º 41.14'	-121º 53.42'	153

80.1782	**-127.7813**	**80° 10.70'**	**-127° 46.88'**	**154**
80.5090	**-129.3124**	**80° 30.54'**	**-129° 18.74'**	**155A**
80.6089	**-128.6271**	**80° 36.53'**	**-128° 37.62'**	**155B**
80.7269	**-128.4700**	**80° 43.61'**	**-128° 28.20'**	**155C**
80.8231	**-128.2945**	**80° 49.39'**	**-128° 17.67'**	**155D**
80.8428	**-127.9563**	**80° 50.57'**	**-127° 57.38'**	**155E**
80.7378	**-127.1365**	**80° 44.27'**	**-127° 08.19'**	**155F**
80.8239	**-126.1814**	**80° 49.43'**	**-126° 10.88'**	**155G**
80.8471	**-126.0540**	**80° 50.83'**	**-126° 03.24'**	**155H**
80.9084	**-126.2457**	**80° 54.51'**	**-126° 14.74'**	**155I**
80.9589	**-125.9136**	**80° 57.54'**	**-125° 54.82'**	**155J**

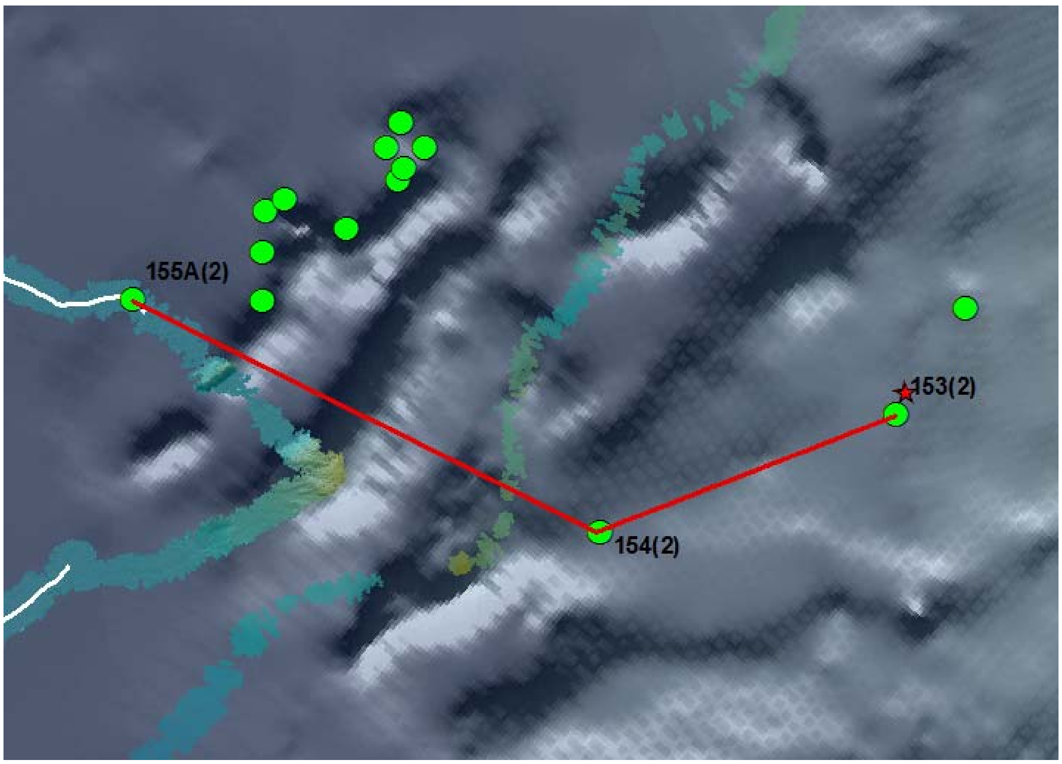


David, Chief Scientist

Bridge Instructions. Sept. 14, 2011

From present position head to Waypoint 153(2) – or pick up the transit line to 154(2). If both ships are required to assist in getting through multiyear pans, then they should be utilized, otherwise Louis should break for Healy. As ice conditions permit, deploy seismics along the route and Healy will break for Louis. Proceed to 155A(2) and seismic gear will be recovered. Total route distance is 125 nMi.

LatDD	LongDD	LatDM	LongDM	Waypoint
79.899876º	-120.197913º	79º 53.9926'	-120º 11.8748'	153(2)
79.849365º	-124.679204º	79º 50.9619'	-124º 40.7522'	154(2)
80.673239º	-130.569263º	80º 40.3943'	-130º 34.1558'	155A(2)



David, Chief Scientist

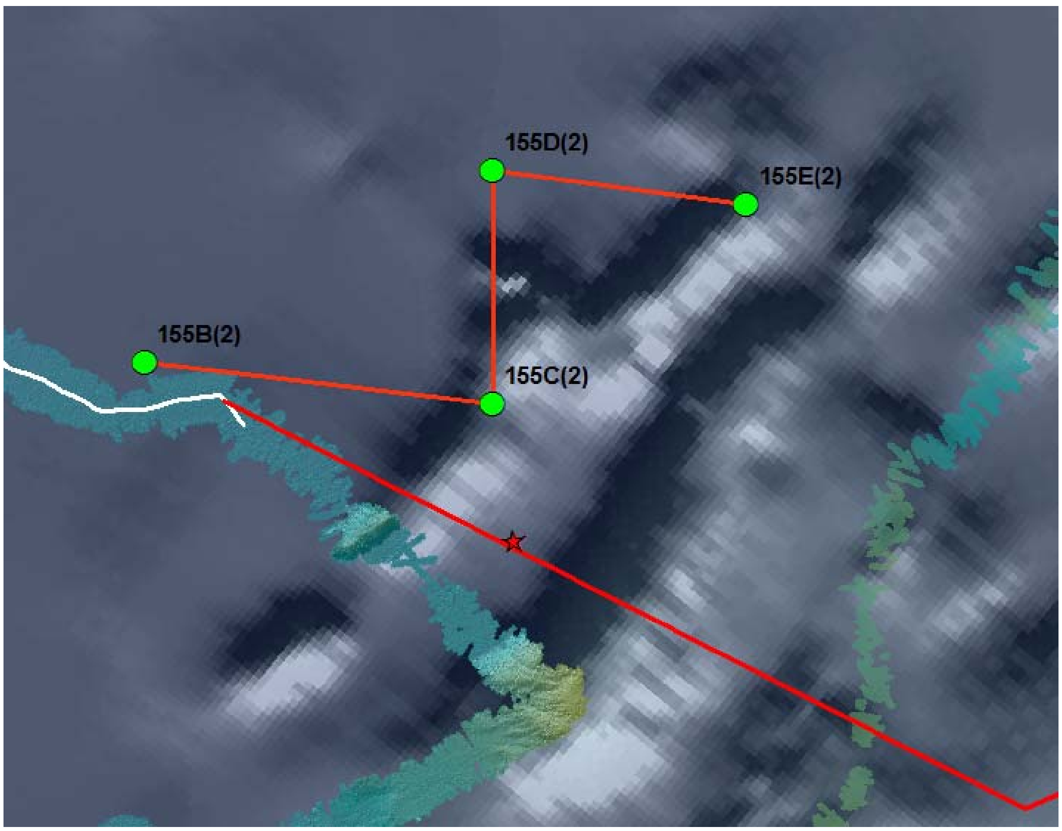
Bridge Instructions. Sept. 15, 2011

Assessment of the foot of the slope requires design of new waypoints, so please scrap the early survey design of the outer ridge of Sever Spur provided on September 12.

Continue from WP 155A(2) to 155B(2) and terminate seismic operations (if not already done). Continue with Louis breaking ice for Healy for multibeam and chirp data acquisition through the following waypoints. Break in the morning of Sept. 16th to commence AUV operations (contingent on finding suitable open water for deployment and recovery). Plan for set up of AUV operations at 0800h (local time), Sept. 16. While Louis is engaged in AUV operations, Healy can continue with MB survey (below) and engage in ancillary programs. AUV operations are expected to take between 3 and 4 days. The programmed track is 44 hours and a day for deployment and a day for recovery are allotted.

LatDD	LongDD	LatDM	LongDM	Name
80.750724	-131.217299	80º 45.0434'	-131º 13.0379'	155B(2)
80.595547	-128.235952	80º 35.7328'	-128º 14.1571'	155C(2)
80.924599	-127.773437	80º 55.4759'	-127º 46.4062'	155D(2)
80.788054	-125.606827	80º 47.2832'	-125º 36.4096'	155E(2)

81 nMi total distance



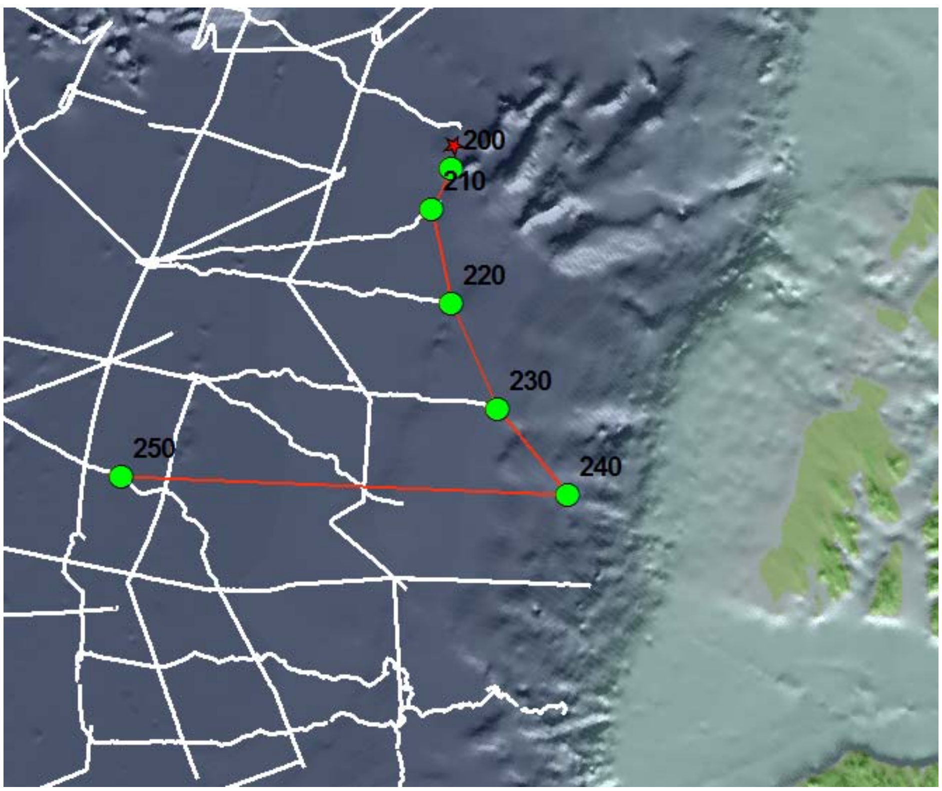
David, Chief Scientist

Bridge Instructions. Sept. 17, 2011

The objectives are to obtain an "inside tie" to various seismic transects and to complete a margin profile and basin transect at about 77.5º latitude. Following recovery of the AUV, deploy seismic equipment as soon as feasible and survey through successive waypoints to WP 240. Distance from WP200 to 240 is 193nMi. Depending upon the time of commencement of the survey (approx. mid-day Sept 18), WP240 should be about the appropriate time and position to raft together. Note that rafting can take place at any position, with recovery of the seismic equipment. Following rafting, continue with seismic survey to Waypoint 250. According to the present schedule, we anticipate making waypoint 250 on Sept. 23rd, which would be the departure time for Healy. Timing will have to be assessed during the survey and allowances made for this deadline, however.

LatDD	LongDD	LatDM	LongDM	Waypoint
80.309169	**-131.272083**	**80° 18.550'**	**-131° 16.32'**	**200**
79.991200	**-132.620739**	**79° 59.472'**	**-132° 37.244'**	**210**
79.154755	**-132.297394**	**79° 09.285'**	**-132° 17.844'**	**220**
78.189238	**-131.016138**	**78° 11.354'**	**-131° 00.968'**	**230**
77.354364	**-128.851264**	**77° 21.262'**	**-128° 51.076'**	**240**
77.722678	**-146.787486**	**77° 43.361'**	**-146° 47.249'**	**250**

430 nMi total distance

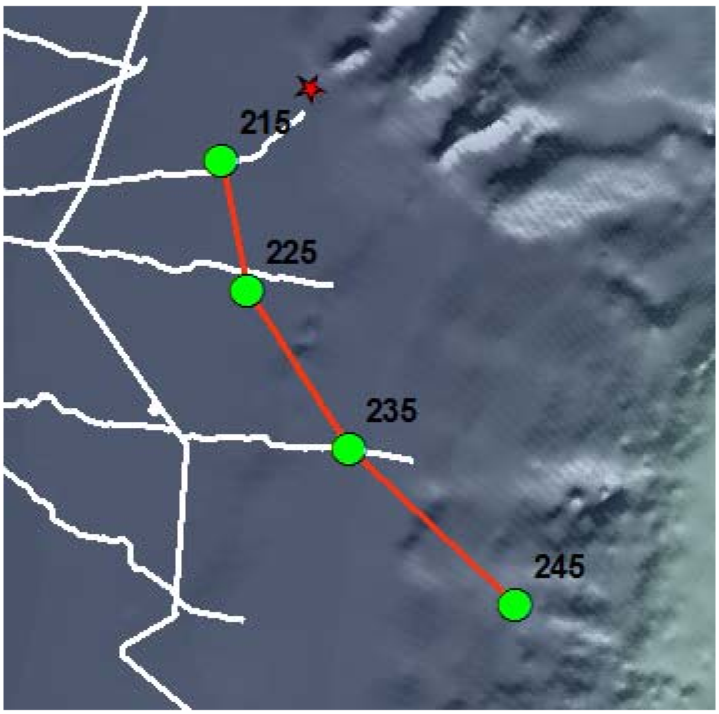


David, Chief Scientist

Bridge Instructions. Sept. 18, 2011
ALTERNATE TO BRIDGE INSTRUCTIONS OF SEPT 17

If ice is too difficult at WP 210, we will try moving the line to the west, expecting lighter ice conditions. In this case, we will attempt to shoot seismics, following through WP215, 225, 235, 245. We should “set up” slightly north (1 nMi) of WP 215 in order to deploy the seismics.

LatDD	LongDD	LatDM	LongDM	WP
79.852883	**-134.724239**	**79º 51.173'**	**-134º 43.4543'**	**215**
79.180815	**-134.362917**	**79º 10.8489'**	**-134º 21.775'**	**225**
78.302580	**-132.279987**	**78º 18.1548'**	**-132º 16.7992'**	**235**
77.358641	**-128.927344**	**77º 21.5185'**	**-128º 55.6406'**	**245**



David, Chief Scientist

Appendix 4: CHS Major Equipment and Software Programs

2011 CHS Louis S. St. Laurent Survey
Survey Equipment Summary
Technical Services

Date: 10 June 2011 **Survey Name:** Louie St. Laurent (UNCLOS)
Survey HIC: Jon Biggar

Deployment: Aug. to Oct. 2011 **Shipping Date:** 10 June 2011
Lead Tech: Rudy Cutillo

Launches: CCGS Louis S. St. Laurent **Assisting Techs:** Bob Johns, Dave Tobio

Survey "Platforms":	Louie	Spares	Total
GPS Related Equipment			
GPS Helipak System (Novatel OemV3)	**1**	**1**	**2**
GPS Helipak Accessories Kit	**1**	**0**	**1**
Novatel GPS702L GPS Antenna	**1 (Helipak)**	**1**	**2 (Helipak)**
Garmin 276C GPS Receiver Kit	**1**	**0**	**1**
Garmin 276C GPS Receiver Serial Data Interface Kit	**1**	**0**	**1**
Novatel DL-V3 GPS Receiver	**1**	**1**	**2**
Novatel GPS702GGL GPS Antenna	**1 (DL-V3)**	**1**	**2 (DL-V3)**
Trimble NetR8 GPS System	**1**	**0**	**1**
Trimble NetR8 GPS System Controller	**1**	**0**	**1 (Netbook Laptop)**
Trimble NetR8 GPS Antenna Mounting Pole (For Mounting Antenna on Ship)	**1**	**0**	**1**

Sonar and Related Equipment			
Lockheed Martin MK21 XSVP Control Unit and Launcher	**1**	**0**	**1**
Knudsen 320ASounder	**1**	**2**	**2**
320A Sounding Rolls	**3**	**0**	**3**
Knudsen 320M (Arctic) Sounder	**1**	**1**	**2**
320M Sounding Rolls	**5**	**0**	**5**
Knudsen 3212 USB Sounder	**1**	**0**	**1**
Airmar/KEL571 Transducer	**2**	**0**	**2**
Airmar/KEL671 Transducer	**1**	**0**	**1**
Rectangular Transducer Drip Trays	**2**	**0**	**2**
AML SVPlus V2 Probe	**1**	**0**	**1**
AML Plus X Probe	**1**	**0**	**1**

Survey "Platforms":	Louie	Spares	Total
<u>**Radio & Communications Related Equipment**</u>			
Iridium 9505A Satellite Phone packed in Black Nylon Carry Case	**1**	**0**	**1**
Iridium 9505A Satellite Phone ASE Docking Station	**1**	**0**	**1**
Toshiba Laptop P.C. (Primary Unit for GMN Email)	**1**	**0**	**1**
Fuji Life Book Laptop P.C. (Spare Unit for GMN Email)	**1**	**0**	**1**
<u>**Data Logging & Related Equipment**</u>			
DAS 120Vac System (Single Beam)	**1**	**1**	**2**
Transtector 120Vac Power Bars	**2**	**0**	**2**
Go Book Laptop	**1**	**0**	**1**
Go Book 28Vdc Adapter (For Use in Helicopter)	**1**	**0**	**1**
Panasonic Tough Book Laptop	**1**	**0**	**1**
<u>**Misc. Items**</u>			
Helicopter 28Vdc Power Distribution Box (4 Outlet Type)	**1**	**0**	**1**
Applied Analytics 120Vac to 28Vdc Power Supplies	**1**	**1**	**2**
Dell laptop M6400			

Operating Software:
HyPack 7.0
CARIS 4.4A
CARIS Hips/Sips 7.0
Smartalk v2.27 software
Knudsen Echo Control Client v1.77 and Echo Control Server v1.55 software

Appendix 5: XSVO2 and SVP locations

Locations XSV02 (eXpendable Sound Velocity) and SVP plus (Sound Velocity Probe)

Latitude (N)	Longitude (W)	Time (GMT) Date		Type
N77.336667	**W159.646389**	**2011-234**	**23:22:00**	**SVP**
N82.915000	**W167.988611**	**2011-239**	**15:15:00**	**SV02**
N85.757778	**W168.095556**	**2011-241**	**16:48:36**	**SV02**
N85.924167	**W169.426667**	**2011-242**	**02:56:48**	**SVP**
N88.429722	**E157.416111**	**2011-245**	**03:46:14**	**SV02**
N87.825278	**E177.172778**	**2011-245**	**15:15:00**	**SV02**
N88.147500	**W157.677222**	**2011-248**	**00:20:53**	**SVP**
N83.932778	**W137.417500**	**2011-253**	**14:49:01**	**SVP**
N80.560833	**W131.353611**	**2011-259**	**19:59:57**	**SVP**
N80.369722	**W130.743611**	**2011-261**	**21:50:31**	**SVP+**
N79.132222	**W131.845833**	**2011-263**	**20:55:58**	**SV02**
N77.990833	**W137.093889**	**2011-264**	**22:13:42**	**SV02**
N75.338611	**W138.473611**	**2011-266**	**02:31:56**	**SV02**
N73.032778	**W138.055000**	**2011-267**	**02:35:33**	**SV02**
N70.689722	**W123.694444**	**2011-268**	**14:57:44**	**T-6**

Appendix 6 – CHS Daily Ship log

Activity Log Louis S. St-Laurent 2011

Line Length to date: JD 270 6823km

Total SVP Casts 19

casts	#
XCTD2	
XBT	1
XSV2	12
XCTD1	
SVP	6

Date	JD	Time (UTC)	Activity
18-Aug	230	1300	Board Ship
		1800	Fire up system – check if working
19-Aug	231	0930-1100	Safety Orientation
		1200	Mount backup computer w/ modified rack brackets (holes didn't line up)
		1300-1400	Ship Tour
		1700	Setup/Assemble/Test SVP - Working
20-Aug	232	0800	Trimble3 Start setup
		1000	Ship Anchor waiting for fuel off Tuk
		1100	Prep log/processing files fro 2011
		1300	Helicopter safety briefing - Mr. Biggar
		1300	Setup/test/tear down Trimble GPS for Tides
			- distance from top of deck rail to waterline at polemount holes starting port aft (by light pole)
			- shipped anchored - took rail to water measurements - best time to do
			- hole 1 5.60m
			- hole 2 5.65m
			- hole 3 5.68m
			- hole 4 5.60m
			- hole 5 5.58m
		1830	Ship weigh anchor proceeding to Healy rendezvous point
21-Aug	233	1432	Start HyPack Logging
		1545	Restart computer - screen frozen
		1547	start/stop logging sounder- turn off SEG-Y file config - start logging
		1603	restart logging
		1605	restart program
			Various sounder problem (continuous logging of HyPack)
		1635	Start Sounder recording again - log KEB files to Knudsen_KEB_2011 directory
		1648	adjust time sounder computer/HyPack computer
		1755	computer frozen - turn off sounder and back on
		~	light ice off and on
		1800	sync sounder/HyPack computer
			still problems with sounder file record times

		1838	sounder off - continue logging HyPack	
			open up sounder - check boards	
		1922	Sounder on - recording - continued logging HyPack	
			reset to temp directory for KEB files	
		2131	change HyPack to Polar Stereographic	
			restart HyPack survey w/ new protection 2332131.raw	
		2235	LF started - stacked display	
22-Aug	234	0024	sync times	
		0038	sounder quit working	
		0111	sounder not turning on	
		0133	sounder working	
		0142	sounder not working	
		0327	sounder back working	
		2222	ship stopped	
		2322	rosette SVP cast #1 ~750m 77°20'12"N 159° 38' 47"W	1
23-Aug	235	0000	GPS Flaky - invalid numerous times	
		0100	work on setting up remote control of 3.5kHz sounder	
		0900	ship waiting near rendezvous point	
		1445	ship heading to meet Healy	
		1645	Along side Healy	
		1741	switch hardware sounder in HyPack to single 12kHz	
24-Aug	236	0348	Louis sailing again - Healy following to starting point	
		0421	3.5 kHz sounder recording on laptop in forward lab	
		0636	Ship stopped - preparing air guns	
		0720	deploy streamer / air guns	
		0754	start air guns	
		0758	problems w/ streamer - retrieve gear	
		0828	return to start of line	
		0947	deploy gear again	
		1000	Start line 1 (pt10 - pt20)	
		1955	start Trimble GPS tide logging - Antenna height 1.18m from top of deck rail at aft most curtain post - port side - distance to waterline from top of deck rail 5.60m - total antenna height from water 6.78m (restricted to 4.00m or less for antenna height entry in Trimble receiver) Entered 1.18m in Trimble	
		2051	change GPS antenna ship	
		2100	finish changing GPS antenna (still jumpy)	
		2300	replace GPS receiver (still jumpy)	
25-Aug	237	2129	sync 12kHz sounder/computer to UTC time w/ rest of network	
		2200	reset computer/sounder time on 12kHz (keep an eye on it)	
		2200	Start line 2 (pt20 - pt21)	
26-Aug	238	1400	Start line 3 (pt21 - pt30)	
		1612	Change GPS antenna - beside bridge - just as bad/worse	
		1640	Adjust antenna - not much better	
		1700	check main GPS cable - okay - go back to original set up - GPS still jumpy	

		1751	Ship Draft 9.0m Forward 9.0m Aft	
27-Aug	239	0651	seismic mid air gun shut down	
		0728	another air gun shut down	
		0756	pull gear for repairs - ship stopped	
		0908	ship moving again	
		0934	ship stopped - repairs to seismic gear	
		1103	ship moving again	
		1110	streamer leakage - gear pulled - ship stopped	
		1515	XSV2 SVP Cast 2000m down in 3445m water 82°54'53.1952"N 167°59'20.3256"W	1
		1910	preparing seismic gear	
		1950	ship moving again - back to line	
28-Aug	240	2206	XSV2 SVP Cast 236m down in 1870m water 84°38'04.6590"N 167°17'33.6696"W	2
		2209	XSV2 SVP Cast 1812m down in 1870m water 84°38'22.2866"N 167°17'39.9167"W	3
29-Aug	241	0325-1346	lost bottom / found bottom at various times during the night	
		1000	ship stopped (pressure ridge)	
		1043	ship moving	
		1051	ship stopped	
		1112	ship moving	
		1647	ship stopped Healy coming back	
		1648	XSV2 SVP Cast 1829m down in 2298m water 85°45'28.2887"N 168°05'43.8110"W	4
		1711	ship moving	
		1815	stopped in ice	
		1900	moving again	
		1934	shipped stopped	
		2008	ship moving	
		2015	ship stopped	
		2039	ship moving	
		2043	shipped stopped	
		2110	ship moving	
		2120	ship stopped	
		2140	ship stopped	
		2207	ship stopped	
		2230	untangle gear	
30-Aug	242	0000	changed from Polar Stereographic to UTM zone 8 in HyPack	
		0130	shipped stopped - bring in all gear	
		0256	SVP cast in 3400m water on rosette 85°55' 27.3584" N 169° 25' 36.2776"W	2
		0900	3.5 kHz computer not connecting to server	
		1443	restart 3.5kHz computer to fix problem	
		1600	Gear In - ship moving	
		1744	ship stopped Healy Stuck	
		1828	ship moving	
		2010	ship stopped in ice	
		2044	ship moving	
		2050	ship stopped in ice	
		2129	ship moving	
		2206	ship stopped in ice	

		2258	ship moving	
31-Aug	243	0000	Ship stopped - Healy problems with steering	
		0024	ship moving	
		1455	Cross International Dateline	
		1559	ship stopped in ice	
		1625	ship moving	
		1655	Sounder for Heli cutting out with HF Heli Radio - change sounder	
		1745	Jon out testing sounder in Heli	
		1800	Sounder in Heli paper won't spool - change sounder again	
		1910	HyPack computer froze when connect USB drive - reboot	
		1920	HyPack computer restarted / logging	
		1930	Jon out sounding in Heli	
		2056	Jon return from sounding in Heli	
1-Sep	244	various	ship stop/start various times in the ice	
		2128	EOL for seismic survey	
		2200	XSV2 SVP cast down in 1200m of water 88° 11.4723064"N 143° 19.8185892" E	5
		2206	Reboot HyPack computer - reset entire system	
		2208	Louis starts breaking for Healy	
2-Sep	245	various	Breaking Ice - Sounders poor - writing soundings time/depth throughout shifts	
		0346	XSV2 SVP Cast 2000m down in ~2500m water 88° 25' 46.914"N 157° 24' 58.056"E	6
		various	Ship stop/start in ice either due to breaking or waiting	
		1515	XSV2 SVP Cast 2000m down in ~3500m water 87° 49' 31.42"N 177° 10' 21.93"E	7
		1730	stop/start logging - crossed back over International Dateline	
		~2200	Jon off sounding in Heli	
3-Sep	246	various	Breaking Ice - Sounders poor - writing soundings time/depth throughout shifts	
		0018	Jon return in Heli	
		0012	ship stopped for extended time 0012-0143	
		various	Ship stop/start several times while breaking ice	
		1450	Shipped stopped moving - stopped for AUV Operations	
		1617	AUV in water for ballast test - come back out	
		??	deploy AUV sled prior to AUV launch	
4-Sep	247	~0000	AUV back in water	
		???	retrieving sled prior to retrieving AUV	
		0115	moving to retrieve AUV	
		0130	retrieving AUV	
		0200	AUV out of water	
		0320	ship run boxes at night to calibrate AUV INS	
		various	ship stopped/started throughout night while breaking ice	
		1253	ship stopped - AUV sled and sub to go in water	
		1433	Sounders off for AUV testing/Operations	
		1500	Sounders still off for AUV Operations - descending towards bottom	
		1800	Sounders still off for AUV Operations - descending towards bottom	
		2002	Jon off to sound in Heli	
		2100	Sounders still off for AUV Operations - descending towards bottom	

		2200	Jon return from Sounding in Heli	
5-Sep	248	0043	Turn on Sounders again	
		0152	Turn off sounders for AUV	
		0300	Sounders off still for AUV retrieval	
		0600	Sounders off still for AUV retrieval	
		0900	Sounders off still for AUV retrieval	
		1200	Sounders off still for AUV retrieval	
		1500	Sounders off still for AUV retrieval	
		1800	Sounders off still for AUV retrieval	
		2015	AUV located - retrieving at bow of ship	
		2100	Sounders off still for AUV retrieval	
		2230	AUV on board	
		2257	Start Sounders again	
6-Sep	249	0020	SVP cast in 3800m of water on rosette 88° 08' 50.994"N 157° 40' 38.400"W (JD248 listed)	3
		various	ship stop/start moving during ice breaking for Healy	
		1755	Jon off sounding in Helicopter	
		2005	Jon return from sounding in helicopter	
		2110	Stopped for Helicopter to Healy	
		2130	Entered Draft of 8.7m in vessel config file for Sept 6 - JD249	
		2345	started moving again	
7-Sep	250	various	ship stop/start moving during ice breaking for Healy	
		2105	turning for air drop	
		2116	stopped for Air drop from C-130	
		2336	moving again after drop	
8-Sep	251	0000	restart HyPack / load updated line file / hard lock issue	
		various	ship stop/start moving during ice breaking for Healy	
9-Sep	252	0035	Fire & Boat Drill Start	
		0130	Fire & Boat Drill End	
		0140	Fire & Boat Drill Review Start	
		0200	Fire & Boat Drill Review End	
		various	ship stop/start moving during ice breaking for Healy	
		2147	DRAFT 8.8m entered in vessel profile for JD 252	
10-Sep	253	various	ship stop/start moving during ice breaking for Healy	
		1350	SVP cast in 2350m of water on rosette 83° 55' 58.2"N 137° 25' 03.54"W	4
		1720	start seismic line	
		various	ship stop/start while seismic in water	
		2125	Jon off sounding in Helicopter	
		2300	Jon back from sounding in Helicopter	
11-Sep	254	0024	End of line Seismic Gear coming out	
		0052	Breaking Ice for Healy	

		1015	ship electrical problems until 1434
		various	ship stop/start moving during ice breaking for Healy
12-Sep	255	0110	HIPS LOUIS2011 backed up to Office Computer to end of JD254
		0203	Healy in front to assess running on 2 shafts
		0203	End breaking ice for Healy
		0214	Seismic gear in water
		0658	Seismic gear out of water
		0714	Breaking ice for Healy
		various	ship stop/start moving during ice breaking for Healy
		1832	Jon off sounding in Helicopter
		1900	Seismic Gear in Water
		2005	Jon return from sounding in Helicopter
		2102	Jon off sounding in Helicopter
		2308	Jon return from sounding in Helicopter
13-Sep	256	0048	HIPS LOUIS2011 backed up on External Drive to end JD255
		various	ship stop/start moving through ice / waiting for Healy to break
		1141	stopped - waiting to take in gear
		1400	take in seismic gear
		1450	start breaking ice for Healy
		various	ship stop/start moving during ice breaking for Healy
		2000	heavy ice - stop/reverse/forward several times along the way
14-Sep	257	various	heavy ice - stop/reverse/forward several times along the way
15-Sep	258	0018	Jon off sounding in Helicopter
		various	heavy ice - stop/reverse/forward several times along the way
		0147	HIPS LOUIS2011 backed up on External Drive to end JD257
		0200	Jon return from sounding in Helicopter
		1500	test breaking for gear deployment
		1555	gear starting to go in water
		1630	gear in water - underway
16-Sep	259	0447	Pulling Seismic Gear out of water
		0507	Breaking for Healy
		1937	Stopped at AUV pool position
		1959	SVP cast in 3615m of water on rosette 80° 33' 38.85"N 131° 21' 13.11"W 5
		2230	SVP cast end
		2316	Restart 3.5 Laptop logging computer
		2340	3.5 laptop logging computer back in business
17-Sep	260	0035	Both 3.5kHz and 12kHz sounders off for AUV operations
		0300	Sounders off during AUV operations
		0600	Sounders off during AUV operations
		0900	Sounders off during AUV operations
		1200	Sounders off during AUV operations
		1500	Sounders off during AUV operations

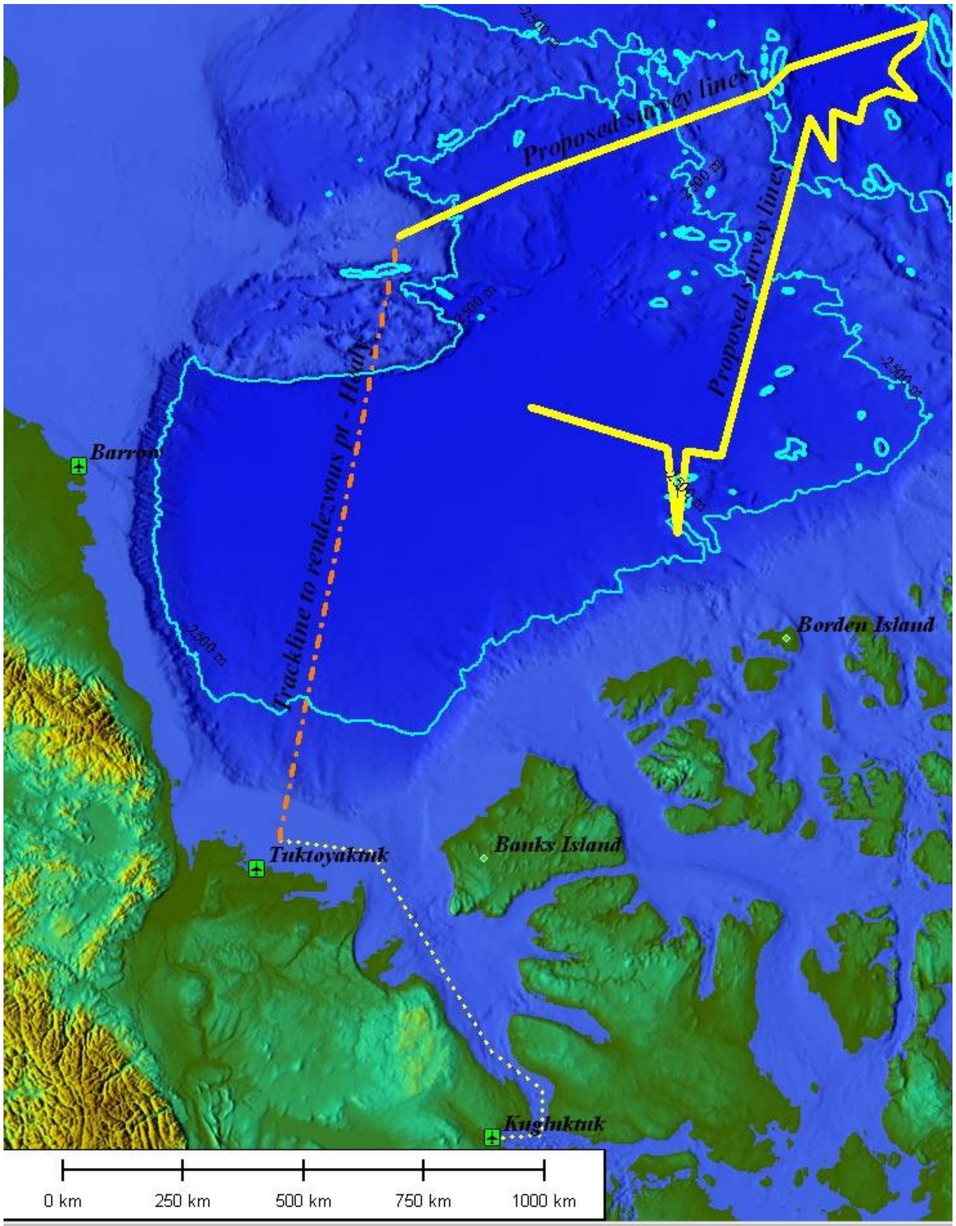
		1730	Unpack New SVP, set up / test	
		1800	Sounders off during AUV operations	
		1815	Installed new SVP in rosette	
		2100	Sounders off during AUV operations	
18-Sep	261	0000	Sounders off during AUV operations	
		0300	Sounders off during AUV operations	
		0600	Sounders off during AUV operations	
		0900	Sounders off during AUV operations	
		1200	Sounders off during AUV operations	
		1500	Sounders off during AUV operations	
		1800	Sounders off during AUV operations	
		1941	Sounders on - AUV beside ship	
		2030	AUV on board	
		2150	SVP cast in 3530m of water on rosette 80° 22' 10.818"N 130° 44' 37.092"W	6
		2310	restarted 12kHz sounder	
19-Sep	262	0050	12kHz restarted	
		1700	Stopped to check prop (centre)	
		1800	Stopped to check prop	
		2100	Stopped for prop options	
20-Sep	263	0000	Stopped for prop options	
		0300	Stopped for prop options	
		0600	Stopped for prop options	
		0900	Stopped for prop options	
		1200	Stopped for prop options	
		1500	Stopped for prop options	
		1800	Stopped for prop options	
		1836	Rafted to Healy for BBQ	
		2055	XSV2 SVP Cast 2000m down in 3597m water 79° 07' 56.45"N 131° 50' 45.10"W	8
21-Sep	264	0000	Science Over - heading south	
		0500	Ship moving again following Healy	
		2112	stop to check prop	
		2213	XSV2 SVP Cast 2000m down in 3738m water 77° 59' 27.02"N 137° 05' 37.62"W	9
		2218	moving	
22-Sep	265	1748	stopped to check prop until 1930	
		1930	still stopped until 2030	
		2030	depart from Healy	
23-Sep	266	0232	XSV2 SVP Cast 744m down in 3600m water 75°20'19.38"N 138°28'24.84"W	10
		0239	XSV2 SVP Cast 586m down in 3600m water 75°19'36.48"N 138°27'32.64"W	11
		1530	stopped to check prop until 1745	
		1900	stopped to check prop until 2000	
		2225	Entered Draft of 8.5m in vessel config file for Sept 20 - JD263	

24-Sep	267	0020	HyPack Computer reboot itself after plugging in USB drive	
		0032	HyPack logging again	
		0235	XSV2 SVP Cast 1962m down in 2984m water 73°01'58.20"N 138°03'18.00"W	12
		0439	stop/start 12kHz sounder (logging error message)	
25-Sep	268	1457	XBT SVP Cast 460m down in 460m water 70°41'22.59"N 123°41'40.17"W	1
26-Sep	269	0006	Restart HyPack w/ new chart - UTM Zone 12	
		0231	slowed down to transfer items to Laurier	
		1206	HyPack crash - restart computer	
		1232	Restart HyPack	
27-Sep	270	2030	At Anchor	
		2031	Sounders Off - Stop Logging	

Appendix 7 – CHS Weekly Reports

UNCLOS – CCGS Louis S. St Laurent 2011 – Canada Basin
Highlights: departed Burlington, bathymetry program started

Weekly Summary: August 17 to 21
Aug 17 Wednesday – CHS staff traveled to Edmonton, overnight for charter flight next day
Aug 18 Thursday –staff departed on charter flight to Kugluktuk, departed shortly after 9:30 AM, direct flight, arrive at Kugluktuk midday, onboard ship early afternoon, crew change arrived mid afternoon, boat and fire drill that evening, departed for Tuktoyaktuk for fuel transfer



Aug 19 Friday – started computers, sorting equipment, training, ship orientation for staff, issues with the Knudsen 320B/R sounder shutting down for unknown reasons, setting up Trimble R8 GPS receiver for logging data for Tides section, enroute to Tuk
Aug 20 Saturday – sitting off Tuk at anchor waiting for fuel barge in the AM, installing Trimble R8

receiver, reconfiguring older Knudsen sounder (320B/R) to run just the 12.5 kHz and the new Knudsen unit (3260) to run the 3.5 kHz from aft seismic lab, the graph (return) appears to be better represented on the new Knudsen (3260), departed early evening to rendezvous with Healy, no fuelling took place
Aug 21 Sunday – enroute to rendezvous with Healy, into ice now, still problems with 320B/R sounder stopping for unknown reasons, working on connecting the Knudsen 3260 to the aft lab, sounding operations started

Plans: start seismic / bathymetry survey operations 24/7 after rendezvous with Healy Monday evening

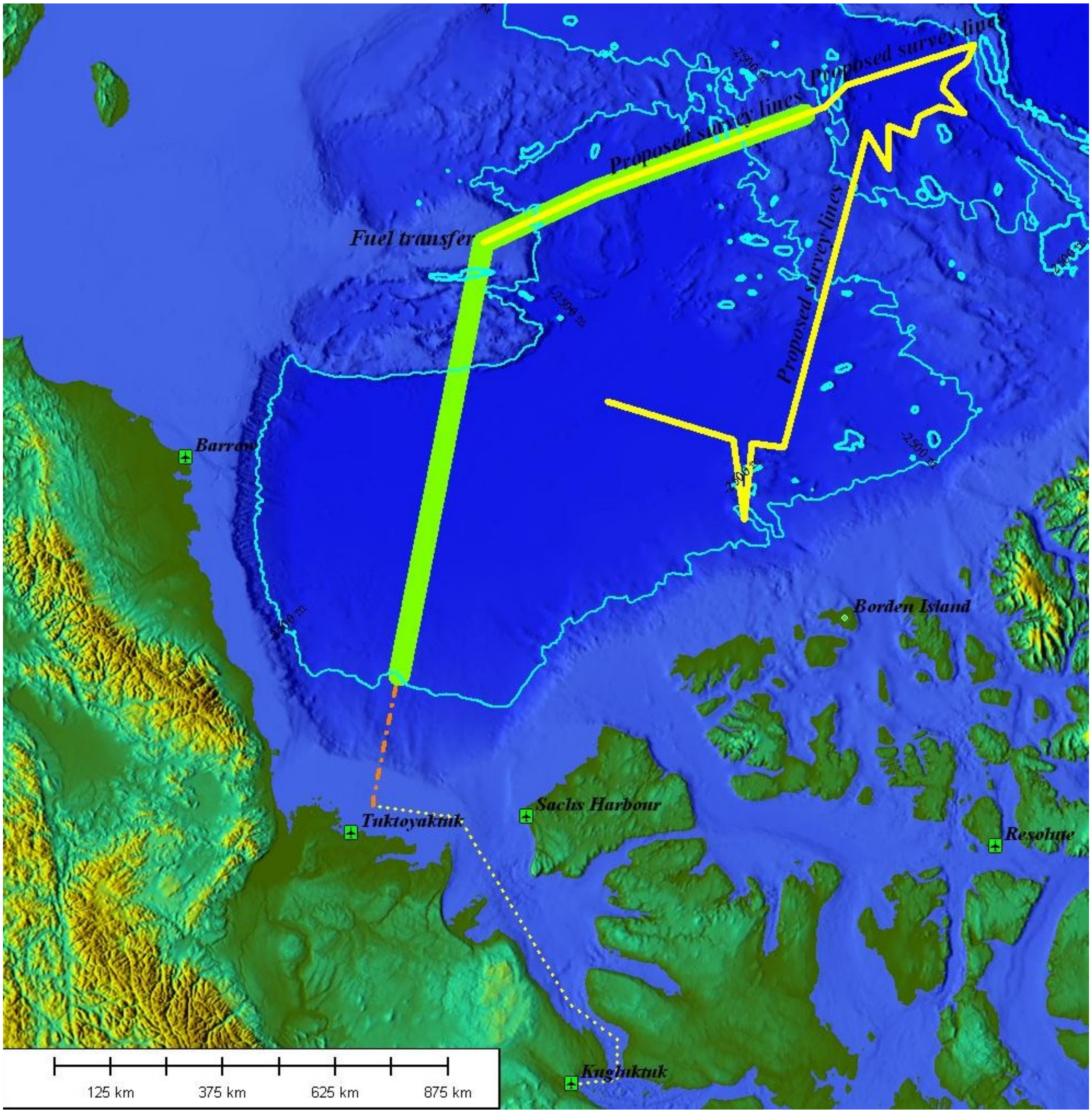
The Plan: yellow lines – proposed survey lines

UNCLOS – CCGS Louis S. St Laurent 2011 – Canada Basin
Highlights: bathymetry and seismic program is fully operational, 1857 line kilometres collected to date.
Blog site started at www. Science.gc.ca/Blogs-WSE6EBB690-1 En.htm

Weekly Summary: August 22 to 28
Aug 22 Monday – enroute to rendezvous point to meet Healy, Knudsen 320BR sounder is problematic starting and stopping, installed deep water SVP probe on water sampling rosette, SVP cast was done to 750 m, a laptop was setup in the forward lab to control the Knudsen 3260 which is using the 3.5 KHz transducer, the 3.5 kHz transducer performs better on the new Knudsen 3260, remote access software was installed to be able to monitor/control the sounder from aft seismic lab, the Knudsen320BR is operating on the 12 kHz and the new Knudsen 3260 is operation the on 3.5 kHz transducer, experiencing GPS position jumps/drop outs
Aug 23 Tuesday – arrived at start point around 3AM, along side Healy at 9:30, refuelling Louis, personnel exchange etc., changed output format of Knudsen 320BR sounder to singe frequency "HF" nema string for NRCan group, GPS jumps continue, rearranged CHS monitor setup for sounding operations, ships separated at 20:30, heading for start of line, arrived early morning deployed seismic gear problem with streamer, recovered and spare was deployed, operational approximately 2AM, CHS sounding ops 24 hour now, Andrew working the night shift
Aug 24 Wednesday – sunny day, sounding and seismic ops, everything ran well all-night, setup R8 and logging, still problems with GPS position outages, replaced antenna then receiver no differences were noticed, email Bob for suggestions
Aug 25 Thursday – foggy day, sounding and seismic ops, Bob returned email, tried his suggestions, still outages, position jumps, discussions with captain and helicopter pilot/engineer about flying in additional parts for helicopter Navlink to ship setup,

the helicopter was limited to 16 miles from the ship but now is capable of working 50 miles from the ship with the Navlink, system is working but limited to one frequency on the HF, many other navigation options and communications available as backup, working on spot sounding plan
Aug 26 Friday – foggy day temperature around zero, sounding and seismic ops, ran new antenna cable and tried new antenna to improve GPS, no difference, metered original antenna cable no short, another Arctic mystery, working on the helicopter sounding installation,
Aug 27 Saturday – sun and cloud, sounding and seismic ops, early morning problems with air guns then streamers, stopped until noon for repairs, a XSV02 cast (expendable) to 2000m while stopped, helicopter spot sounding setup competed
Aug 28 Sunday – overcast and fog, sounding and seismic ops, into heavy ice now, a XSV02 cast (expendable) to 1800m was done

Plans: continue seismic / bathymetry survey operations working north, on southern lines deploy AUV and start helicopter spot sounding program



Yellow lines – proposed survey lines
Green highlighted lines are sounded to date

UNCLOS – CCGS Louis S. St Laurent 2011 – Canada Basin
Highlights: bathymetry and seismic program is operational, 2720 line kilometres collected to date along with 21 helicopter spot soundings. 4.9 hours flown, AUV deployed twice and recovered due to problems
Blog site at www. Science.gc.ca/Blogs-WSE6EBB690-1 En.htm

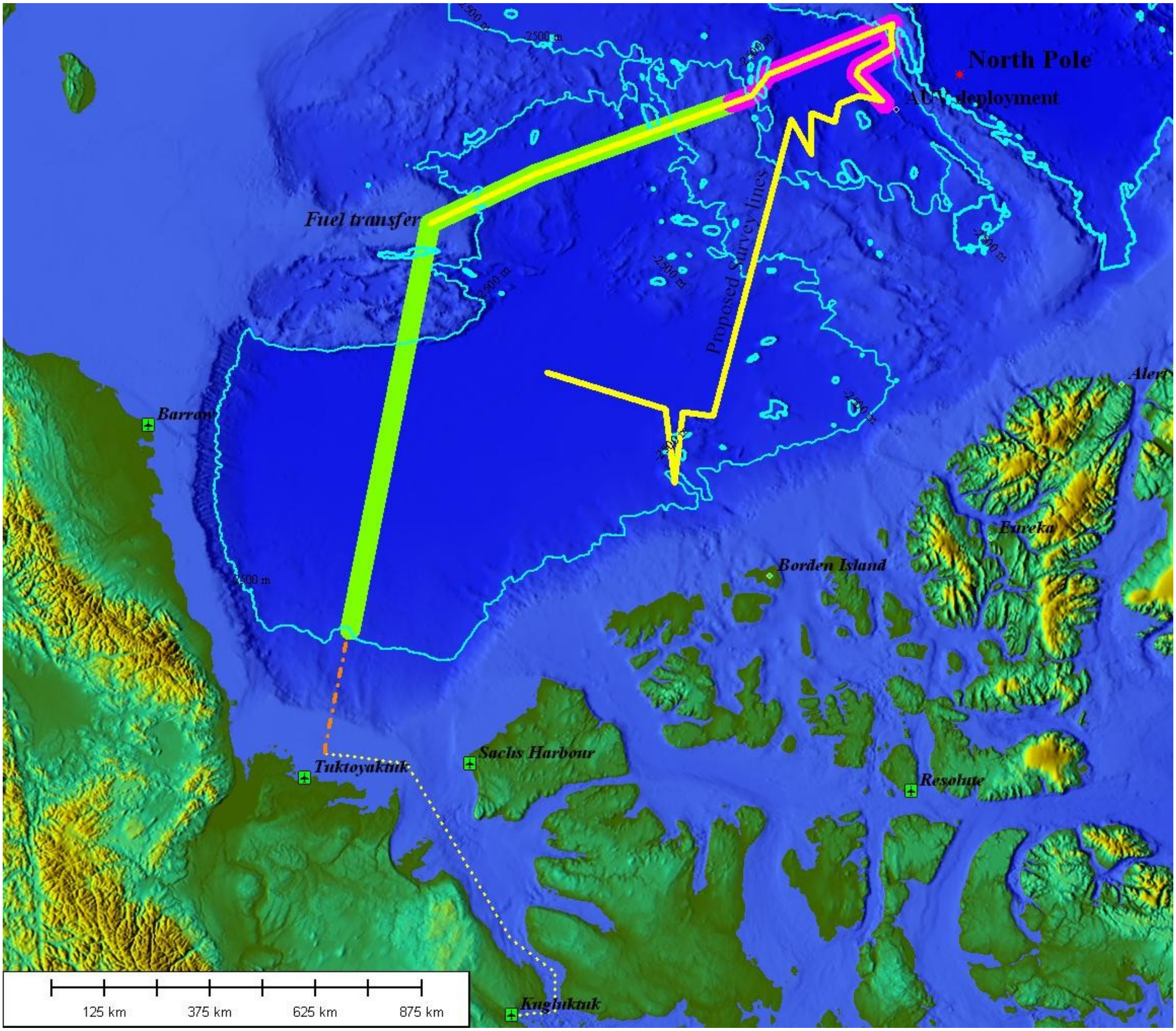
Weekly Summary: August 29 to Sept 4

Aug 29 Monday – cloud and sun, sounding and seismic ops, heavy ice several stops and Healy required to break us out, tried to recover seismic gear to take out twists in cables, problems, redeployed and damaged streamer, recovered around 7PM, estimate for repairs is 12 hours, XSV early in the day, deep water SV late day/evening after gear onboard, Hypack presentation software is not working properly this far north but still able to log
Aug 30 Tuesday – snowing, seismic gear back in water around 9AM, continuing north on line, heavy ice many stop and starts, helicopter spot soundings work is possible if weather clears
Aug 31 Wednesday – light snow, sounding and seismic ops, crossed over international date line, created problems with HyPack software and Caris processing, Helicopter spot soundings but problem with Knudsen 320M resetting with helicopter HF transmission, then Knudsen 320A paper take up not working properly, then tried second Knudsen 320M and working, 2 spot soundings completed then weather closed in
Sept 1 Thursday – sun and cloud cooler, sounding and seismic ops, seismic program ended at 15:00, pulled gear, XSV cast, Louis lead for Healy to collect multibeam data, another XSV cast that evening, made 88-27-30 North
Sept 2 Friday – overcast, sounding ops –data is sparse because of ice breaking, XSV cast in the morning, helicopter flight in afternoon, Knudsen 320M sounder blew a fuse, repaired on the ice and 7 spots soundings collected
Sept 3 Saturday – sunny and cool -10C, stopped in ice to deploy AUV, AUV recovered because of problems, ship ran a box pattern overnight to align the inertia navigation system in AUV
Sept 4 Sunday – stopped in ice, deployed AUV early morning, running 6 hour of tests before decision on mission go/no-go, sounders off during testing, helicopter spot soundings flight, 12 spots sounding collected, AUV recover late afternoon with problems

Plans: seismic / bathymetry survey operations are on suspended until AUV mission is completed. Helicopter spot sounding program will continue at next opportunity. O-buoy project planned to be deployed during AUV ops.

Survey Plan:

Yellow lines – proposed survey lines
Highlighted lines are sounded to date



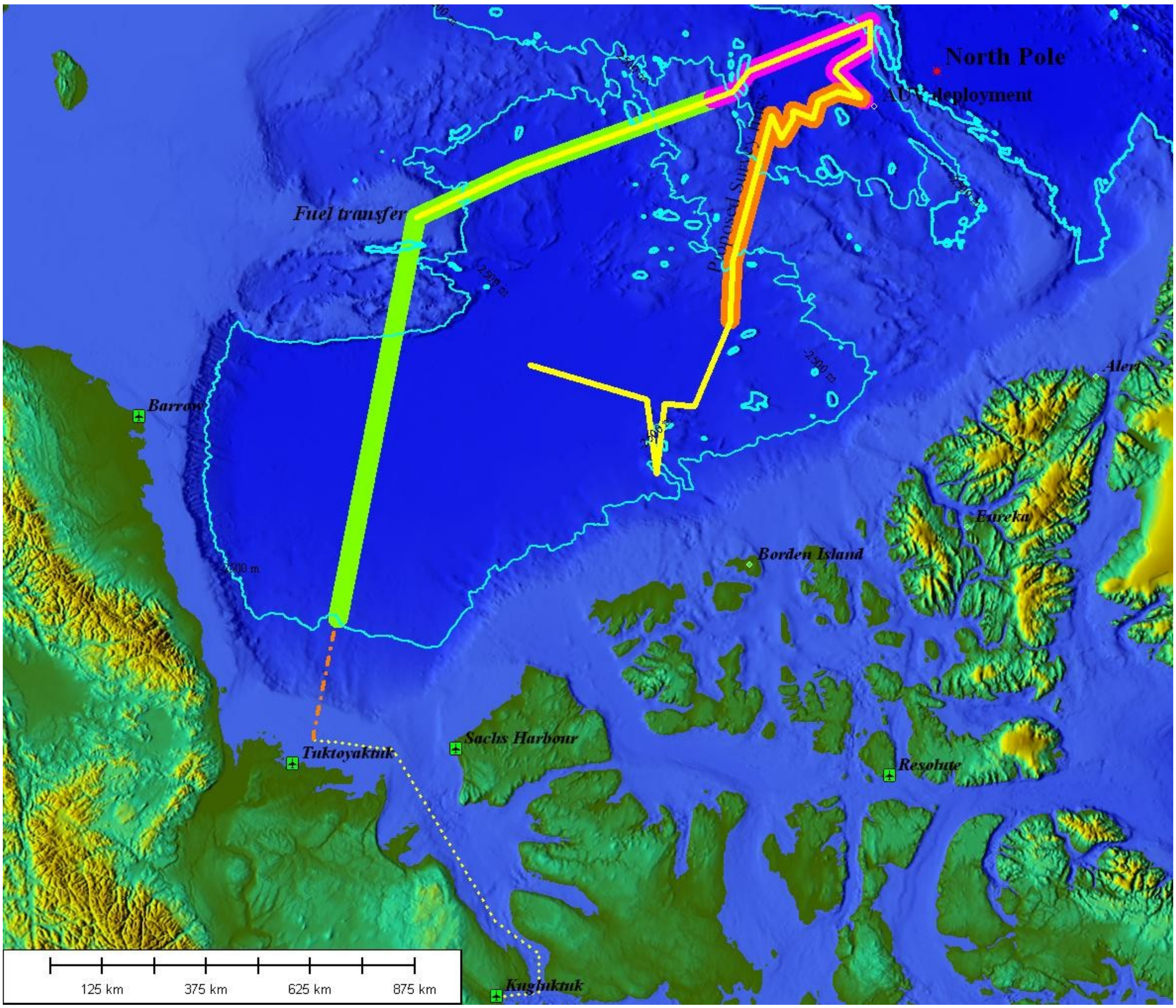
UNCLOS – CCGS Louis S. St Laurent 2011 – Canada Basin

Highlights: bathymetry program continues, 3711 line kilometres collected to date along with 40 helicopter spot soundings. 8.7 hours flown, AUV recovered Monday problems with forward-looking sonar system, O-Buoy successful deployed, Louis is escorting the Healy during this leg. This will provide a better quality of multibeam and sub bottom data.
Blog site at www. Science.gc.ca/Blogs-WSE6EBB690-1 En.htm

Weekly Summary: August 29 to Sept 4
Sept 5 Monday –AUV recovery ops all day, O-buoy was setup on the ice, The O-Buoy is a self container solar powered unit frozen in the sea ice that measures ozone, carbon dioxide and bromine oxide in the air and metrological parameters as well as records buoy/ice drift (GPS) along with sky and ice conditions (web camera). Collected information is transferred to Environment Canada via satellite on a daily schedule, late day deep SVP cast, sounding ops started around 20:30 with Louis escorting Healy
Sept 6 Tuesday – sun and cloud cool, sounding op, Louis lead for Healy, 1 helicopter flight 10 spots soundings collected, 2.2 hours flown
Sept 7 Wednesday – overcast light snow windy cool, sounding ops 24/7, Louis lead ship working south, standby for helicopter work, air drop by US Coast Guard C-130 mid afternoon with parts for the Healy and helicopter radio parts
Sept 8 Thursday – overcast light snow/fog, sounding ops 24/7, started south on the long transect, Louis lead ship standby for helicopter work, fire and boat drill after supper
Sept 9 Friday - overcast light snow/fog, sounding ops 24/7, heading south, standby for helicopter work
Sept 10 Saturday – cloud, snow and wind, seismic gear in the water at 10:15, sounding and seismic ops started, Healy in lead, early morning SVP cast, 1 flight 9 spot soundings collected, 1.6 hours flown, seismic gear recovered at 18:00 because of heavy ice conditions, sounding ops continue
Sept 11 Sunday – snow and wind, sounding ops 24/7, Louis down for repair with electrical problem for 4 ½ hours overnight operational at 7:30 running south as lead ship

Plans: bathymetry survey operations to continue, seismic gear may be deployed if ice conditions improve, an AUV mission is tentative if open water/ice conditions exist for deployment/recovery. Helicopter spot sounding program will continue at every opportunity.

Survey Plan:
Yellow lines – proposed survey lines
Highlighted lines are sounded to date



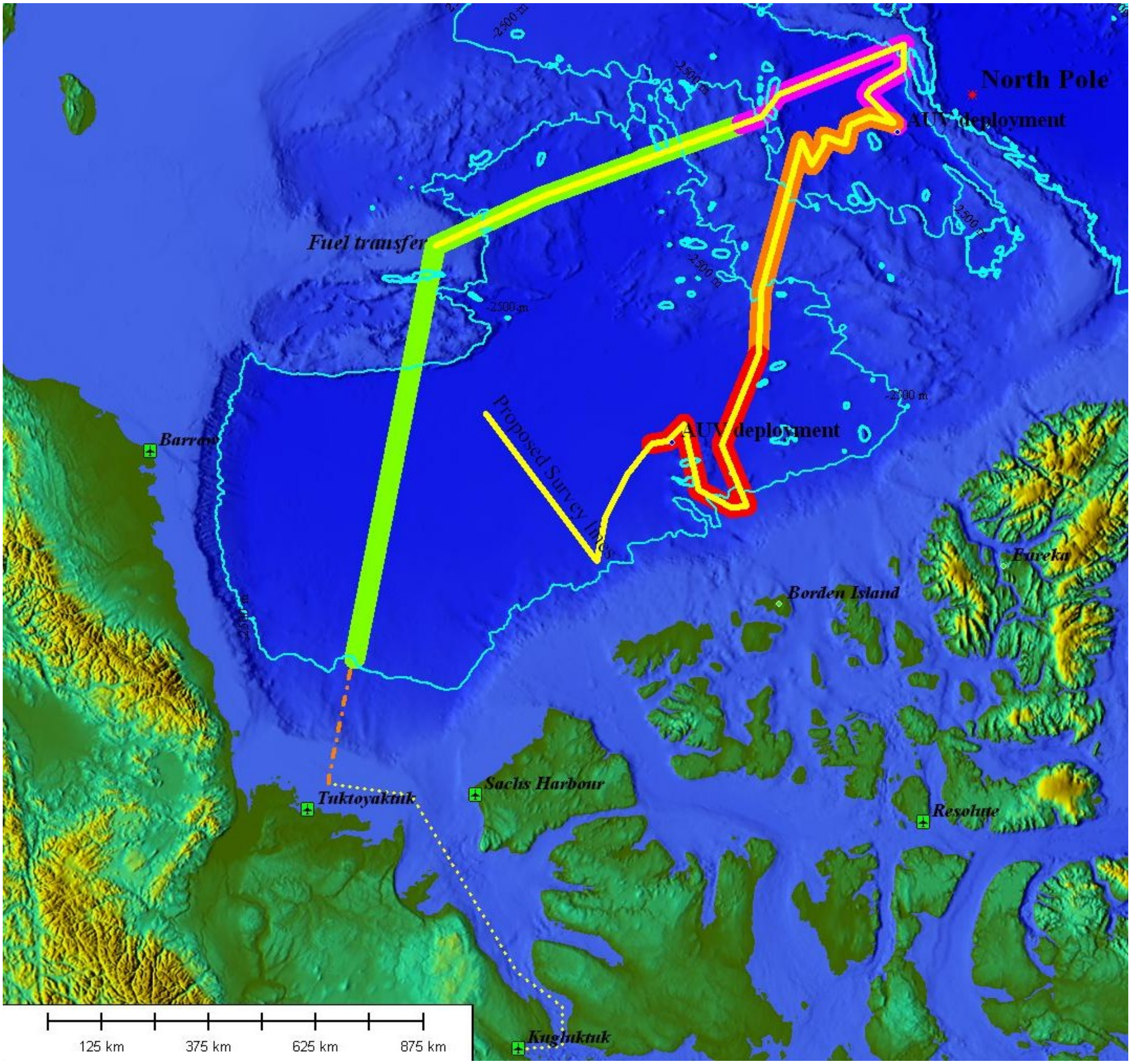
UNCLOS – CCGS Louis S. St Laurent 2011 – Canada Basin

Highlights: bathymetry/seismic program continues, 4399 line kilometres collected to date along with 75 helicopter spot soundings. 14.1 hours flown, AUV deployed and successfully recovered. Healy continued surveying the Sever Spur while Louis on standby for AUV ops, sounding and seismic operations resumes
Blog site at www. Science.gc.ca/Blogs-WSE6EBB690-1 En.htm

Weekly Summary: Sept 12 to 18
Sept 12 Monday – overcast, sounding ops, running south on long leg, 2 flights 20 spot sounding collected, 1.5 hrs and 2.2 hrs logged, seismic gear deployed in the morning
Sept 13 Tuesday – sun and fog cool, sounding ops, stuck the in ice over night stopped seismic ops around 4 AM recovered gear at 7 AM, lead for Healy, helicopter work on hold because low on hours and 100 maintance check scheduled, slow going in heavy ice
Sept 14 Wednesday – sun, cloud, cool -12C, sounding ops, slow moving average about 7 k/hour, one late day helicopter flight to tie in previous spot soundings to ship track, 14 spots, 1.7 hours logged
Sept 15 Thursday – fog, seismic gear in water around 9AM, sounding and seismic ops, recovered seismic gear at 10PM, heavy ice and guns issues, broken air lines, back tracked over Sever Spur with multibeam
Sept 16 Friday – cold day, sounding ops, stopped around 13:30 in pool (no ice/thin) to deploy AUV, deep water SVP cast, problem with 3.5 kHz laptop required a reboot, AUV departs around 19:00, Healy continuing sounding ops over the Sever Spur
Sept 17 Saturday – stopped, AUV ops, changed out SVP probe with new unit for testing, AUV returned in the evening on standby overnight
Sept 18 Sunday – AUV recovery mid afternoon, deep water SVP cast, Healy returns, sounding ops and seismic gear to be deployed if ice conditions improve

Plans: bathymetry/seismic survey operations to continue, on Sept 20 Louis and Healy will raft together for data transfer and social event, Helicopter spot sounding program will continue at every opportunity. Survey ops will continue until Sept 23/24 then make way for Kugluktuk and crew change scheduled for Sept 29.

Survey Plan:
Yellow lines – proposed survey lines
Highlighted lines are sounded to date


North Pole
AUV deployment
Fuel transfer
-2500 m
Proposed Survey lines
AUV deployment
Barrow
Eureka
Borden Island
Sachs Harbour
Tuktoyaktuk
Resolute
Kugluktuk
125 km
375 km
625 km
875 km

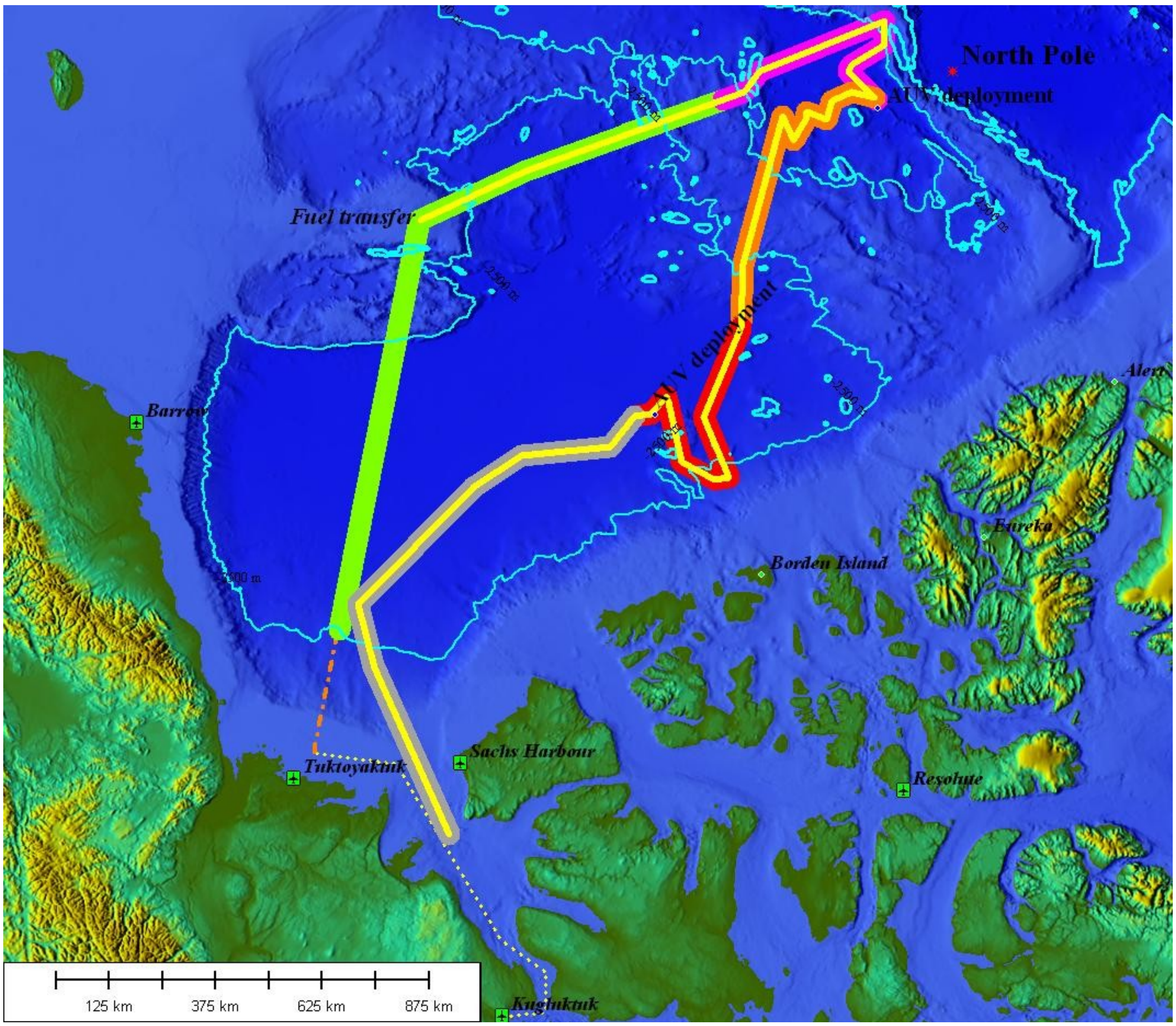
UNCLOS – CCGS Louis S. St Laurent 2011 – Canada Basin

Highlights: bathymetry program continues seismic program ends 5 days early because of center shaft propeller problems, 5854 line kilometres collected to date along with 75 helicopter spot soundings with 14.1 hours flown – spot sounding program completed, AUV deployed and successfully recovered. Healy departs from Louis on Sept 22.
Blog site at www. Science.gc.ca/Blogs-WSE6EBB690-1 En.htm

Weekly Summary: Sept 19 to 25
Sept 19 Monday – snow fog wind, sounding ops over night, attempted seismic gear deployment at 9AM, problems discovered with centre shaft propeller - sliding off, seismic program ends, sounding ops continue
Sept 20 Tuesday – raft up to Healy, social event, people/data transferred, separated around 9PM heading south west following Healy, sounding ops resumes
Sept 21 Wednesday – sounding ops, heading southwest following Healy, stopped mid morning to check propeller for movement, XSV02 cast was done, into lighter ice
Sept 22 Thursday – sounding ops, stopped around noon to check propeller for movement, Healy departs heading for Dutch Harbour, 2 XSV02 casts both only down to 750m, heavier ice overnight
Sept 23 Friday – sounding ops, stopped at 8 AM to check propeller for movement, XSV02 cast
Sept 24 Saturday – sounding ops, started organizing/packing of survey equipment
Sept 25 Sunday – sun and fog, sounding ops, XSV-T6 cast in the morning

Plans: bathymetry survey operations to continue until Cambridge Bay. (Sept 27th). Pack and store equipment. Crew and science staff charter flights scheduled for Sept 29. CHS staff will fly to Edmonton overnight and fly commercial to Toronto on Sept 30th.

Survey Plan:
Highlighted lines are sounded to date



Appendix 8 - Weather and Ice Conditions

Barbara Molyneaux

August 18 – Crew Change – St. John's to Iqaluit to Kugluktuk (10 NM)

~ Prior to joining the vessel, ice and weather was assessed in order to prepare for UNCLOS operations. Upon arriving and crew change completion, the vessel lifted her anchor and began her steam towards Tuktoyaktuk for fuel transfer via NTCL composite unit. Vessel met by crew at anchor in Kugluktuk Harbour. A meeting conducted with science staff and Commanding Officer to discuss ship schedule and briefing times.

Weather: Trough from 999mb Low pressure system extending to the northwest over Banks Island with the center of system located over Kugluktuk and tracking to the east.
~ Winds: Westerly 15-20 increasing to 25-30 by late afternoon
~ Seas: 3' chop due to protection of harbour
~ Skies: Overcast
~ Bar: 1002 hPa and falling then rising slowly
~ Temp: High of 10*C; Low of 8*C

***Ice Conditions*:** Ice free

August 19 – Bound for Tuktoyaktuk (390 NM)

Weather: Center of 999mb low pressure system located to the east of Kugluktuk with a trough extending to the northwest over Banks Island becoming quasi-stationary. 1019 mb high pressure system located at 72N 172W with a ridge extending to the east then southeast over the Mackenzie Delta tracking slowly to the east with a new center developing over central Mackenzie River. This high pressure system will not influence the area long as she dissipates due to incoming low pressure systems.
~ Winds: NE 5-10 backing and increasing to NW 25-30 then backing to SW
~ Seas: 2' chop
~ Skies: Overcast then cloudy with good visibility
~ Bar: 998 hPa and rising then steady
~ Temp: High of 8*C; Low of 2.5*C

Ice Conditions: Ice free

August 20 – Departed Kugluktuk Bound for Healy Rendezvous (238 NM)

~ 1013hrs - Anchored off Tuktoyaktuk – 69* 50.3'N 133* 12.9'W
~ 1830hrs - Fuelling cancelled due to inclement weather for NTCL composite unit
~ Haul anchor and commence steam towards rendezvous point.

Weather: Quasi-stationary 1003mb continues to fill. Remnants of the 1012 mb high, with the center now located over Baillie Island, is absorbed as the day progresses. A 984 low approaching from the Alaskan Aleutian Islands will track to the east towards Kodiak Alaska then to the north as it extend a small trough to the north over Demarcation Point.
~ Winds: SW 5-10 then veering and increasing to become E 25-30
~ Seas: 2' chop building to 1-2 meter easterly swell
~ Skies: Overcast skies becoming cloudy with good visibility
~ Bar.: 1010 hPa and falling
~ Temp: High of 10*C; Low of 6*C

Ice Conditions: Open water

August 21 – Enroute to Healy rendezvous point (355 NM)

~ 0911hrs – First ice encountered at 72* 10.5'N 137* 24.2'W
~ 1415hrs – XCTD – 73* 20.0'N 141* 48.1'W

Weather: 981mb low pressure system will deepen slowly before filling as it continues to track to the north over Demarcation Point then over the ship's position. A deep 1017mb high pressure system developed just north of Resolute forcing the two air masses to merge before relocating east of Ellesmere Island to track over central Greenland.
~ Winds: E 25-30 backing and easing to N 15-20
~ Seas: Swell reduced due to close proximity of ice pack
~ Skies: Overcast with periods of light drizzle
~ Bar.: 991 hPa and falling steadily
~ Temp: High of 8*C; Low of 0.5*C

Ice Conditions: Light ice conditions of 2/10 multiyear with a trace of thick first year greeted the vessel by mid morning. Conditions remained fairly uniform as the vessel picked its way through the ice and in and out of strip and patches of 6-8/10 predominant multiyear ice embedded with Thick First Year.

August 22 – Bound for Healy rendezvous point (309 NM)

~ 0911hrs – XCTD – 76* 21.3'N 154* 48.6'W
~ 1415hrs – XCTD – 77* 10.4'N 158* 48.7'W
~ 2007hrs – XCTD – 77* 49.6'N 161* 54.9'W (Position approximate)
~ 1619hrs – CTD – 77* 20.2'N 159* 38.7'W

Weather: 982mb low pressure system with the center being located at 74N 147W will track slowly to the northwest and has started to fill. Another 985mb low pressure system developed over Slave Lake and will track to the north towards Banks Island.
~ Winds: N 15-20 veering and increasing to E 15-20
~ Seas: 1.5' chop continues to subside
~ Skies: Patchy fog and overcast with periods of light rain
~ Bar.: 981 hPa and rising steadily
~ Temp: High of 0*C; Low of -0.5*C

Ice Conditions: Vessel steamed through fairly easy conditions in 2 to 3/10 of Multiyear with a trace of Thick First Year for most of the day. By late evening, she entered a field of heavier concentration in 5 to 6/10 of predominant Multiyear with embedded Thick First Year before easing again to looser ice concentrations of 2-3/10. Conditions remained loose with no problems encountered.

August 23 – Arriving at Healy rendezvous point (62 NM)

~ 0842hrs – XCTD – 78* 36.1'N 163* 46.2'W (Position approximate)
~ 1042hrs – Commence fuel transfer off of Healy – 78* 35.0'N 163* 36.9'W
~ 2341hrs – Seismic streamer deployed. Commence start of UNCLOS 2011 science program
~ A meeting conducted with science staff and Commanding Officer to discuss ship schedule and briefing times.

Weather: Low pressure system near 78n 170w moving westward with a trough extending to the southeast from the low.
~ Winds: West 5-10 then easing to light and variable
~ Seas: Vessel in ice
~ Skies: Overcast stratus then becoming cloudy
~ Bar.: 991 hPa and rising steadily

~ Temp: High of 2.5*C; Low of -2.5*C

Ice Conditions: Vessel easily navigated in very light and loose conditions of 2 to 3/10 of Multiyear with embedded Thick First Year for the majority of the day with only a few strips of 4 to 5/10 of Multiyear with embedded Thick First Year. No ice pressure issues were encountered during fuelling or during the deployment of seismic gear.

August 24 – 78*13.0'N 164* 17.7'W (90 NM)

~ 0322hrs – Sonobuoy – 78* 13.6'N 164* 17.8'W
~ 0338hrs – XCTD – 78* 14.58'N 164* 18.85'W
~ 1129hrs – CG360 Navlink trials
~ 1140hrs – Sonobuoy – 79* 03.7'N 165* 01.39'W
~ 1210hrs – CG360 Navlink/Communication trials
~ 1225hrs – XCTD – 78* 48.5'N 164* 47.5'W (Position approximate)
~ 1355hrs – XCTD x2 – 78* 54.0'N 164* 52.6'W
~ 1713hrs – XCTD x2 – 79* 06.7'N 165* 04.4'W
~ 2137hrs – XCTD – 79* 23.9'N 165* 20.6'W

Weather: A deep 1036mb high pressure system over central Greenland has a broad trough extending from the North Pole to 77N 175W in a northwest line. 1005mb low continues to fill over 79N 149E and has become quasi-stationary.
~ Winds: N 5-10
~ Seas: Vessel in ice
~ Skies: Fine and clear becoming cloudy with fog patches
~ Bar.: 1010 hPa and rising then steady
~ Temp: High of 1*C; Low of -3.5*C

Ice Conditions: Total ice concentration started to increase to 7/10 immediately upon starting the seismic towing to become 2/10 of multiyear and 5/10 of Thick First Year. No ice pressure issues were encountered.

August 25 – 79* 33.0'N 165* 30.0'W (100 NM)

~ 0150hrs – XCTD – 79* 40.9'N 165* 38.2'W (Position approximate)
~ 0803hrs – XCTD x2 – 80* 04.5'N 166* 04.0'N
~ 1218hrs – Sonobuoy – 80* 22.59'N 166* 25.6'W
~ 2001hrs – XCTD – 80* 54.8'N 167* 07.9'W

Weather: High pressure ridge extending across 80N/177W then to 7430N/17430E then extends to the southwest while moving westward during the period. Light to moderate north to northeasterly flow east of ridge.
~ Winds: N 5-10 then increasing to 10-15
~ Seas: Vessel in ice
~ Skies: Over cast in shallow fog
~ Bar.: 1015 hPa and steady
~ Temp: High of 0*C; Low of -1*C

Ice Conditions: Ice field began to increase in concentration by mid morning to 6-7/10 of predominantly Thick First Year with a 1-2/10 of Multiyear. All puddles were frozen with thaw holes visible under the ice.

August 26 – 81* 11.0'N 167* 31.7'W – (102 NM)

~ 0809hrs – XCTD x2 – 81* 43.9'N 168* 15.9'W (Position approximate)
~ 0936hrs – CG360 takes USCGC Healy drafts
~ 0956hrs – Sonobuoy – 81* 52.5'N 168* 14.3'W
~ 1459hrs – XSV (Velocity Measuring Device) – 82* 13.2'N 168* 04.8'W (Position approximate)
~ 1818hrs – Sonobuoy – 82* 27.2'N 168* 06.1'W

~ 2355hrs – Seismic airgun shut down – 82* 51.5’N 167* 58.8’W

Weather: North-south ridge of high pressure along 180W Friday morning moving slowly westward.
~ Winds: S 5-10 backing to E 5-10
~ Seas: Vessel in ice
~ Skies: Stratus fractus and alto stratus with fog patches by late morning
~ Bar.: 1016 hPa and steady
~ Temp: High of 0.5*C; Low of 0*C

Ice Conditions: Ice concentration continued to increase throughout the day. The vessel steamed through a small patch of 9+/10 in the early hours of the morning and gradually decreased to 8/10 of predominant Thick First Year with only a trace of Multiyear by late morning. As the day progressed, the concentration increased again to 8/10 of Thick First Year with 1-2/10 of Multiyear. Ridging was starting to be noticed (trace to 1/10) as the concentration again increased. The field consisted of many frozen ponds with thaw holes still visible under the new ice and easily navigated.

August 27 – 82* 51.5’N 167* 58.8’W (52 NM)
~ 0055hrs – Recover seismic gear – 82* 54.6’N 167* 57.4’W
~ 0426hrs – Redeploy gear and found streamer leaking – 82* 54.9’N 167* 58.9’W
~ 0443hrs – Seismic gear recovered
~ 0613hrs – Redeploy gear and found streamer leaking – 82* 54.8’N 167* 58.4’W
~ 0639hrs – Seismic gear recovered to be fixed
~ 1223hrs – Redeploy seismic gear – 82* 55.1’N 168* 00.7’W
~ 1241hrs – UAV (Unmanned aircraft)
~ 1326hrs – XCTD – 82* 58.3’N 167* 57.6’W (Position approximate)
~ 1415hrs – Sonobuoy – 83* 18.23’N 167* 51.04’W via CG360
~ 1449hrs – Ice recco CG360 (1 hour 44 minutes)
~ 1923hrs – XCTD – 83* 22.03’N 167* 49.68’W

Weather: Quasi-stationary north-south ridge of high pressure along 180W.
~ Winds: Steady at NE 5-10
~ Seas: Vessel in ice
~ Skies: Overcast then clear skies with shallow fog patches
~ Bar.: 1016 hPa and steady then falling slowly
~ Temp: High of -1*C; Low of -2*C

Ice Conditions: Ice concentrations remained fairly uniform throughout the day in a field of 9+/10 with only a trace of ridging. The field consisted of 2/10 Multiyear and 7-8/10 of Thick First Year with no pressure issues encountered. Ice field was in an advanced state of decay and easily navigated with all puddle frozen and thaw holes still visible through the ice.

August 28 – 83*38.3’N 167* 43.1’W (97 NM)
~ 0540hrs – XCTD – 84* 00.2’N 167* 35.3’W
~ 0854hrs – Sonobuoy – 84* 12.8’N 167* 30.12’W
~ 1415hrs – Ice recco CG360 (1 hour 21 minutes)
~ 1501hrs – XSV – 84* 37.9’N 167* 17.5’W
~ 1610hrs – Sonobuoy – 85* 08.04’N 166* 58.6’W via CG360
~ 1919hrs – XCTD x2 – 84* 53.5’N 167* 08.25’w (Position approximate)
~ 2218hrs – Sonobuoy – 85* 08.2’N 167* 00.6’W

Weather: Quasi-stationary north-south ridge of high pressure over the area.
~ Winds: E 5-10 then easing to light and variable

~ Seas: Vessel in ice
~ Skies: Continuous thick fog dissipating by late evening
~ Bar.: 1014 hPa and falling slowly
~ Temp: High of -2*C; Low of -2.5*C

Ice Conditions: Ice concentrations continued to remain fairly uniform throughout the day in a field of 9+/10 with only a trace of ridging. The field consisted of 2/10 Multiyear and 7-8/10 of Thick First Year with no pressure issues encountered. Ice field was in an advanced state of decay and easily navigated with all puddle frozen and thaw holes still visible through the ice.

August 29 – 85* 14.6'N 166* 57.1'W (46 NM)

~ 0624hrs – Sonobuoy – 85* 34.78'N 167* 04.41'W
~ 0848hrs – XCTD – 85* 42.89'N 167 50.48'W
~ 0943hrs – XSV – 85* 45.5'N 168* 05.8'W
~ 1349hrs – Ice recco CG 360 (1 hour 21 minutes)
~ 1630hrs – Recover seismic gear due to difficult ice conditions
~ 1730hrs – Redeploy gear – 85* 53.9'N 169* 12.4'W (Position approximate)
~ 1825hrs – Recover seismic gear for main engine shut down – 85* 55.0'N 169* 30.2'W
~ 1935hrs – CTD – 85* 55.4'N 169* 25.8'W
~ 2257hrs – Drift buoy from Healy deployed and departing Louis for multibeam program

Weather: Low pressure area near 76N/176E this morning and tracking to the north. A ridge of High pressure lies at 74N/144W to 81N/155W to 83N/179W then north-westward.
~ Winds: Light and variable increasing to e 5-10
~ Seas: Vessel in ice
~ Skies: Overcast stratus layer with fog patches and light snow flurries
~ Bar.: 101 hPa and steady
~ Temp: High of 0*C; Low of -2*C

Ice Conditions: Ice concentrations began to increase in ridging, multiyear concentration as well as ridging as the day progressed. Multiyear concentration increase to 3-4/10 with 6-7/10 of Thick first year and a trace of new ice as temperatures cooled. A light dusting of snow blanketed the field making it more difficult to see the Multiyear ice coupled with the increase in ridging in some areas (up to 3/10) enhanced difficulties. Ship encountered a few moments being beset in the field as pressure came up in the first half of the day but eased as the vessel steamed further north.

~ 0300hrs – Headway lost – 85* 26.45'N 166* 48.89'W – 1 hour 10 minutes
~ 1004hrs – Headway lost – 85* 45.50'N 168* 05.70'W – 10 minutes
~ 1237hrs – Headway lost – 85* 50.32'N 168* 35.47'W – 2 hours 30 minutes

August 30 – 85* 55.5'N 169* 22.9'W (46 NM)

~ 0844hrs – Redeploy seismic gear – 85* 56.5'N 169* 39.4'W
~ 1032hrs – Sonobuoy – 86* 01.3'N 170* 07.8'W
~ 1700hrs – Healy stopped to repair steering gear hydraulic leak – 86* 11.2'N 171* 18.3'W
~ 1936hrs – XCTD – 86* 20.39'N 172* 18.79'W

Weather: Low pressure area near 74N/171E in the morning and a high pressure area near 76N 135W with ridge extending northward to near 85N 125W then curving (westward) between ship and North Pole.
~ Winds: E 5-10 then backing to become S 5-10
~ Seas: Vessel in ice
~ Skies: Sunny and clear then overcast with light snow flurries and shallow fog patches
~ Bar.: 1012 hPa and falling slowly
~ Temp: High of 0*C; Low of -2*C

Ice Conditions: Ice conditions continued to worsen as the vessel steamed further and further into the polar pack. All puddles remained frozen as the Multiyear concentrations increased to 6/10 in some areas with light to moderate pressure in the areas of higher multiyear influence. Ridging remained scattered with areas of 1-2/10 under a light dusting of snow. Thaw holes are no longer visible and new ice continues to increase in thickness.

~ 0820hrs – Healy relieves pressure for seismic gear deployment – 85* 50.5'N 169* 39.4'W
~ 1200hrs – Headway lost – 86* 01.8'N 170* 12.7'W – 17 minutes
~ 1253hrs – Healy backs and rams through tough ridge – 86* 05.5'N 170* 25.1'W – 40 minutes
~ 1335hrs – Moderate pressure in field – 86* 06.0'N 170* 30.0'W – 2 hours 15 minutes

August 31 – 86* 35.3'N 174* 34.3'W (95 NM)

~ 0324hrs – Sonobuoy – 86* 47.3'N 176* 40.4'W
~ 0800hrs – Vessel crosses International dateline at latitude 87* 03.5'N
~ 0802hrs – XCTD - 87* 03.5'N 179* 56.3'E
~ 0900hrs – Sonobuoy – 87* 24.6'N 174* 09.69'W via CG360 along with spot CHS soundings
~ 1046hrs – CHS spot soundings via CG360
~ 1244hrs – CHS spot soundings via CG360
~ 1452hrs – XSV – 87* 23.9'N 174* 18.2'E
~ 1939hrs – XCTD – 87* 36.7'N 169* 32.0'E (Position approximate)
~ 2105hrs – XSV – 87* 41.4'N 167* 33.0'E
~ Continuing seismic survey

Weather: Weak low pressure area centered near 84N 170W in am and slowly tracking northward with an east-west ridge of high pressure through 78N 175W in the morning then moved slowly northward.
~ Winds: SE 5-10 then veering to N 5-10
~ Seas: Vessel in ice
~ Skies: Overcast with fog patches and light snow
~ Bar.: 1004 hPa and steady then rising
~ Temp: High of 0*C; Low of -2*C

Ice Conditions: Ice conditions eased overnight to become 9/10 Thick First Year and 1/10 Multiyear with only a trace of ridging. Ice is becoming healthier and healthier as we continue to trek to the north with more ice isolating the surrounding field from melt. By early afternoon, ice conditions deteriorated again to become 3-5/10 Multiyear and 5-7/10 of Thick First Year. Pressure again began to build to light as the Multiyear concentrations increased. Any new ice that had formed had rafted under the movement of the surrounding ice field

~ 2053hrs – Headway lost – 87* 51.8'N 162* 01.2'W – 30 minutes

September 01 – 87* 48.1'N 164* 00.2'E (97 NM)

~ Vessel reached farthest north position at 88*27.49'N 159*21.18'E
~ Vessel reached farthest east position at 88* 11.5'N 143* 19.8'E
~ 0118hrs – Sonobuoy – 87* 51.35'N 162* 18.08'E
~ 0826hrs – XCTD x2 – 88* 03.60'N 153* 32.30'E (Position approximate)
~ 1428hrs – Seismic gear recovered – First line complete – 88* 11.5'N 143* 20.3'E
~ 1452hrs – XCTD – 88* 11.5'N 143* 19.8'E
~ 1512hrs – Begin escorting USCGC Healy for multi-beam program – 88* 23.8'N 155* 23.4'E
~ 2040hrs – XCTD – 88* 25.9'N 157* 54.2'E
~ 2048hrs – XCTD/XSV – 88* 26.4'N 158* 05.2'E

Weather: A Weak low pressure center near the North Pole moving towards the southeast with another low pressure center near 78N 160E and moving slowly northward.
~ Winds: Steady NW 5-10
~ Seas: Vessel in ice

~ Skies: Early morning freezing fog patches dissipated to a fine mist by afternoon. Hoar frost slowly gathering on rigging and rails (1-2cm)
~ Bar.: 1005 hPa and rising slowly
~ Temp: High of -3*C; Low of -7*C

Ice Conditions: Ice conditions remained fairly tough until mid morning when the multiyear concentrations started to wane. By afternoon, the vessel found herself in predominant Thick First Year with only 1/10 of multiyear and ridging decreasing to a trace. Snow cover amounts rose throughout the day to 4-5/10 of coverage with all puddles frozen, no thaw holes visible and new ice developing into nilas as the temperatures continued to drop

~ 0136hrs – Headway lost – 87* 51.8’N 162* 01.2’E – 30 minutes
~ 0415hrs – Headway lost – 87* 55.5’N 159* 36.1’E – 45 minutes
~ 0930hrs – Headway lost – 88* 04.8’N 151* 57.7’E – 45 minutes

September 02 – 88* 18.6’N 164* 35.3’E (89 NM)

~ 0814hrs – XCTD – 87* 49.5’N 177* 10.3’E
~ 1025hrs – Vessel crossed International Date Line at latitude 87* 47.60’N
~ 1346hrs – Ice recco CG360 (56 minutes) - CHS Spot soundings
~ 1514hrs – CHS spot soundings
~ 1801hrs – Personnel transfer via CG360 – USCGC Healy and CCGS Louis S. St-Laurent
~ 2153hrs – XCTD x2 – 88* 05.8’N 166* 51.2’W
~ Continuing escort for Healy

Weather: 1000mb low centered over Iceland extends a trough from 85N 020E over the North Pole to 87N 175E. Another trough extends from the Quasi-stationary low centered at 76N 157E to 86N 170E over the ship’s area.
~ Winds: NW 5-10 easing to light and variable
~ Seas: Vessel in ice
~ Skies: Partly cloud and clear.
~ Bar.: 1010 hPa and steady
~ Temp: High of -2*C; Low of -7*C

Ice Conditions: By early morning, multiyear concentrations increased to 2-3/10 with 6-7/10 of Thick First Year. The Thick First Year continues to increase in strength as the vessel steamed towards the center of the polar pack. Ridging remained constant at 1/10 although, despite the increase in ice strength, no difficulties were encountered during the escort. Nilas continues to thicken over the once ponds of melted water and snow cover remained constant at 4-5/10.

September 03 – 88* 09.4’N 164* 41.6’W (42 NM)

~ 0254hrs – Healy stopped to conduct repairs – 88* 15.1’N 160* 34.7’W
~ 0615hrs – Escort complete – 88* 11.9’N 160* 37.5’W
~ 0633hrs – Ice recco CG360 to find cleared area for AUV testing and deployment (07 minutes)
~ 0914hrs – AUV deployed for calibration tests – 88* 09.15’N 158* 59.8’W
~ 0936hrs – AUV recovered – 88* 09.12’N 158* 54.59’W
~ 1122hrs – XSV – 88* 09.06’N 158* 48.92’W
~ 1610hrs – AUV deployed for release – 88* 09.15’N 158* 27.75’W
~ 1758hrs – AUV recovery process started due to ballasting issues
~ 1850hrs – AUV recovered – 88* 09.4’N 158* 18.5’W

Weather: High near 79N 126W with ridge extending to 84N 176W this morning. High pressure moving to 80N 123W with ridge extending northwestward through 88N 178W by Sunday morning
~ Winds: Light and variable increasing to W 5-10
~ Seas: Vessel in ice

~ Skies: Partly cloudy with good visibility. Hoar frost still accumulating on rigging and rails (3-4cm)
~ Bar.: 1010 hPa and rising very slowly
~ Temp: High of -3*C; Low of -8*C

Ice Conditions: For the most part, ice remained fairly consistent with the previous day's account although larger floes of multiyear are now being seen. No ice pressure issues were encountered during the AUV operations.

~ 0730hrs – Vessel steams toward frozen pool covered in dark nilas for AUV operations

September 04 – 88* 11.7'N 159* 16.6'W (45 NM)

~ 0725hrs – AUV redeployed – 88* 10.7'N 158* 16.9'W
~ 1302hrs – CHS Spot soundings viaCG360
~ 1757hrs – AUV ordered back to vessel. ROV and modem deployed to assist in AUV recovery over next 6 hours

Weather: High near 87N 135W with ridge extending to 77N 110W by early morning with another high pressure system moving westward to be near 85N 150E with ridge extending through 80N 118W by Monday morning. .A trough of low pressure is also building along the coasts of Greenland and Ellesmere Island during the period.
~ Winds: SW 5-10 easing to light and variable then becoming NW 5-10
~ Seas: Vessel in ice
~ Skies: Intermittent fog and low level stratus. Hoar frost starting to fall off rigging and rails due to weight accumulated
~ Bar.: 1010 hPa and rising slowly
~ Temp: high of -3*C; Low of -4.5*C

Ice Conditions: No ice pressure problems were encountered during the AUV operations other than the ice being pulled into the stern or bow of the vessel as she tried to manoeuvre in the open pool of water found for the operations.

September 05 – 88* 10.5'N 157* 51.6'W (25 NM)

~ 0845hrs – Science staff and crew members transfer onto ice for O-Buoy placement via CG360
~ 0900hrs – Transducer deployed and recovered to assist in AUV recovery over next 4 hours
~ 1300hrs – AUV spotted. Start of recovery process – 88* 09.4'N 157* 26.8'W
~ 1535hrs – AUV on deck – 88* 09.0'N 157* 22.0'W
~ 1641hrs – CTD – 88* 09.03'N 157* 42.56'W

Weather: Quasi-stationary ridge of high pressure through 84n 170w. A low pressure center north of Greenland in the early morning moved slowly northward with an increasing west-northwester flow between the ridge and the low pressure center.
~ Winds: NW 5-10 increasing to 20-25 then easing to 15-20
~ Seas: Vessel in ice
~ Skies: Intermittent snow showers and mist patches under overcast skies. Hoar frost continues to slowly break up.
~ Bar.: 1007Pa and falling slowly
~ Temp: High of -2*C; Low of -5*C

Ice Conditions: No ice pressure problems were encountered during the AUV operations other than the ice being pulled into the stern or bow of the vessel as she tried to manoeuvre in the open pool of water found for the operations.

September 06 – 87* 55.9'N 164* 03.1'W (83 NM)

~ 0250hrs – Begin escort for the Healy to conduct multibeam program = 87* 46.1'N 169* 31.5'W
~ 1052hrs – CHS Spot soundings via CG360

~ 1406hrs – CHS Spot soundings via CG360
~ 1629hrs – Personnel transfer via CG360 – USCGC Healy and CCGS Louis S. St-Laurent

Weather: A ridge of high pressure through 84n 170w is drifting slowly southward along with a low pressure center north of Greenland this morning moving slowly northward to near the North Pole Wednesday morning. Moderate west to northwest flow between the ridge and the low pressure center.
~ Winds: W 10-15 veering to NW 20-25 then backing to SW 20-25
~ Seas: Vessel in ice
~ Skies: Freezing fog dissipating by early morning to become cloudy then overcast
~ Bar.: 1011 hPa and falling slowly
~ Temp: High of 2*C; Low of -6.5*C

Ice Conditions: As the vessel steamed further into the main pack, multiyear concentrations increased from 4/10 to become 8/10 with 2/10 of Thick First Year. Ridging was also seen to increase upwards of 3/10 with puddles were completely frozen and about 4-5/10 of snow. This snow cover will begin to add to the difficulties of the leading vessel as the multiyear ridging becomes more and more difficult to spot in advance for tactical avoidance. No ice pressure issues

September 07 – 87* 20.0'N 86* 16.7'W (101 NM)
~ Continuing escort for Healy multibeam program
~ 0723hrs – XCTD – 86* 46.4'N 164* 22.6'W
~ 1412hrs – V/l manoeuvres in preparation for US air drop
~ 1727hrs – XCTD – 86* 24.8'N 157* 52.75'W (Position approximate)

Weather: A low pressure center near 8730N 65W this morning will move southeast to be near 87N 40W Thursday morning. A trough of low pressure will extend west-northwest from low during period forecast to lie through 88N 175W by Thursday morning. A strong westerly flow south of trough becomes a moderate northerly flow north of trough.
~ Winds: SW 20-25 increasing and veering to become W 25-30
~ Seas: Vessel in ice
~ Skies: Intermittent snow showers and mist patches under overcast skies with moderate snow showers by late morning with patches of freezing fog
~ Bar.: 1007Pa and falling slowly
~ Temp: High of -2*C; Low of -4*C

Ice Conditions: Ice concentration remained uniform throughout the day in a field consisting of 3/10 of multiyear with 7/10 of thick first year. Conditions started to show more multiyear overnight. Ridging also remained constant at 1/10 with nilas continuing to develop and a dusting of 3/10 snow. No ice pressure issues were encountered.

September 08 – 86* 16.7'N 161* 33.5'W (103 NM)
~ Continuing escort for Healy multibeam program
~ 0315hrs – XCTD – 86* 15.3'N 164* 31.0'W

Weather: A low pressure centre near the North Pole will develop significantly by Friday. On Friday morning, the low was near 83N 158E and by late Friday the low pressure centre was near 8345N 169E. Today, a moderate to strong westerly flow prevailed roughly south of 86N with light variable winds north of 8620N. On Friday, forecast calls for a strong southerly flow to develop east of the low. Gale force winds were expected southeast of the low.
~ Winds: W 25-30 veering and easing to N 5-10 then backing and freshening to SW 15-20
~ Seas: Vessel in ice
~ Skies: Light to moderate snow showers and shallow fog; Sky invisible.
~ Bar.: 1003hPa and falling slowly
~ Temp: High of -1.5*C; Low of -4*C

Ice Conditions: Early morning conditions consisted of 6/10 of multiyear with 4/10 of Thick First Year but eased by mid morning to 2/10 of multiyear and 8/10 of Thick First Year. Another strip of 6/10 multiyear was encountered by the afternoon but eased again by evening although ridging was noted to have increased to approximately 2/10. Snow covered decreased during the day to a mere 1-2/10 with nilas over the puddles. No ice pressure issues were encountered.

September 09 – 85* 34.8'N 152* 17.2'W (105 NM)

~ Continuing escort for Healy multibeam program
~ 0432hrs – XCTD – 85* 21.0'N 149* 20.2'W
~ 0946hrs – Personnel transfer via CG360 – USCGC Healy and CCGS Louis S. St-Laurent
~ 1130hrs – XCTD planned then cancelled
~ 1250hrs – XCTD – 84* 55.0'N 144* 40.5'W
~ 2046hrs – XCTD – 84* 30.3'N 141* 10.8'W (Position approximate)

Weather: A deep low pressure center near 84N 155E this morning will move to near 83N 170E by this afternoon and remain near this position until late Saturday. Northeast of the low Winds will generally be from the south at about 20 to 25 knots on Friday diminishing to about 15 to 20 knots by Saturday as the low starts to fill. Gales force winds were expected close to the low on both days.
~ Winds: SW 10-15 backing to S 15-20
~ Seas: Vessel in ice
~ Skies: Light to moderate snow showers and shallow fog; Sky invisible.
~ Bar.: 994 hPa and falling steadily then rising slowly
~ Temp: High of -3*C; Low of -4.5*C

Ice Conditions: Day started a field of half multiyear and half Thick First Year until mid morning where conditions changed to a predominant Multiyear field covering 8/10 with only 2/10 of Thick First Year. Ridging consisted of 1-2/10 throughout the day with snow concentration increasing due to light to moderate showers as the day progressed. No ice pressure issues encountered.

September 10 – 84* 18.1'N 139* 42.0'W (79 NM)

~ Continuing escort for Healy multibeam program
~ 0615hrs – Multibeam escort complete – 83* 57.2'N 137* 59.9'W
~ 0646hrs – CTD – 83*55.8'N 137* 28.9'W
~ 1002hrs – Deploy seismic gear – 83* 56.4'N 137* 19.8'W
~ 1425hrs – CHS Spot soundings
~ 1624hrs – Ice recco CG 360 (16 minutes)
~ 1726hrs – Recovered seismic gear due to difficult ice conditions – 83* 46.0'N 136* 08.0'W
~ 1750hrs – Resume escort for Healy multibeam program – 83* 44.9'N 136* 05.1'W
~ 2021hrs – XCTD – 83* 35.5'N 135* 25.9'W (Position approximate)

Weather: A deep low pressure center near 84N 170W is moving slowly to the southeast. East of the low winds are expected to be from the south to southwest at about 20 to 25 knots in the next 2 days.
~ Winds: S 15-20 increasing to 20-25
~ Seas: Vessel in ice
~ Skies: Moderate snow showers and fog patches; Sky invisible. Cleared to partly cloudy with good visibility
~ Bar.: 994 hPa and rising steadily
~ Temp: High of -3*C; Low of -4.5*C

Ice Conditions: Day started a field of half multiyear and half Thick First Year until mid morning where conditions changed to a predominant Multiyear field covering 8/10 with only 2/10 of Thick First Year. By mid afternoon conditions once again strengthened in a field of 9/10 of multiyear with only 1/10 of Thick First Year. Conditions worsened as light pressure came up on the ice in moderate to strong winds causing the vessel to become beset a couple of times during seismic work. Ridging had also increased to 3/10 adding to the prevailing conditions with 2/10 of snow coverage.

~ 1141hrs – Headway lost – 83* 52.0'N 136* 55.7'W – 20 minutes
~ 1445hrs – Headway lost – 83* 45.5'N 136* 25.8'W – 2 hours

September 11 – 83* 18.2'N 133* 54.5'W (90 NM)

~ Continuing escort for Healy multibeam program
~ 0315hrs – LSSL experiencing inverter issues – 83* 02.4'N 132* 39.1'W
~ 0400hrs – LSSL steering gear and propulsion shut down for 3 hours – 83* 03.3'N 132* 28.3'W
~ 0733hrs – Resume escort for Healy multibeam program – 83* 00.8'N 132* 26.8'W
~ 0826hrs – XCTD – 82* 58.6'N 132* 21.4'W (Position approximate)
~ 1847hrs – Escort complete
~ 1940hrs – Deploy seismic gear – 82* 05.2'N 129* 51.9'W
~ 2115hrs – Sonobuoy – 82* 05.2'N 129* 47.6'W
~ 2352hrs – Recover seismic gear due to difficult ice conditions – 82* 01.0'N 129* 37.9'W

Weather: Weakening low pressure center near 83N 180W this morning moved to the northeast to lie near 85N 150w by Monday evening. East of the low winds will be from the southwest at 20 to 25 knots on Sunday diminishing to west 15 knots by Monday afternoon.
~ Winds: S 20-25 backing and increasing to SW 25-30 then veering to become S 25-30
~ Seas: Vessel in ice
~ Skies: Mix of fog patches and light snow flurries under overcast skies
~ Bar.: 1003 hPa and rising slowly then falling
~ Temp: High if -2*C; Low of -5.5*C

Ice Conditions: Conditions eased slightly within the ice pack during the day in 7-8/10 of multiyear and 2-3/10 Thick First Year although pressure increased from light to moderate by late in the day causing problems with the seismic array. Ridging increased in some portions of the pack to 4/10 due to the increase in pressure.

~ 2015hrs – Headway lost – 82* 05.0'N 129* 49.7'W – 1 hour
~ 2206hrs – Headway lost – 82* 02.5'N 129* 42.6'W – 25 minutes
~ 2316hrs – Headway lost – 82* 00.7'N 129* 39.5'W – 25 minutes

September 12 – 82* 01.0'N 129* 37.9'W (101 NM)

~ 0015hrs – Resume escort for Healy multibeam program – 82* 00.4'N 129* 36.8'W
~ 0900hrs – Escort complete; Commence deploying seismic gear – 81* 20.9'N 127* 17.3'W
~ 0905hrs – XCTD – 81* 20.9'N 127* 17.3'W
~ 1034hrs – Ice recco (40 minutes) conducted to find easier path through difficult conditions.
~ 1133hrs – CHS Spot soundings via CG360
~ 1144hrs – Deploy seismic gear – 81* 15.6'N 126* 52.2'W (Position approximate)
~ 1238hrs – Sonobuoy – 81* 12.5'N 126* 42.7'W
~ 1404hrs – CHS Spot soundings via CG360
~ 1728hrs – Ice recco (1 hour 08 minutes) conducted for tactical assistance through predominant MY ice field. This flight also clarified the information given on the ice charts produced by ICEggs on the Healy and any discrepancies between NIC/NOAA observers.
~ 2050hrs – Sonobuoy – 80* 48.64'N 124* 52.77'W

Weather: Weakening low pressure center near 84N 150W moved east to southeast to lie near 82N 99w by Tuesday evening. South of the low winds forecast to blow from the west at 15 to 20 knots on Monday diminishing to northwest 15 knots by Tuesday afternoon.
~ Winds: S 25-30 veering to the west by late afternoon
~ Seas: Vessel in ice
~ Skies: Visibility reduced in light snow showers intermittent throughout the day.

~ Bar.: 1001 hPa and steady then rising
~ Temp: High of -3.5*C; Low of -5.5*C

Ice Conditions: By early morning both vessels were encountering difficulty in the ice field due to the increase in pressure and constant strong winds. Area in that portion of the ice field consisted f 7-9/10 of multiyear and 1-3/10 of Thick First Year. By evening, the conditions seemed to have improved only slightly sue to the change in wind direction but ridging seemed only to lessen to approximately 2/10. Rubble fields were noted during the ice recco as an area to avoid and a suggested track was given for avoidance as the ridging in those areas was upwards of 6-8/10.

~ 0540hrs – Heavy and difficult ice conditions encountered – 81* 35.7'N 128* 11.4'W
~ 1613hrs – Headway lost – 81* 01.9'N 126* 00.2'W – 5 minutes
~ 1655hrs – Headway lost – 80* 59.7'N 125* 55.0'W – 15 minutes

September 13 – 80* 40.2'N 123* 41.4'W (64 NM)

~ 0628hrs – XCTD – 80* 34.34'N 122* 56.73'W
~ 0700hrs – Recover seismic gear due to difficult ice conditions – 80* 34.2'N 122* 56.5'W
~ 0722hrs – Resume escort for Healy multibeam program – 80* 33.1'N 122* 56.1'W
~ 0909hrs – Ice recco CG360 – 1 hour 05 minutes for tactical assistance
~ 1341hrs – XCTD – 80* 21.2'N 120* 56.5'W (Position approximate)
~ 2311hrs – XCTD – 80* 06.0'N 119* 10.7'W (Position approximate)

Weather: Weakening low pressure center near 84N 95W this morning moving east to northeast to lie near 85N 85W by Wednesday evening with a second low pressure centre near 77N 177W this morning moving eastward to lie near 76N 103W Wednesday evening.
~ Winds: W 25-30 easing to light and variable over the course of the day
~ Seas: Vessel in ice
~ Skies: Overcast with a mix of snow flurries and sunny breaks
~ Bar.: 1003 hPa and rising slowly, steady then falling
~ Temp: High of -6*C; Low of -9.5*C

Ice Conditions: Early morning conditions proved difficult in a predominant multiyear field with only a trace of Thick First Year to be seen. Very little headway was made during the early hours with moderate pressure on the ice. Pressure eased slightly to light as the winds eased throughout the day and proved not as difficult with no seismic gear being towed given the vessel a little more power to conquer the ridges and pressure still present within the floes. Multiyear ice concentrations remained upward of 9/10 throughout the period.

~ 0100hrs – Headway lost – 80* 37.9'N 123* 21.3'W – 25 minutes
~ 0132hrs – Headway lost – 80* 37.4'N 123* 17.9'W – 50 minutes
~ 0334hrs – Headway lost – 80* 36.8'N 123* 12.7'W – 50 minutes
~ 0440hrs – Healy encounters difficult ice – 80* 34.4'N 122* 57.2'W

September 14 – 80* 04.2'N 119* 11.0'W (77 NM)

~ Continuing escort for Healy multibeam program
~ 0913hrs – Ice recco CG360 (1 hour 51 minutes) for tactical assistance and included a CIS drift beacon placement on the ice in position 79* 55.84'N 120* 07.43'W
~ 1400hrs – XCTD – 79* 53.4'N 122* 02.2'W
~ 1718hrs – CHS Spot soundings
~ Continuing escort fr USCGC Healy multibeam program

Weather: Quasi-stationary NW-SE ridge of high pressure through 76N 150W as well as a deepening low just north of Banks Island this morning moving east today and tomorrow with an increasing northwest flow between the ridge and the low.
~ Winds: Light and variable becoming NE 10-15 then backing while still increasing to NW 20-25

~ Seas: Vessel in ice
~ Skies: Overcast skies clearing for the day then cloud cover increases again to overcast by mid evening
~ Bar.: 1002 hPa steady then rising slowly
~ Temp: High of -7*C; Low of -11.5*C

Ice Conditions: Ice conditions remained the same as the previous day in a field consisting of 9/10 of multiyear and 1/10 of Thick First Year. Ridging also remained fairly constant at 3/10 although, due to the snow from the day before, navigation still remained difficult as ridging became more difficult to see in advance for avoidance.

~ 0500hrs – LSSL encountered difficult ice – 79* 56.9'N 119* 53.2'W – 1 hour

September 15 – 79* 55.5'N 125* 08.6'W (78 NM)

~ Continuing escort for Healy multibeam program
~ 0700hrs – Escort complete – 80* 11.2'N 126 54.2'W
~ 0829hrs – XCTD – 80* 11.9'N 126* 59.7'W
~ 0845hrs – XSV – 80* 12.0'N 127* 02.0'W
~ 0913hrs – Deploy seismic gear – 80* 11.7'N 127* 02.4'W
~ 1016hrs – Ice recco CG360 (59 minutes) and included a CIS drift beacon placement on the ice in position 80* 29.71'N 129* 21.78'W as well as attempt to locate lead large enough for AUV deployment.
~ 1123hrs – Sonobuoy – 80* 15.2'N 127* 22.8'W
~ 1721hrs – Ice recco CG360 (46 minutes) for tactical assistance
~ 2151hrs – Recover seismic gear due to difficult ice conditions – 80* 33.9'N 129* 40.0'W
~ 2207hrs – Resume escort for Healy multibeam program

Weather: Quasi-stationary NW-SE ridge of high pressure through 76N 140W bringing a moderate northwest flow east of the ridge today and Friday.
~ Winds: NW 20-25 easing slightly to 15-20
~ Seas: Vessel in ice
~ Skies: Cloudy with good visibility with periods of overcast skies
~ Bar.: 1009 hPa and rising slowly then steady
~ Temp: High of -7*C; Low -11*C

Ice Conditions: Ice conditions eased slightly to 7-8/10 of multiyear and 2-3/10 of Thick First Year. Inherent stresses within the ice from the winds over the previous few days remained within the floes rendering navigation difficult in light to moderate pressure. This internal pressure causes the track to continue closing behind the leading vessel while doing seismic work as speeds do not exceed 3-4 knots. Ridging decreased some more during the day to become 1-2/10 with only sporadic areas of snow cover remaining.

~ 0945hrs – Headway lost – 80* 12.0'N 127* 04.8'W – 25 minutes
~ 1425hrs – Headway lost – 80* 23.6'N 128* 19.1'W – 15 minutes
~ 1840hrs – Headway lost – 80* 33.5'N 129* 21.4'W – 1 hour 30 minutes
~ 2137hrs – Healy encounters difficult ice conditions – 80* 33.7'N 129* 28.0'W

September 16 – 80* 28.8'N 128* 52.7'W (54 NM)

~ Continuing escort for Healy multibeam program
~ 0823hrs – LSSL stopped to tighten stern gland – 80* 29.6'N 129* 48.9'W – 40 minutes
~ 0835hrs – CG360 ice recco (23 minutes) flown to reconfirm location of open pool of water for AUV deployment.
~ 1230hrs – Escort complete – 80* 33.6'N 131* 21.2'W
~ 1256hrs – CTD/XSV – 80* 33.6'N 131* 21.2'W
~ 1900hrs – AUV launched – 80* 32.3'N 131* 14.8'W

Weather: Quasi-stationary NW-SE ridge of high pressure through 75N 140W brining a moderate northwest flow east of the ridge today and Saturday.
~ Winds: NW 15-20 backing to W
~ Seas: Vessel in ice
~ Skies: Intermittent and isolated light to moderate snow showers under partly cloudy skies
~ Bar.: 1010 hPa and steady then falling rapidly
~ Temp: High of -5*C; Low of -12*C

Ice Conditions: Multiyear ice concentrations once again increased slightly to 8-9/10 with only 1-2/10 of Thick First Year. Ridging remained fairly constant at 2/10 with only a small area noted as having only a trace. Snow cover was slight at 2/10 and ponds were once again been seen within the pack due to lack of coverage. A small pond was located during the morning ice recco and the vessel her made her way into it for AUV operations. No ice pressure issues were encountered.

September 17 – 80* 31.7'N 131* 10.5'W (0 NM)
~ 1538hrs – Sensor deployed to assist in AUV recovery – 80* 29.7'N 131* 05.3'W
~ 1745hrs – ROV deployed to assist in AUV recovery – 80* 28.85'N 131* 00.4'W

Weather: Quasi-stationary W-E ridge of high pressure through 75N 145W. Low pressure area near the North Pole this morning will move southwards and be located near 83N 130W by Sunday evening. A moderate northwest flow north of the ridge and south of the low will become light and variable near the ridge today and Sunday.
~ Winds: W 15-20 eases to light and variable through the day and freshens to become NW 15-20 by late evening
~ Seas: Vessel in ice
~ Skies: Intermittent isolated light snow flurries along with fog patches under overcast skies
~ Bar.: 1005 hPa and steady then falling slowly
~ Temp: High of -2*C; Low of -5*C

Ice Conditions: Ice conditions remained unchanged from the previous day during AUV operations. No ice pressure issues were encountered.

September 18 – 80* 6.1'N 130* 54.2'W (40 NM)
~ 0111hrs – Continue with recovery process of the AUV – 80* 25.8'N 130* 53.0'W
~ 0847hrs – CG360 back in operation – 80* 23.6'N 130* 44.5'W
~ 0936hrs – Deployed and recovered modem over next 2.5 hours – 80* 23.4'N 130* 44.3'W
~ 1104hrs – AUV stopped in vicinity of vessel – 80* 23.14'N 130* 44.44'W
~ 1330hrs – AUV recovered – 80* 22.7'N 130* 44.3'W
~ 1435hrs – CTD – 80* 22.2'N 130* 44.7'W
~ 1525hrs – XSV – 80* 22.2'N 130* 44.5'W
~ 1935hrs – Resume Healy escort for bathymetric multibeam program – 80* 16.4'N 131* 25.5'W

Weather: Quasi-stationary W-E ridge of high pressure through 74N 145W. A first low pressure area near 80N 104W this morning will move eastward and be located near 77N 74W by Monday evening while a second low pressure area near the north pole this morning is moving southwards and be located near 80N 116W by Monday evening. Moderate northwest winds north of the ridge and south of the low pressure areas becoming light and variable near the ridge today and Monday.
~ Winds: NW 15-20 backing to W
~ Seas: Vessel in ice
~ Skies: Overcast skie with isolated light snow flurries by late evening
~ Bar.: 999 hPa and falling slowly then steady
~ Temp: High of -1*C; Low of -4*C

Ice Conditions: Ice conditions remained the same for the AUV recovery operations. Once the vessel departed the area in the evening, conditions deteriorated rapidly under light to moderate pressure in a field of 8-9/10 of multiyear and 1-2/10 of Thick First Year. Ridging had again started to increase to 3/10 proving navigation very difficult within the ice pack and within the floes.

~ 1935hrs – Vessels encounter difficult ice under pressure – 80* 16.4'N 131* 25.5'W – 4 hours

September 19 – 79* 56.0'N 132* 36.3'W (54 NM)

~ Continuing escort for Healy multibeam program
~ 0800hrs – Escort complete – 79* 21.2'N 130* 48.2'W
~ 0838hrs – XCTD – 79* 13.3'N 132* 19.7'W (Position approximate)
~ 0900hrs – Seismic gear deployed – 79* 11.6'N 132* 21.1'W
~ 0909hrs – Gear recovered due to centre shaft and propeller issues – 79* 11.1'N 132* 20.2'W
~ 0935hrs – ROV launched to inspect shafts and propellers over the next 4.5 hours – 79* 11.1N 132* 18.9'W
~ 1400hrs – USCGC Healy advised of vessel issues and the need for a full escort out of ice field marking the end of seismic data potential
~ 1529hrs – Crew member flown to USCGC Healy for x-ray due to injury

Weather: 990 mb low near 82N 135W this morning moving southeast to lie 81N 130W at 21Z today then continuing eastward along 81N before pulling up to the northeast and filling late Tuesday (east of ship's position). Weak inverted ridge expected to develop over region late Tuesday.
~ Winds: W 15-20 backing then veering to the NW
~ Seas: Vessel in ice
~ Skies: Overcast with periods of light to moderate snow showers
~ Bar.: 997 hPa and falling very slowly then steady then rising slowly
~ Temp: High of -0.5*c; Low of -3*C

Ice Conditions: Pressure eased throughout the field overnight but the ice remained constant at 8/10 multiyear and 2/10 Thick First Year. Ridging amounts also eased to 1/10 with only a trace of snow. No ice pressure issues were encountered.

September 20 – 79* 09.0'N 131* 57.2'W (14 NM)

~ 1030hrs – Aerial photos via CG360 of both vessels together and AUV recovery
~ 1138hrs – Raft up with USCGC Healy after conclusion of joint UNCLOS 2011 science
~ 1335hrs – XSV – 79* 07.9'N 131* 50.8'W
~ 2144hrs – USCGC Healy and CCGS Louis S. St-Laurent part ways to begin final escort and the close of UNCLOS 2011 – 79* 08.2'N 131* 48.1'W

Weather: 993 mb low near 8030N 115W with a weakening inverted ridge roughly north-south along 150W and a weak saddle shaped pattern in east-west line along 7230N moving northward to about 75N this evening. A new QS elongated low near 81N 155W forming this evening. Saddle pattern continuing northward motion to 7730N by Wednesday morning as well as a deep Aleutian low developing strong wind gradient in southern Beaufort (south of 75N) by Wednesday morning.
~ Winds: NW 15-20 easing to light and variable as the day progressed
~ Seas: Vessel in ice
~ Skies: Partly cloudy increasing to overcast with low visibility in mist then fog
~ Bar.: 996 hPa and rising very slowly the steadily
~ Temp: High of -1.5*C; Low of -9*C

Ice Conditions: Ice conditions were as the previous day with no ice pressure issues encountered.

September 21 – 79* 00.8'N 132* 27.7'W (139 NM)

~ 1025hrs – XCTD – 78* 16.1'N 135* 57.6'W
~ 1408hrs – ROV deployed to inspect center shaft – 77* 59.4'N 137* 05.7'W
~ 1504hrs – XCTD – 77* 59.4'N 137* 05.7'W
~ 2256hrs – XCTD – 77* 15.9'N 138* 30.7'W

Weather: First Qusai-Stationary 996 mb low near 8140N 15740W weaking during the period. Second 987 mb low near 7010N 13010W moving eastward and deepening. By Thursday evening second 970 mb low located near 7020N 10600W. Strong wind gradient in southwestern Queen Elizabeth Islands and eastern Beaufort Sea area.
~ Winds: Light and variable increasing to become NE 10-15
~ Seas: Vessel in ice
~ Skies: Overcast with light snow flurries in the morning and breaking to become partly cloudy
~ Bar.: 1002 hPa and steady
~ Temp: High of -0.5*C; Low of -1*C

Ice Conditions: Conditions again remained the same as the previous days with light pressure still on the ice field and floes. Multiyear ice concentrations started to decrease to 7/10 with Thick First Year increasing to 3/10 with only a trace of ridging as the vessels made their way south. Ice conditions continued to improve over the course of the evening and overnight.

~ 0539hrs – Vessels encounter difficult ice conditions – 78* 38.9'N 134* 14.3'W

September 22 – 77* 08.9'N 138* 35.6'W (63 NM)
~ 1051hrs – ROV deployed to inspect center shaft – 75* 56.9'N 138* 34.3'W
~ 1305hrs - **USCGC Healy and CCGS Louis S. St. Laurent part ways in conclusion of the UNCLOS 2011 joint mission**
~ 1235hrs – Aerial photos via CG360 of both vessels together
~ 1446hrs – XCTD – 75* 54.25'N 138* 41.0'W (Position approximate)

Weather: A broad area of low pressure (983 mb) with a east-west orientation thru 7220N 11620W will move eastward to 7000N 8120W (978 mb) with a trough extending westward over southern Banks Island. Strong winds from the east north of the low pressure area becoming northeast over the Beaufort Sea.
~ Winds: NE 10-15 freshening to 15-20
~ Seas: Vessel in ice
~ Skies: Clear becoming overcast with isolated light snow flurries by late afternoon
~ Bar.: 1002 hPa and falling slowly then rising slowly
~ Temp: High of -2*C; Low of -4*C

Ice Conditions: As the vessels continued to make their way south towards open water a marked difference in the ice field was noted. Multiyear concentrations were reduced to 2-3/10 with a small patch of 5/10 and Thick First Year rose to be the predominant ice type at 6-8/10 with an increased in new ice within the regime. Ridging also decreased to only a trace. Conditions were favourable for both vessels in their condition allowing the Healy to part ways as the total concentration decreased to 7-9/10 with upwards of 7/10 of nilas and new ice starting to dominate the area. This marked difference in the ice allowed for the vessel to pick her way around the ice preventing her from having to back and ram without an escort's assistance.

September 23 – 74* 49.8'N 138* 10.5'W (163 NM)
~ 0013hrs – XCTD – 74* 49.8'N 138* 10.5'W (Position approximate)
~ 0835hrs – Deploy ROV to inspect center shaft – 74* 01.2'N 138* 19.4'W
~ 1207hrs – XCTD – 73* 53.2'N 138* 30.6'W
~ 1227hrs – ROV deployed to inspect center shaft – 73* 51.1'N 138* 30.6'W

Weather: A deep low pressure over King William Island coupled with 1019 mb high north of Wrangle Island with e-w ridge along 75N. At 00Z this evening, a 1021 mb high near 80N 177W will be coupled with filling low over the Gulf of Boothia. By 12Z Saturday, a 1020 mb High center will be located near 78N 180W.
~ Winds: NE 15-20 backing then veering and freshening to N 25-30
~ Seas: Vessel in ice approaching ice edge. No swell detected

~ Skies: Isolated light snow flurries under overcast skies
~ Bar.: 1004 hPa and rising slowly
~ Temp: High of -2*C; Low of -4*C

Ice Conditions: Ice conditions worsened slightly as strips and tongues of multiyear and Thick First Year ice entered the route. Multiyear did not 5-6/10 and Thick First Year was down again to 1-2/10 with new ice and nilas littered though the field throughout the day and overnight. No pressure was on the ice field although this increased in the healthier older ice was required to be avoided to prevent the vessel from going astern. Ridging was barely visible throughout the day.

September 24 – 72* 48.2'N 136* 34.0'W (201 NM)

~ 0148hrs – 72* 43.9'N 136* 09.3'W – Entering heavier ice field making transit a little more difficult due to the vessels center shaft issues
~ 0309hrs – XCTD – 72* 42.1'N 135* 55.0'W
~ 0530hrs – Concentration and ice conditions ease again – 72* 30.2'N 134* 00.4'W
~ 1423 – XCTD – 71* 51.53'N 131* 47.1'W
~ 2300hrs – Vessel crossed into the Territorial 12NM limit – 71* 21.2'N 127* 48.6'W

Weather: A deep 978 mb low centered over central eastern Greenland will start to fill as it tracks to the east. A trough from the system extends to the west over southern Banks Island.
~ Winds: N 25 backing and easing to NE 10-15
~ Seas: Vessel in lighter ice conditions – Residual swell of 2-3 meters noted in easier concentrations from last low pressure system that passed through area
~ Skies: Clear skies increasing to become overcast with periods of light snow by late evening
~ Bar.: 1006 hPa rising steadily
~ Temp: High of 0*C; Low of -4*C

Ice Conditions: By the early, early hours of the morning, the vessel was out of the main pack and steaming in 1-2/10 of multiyear with only a trace of new grease ice and nilas visible. The vessel had broken through the ice edge at approximately 1300hrs and will be in open water for the duration of her trip to Cambridge Bay.

September 25 – 71* 18.0'N 127* 22.9'W (239 NM)

~ 1927hrs – CCGS Laurier FRC alongside to transfer science cargo

Weather: A ridge from 1019 mb high located from 75N 140W to 68N 111W will move southeast to 75N 140W to 72N 93W.
~ Winds: NE 5-10 easing to light and variable then increasing to become NE 25-30
~ Seas: 1-2' chop
~ Skies: Partly cloudy with sunny periods becoming overcast by late afternoon
~ Bar.: 1010 hPa rising steadily
~ Temp: High of 1*C; Low of 0*C

Ice Conditions: Open Water becoming ice free

September 26 – September 29 - En route to Cambridge Bay for Crew Change

Barbara Molyneaux
Ice Service Specialist
Canadian Ice Services
Environment Canada
UNCLOS 2011

Appendix 9 – Unmanned Aircraft Systems

Captain Steve Wackowski

Post Deployment Report

USCGC HEALY/CCGC LOUIS S ST LAURENT
August 15, 2011 – September 28, 2011

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Contents

Executive Summary

From August 15 to September 28, I deployed on the USCGC HEALY during the second leg of her summer 2011 Arctic deployment (HLY 1102). I embarked from Barrow, Alaska as a member of the science party led by Dr. Larry Mayer of the University of New Hampshire Center for Coastal and Ocean Mapping/Joint Hydrographic Center. The mission was funded by the National Oceanic and Atmospheric Administration and the National Science Foundation to continue the joint U.S.-Canadian Extended Continental Shelf mapping effort.

Joint icebreaking/mapping operations were performed with the CCGS LOUIS S. ST. LAURENT (LOUIS). HEALY collected multibeam sonar while LOUIS deployed seismic air cannons to map the seafloor sediments. Both mapping systems are critical to the United States' ability to present claims under the United Nations Convention on the Law of the Sea (UNCLOS), which will determine the extent of Arctic nations' territorial sovereignty as well as their rights to natural and marine resources in the area. Preparing bathymetric and seafloor sediment maps for UNCLOS submission was the primary objective of the mission.

My research on Arctic Unmanned Aircraft Systems (UAS) operations for the Defense Intelligence Agency's National Intelligence University (NIU) and the U.S. Air Force was conducted as a secondary science mission. The proposal was simple: to prove that Small Unmanned Aircraft Systems (SUAS) operations were feasible from moving icebreakers and the products derived from those flights can assist in icebreaking operations, marine mammal detection, and search and rescue operations.

Due to U.S. Coast Guard flight deck certification concerns regarding SUAS operations onboard the HEALY, I transferred to the LOUIS while underway. Dr. Mayer advocated on my behalf for the transfer, with his advocacy and the support of Canadian Chief Scientist Dave Mosher and LOUIS Commanding Officer, Capt Marc Rothwell, I received authorization to conduct a demonstration flight. On August 26th, with myself as Pilot-in-Command and Flight Engineer Steve Lloyd of Transport Canada as mission commander, we conducted the first-ever SUAS flight in the high Arctic from a moving icebreaker. RQ-11A "RAVEN", serial number 0613, flew for nearly 30 minutes for a distance of 4.7 kilometers from its origination point on the LOUIS. It was launched from the roof of her bridge and recovered on her helicopter landing pad. A RAVEN remote video terminal was left onboard the HEALY and the RAVEN's full motion video (FMV) feed was viewed live on her bridge. Flight Engineer Lloyd served as the RAVEN mission commander for the remainder of the deployment, during which we conducted a series of successful day and night flights using both Electro-optical and Infrared cameras, both from the ship and on the sea ice. All flights took place above the 80th parallel north (80° N).

These flights demonstrated the benefits of on-demand, airborne FMV for intelligence, surveillance, reconnaissance (ISR) purposes for the crews of Arctic icebreaking vessels. After the initial demonstration of the system's capabilities, it began to receive tasking from the CO/XO of the LOUIS. These culminated with requests for an ice reconnaissance mission to scout for a launch point for an autonomous underwater vehicle (AUV) and polar bear watch for a deployed ice buoy team. In total, a dozen successful flights were logged while deployed with the LOUIS. Future Arctic missions could benefit from the presence of a UAS similar to the RAVENs used during this deployment.

Mission Genesis

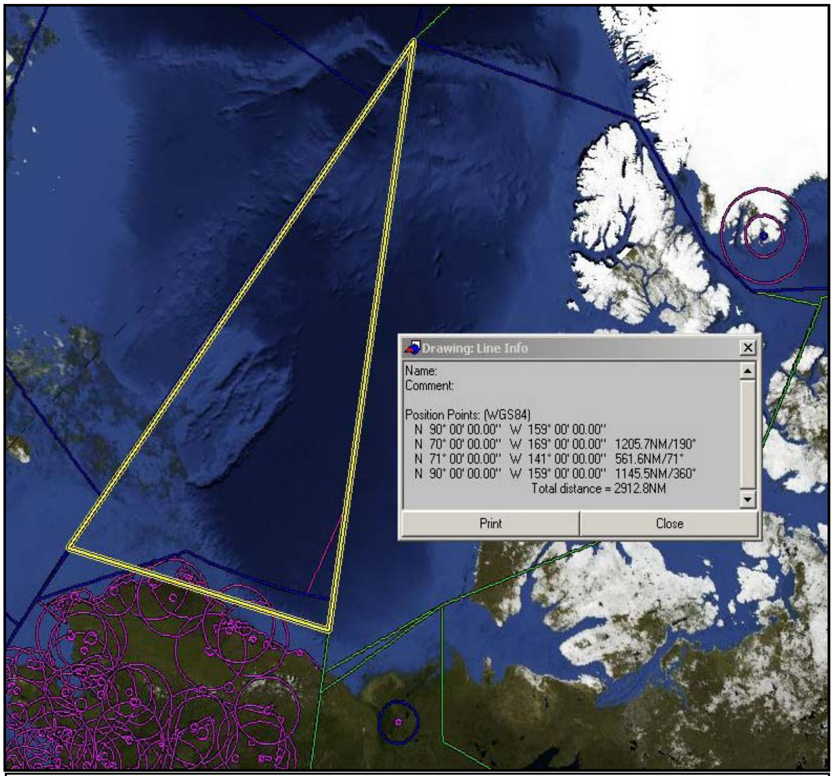
My NIU thesis topic, "National Security Impacts of Ice Free Arctic Summers," was approved in May 2011. Dr. Peter Leitner, NIU Faculty, serves as thesis chair and U.S. Senator Lisa Murkowski of Alaska is its reviewer. At the recommendation of Dr. John Farrell, Executive Director of the U.S. Arctic Research Commission, I pursued the opportunity to gain first-hand experience and perspective in the area by deploying on one of the USCGC HEALY's summer icebreaking missions. Participating in a cruise would offer me the opportunity to interact with Arctic scientists and directly participate in the Coast Guard's Arctic icebreaking mission for my thesis research.

Upon further investigation of the Coast Guard's ISR capabilities in the Arctic, a major shortfall in the ship's ability to collect operational airborne reconnaissance became apparent. The HEALY currently has no capability to conduct air operations because it does not deploy with a helicopter detachment, which is largely due to budget and manning constraints. With this shortfall in mind, my Commander, Mr. James Clark, Director, A2/A2Q ISR Innovations, supported my proposal to deploy with a SUAS system to demonstrate the Air Force's capability to collect ISR from SUAS platforms. This would also give the Air Force valuable data on the effectiveness of SUAS in the high Arctic and the challenges faced in conducting UAS operations in extremely high latitudes.

RAVEN Launch from Arctic buoy camp

After drafting a proposal for SUAS operations in the Arctic, Dr. Farrell then introduced me to his colleague Dr. Mayer, the Chief Scientist for HLY 1102. Dr. Mayer enthusiastically supported my proposal and offered me a position on his science crew. Both Dr. Mayer and I began to engage Headquarters Coast Guard to obtain proper authorization for UAS flights on the HEALY.

A2Q and Air Force Special Operations Command (AFSOC) had several battle-tested and proven RQ-11A "RAVENs" in their inventory slated for retirement and static display. Many of the systems had not been flown since 2004 when they primarily flew in Iraq and Afghanistan, but were still operable. With assistance of the SUAS Program Office at AFSOC, I was provided with extra equipment for the deployment. Additionally, AFSOC also sought a Federal Aviation Administration (FAA) Certificate of Airworthiness (COA) on my behalf for Arctic RAVEN flights encompassing the U.S.-controlled airspace north of Barrow all the way to the North Pole. Two weeks before my scheduled deployment the COA was approved—the largest SUAS COA in history.



Approved operating area in COA for Arctic RAVEN Flights

While my participation in the HEALY's ECS mission for thesis research was approved, the proposal to fly RAVENs from the HEALY was still under consideration by Coast Guard Headquarters. Persuant recommendation of my leadership and SUAS advocates in the Department of Homeland Security, I proceeded to deploy on the HEALY with the necessary equipment to conduct RAVEN flights. Unfortunately, due to flight deck certification issues, permission to conduct ship-borne flights from the HEALY was denied.

Immediately, Dr. Mayer engaged the leadership of the LOUIS on my behalf. After a brief static demonstration, the LOUIS's Commanding Officer and Chief Scientist gave me permission to conduct a test flight on the Canadian vessel. After reviewing the operating frequencies of the RQ-11A, the LOUIS Communications Officer determined the system posed little to no threat of interference with the ships' system. Advantageously, the LOUIS had two flight officers on board that were able to assist in SUAS operations. After the first successful flight demonstration, which resulted in the safe launch and recovery of the system, I was given permission to conduct flight operations for the remainder of the mission.

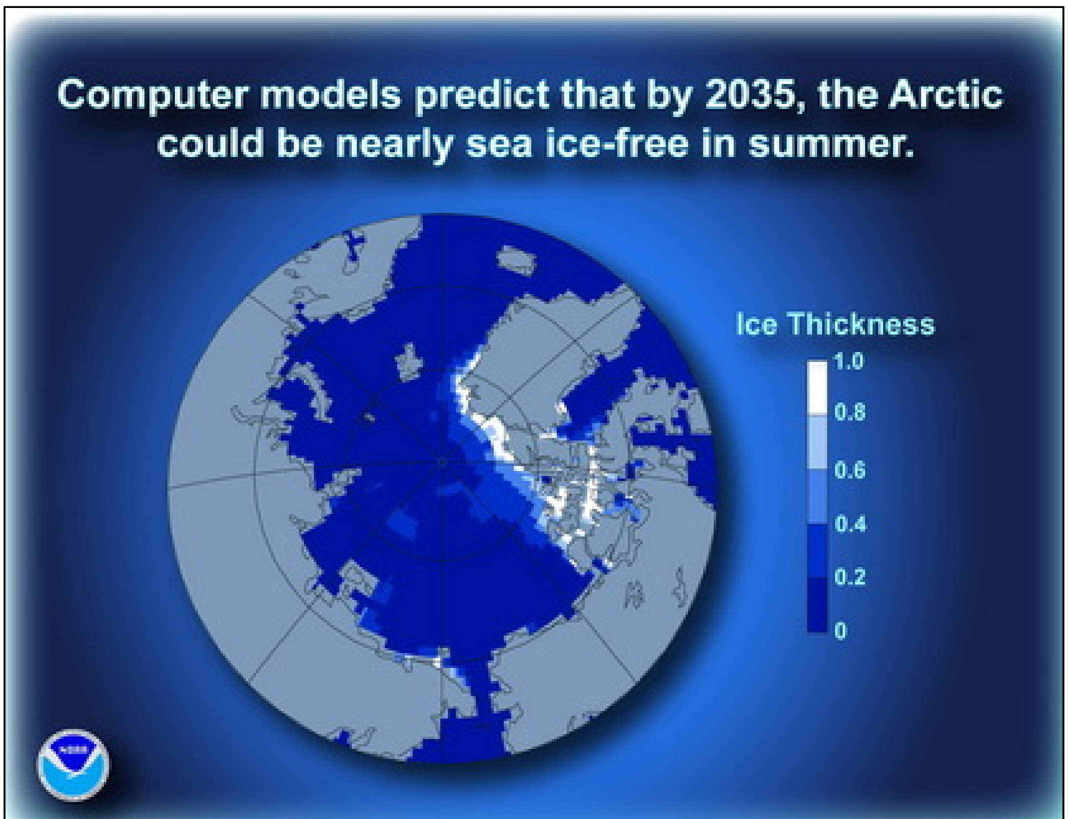
Impact on Intelligence Community

Perhaps the most critical capability gap for the IC to fill in projecting an Arctic presence is the lack of satellite coverage in the area, specifically U.S. Government owned assets. Currently U.S. icebreaking operations are solely reliant on foreign-owned commercial satellites. There is also a capability gap with regard to the ability to validate remote sensing data as airborne and seaborne assets have limited reach and presence in the Arctic. UAS flights offer a way to validate current imagery products for a variety of uses, and are not limited to the traditional ISR mission set. Communications is another challenge in Arctic operations, above most of the 78th parallel north (78° N), the Iridium constellation is the only system available for voice and data communications.

Over the course of the deployment UAS flights above 84° N, encountered several navigation challenges. Specifically, *Falconview*, the National Geospatiall-Intellegence Agency's mission planning system used to load navigation data onto the RQ-11 system did not have the proper coordinate system loaded into the program enabling operations in the high Arctic (MGRS ends at 84° N and 80° S). Falconview is also a mission planning system used for manned bomber, cargo, and fighter aircraft throughout the DoD. These findings led to software updates and integration for new versions of Falconview. More detail on the navigation challenges can be found on page 15 of this report.

NIU Thesis Work

There is a growing consensus from the scientific community that within the next 20 years the arctic will experience ice free Arctic summers. Therefore, from a strategic intelligence perspective, it is critical to U.S. interests to bolster domain awareness, physical presence, and intelligence capabilities in the Arctic. This must be done to properly defend our coastline, resource claims, and interests in the region.



The U.S. National Oceanic and Atmospheric Administration estimates ice free summers by 2035

When the Arctic becomes ice free in the summer months, there will be a dramatic increase in shipping traffic and an enormous push to develop the bountiful resources of the Arctic's extended continental shelf (ECS), as it is estimated by the USGS that almost 30% of the world's petroleum resources lie beneath the Arctic Ocean.

My proposed NIU thesis (anticipated completion: Summer 2012), "*National Security Impacts of Ice-free Arctic Summers*," seeks to answer several questions What impacts will this have on the security posture of the United States? With over 1000 miles of Arctic coastline, and thousands of square miles of potential ECS claims, how can we properly protect and defend America's Arctic? Are the U.S. Government's aerial/underwater drones, satellites, ships, and aircraft ready for Arctic operations? What roles will intelligence, surveillance, and reconnaissance play in this potentially new reality?

Deployment Goals

The goals of my deployment – and their post-mission status – are as follows:

- Demonstrate that SUAS operations can be done *safely* on/off board icebreakers while underway – ***Complete***

- Demonstrate ISR capabilities of SUAS to multi-agency science crews and the Coast Guard – ***Complete***

- Stream Full Motion Video from RAVEN SUAS on to ROVER for:
  - Sea ice ridge detection/monitoring – ***Complete***
  - Marine mammal detection – ***Incomplete/pending (No marine mammals were seen or observed during cruise during flight ops; only one polar bear and two seals observed near beginning of cruise)***
  - Demonstrate usefulness in search and rescue scenarios – ***Complete***
  - Detection and monitoring of oil spilled from ship or oil exploration – ***Inconclusive (there is no way to test this scenario without an actual spill)***

- Integrate lessons learned/ops concept into NDIC thesis research for Masters of Science in Strategic Intelligence – ***Pending***

Alignment to National Strategy

My research mission supported national strategic guidance as set forth in National Security Policy Directive 66, *Arctic Region Policy,* which originated with the Bush Administration and has not been countermanded by the current administration.

- **Policy as it relates to promoting scientific international cooperation**
  - "Continue to play a leadership role in research throughout the Arctic region"
  - "Strengthen partnerships with academic and research institutions and build upon the relationships these institutions have with their counterparts in other nations"

- **Policy as it relates to national security and homeland security interests in the Arctic**
    - “Increase Arctic maritime domain awareness in order to protect maritime commerce, critical infrastructure, and key resources”
    - “Project a sovereign United States maritime presence in the Arctic in support of essential United States interests”

SUAS Airframe: RQ-11A "RAVEN"

RQ-11A seconds before first high Arctic flight

Manufacturer
AeroVironment Inc
Launch Method
Hand-launched
Recovery Method
Deep-stall landing
Camera Payloads
Color/Thermal
Wingspan
4ft 3in
Length
3ft (0.9m)
Weight
4.2lb (1.9kg)
Cruise Speed
30mph
Status
"A" model retired from active military service. "B" and "DDL" in active service

RAVEN "A" model was selected as preferred airframe for Arctic Icebreaker flights for several reasons, including:

- Airframes had fulfilled lifecycle requirements and are retired from active service
    - Several RAVENs in A2Q, Air Force Research Laboratory, and AFSOC inventories were destined for scrap or display
    - Vast majority of airframes were easily repairable to 100% operational status
    - While loss/catastrophic damage to airframe was not preferred, it would not end the mission should an airframe be unrecoverable
- Systems operate on unencrypted analog frequencies
- Systems carry no classified equipment
- Systems are man-portable and requires only one trained pilot and an untrained assistant to operate

RQ11 capture by Canadian Coast Guard Cadet on deck of CGC LOUIS, September 2, 2011 (flight 4)

Myth: "There seems to be doubt that a Raven UAS can be safely recovered on a moving platform the size of Healy's flight deck." –*Senior USCG Official, August 1, 2011*

Flights

- Twelve flights were logged during deployment
    - Two ship borne ended flights ended sea ice and the SUAS had to be recovered by disembarking the ship.
- Nine of the flights originated from the LOUIS. The others occurred during dismounted operations from the ship.
- Nearly 10 hours of flight time was logged on 6 airframes.
- In lower latitudes (south of 80° N) three night flights were conducted from the ship using the infrared nose cameras.

Selected highlights

Flight 1
Date: 26 August 2011

Duration:	27 minutes
Launch:	LOUIS antenna deck
Recover:	LOUIS Helicopter pad
Camera:	DAY/EO
Notes:	Initial safety demonstration for LOUIS CO/XO. Continued flight ops approved.

View of the HEALY from RAVEN flight 1

RAVEN flight 1 on final approach

Flight 2

Date:	27 August 2011
Duration:	50 minutes
Launch:	LOUIS antenna deck
Recover:	LOUIS Helicopter pad
Camera:	Side look IR
Notes:	Cold weather test for battery performance—no effects at 34 F. IR test in day conditions.

LOUIS on IR Camera (white hot)

HEALY on IR Camera (black hot)

Flight 5

Date: 3 September 2011
Duration: 40 minutes
Launch: LOUIS Helicopter pad
Recover: LOUIS Helicopter pad
Camera: Day/EO
Notes: Launch of Defence Research and Development Canada's (DRDC) Autonomous Underwater Vehicle (AUV). RAVEN used to monitor launch and assist in SAR if needed. Due to wind conditions landing approach was from LOUIS port bow direction.

AUV awaiting launch

Bow-directed landing approach

Flight 7

Date: 5 September 2011

Duration: 49 minutes

Launch: Ice buoy camp

Recover: Ice buoy camp – snow

Camera: Day/EO

Note: Performed polar bear safety patrol. AV flew through freezing fog layer and front camera was iced over.

Buoy camp aerial screen capture

Forward-looking camera gathering frost

Flight 9

Date: 14 September 2011

Duration: 18 minutes

Launch: LOUIS helicopter deck

Camera: Forward looking IR (night/near total darkness)

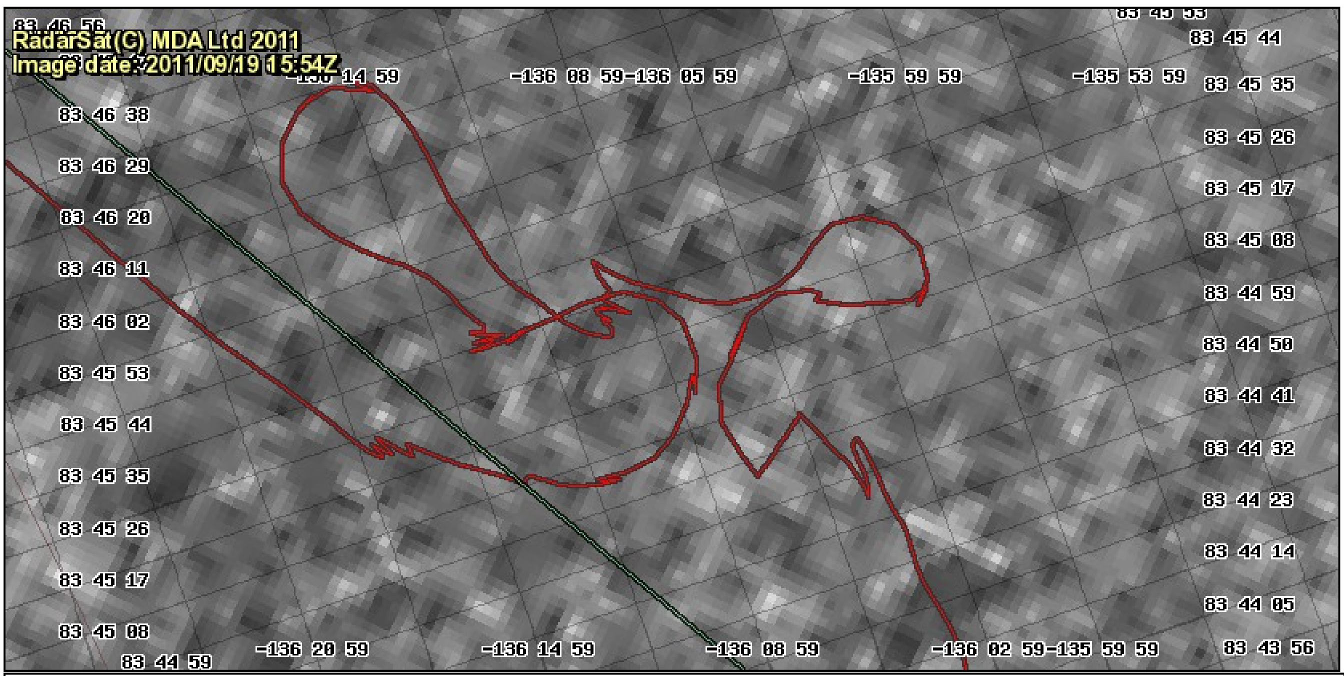
Notes: Performed Ice reconnaissance in light snow. Ice imagery with IR camera is excellent in night conditions. Flight occurred about 120 nautical miles from magnetic north pole. Magnetic compass did not deviate more than 10 degrees in level flight.

Ice ridges 2km ahead of LOUIS (white hot)

Screen shot during flight failure (ice recovered)

Research Conducted/Mission Results

Both ship's crews and science parties had a very positive reaction to the capability demonstrated by the SUAS flights. Of particular interest was the system's ability to scout ahead of the ship for pressure ridges, cracks, and open areas in the ice. Icebreaking consumes extreme amounts of fuel, especially in hardened multi-year ice. The Chief Engineers from both vessels estimate consumption rates of 13,000-30,000 gallons of fuel a day during icebreaking operations, compared to open water consumption averaging 3,000 gallons a day. Much effort goes into finding the path of least resistance in the ice, as following lighter ice conditions means faster transit, and saving tens of thousands of dollars in fuel costs per day.



Screen capture from HEALY mapserver, showing icebreaking path (red) over navigation track (green)
National Ice Center RADARSAT SAR Image overlayed

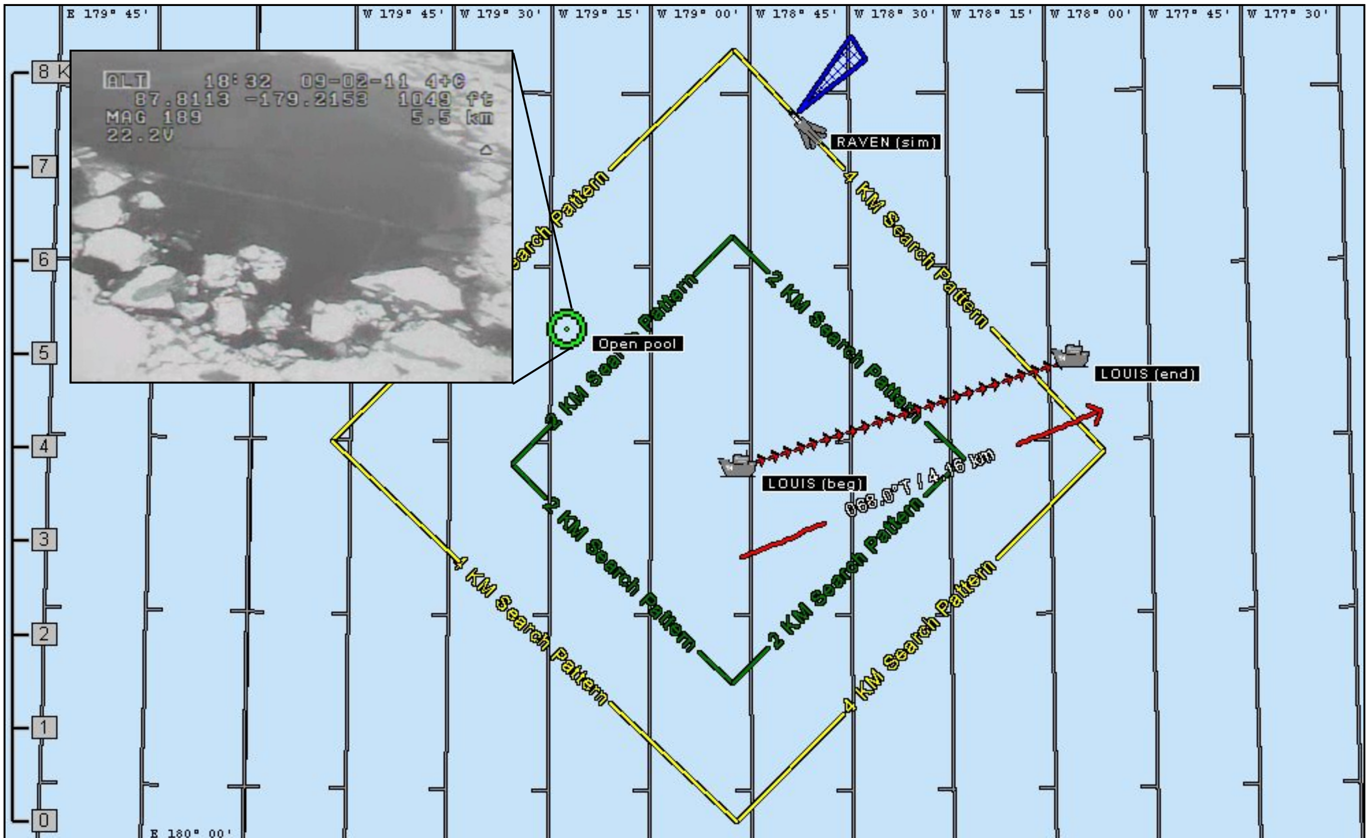
To improve operational efficiency, ice reconnaissance flights occur from the LOUIS and remote sensing data is used from the Canadian RADARSAT satellite constellation to chart ice conditions. Both methods prove effective in many areas of mission planning, but there are several capability gaps that have the potential to be filled by SUAS operations.

The HEALY is dependent on the LOUIS for underway air transportation and airborne ice reconnaissance. The LOUIS deployed with one ME-208 light multi-purpose helicopter onboard with one pilot and flight engineer to man the airframe. Helicopter operations in the Arctic are expensive, with cost estimates of $1000-$2000 per hour of flight time. Ice reconnaissance is also just one of several missions the helicopter has while underway; buoy deployments, gravimetric readings, and ship-to-ship personnel transfers are included in its responsibilities. This limits time and resources available for scouting ice conditions.

Furthermore, during periods of darkness manned ice reconnaissance is not feasible as neither ship is outfitted with a FLIR system. In this scenario, the RAVEN proved most useful. The IR cameras of the system worked very well in little-to-no light conditions. Pressure ridges in the ice showed up wonderfully at night.

Louis in Icebreaking lead, pressure ridges visible

On September 2, LOUIS XO tasked us to investigate whether current ice conditions allowed for open pools of water required for DRDC's AUV launch. If pools were found, we were to report location and disposition to the bridge. This offered an opportunity to display the utility and flexibility of the system. Within 30 minutes of tasking, a flight was in the air and after 45 minutes in the reconnaissance pattern an open pool of water was found that was deemed sufficient size for the AUV launch. We employed a standard search and rescue to find the pool.



Mission plan for Ice-free pond reconnaissance flight (screen capture of pond overlayed)

The National Ice Center (NIC) – a joint NOAA, USCG, and USN organization in Washington, DC – deployed members on the HEALY and LOUIS as part of a sea ice science team. The team, led by the NIC Chief Scientist, Dr. Pablo Clemente-Colón, employed several innovative approaches to relay remote sensing data and provide icebreaking support imagery products onto the ships' mission planning systems. Most of NIC's products are derived from RADARSAT-2, a Canadian-owned commercial satellite. The RADARSAT-2 orbits routinely cover the Arctic and offer valuable remote sensing data for icebreaking operations. The synthetic aperture radar (SAR) images acquired by the system are extremely valuable tools for wide area ice reconnaissance; however, spatial resolution of the images is limited to 100 meters. Above 78°-80° N, IP communications are also limited to a 9600 baud Iridium link. Even with these bandwidth limitations many imagery products are processed, uploaded, and integrated into the ships' map servers within hours of the satellite pass.

Again, the U.S. has no national assets—air or space—that provide on-demand ice data for polar operations. While RADARSAT is a valuable tool, the U.S. Government pays $5,000 on average for a 40km x 40km swath segment. Imagery taskings compete with other customers, and the ice is constantly changing and on the move. During the RAVEN flights from the buoy camp, for example, the ice moved 1.9 miles in less than 4 hours. UAS flights demonstrated an extremely valuable, cost effective method to validate remote sensing data.

Challenges

Environment – The cold temperatures inherent to the Arctic did not seem to degrade the flight performance or endurance of the system. However, wind conditions are extremely unpredictable as there is very little weather data collected in the high Arctic for weather forecast models. Often, bad weather seems to appear out of nowhere on a very short timeframe. At least 50% of the cruise saw wind speeds above 15 knots. (20 knot winds are the recommended limitation of the system).

Icing was also a concern. Several days in late August and early September see average temperatures hover around 32° F. Cloud and ice-fog layers were present almost every day of the cruise. These late-summer conditions increase the difficulty of conducting flights, and could be worse during the harsh Arctic winter.

Navigation – An unexpected problem arose during high Arctic flights. The military coordinate grid system (MGRS) ends at the 84th parallel north (84° N), at which point the polar grid coordinate system-North (PCS-N) is utilized. Falconview, the military mapping program that can input automated navigation points into the RQ-11 before and during flight, does not contain PCS-N therefore rendering the system useless for the RQ-11A’s flight above 84° N. After conversations with the system designers and programmers, this issue has been resolved in newer systems.

More important, the RQ-11A’s magnetic compass is rendered useless within 200 miles of the magnetic north pole. The RAVEN autonav system uses a combination of GPS guidance and magnetic compass to navigate to waypoints, including its “HOME”. In many cases, the AV would not navigate to its waypoint unless the compass reading was within 20 degrees of magnetic north. Manual navigation required constant attention to a handheld GPS system to derive the AV’s location. During two flights the AV was lost for up to five minutes at a time.

Limiting Factors

The system is largely at the mercy of the unpredictable weather in the high Arctic. According to the experienced scientists onboard, HLY 1102 saw mostly good weather conditions during the deployment. Still, on over half of the days during our cruise, we experienced winds over 15 knots. Ice fog impacted visibility and limited flight ops on at least four occasions. Precipitation was not a large factor since most of it came in the form of snow, but icing impacted one of the flights when the AV flew through cloud layers. No noticeable impact to the AV’s flight characteristics was observed when ice accumulated on the propeller.

The extreme cold and landing on a metal helicopter deck caused more damage to the system than normal. The cold tended to make the plastic connectors brittle and more apt to break upon landing. Also, two tailbooms experienced cracking after landing. Field repairs were sufficient to keep the system running but another month's worth of flights would have probably exhausted spares.

Endurance and range are also limiting factors for the system. Due to the manpower limitations and the simplicity/availability of systems, RAVEN A's were chosen as the platform for flights, but a UAS with longer endurance and greater range would be preferred.

Recommendations

The HEALY will deploy for the 2012 Arctic season without the LOUIS. It is highly likely the ship will have no airborne reconnaissance capability next season. A UAS would provide valuable assistance for several aspects of the ship's mission.

While the RAVEN has now proven capable of assisting in icebreaking operations and marine mammal patrols, a larger UAS with longer endurance, variable zoom/pan cameras, and a higher ceiling would be more effective for Arctic operations. Either Scan Eagle or a similar system that can be launched and recovered from the ship while underway would be a more preferable platform. Deployment of a micro SAR or multispectral camera could also prove very effective in verifying the satellite remote sensing data integrated into the HEALY's mission planning system. This has potential to revolutionize Icebreaking mission planning and navigation, with the potential for hundreds of thousands of dollars in fuel savings. It also has huge implications for validation of satellite remote sensing date, ice reconnaissance, shipping/vessel identification, search & rescue, personnel recovery, and oil spill response.

Finally, it is critical for the USCG to develop an expedited process to authorize ship-borne UAS flights. According to CGHQ, the U.S. Navy (USN) is the certifying authority for any air missions taking place on the HEALY. Helicopters as large as the HH-60 down to the 4.2lbs RQ-11 are all treated as aircraft, and must go through an onerous and expensive USN process for aircraft flight deck certification (even if the flight deck is not being used for flights). A flight-deck certification waiver process should be put in place for research-related activities on board the unarmed HEALY; a one-of-a-kind ship primary mission is scientific research.

To my knowledge, these ship-borne RQ-11 flights were a first ever for Arctic scientific research. I am indebted to USCG PACAREA for its advocacy in conducting flights in the Arctic and Air Force Special Operations command for writing the COA and cutting-edge tactical training for the RAVEN flights. Also, this would have never been possible without backing from my NIU thesis advisor, Dr. Peter Leitner and UASF supervisor Mr. James Clark who provided

funding and operational support for this mission. Finally, these flights would have never taken place without the outstanding support from Dr. Larry Mayer and Dr. David Mosher.

I will be forever indebted to Capt Marc Rothwell and the crew of the CGCC LOUIS, who made this all possible “on the fly”. The professionalism demonstrated by both the CGC and USCG during the icebreaking mission was both humbling and astounding.

Appendix 10 – Daily Gravimeter Plots

Deborah Hutchinson

Addendum: LSSL 2011 Daily Gravity Plots
BGM-3 223 Meter

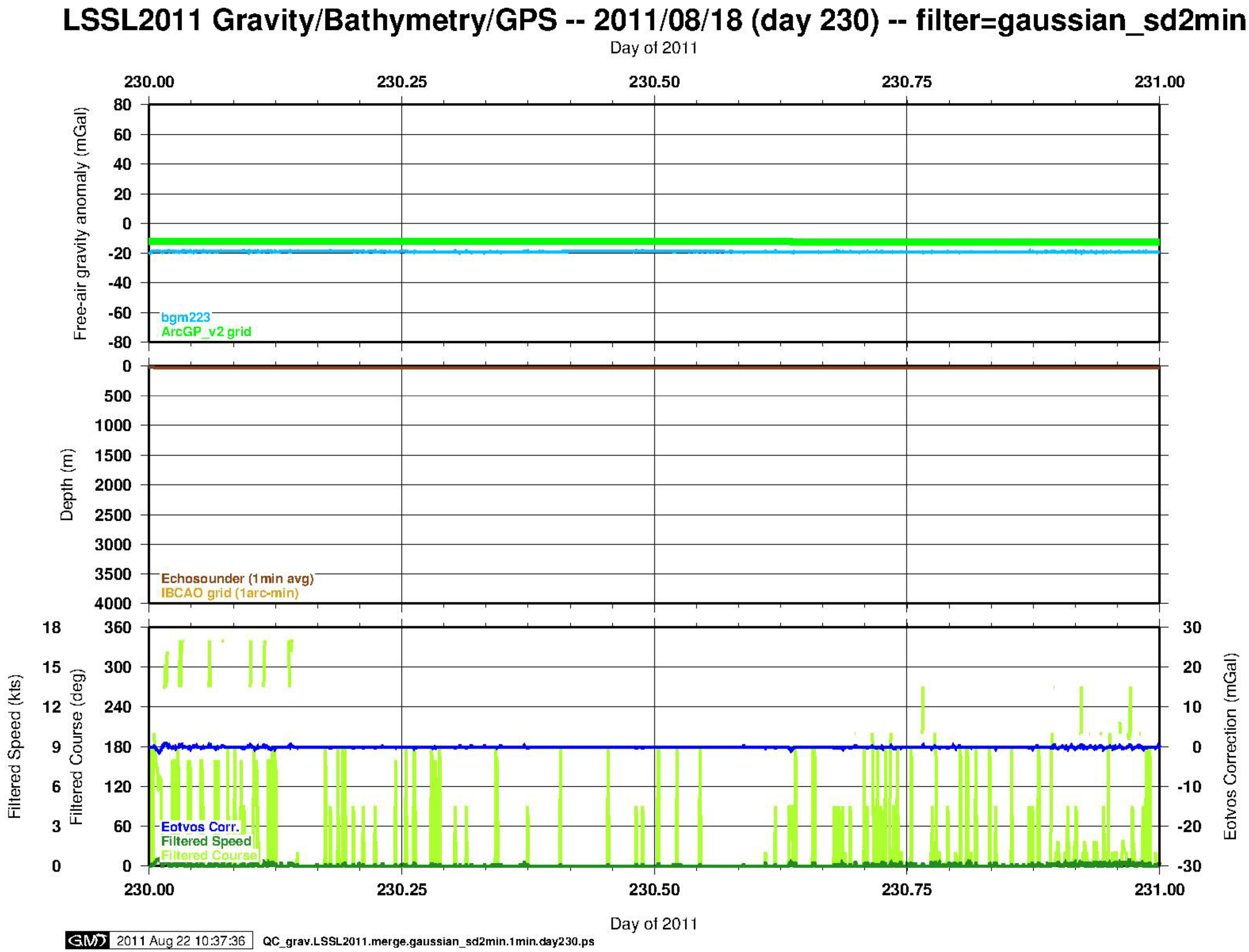
D.R. Hutchinson
USGS

August 18 – September 25, 2011

The following pages show the daily gravity plots done for QA/QC during the cruise, together with notes relevant to gravity analysis and processing (at the bottom of each page). One day per page is shown, with hourly divisions. A description of the daily plots is given in Table 4.

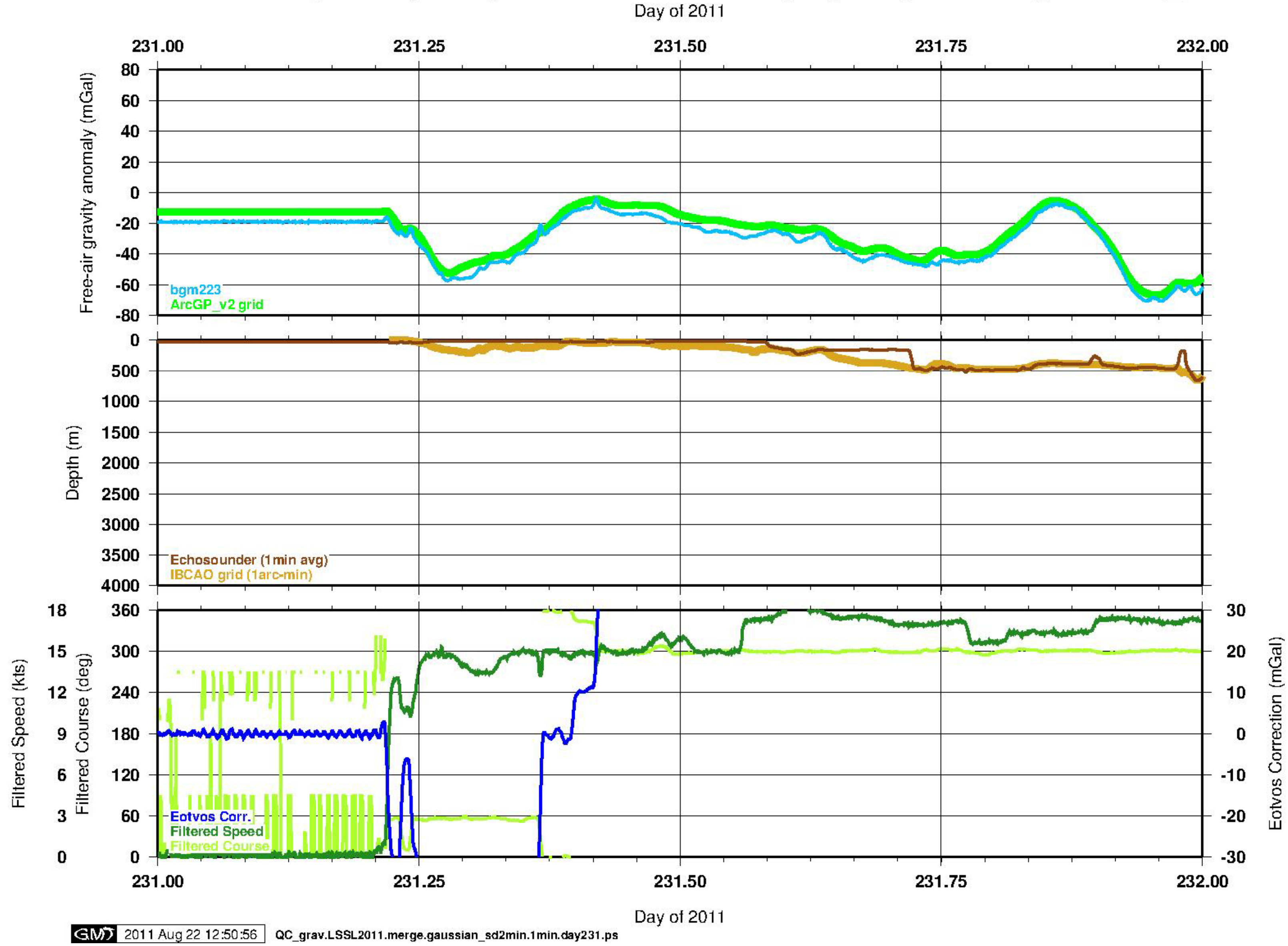
Table 4: Description of Daily Gravity Plots

Panel	Description
Top	Shows the smoothed BGM-3 smoothed Free-air Anomaly (blue) plotted with the Arctic Gravity Grid (http://164.214.2.59/GandG/agp/index.htm) profile. Note: On JD 244, the scale for the gravity was changed to +100 mGal for the maximum gravity value plotted (from +80 mGal).
Middle	Shows the bathymetry measured aboard *Louis* (dark brown line) plotted with the IBCAO values at the same position (tan line). Note: Because the echosounder could not follow the seafloor in areas of rough topography and lost lock on the seafloor from ice interference when *Louis* was icebreaking, there are many points where the depth values go to zero, giving a spike, or default to the top of the monitoring window, giving a box-appearance to the curve. These represent unreliable depth values. A file of the edited, smoothed depths along track was created during the cruise using both the 12-kHz and 3.5-kHz sounders, and needs to be integrated into the post-cruise gravity processing.
Bottom	Shows filtered course (light green), filtered speed (dark green), and Eötvos correction (blue).



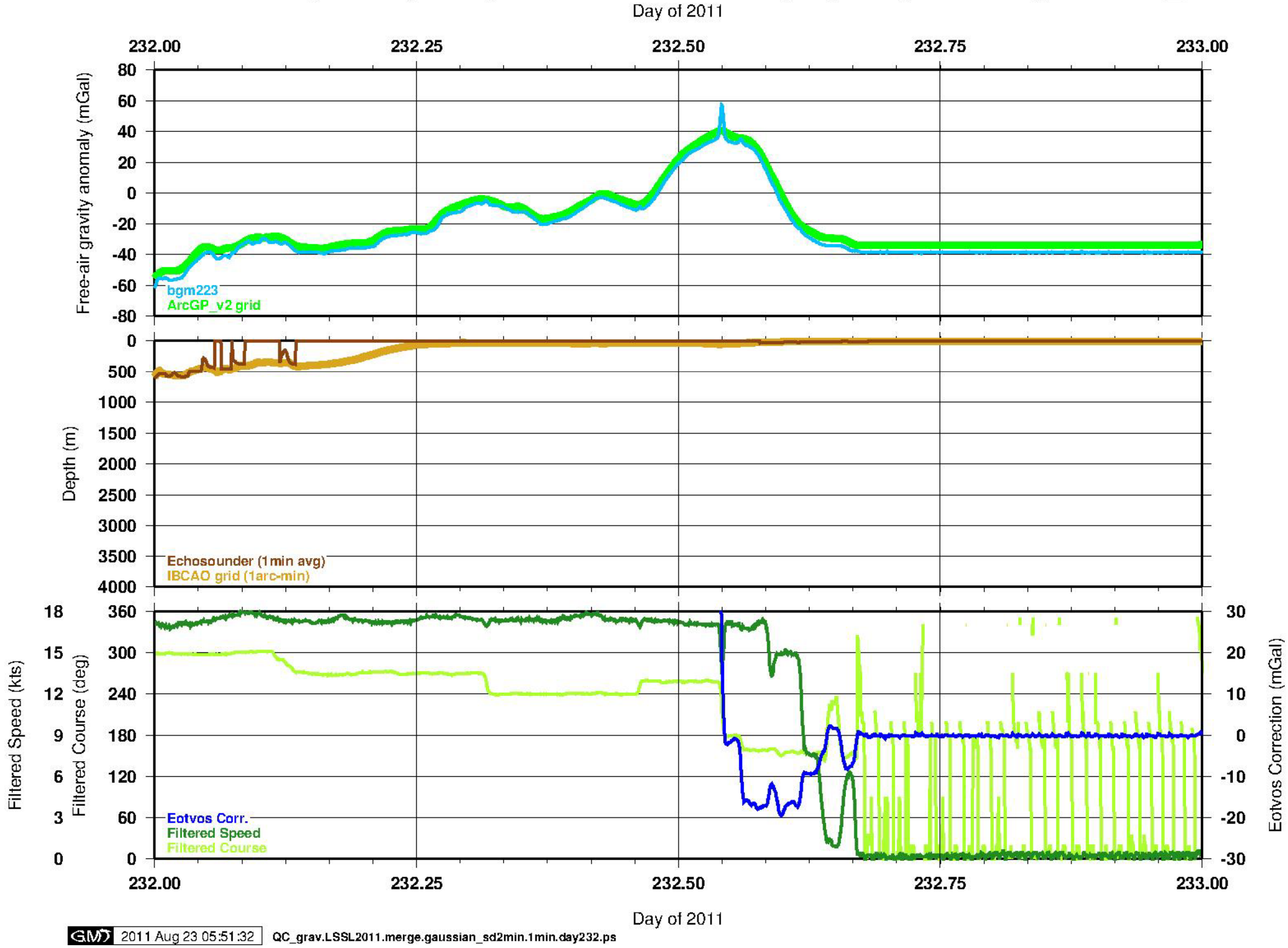
Notes: At anchor in Kugluktuk

LSSL2011 Gravity/Bathymetry/GPS -- 2011/08/19 (day 231) -- filter=gaussian_sd2min



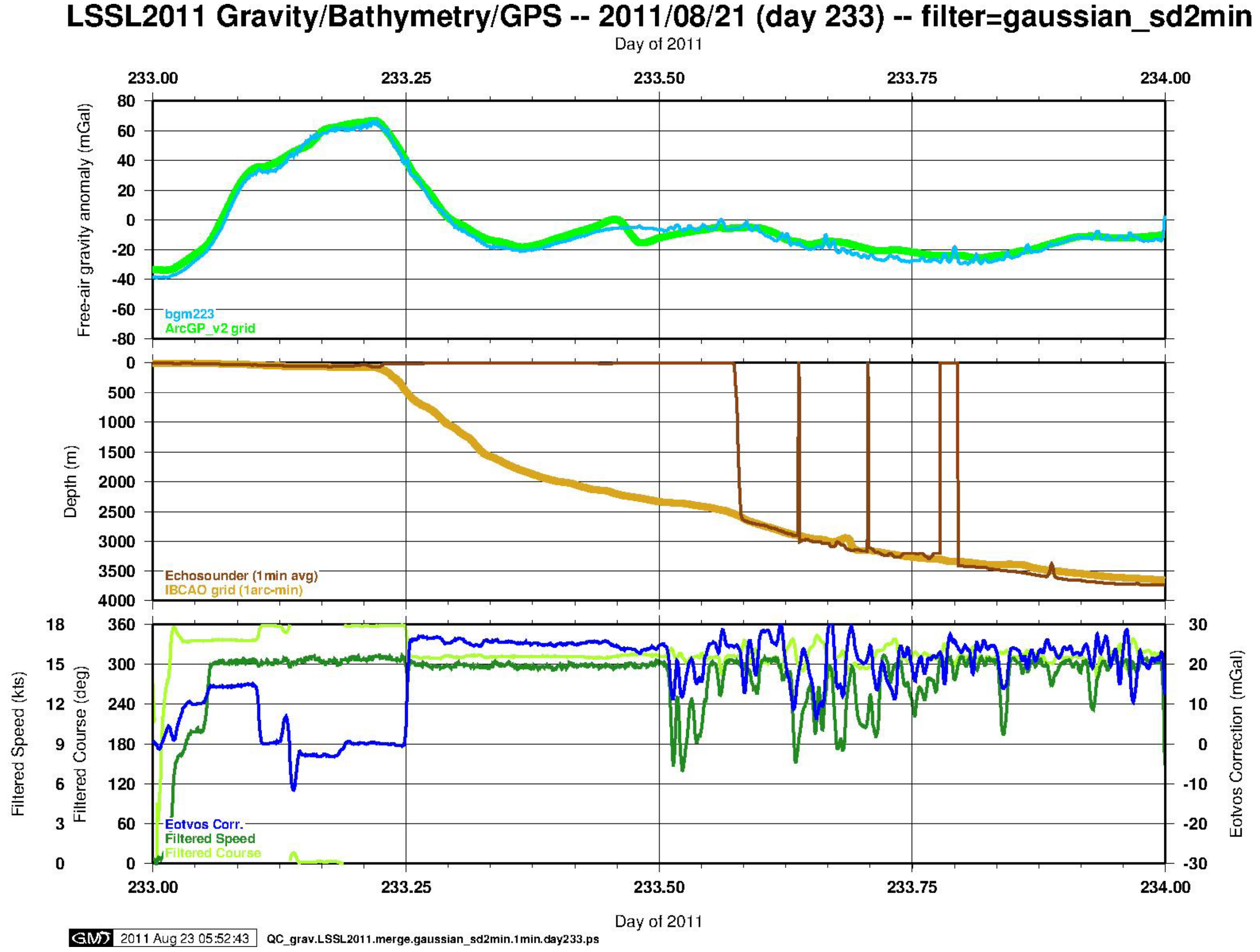
Notes: 05:00 depart Kugluktuk for Tuktoyaktuk

LSSL2011 Gravity/Bathymetry/GPS -- 2011/08/20 (day 232) -- filter=gaussian_sd2min

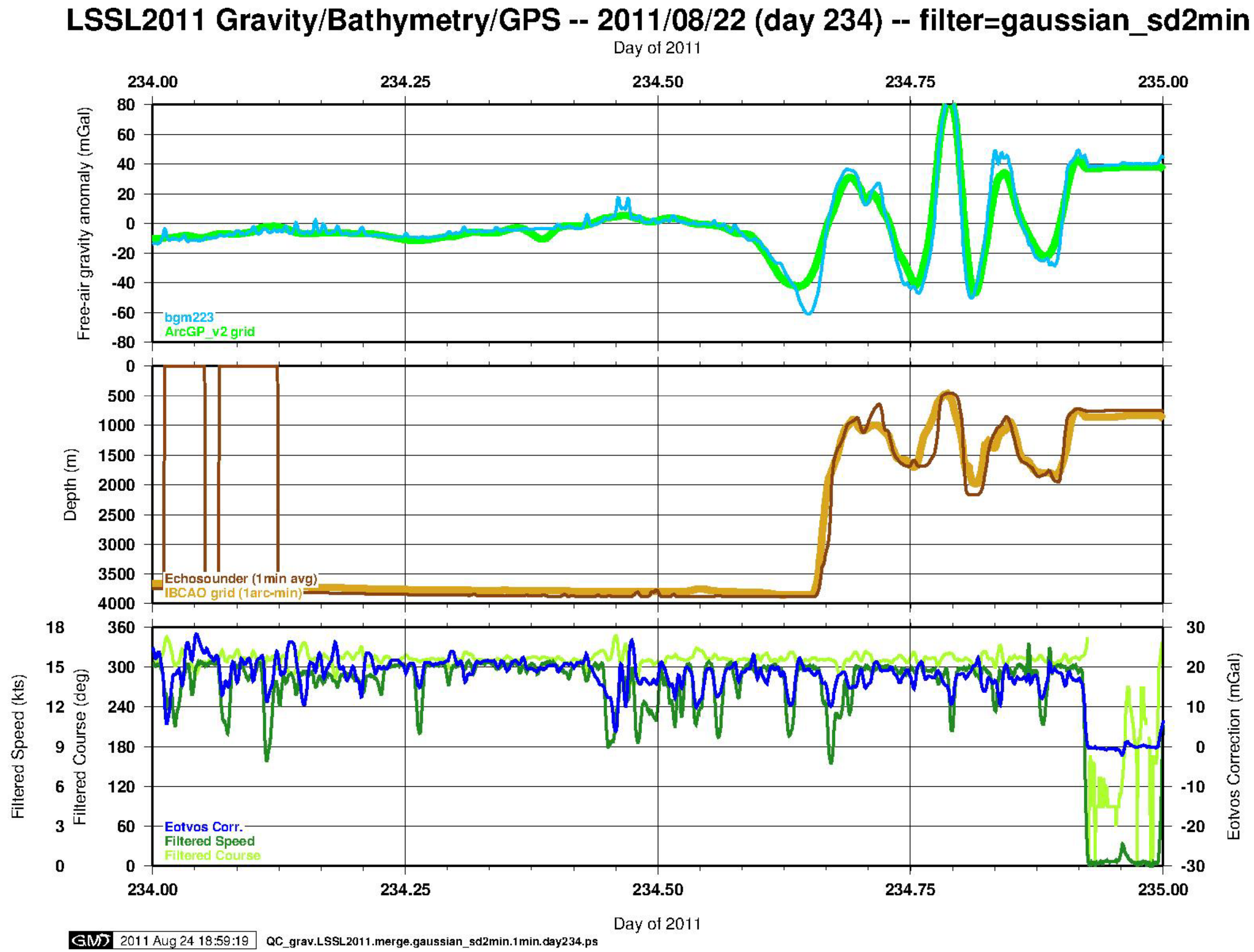


Notes: ~13:00 Drop anchor Tuktoyaktuk,

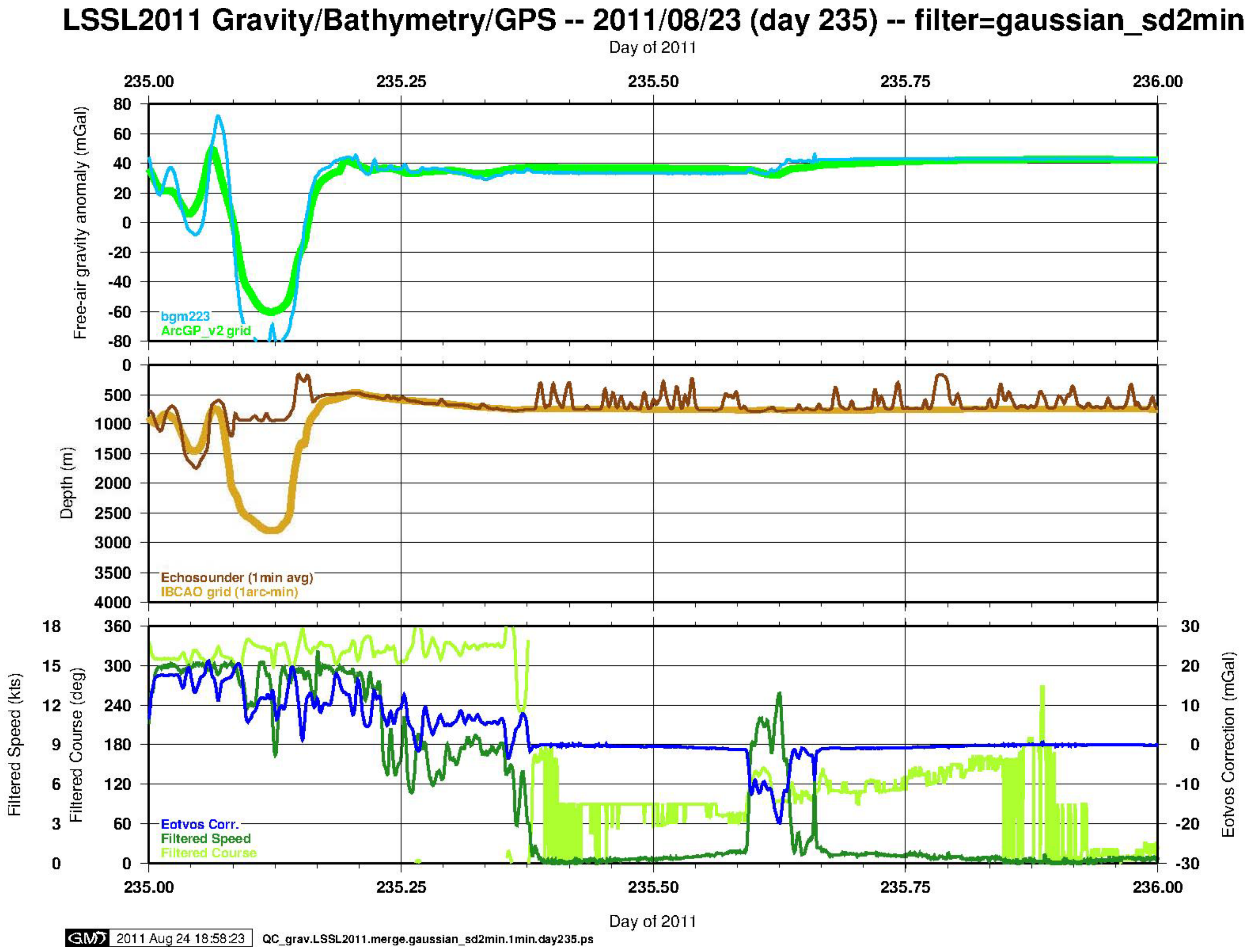
Problems with new 3.5 kHz echosounder formatting/recording; switch between 3.5 kHz and 12 kHz.



Notes: ~00:00 Depart Tuktoyaktuk for first waypoint, Continuing problems with echosounder formatting/recording; continue switching between 3.5 kHz and 12 kHz.

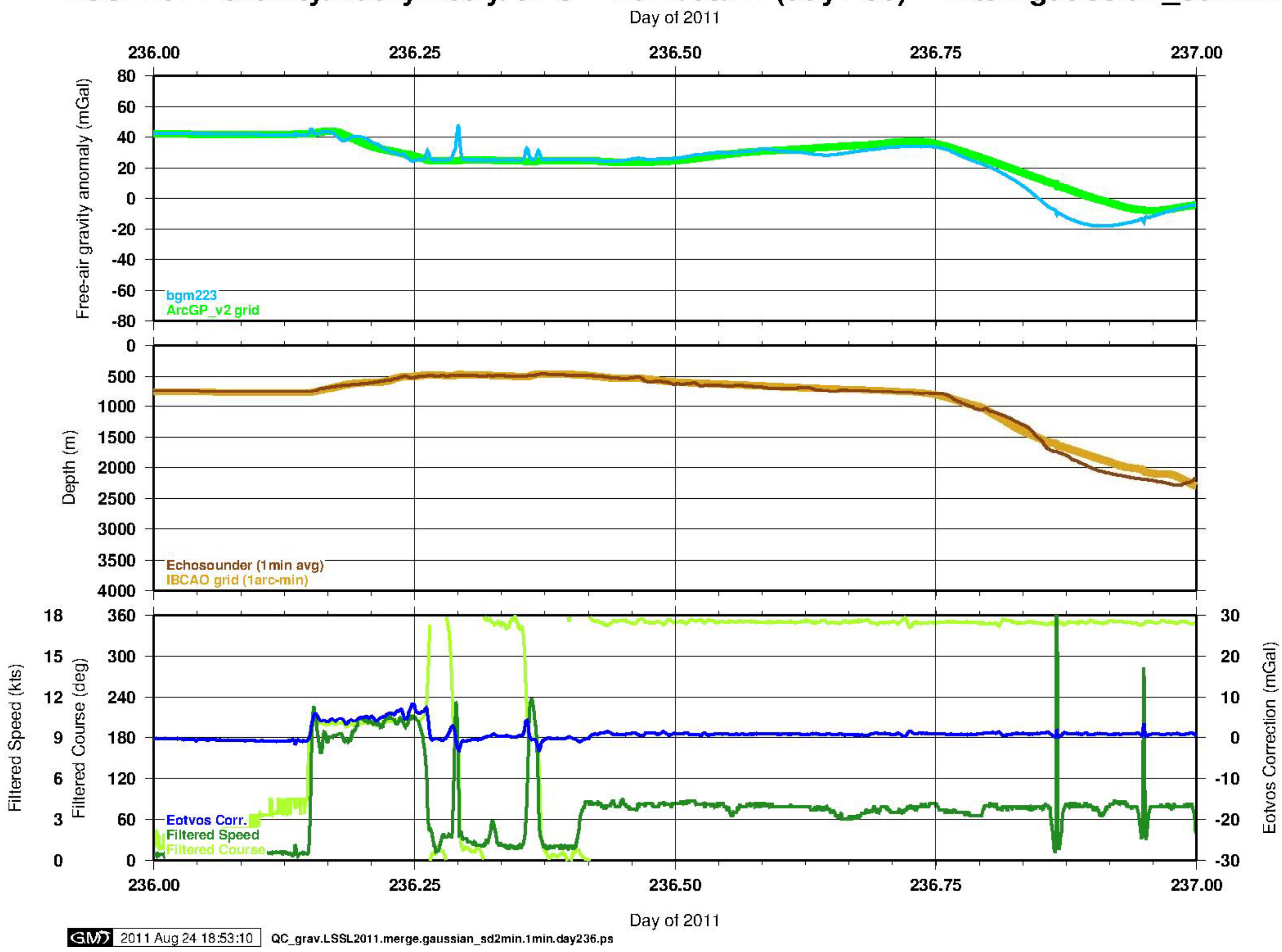


Notes: Steaming across Canada Basin to rendezvous point with Healy; ~22:15 stop for CTD station; GPS a bit erratic



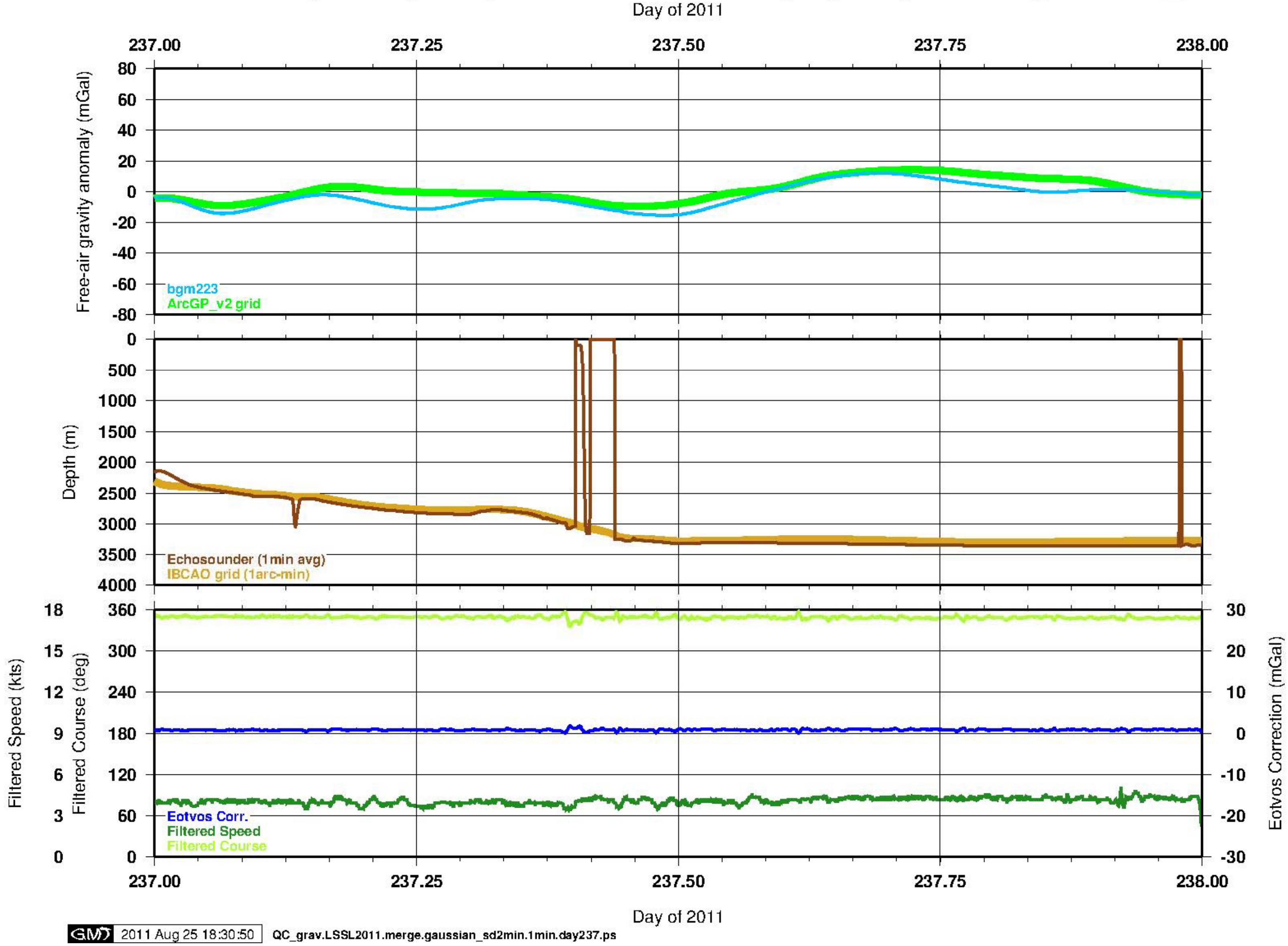
Notes: 00:00 Depart for rendezvous point; ~09:00 arrive at rendezvous and hove to; ~14:00 depart to meet Healy; ~16:15 alongside Healy to refuel. GPS still giving problems .

LSSL2011 Gravity/Bathymetry/GPS -- 2011/08/24 (day 236) -- filter=gaussian_sd2min

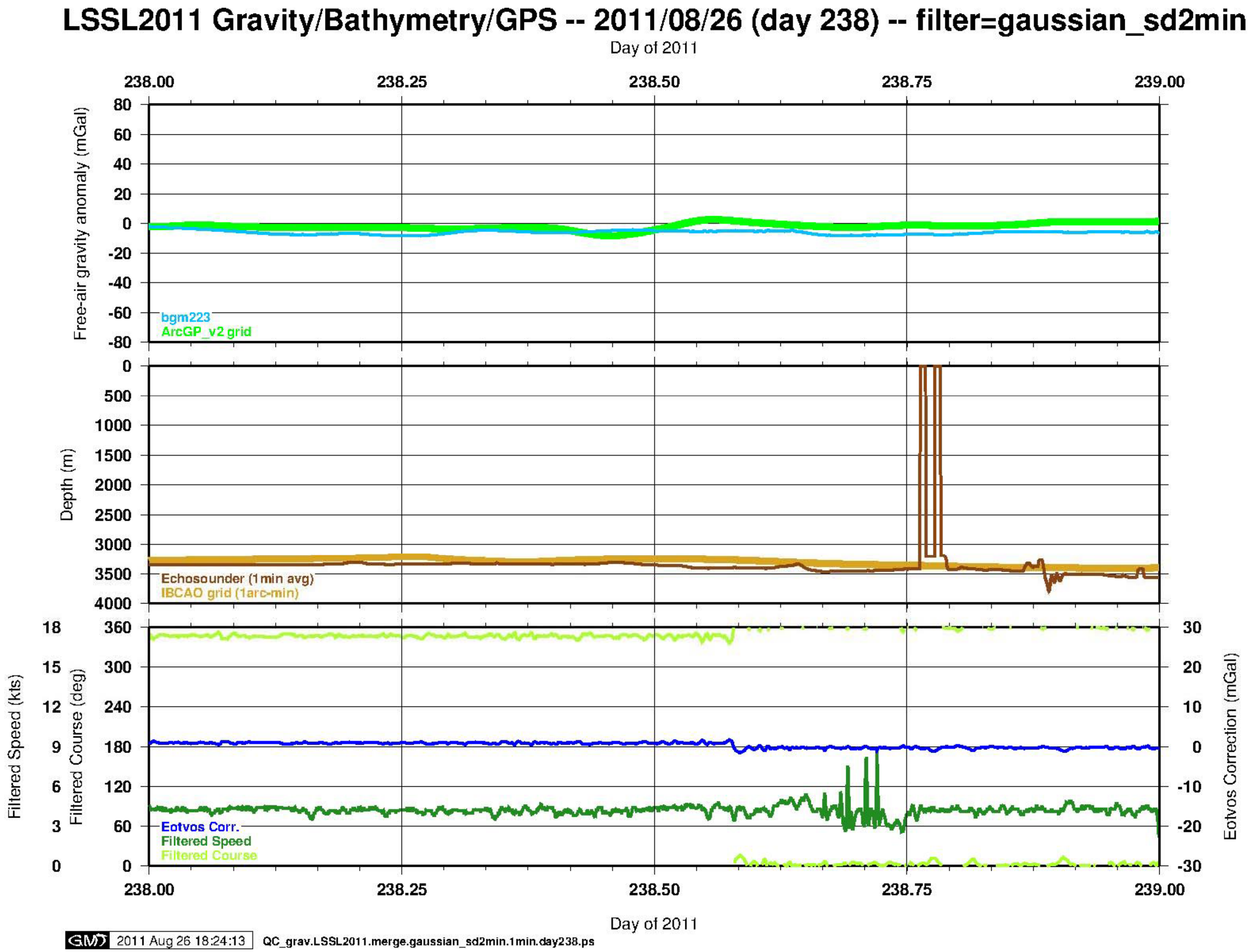


Notes: ~04:00 Clear Healy to steam back to SOL. ~06:30 slow to stream gear; several circles; ~10:00 SOL on Chukchi Plateau. Continuing GPS problems.

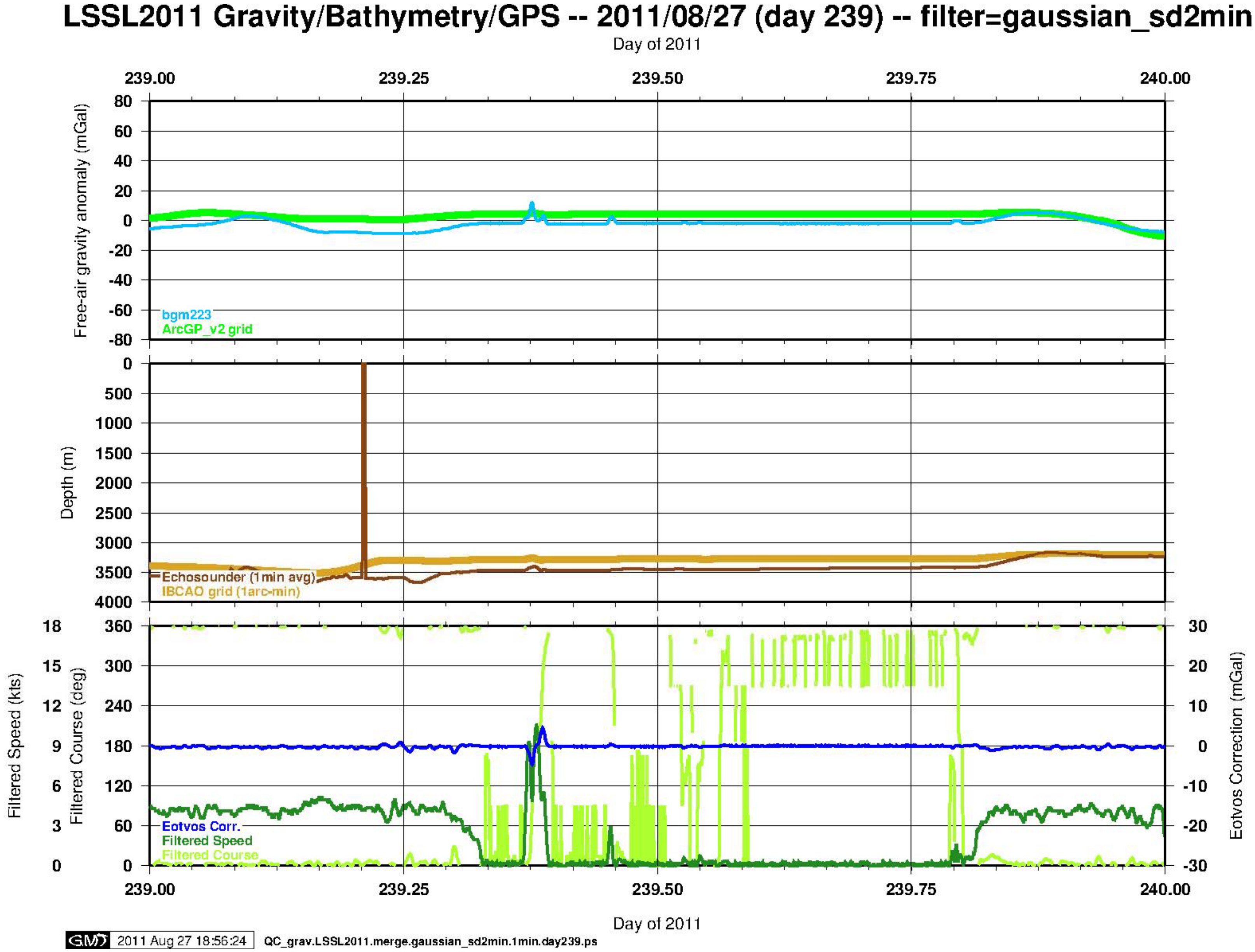
LSSL2011 Gravity/Bathymetry/GPS -- 2011/08/25 (day 237) -- filter=gaussian_sd2min



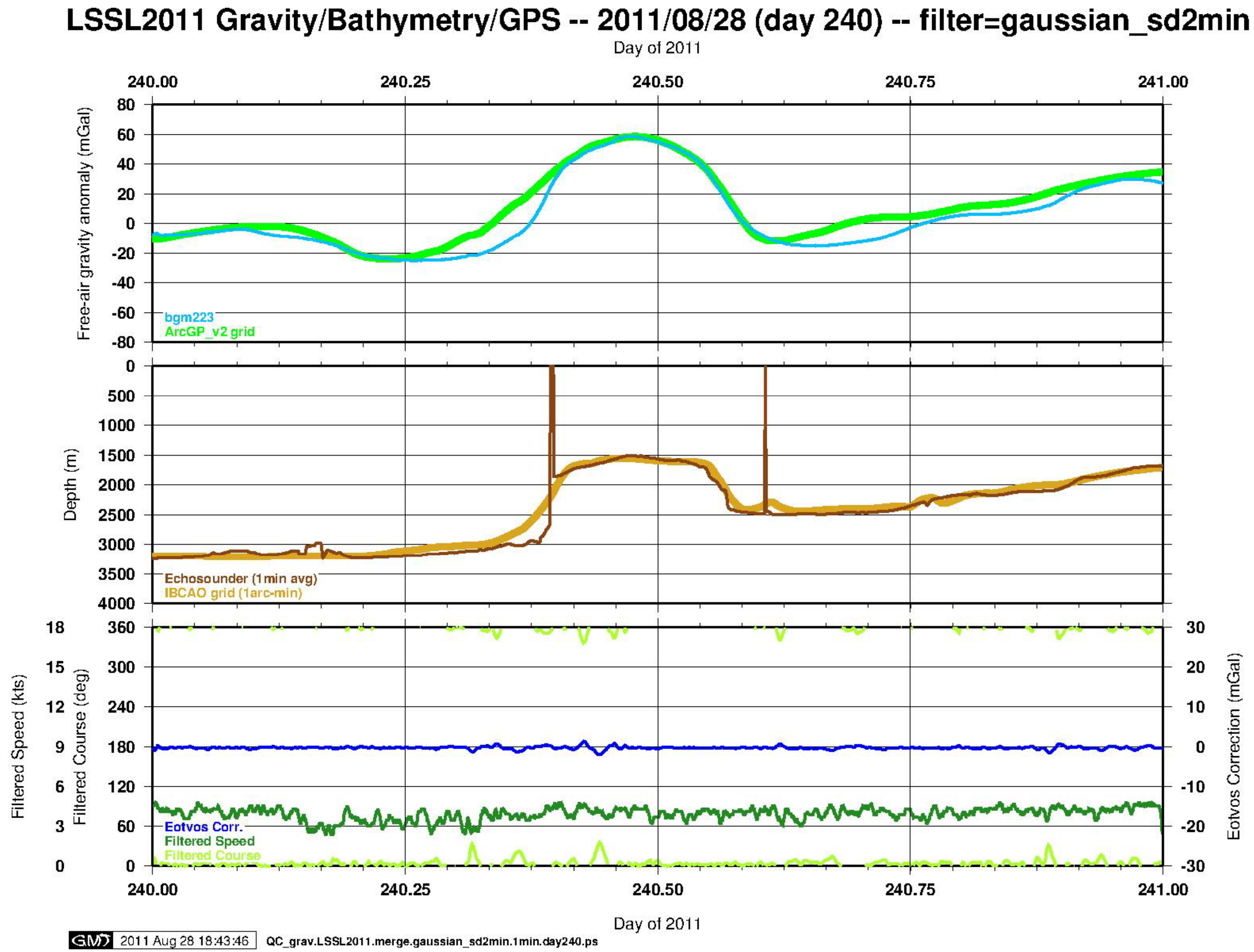
Notes: ~23:20 EOL 1/SOL 2



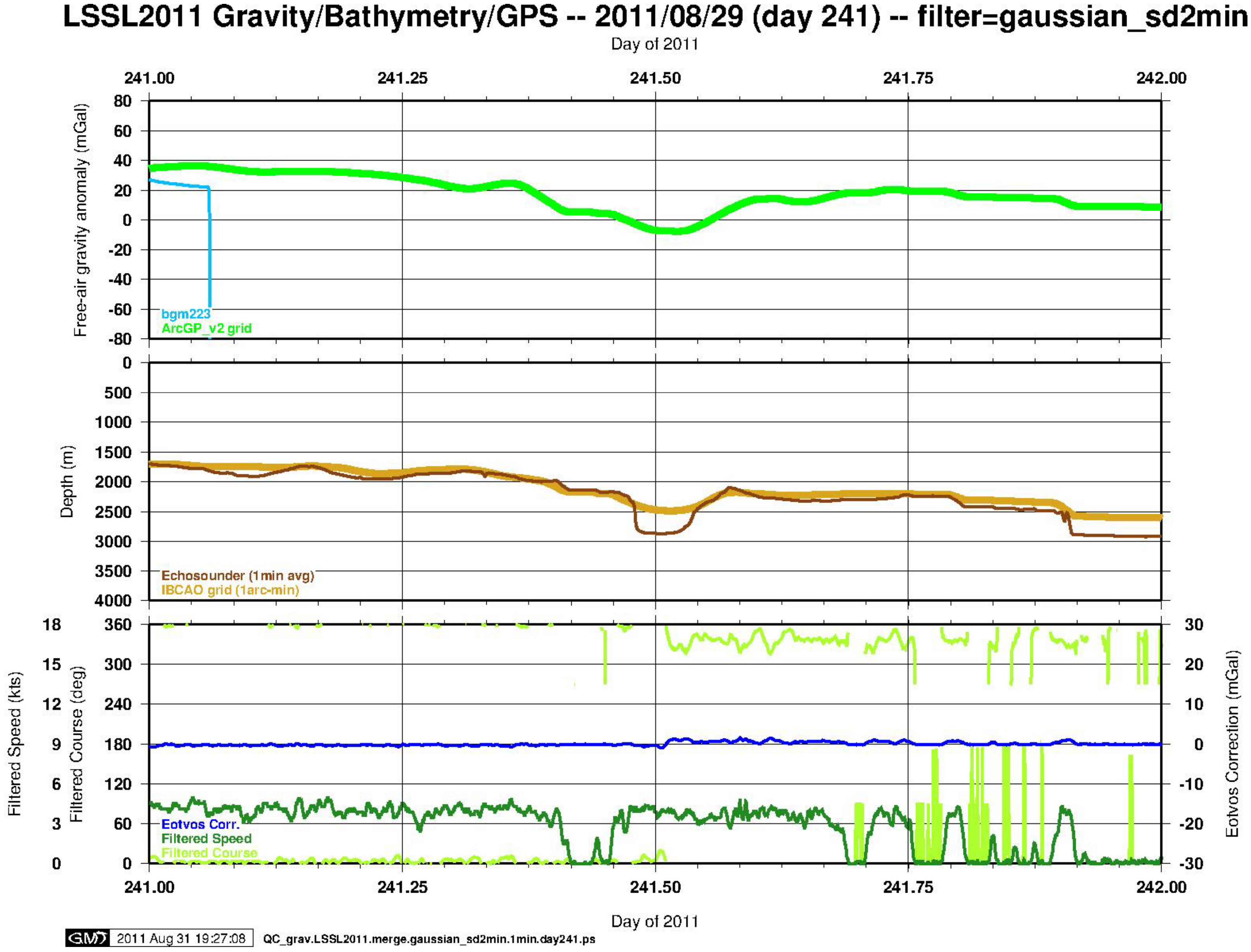
Notes: ~14:00 EOL 2, SOL 3



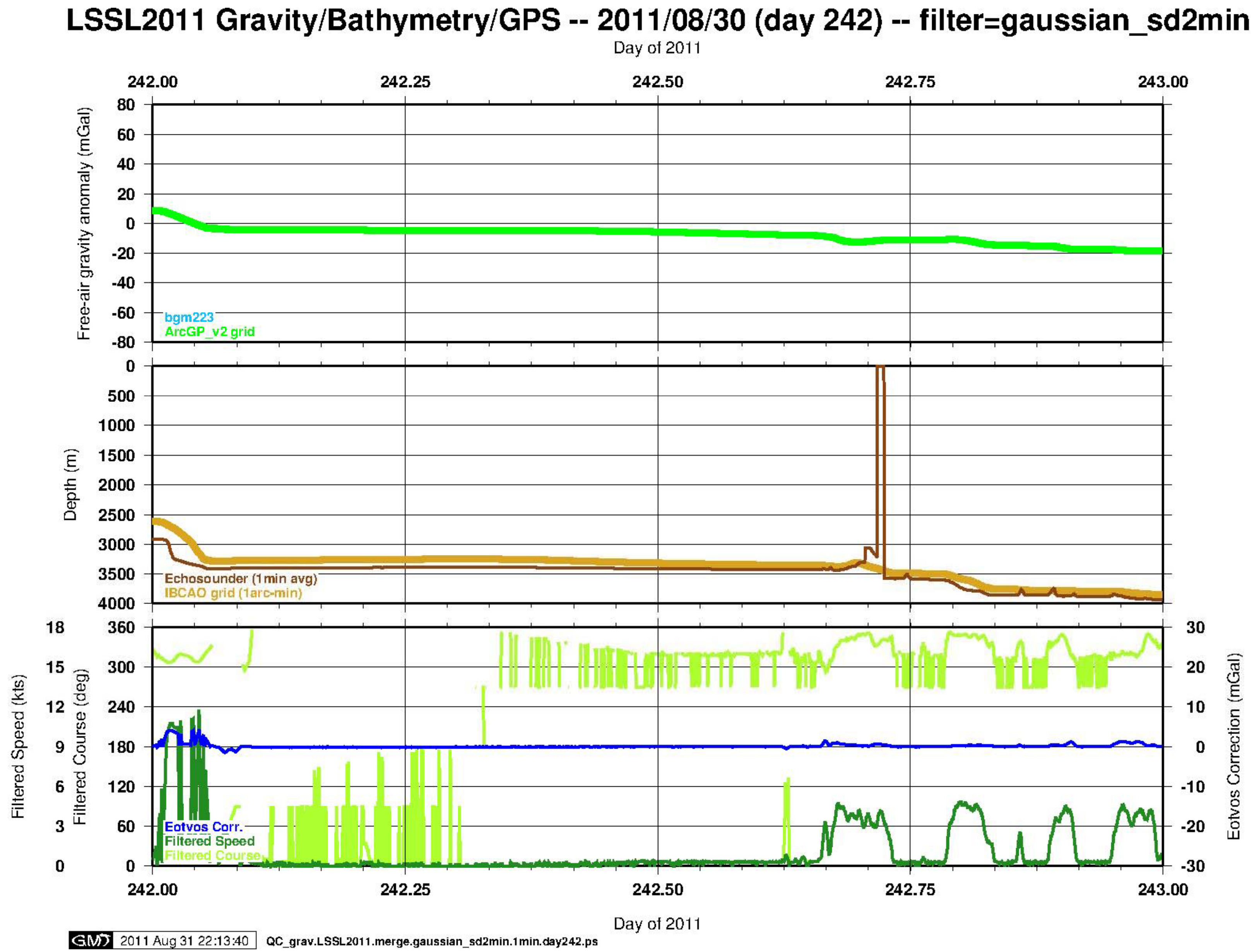
Notes: 07:55 EOL 3; haul gear for repairs (cicrcle and hove to during repairs); 19:46 resume line 3B with all gear working.



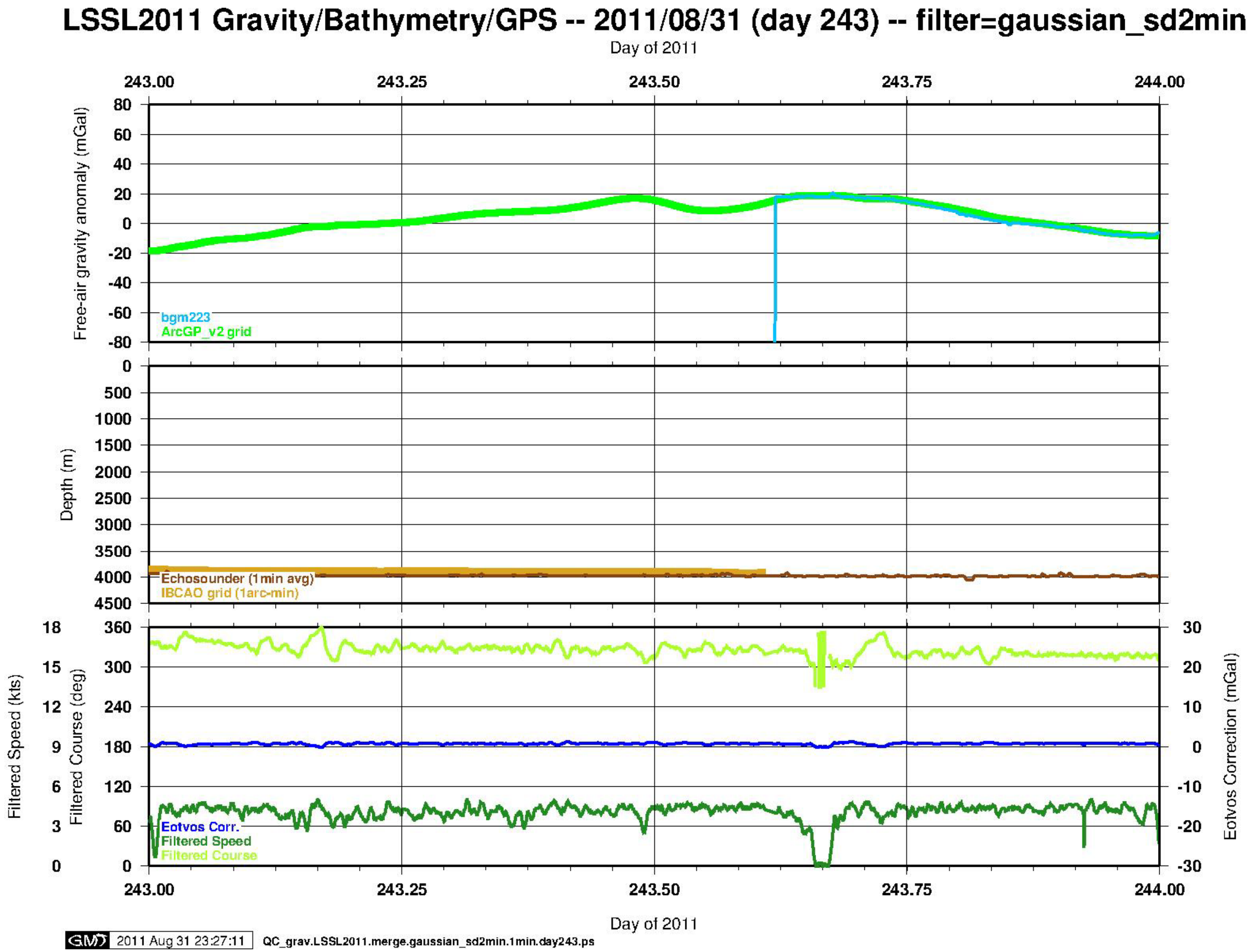
Notes: On Line 3B all day.



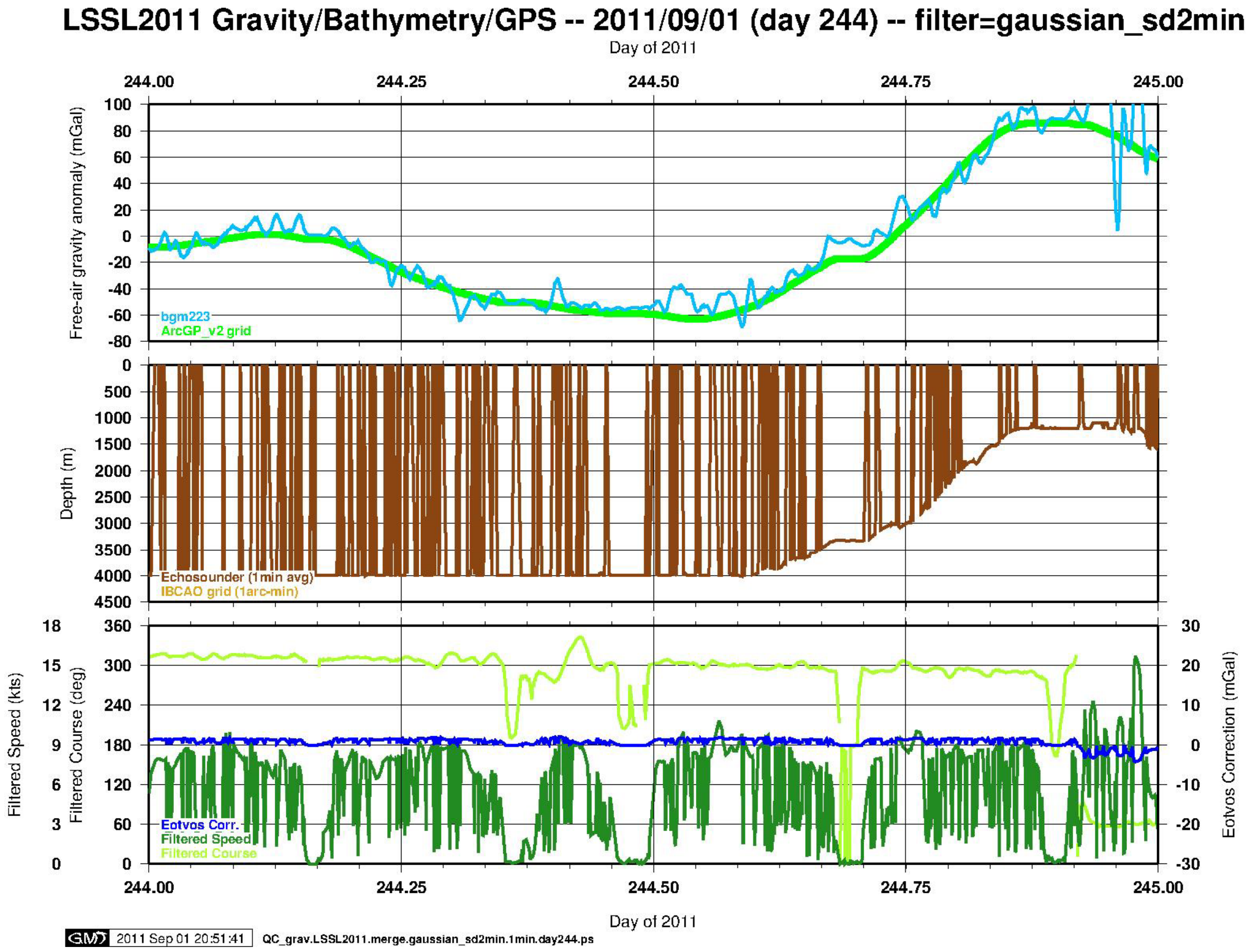
Notes: JD241 01:30z Gravimeter fails – CPS errors



Notes: Gravimeter still down. Healy gravimeters are working. Lots of getting stuck in the ice.

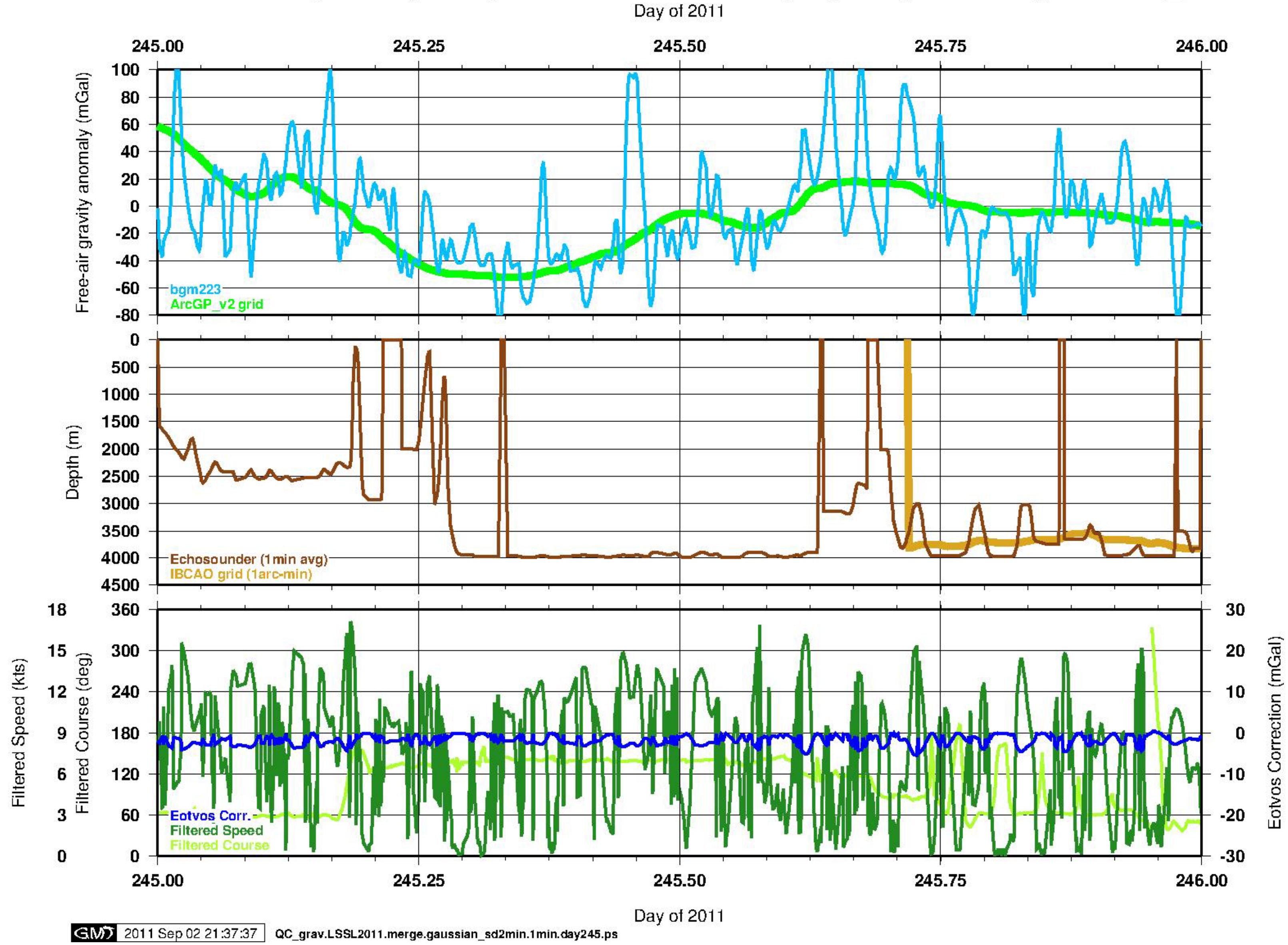


Notes: JD243 15:05 After restarting CPS unit, gravimeter begins logging and working (RGS time = 14:54).



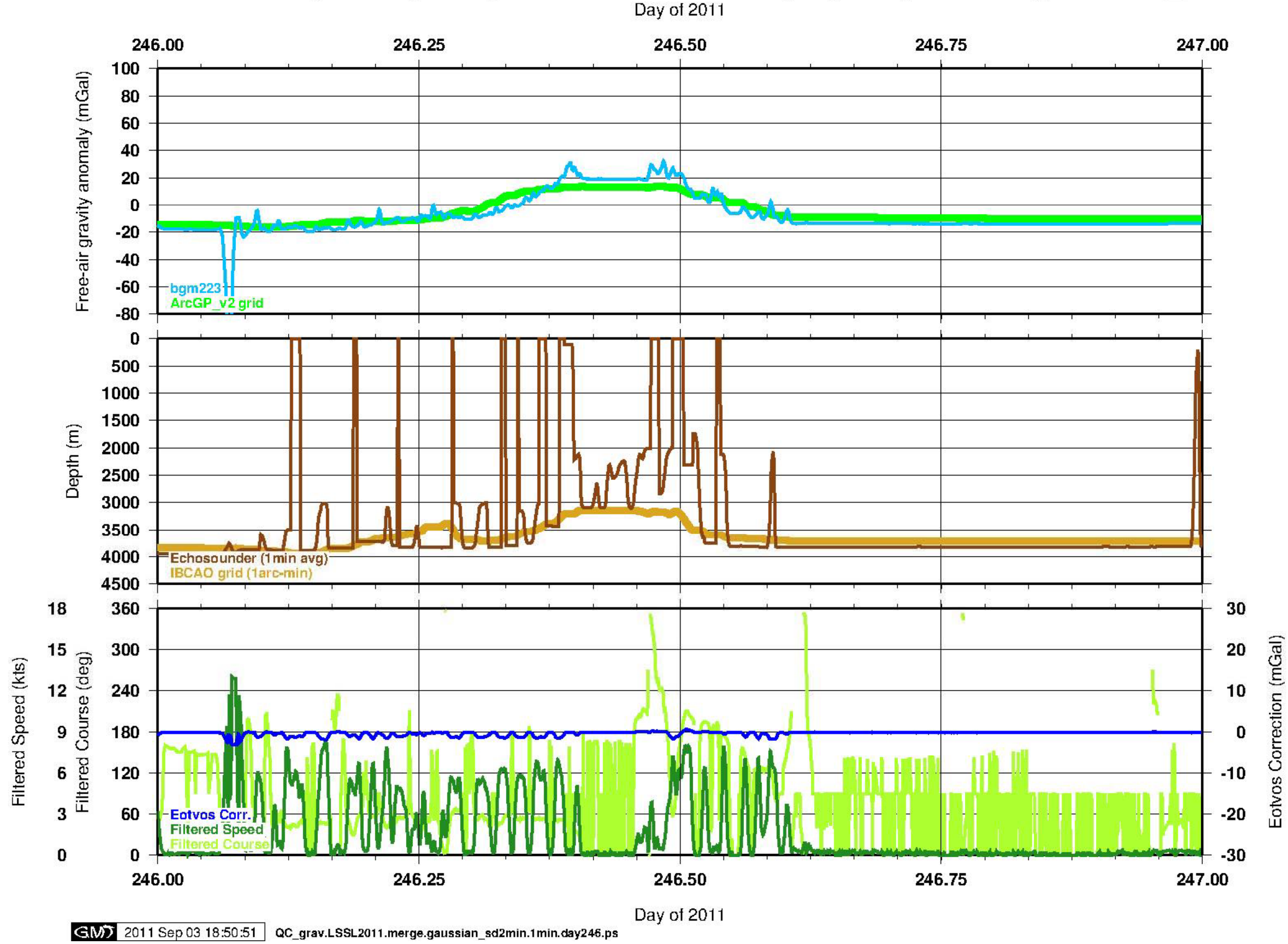
Notes: Noisy record probaby due to two gravlog programs running. 22:11z – Louis begins breaking ice for Healy.

LSSL2011 Gravity/Bathymetry/GPS -- 2011/09/02 (day 245) -- filter=gaussian_sd2min

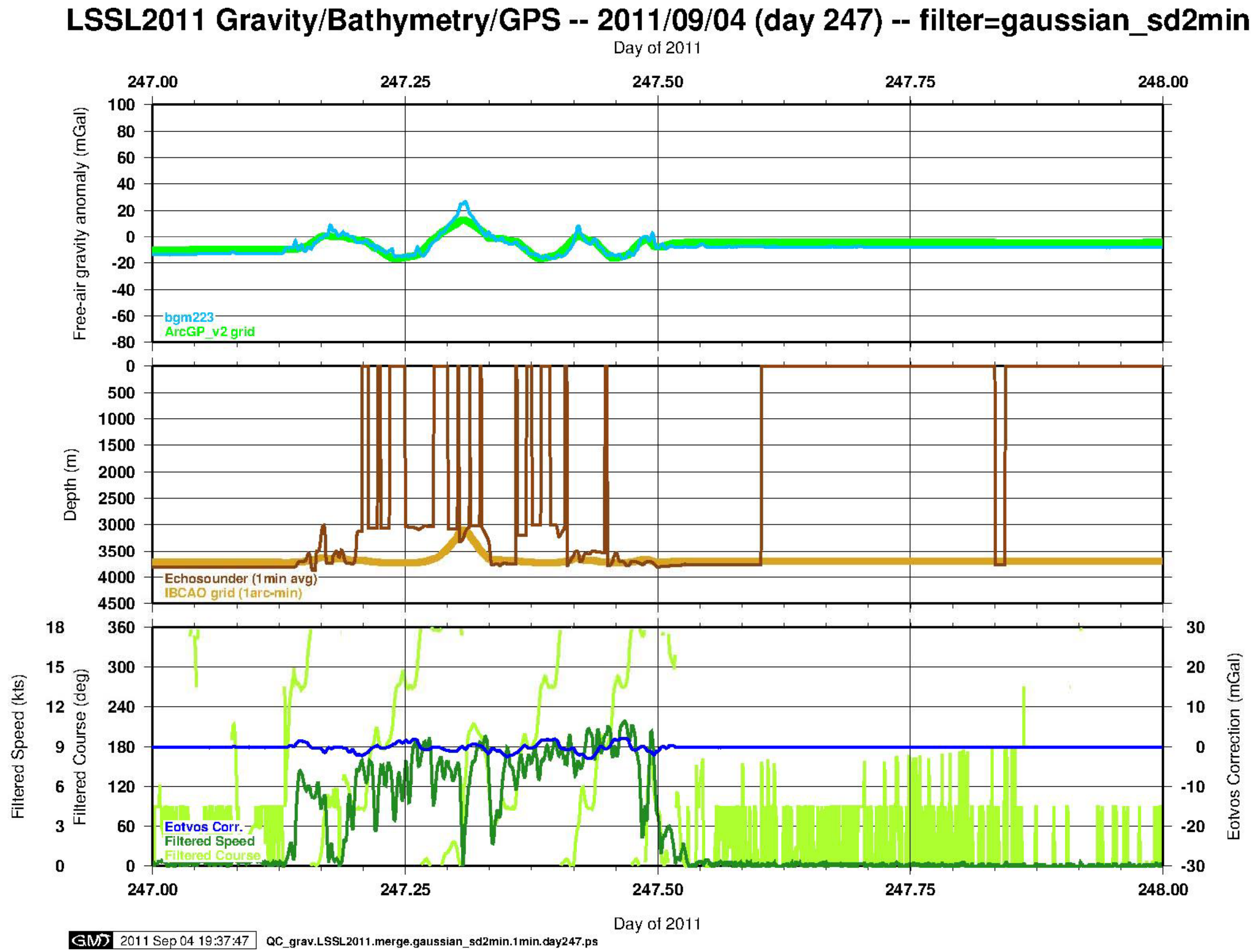


Notes: Noisy record probaby due to two gravlog programs running simultaneously.

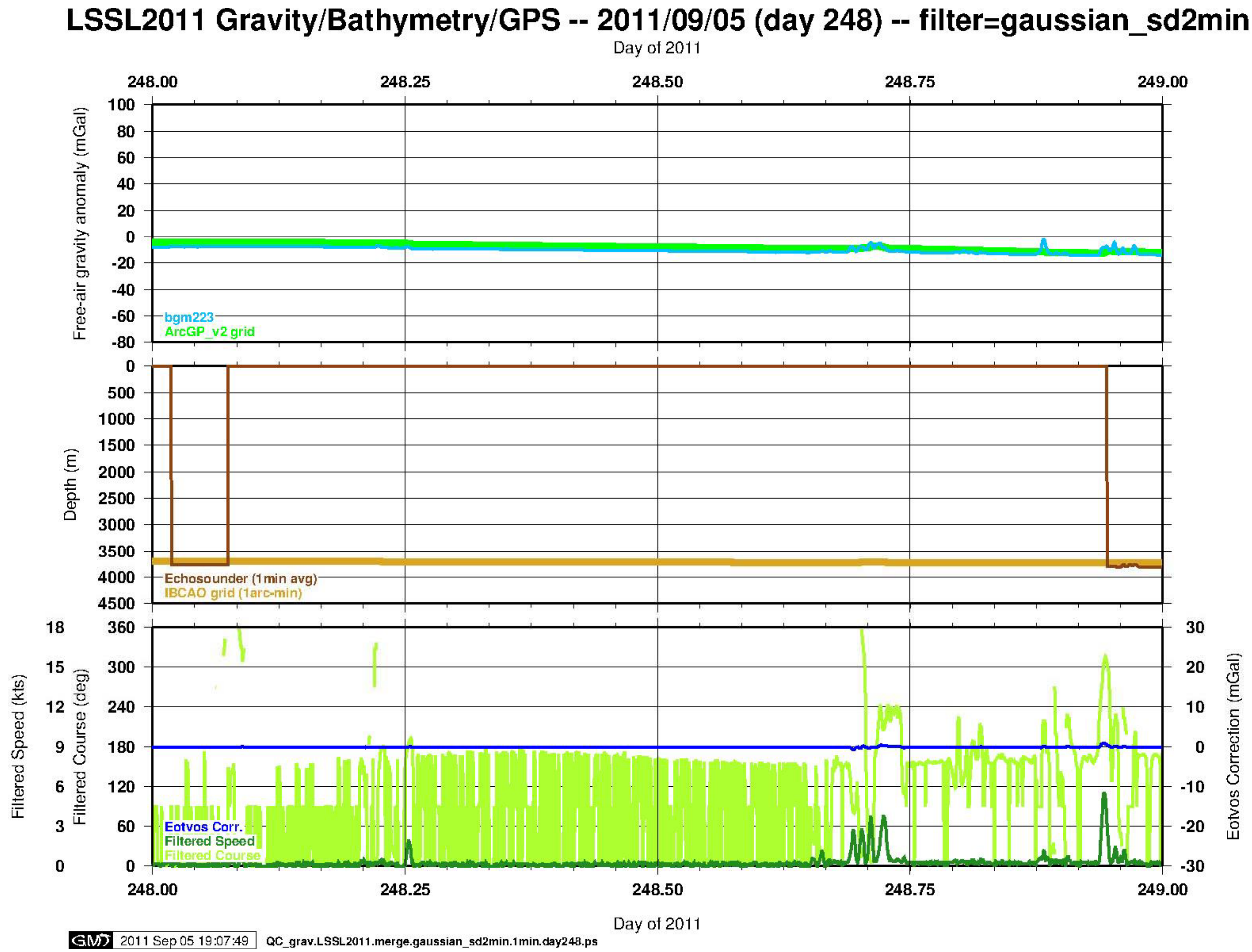
LSSL2011 Gravity/Bathymetry/GPS -- 2011/09/03 (day 246) -- filter=gaussian_sd2min



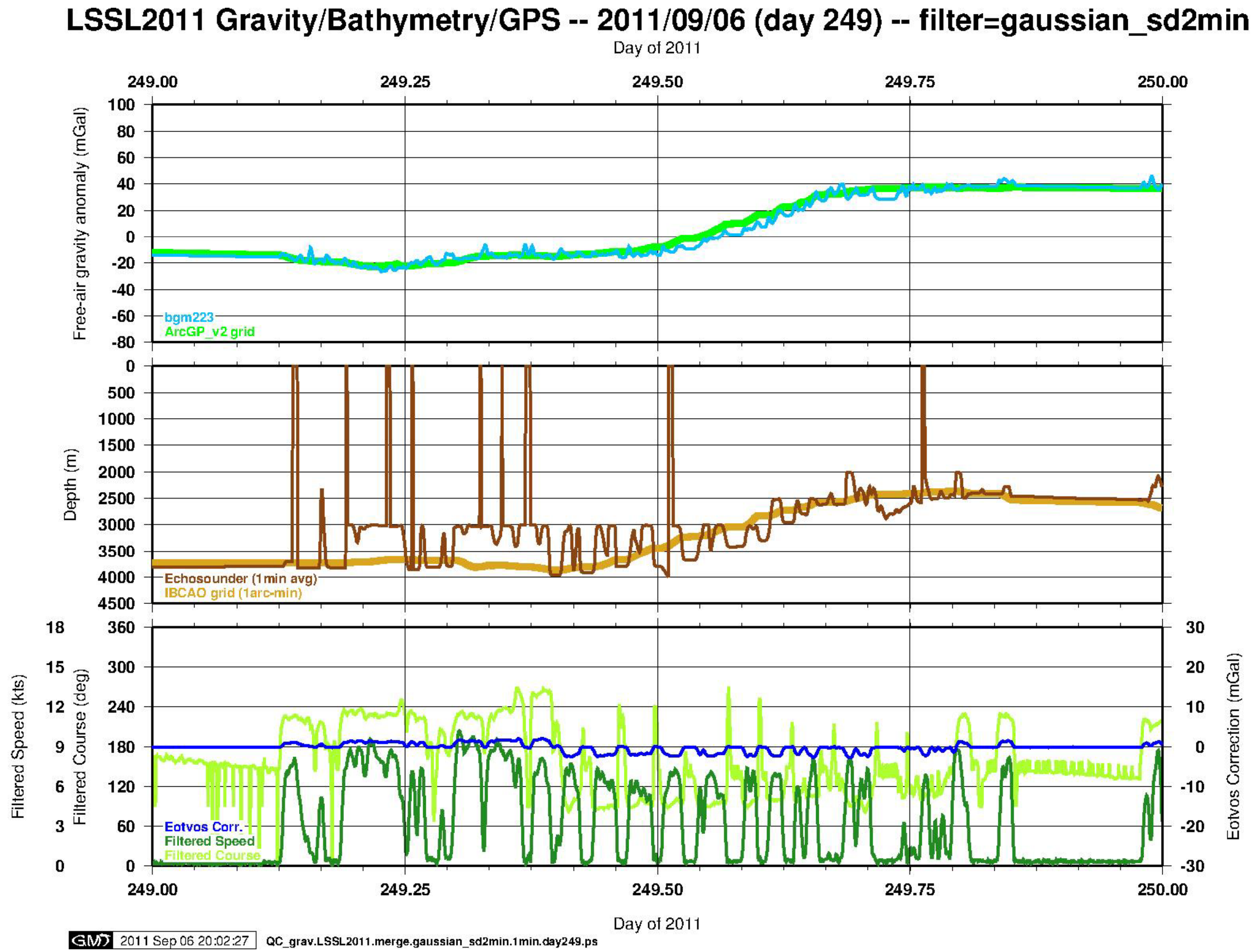
Notes: JD246 02:30z – kill duplicate program of gravlog, Louis breaking ice for Healy; 13:15z stop for AUV deployment



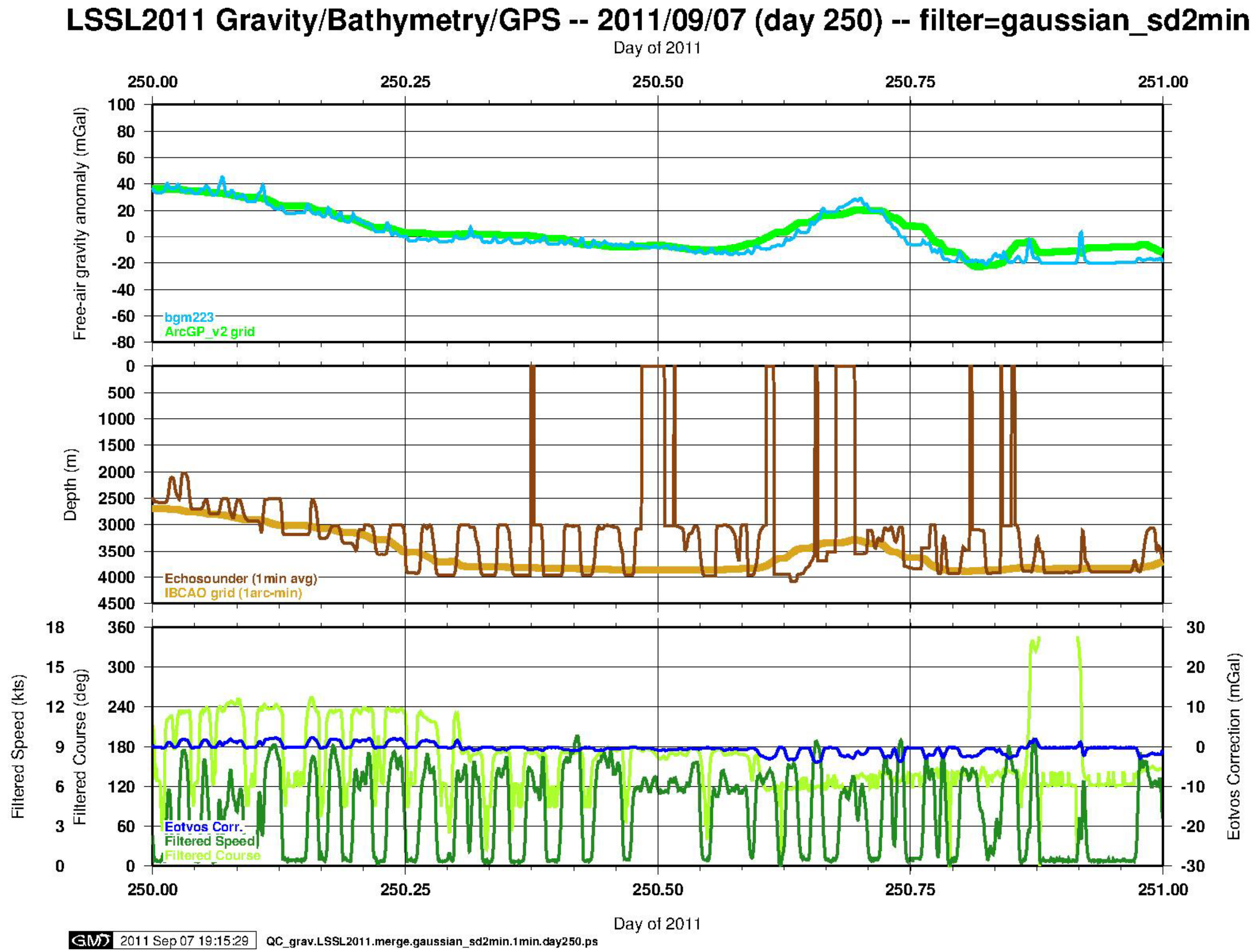
Notes: JD 247 AUV ops; drive a square track three times to calibrate inertial navigation of the AUV.



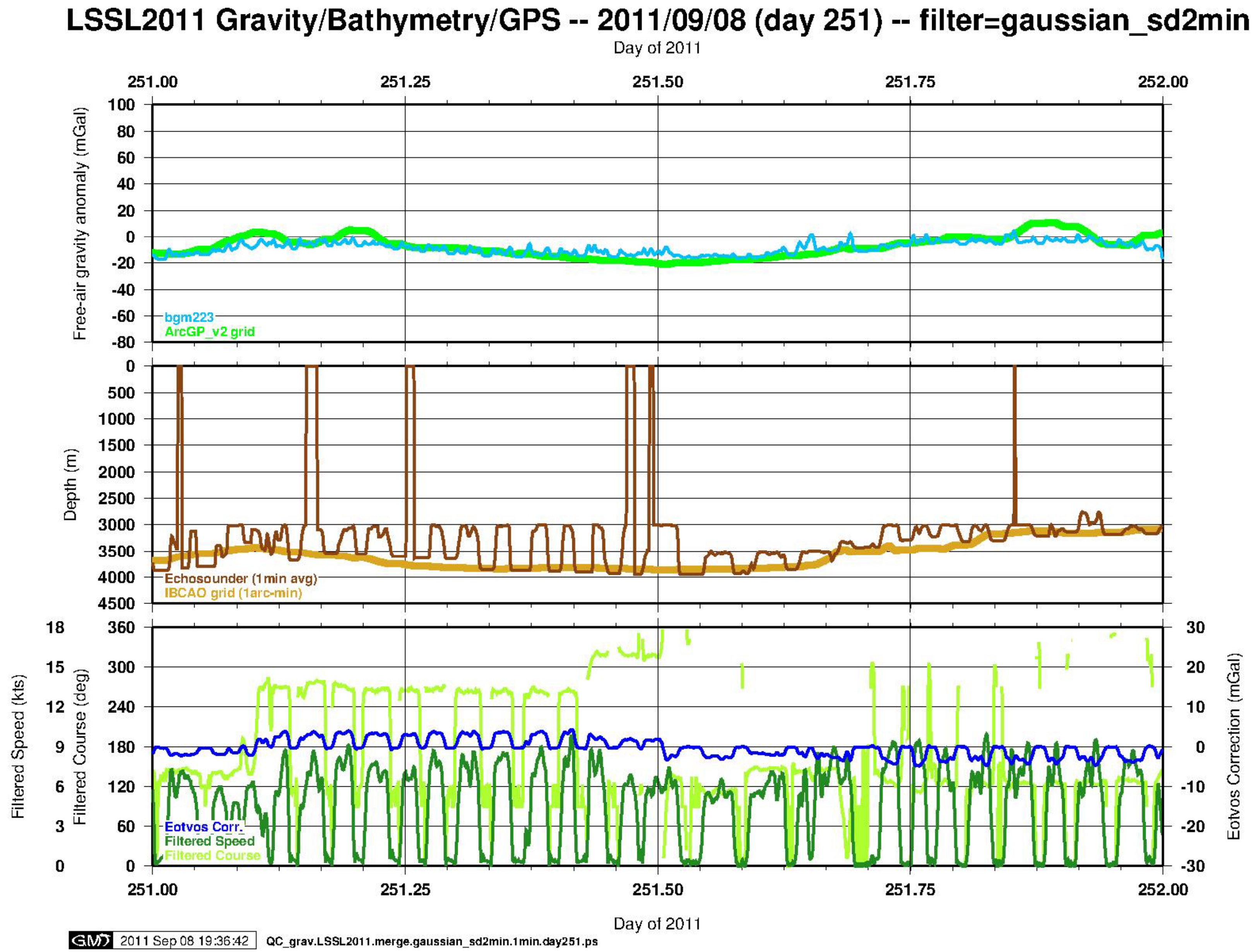
Notes: AUV recovery all day, lots of slow starting and starting;



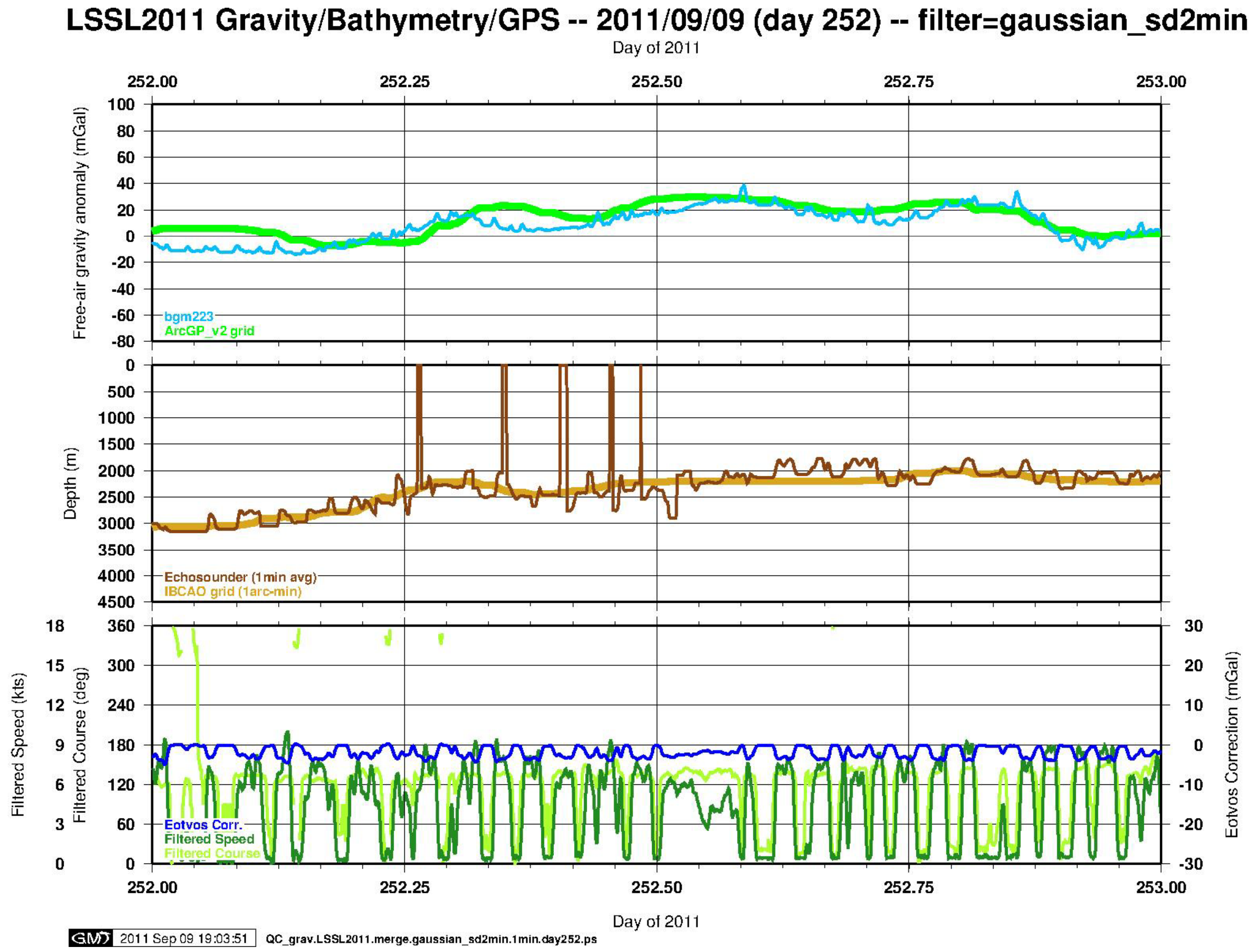
Notes: Louis breaking ice for Healy, tracks are zig-zagging back across bathymetric highs and Alpha Ridge



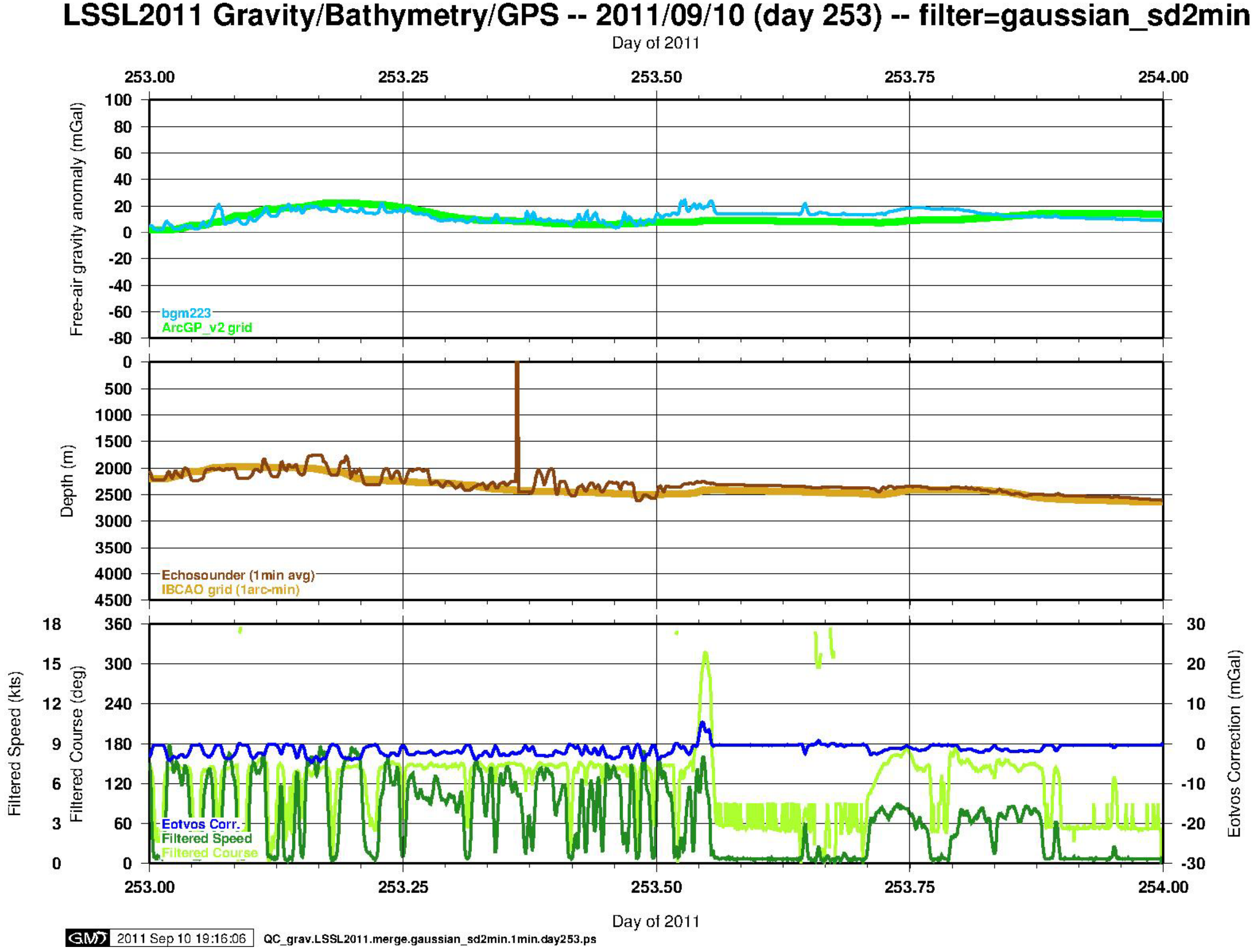
Notes: Louis leading Healy; very windy day; bathymetry profiling along Makarov Basin, north of Alpha Ridge; 21:12-23:35 Stopped and slow maneuvers for USCG air drop for Healy



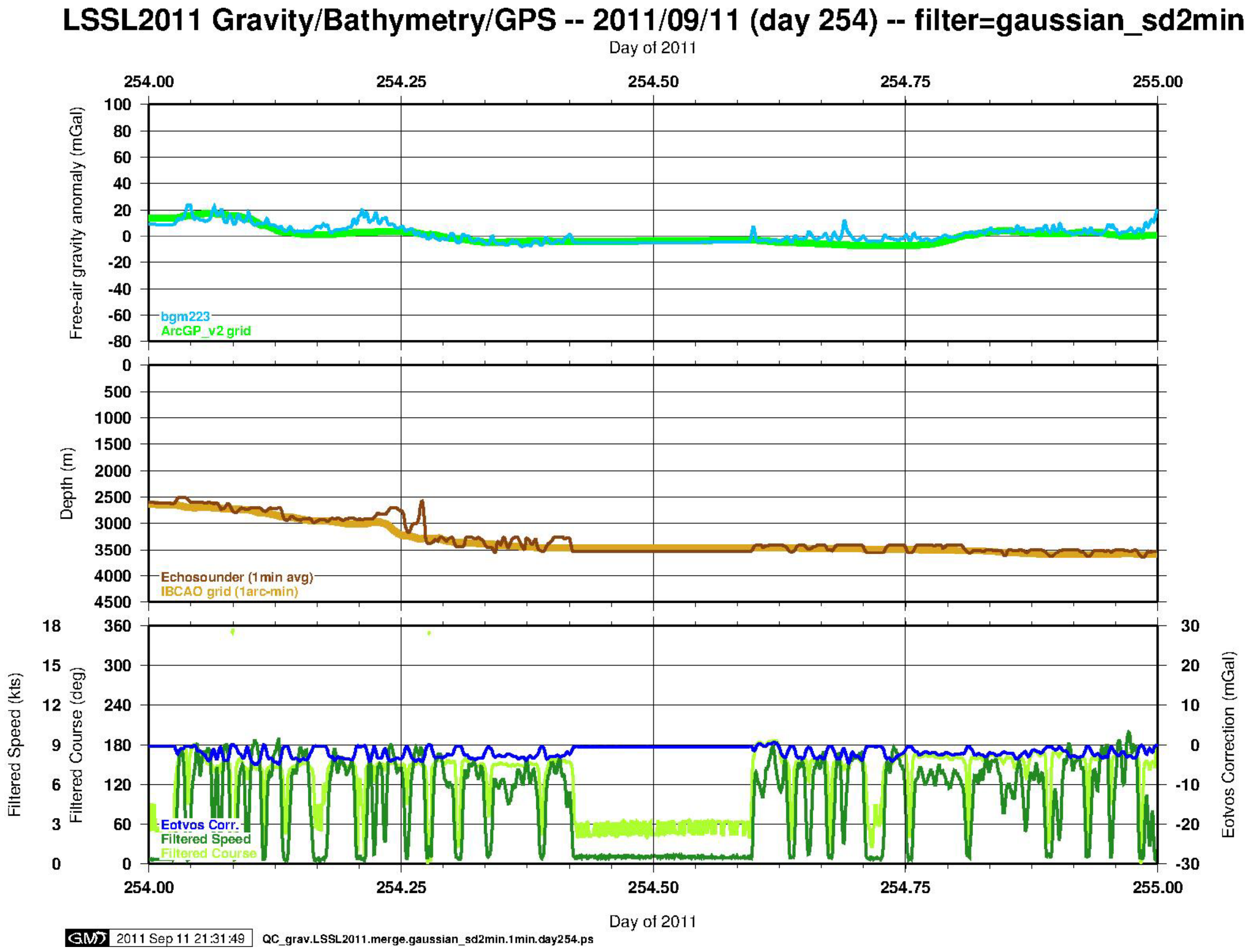
Notes: Louis leading Healy; FOS around Makarov basin, then head southeast across Alpha Ridge.



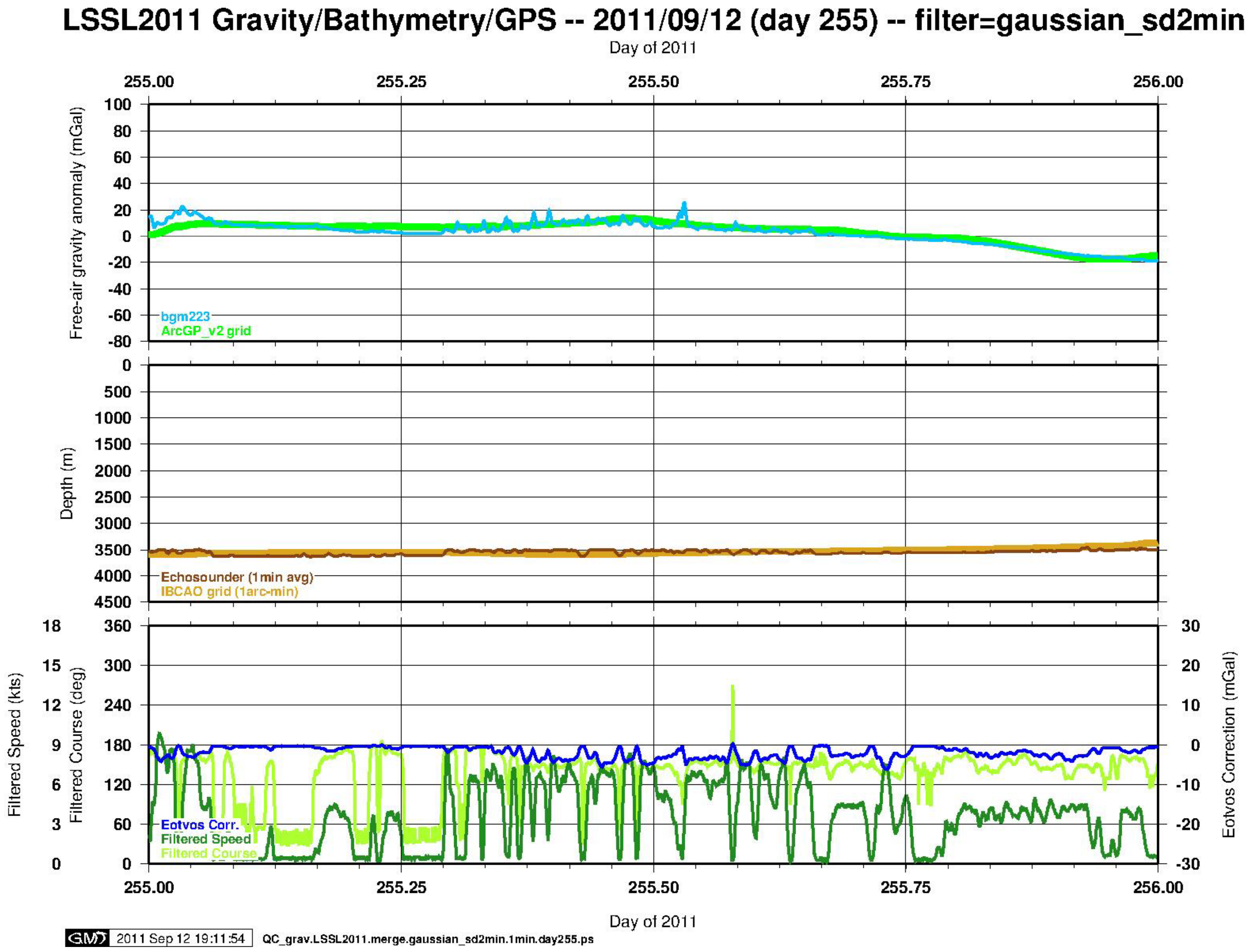
Notes: Louis continue breaking ice for Healy; ~20:10 – 21:24 Stopped, Louis shaft problem.



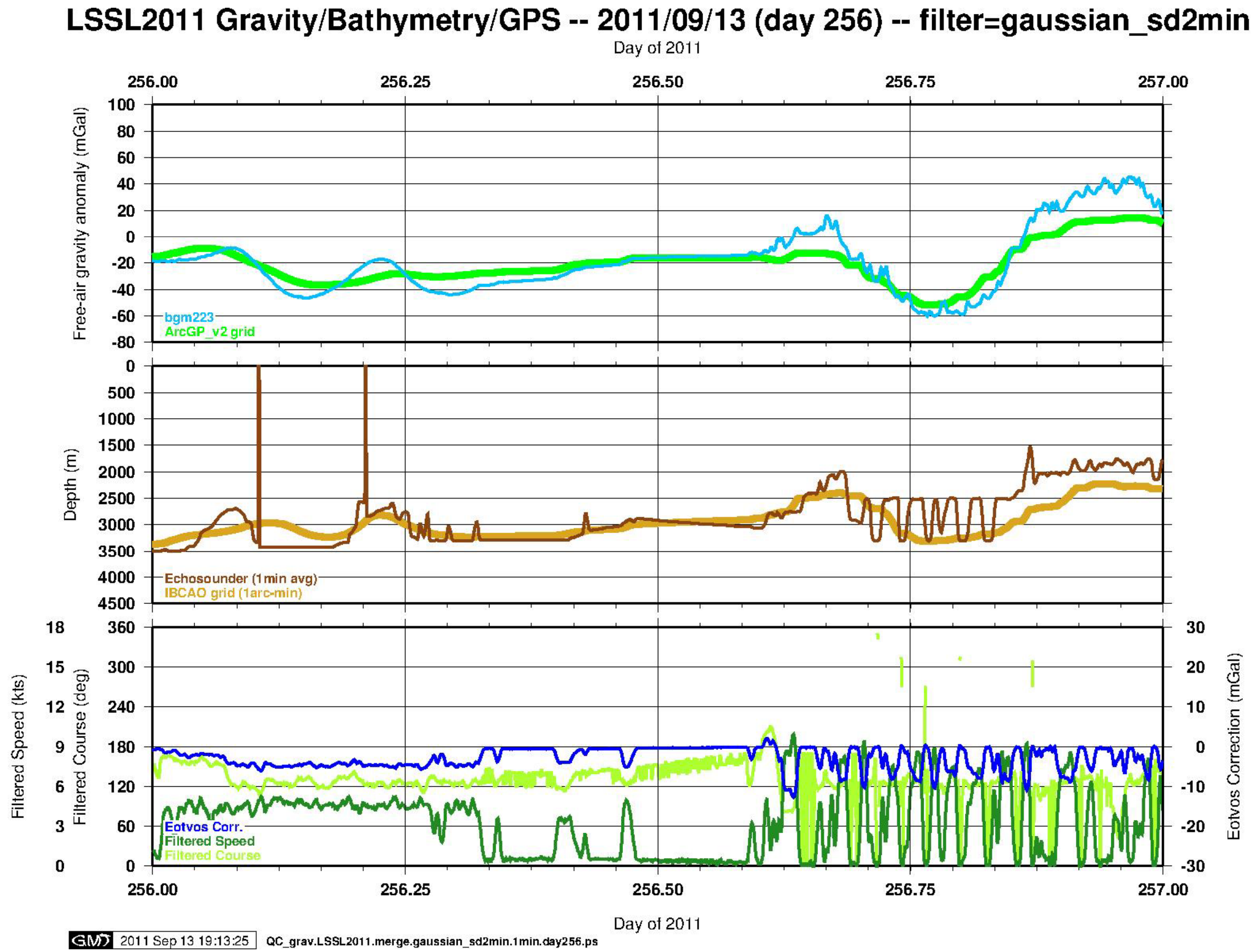
Notes: 13:35z Slow/stop for change to mcs seismics; 17:20z Healy breaking ice for Louis (Line 5) ; Louis stuck badly at 21:24z, then resume line.



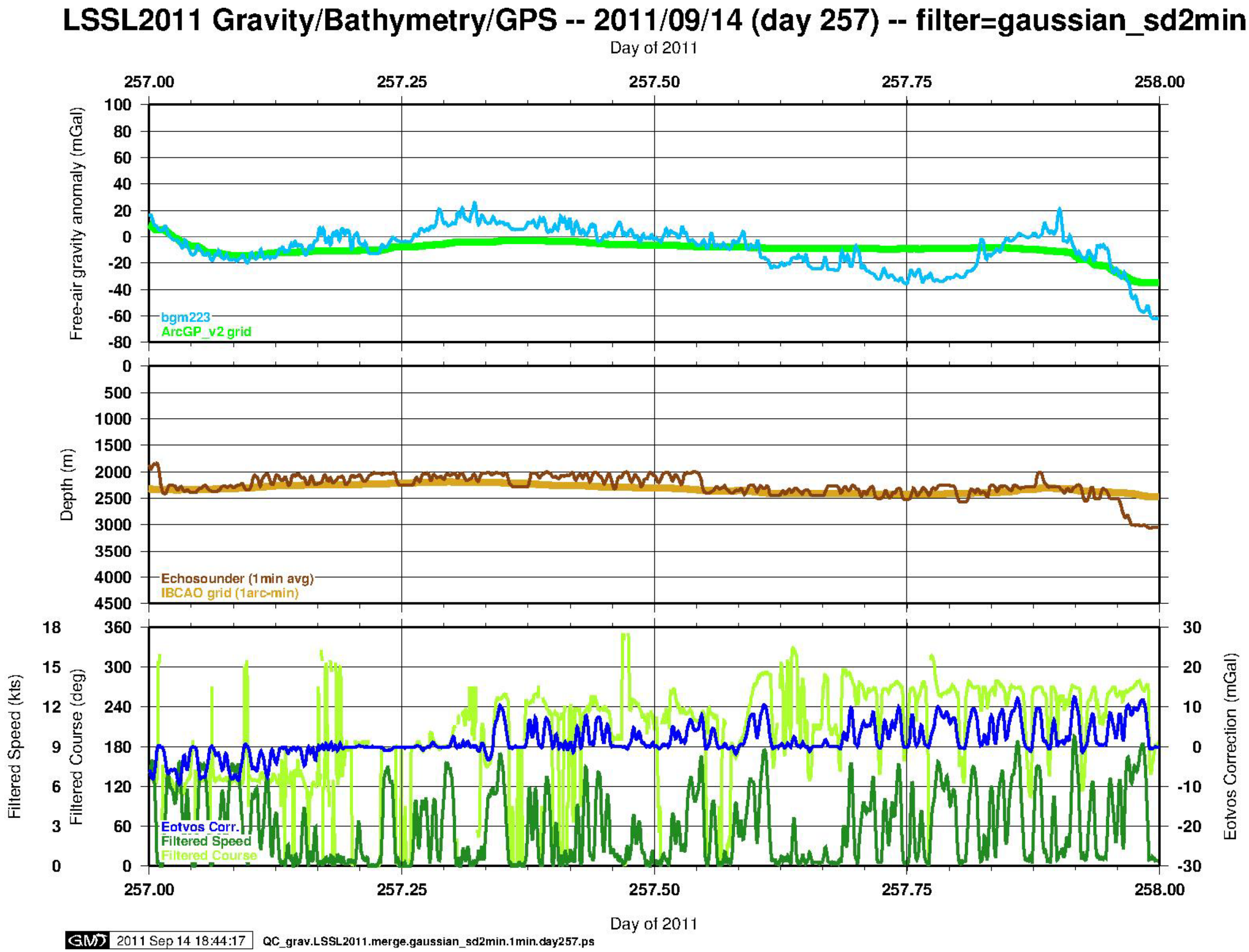
Notes: 00:21z - Pull seismic gear; resume breaking ice for Healy; 10:15z-1430z – power down in Louis.



Notes: 0300-0715z Healy breaking ice for Louis (Line 6); 0715-1900z Louis breaking ice for Healy; 1900z Healy breaking ice for Louis (Line 7).

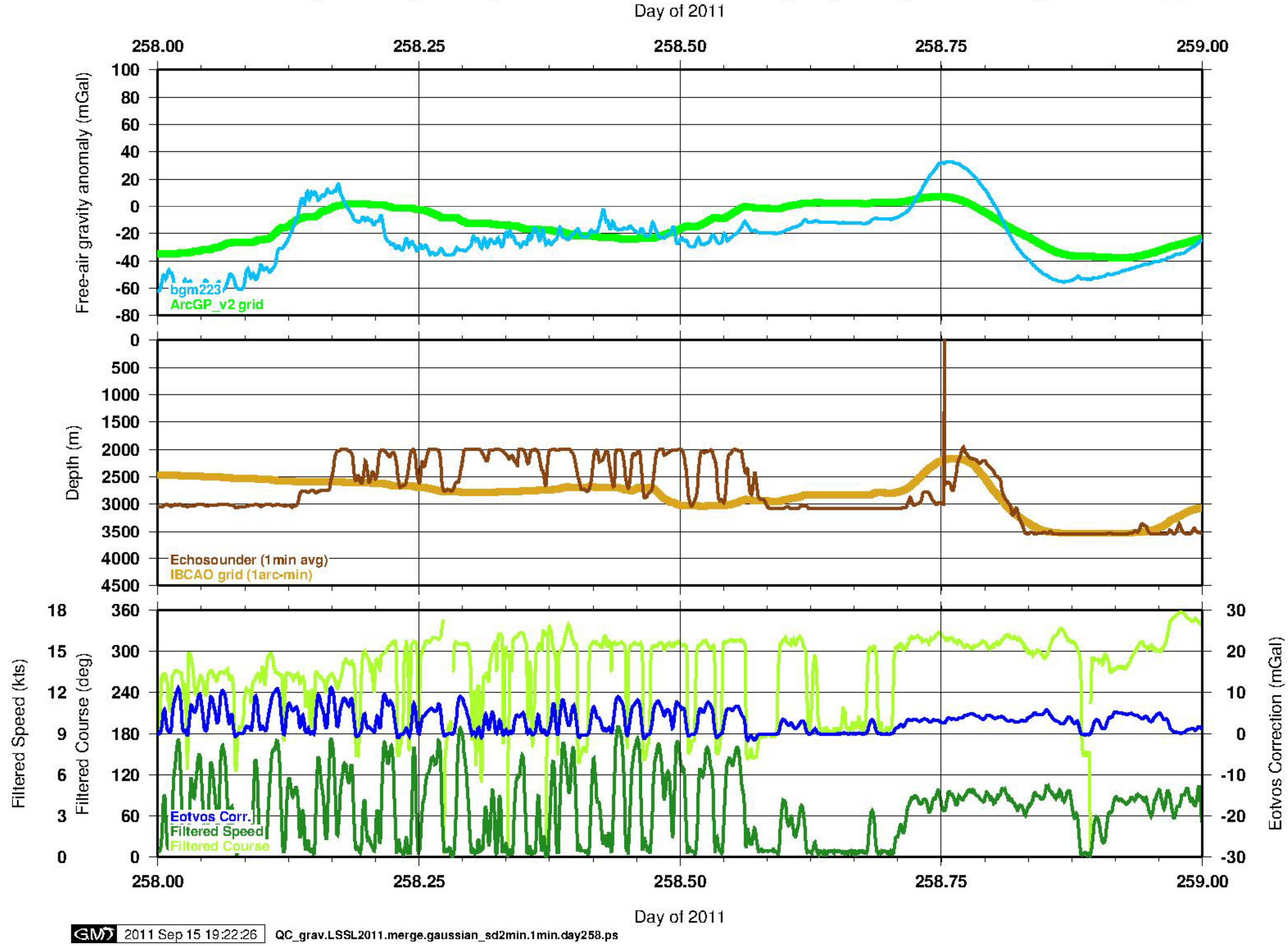


Notes: -1400z Healy breaking ice for Louis over outer ridges of Sever Spur (Line 7); 1400z Louis begins breaking ice for Healy onto Canadian margin.

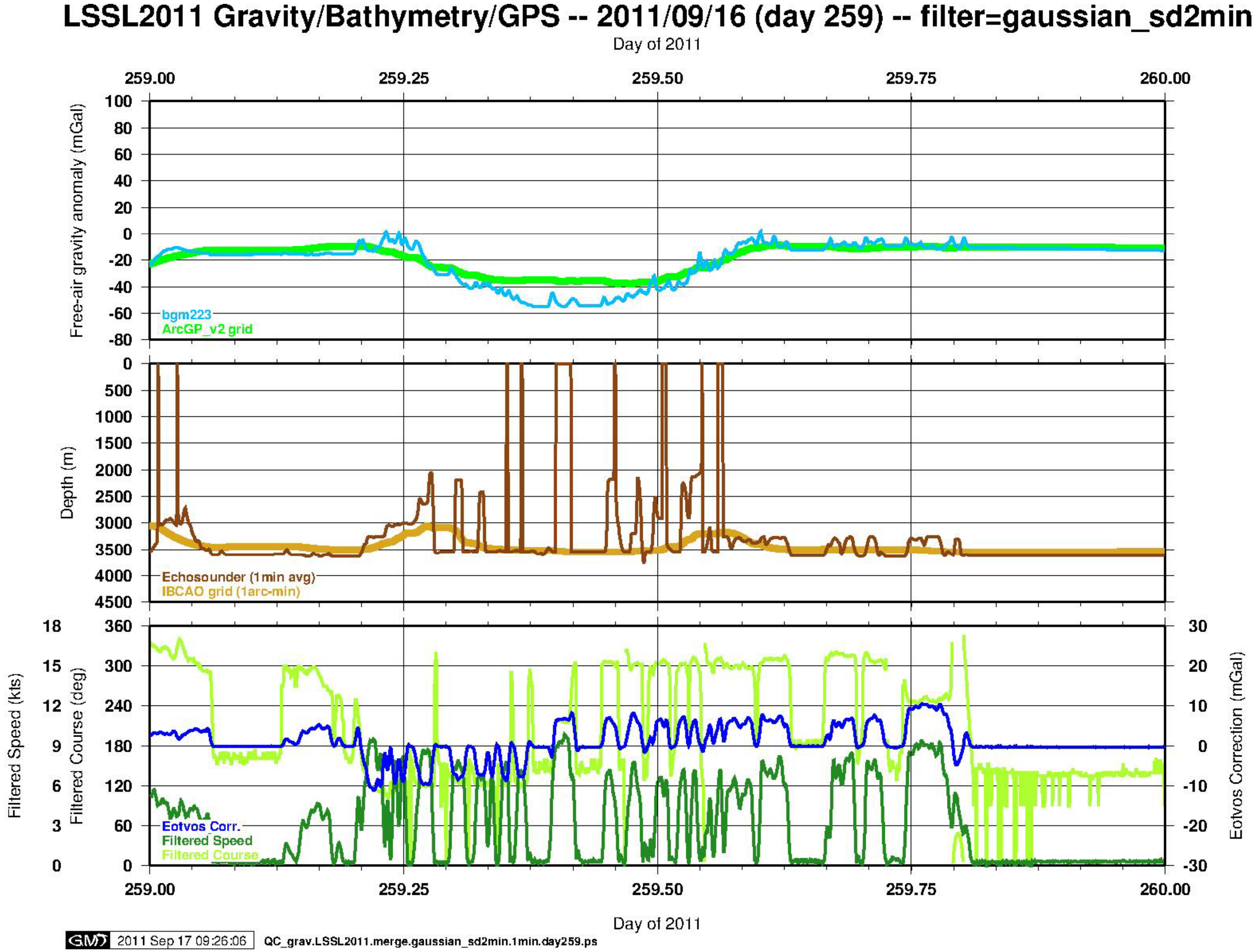


Notes: Louis breaking ice for Healy all day

LSSL2011 Gravity/Bathymetry/GPS -- 2011/09/15 (day 258) -- filter=gaussian_sd2min

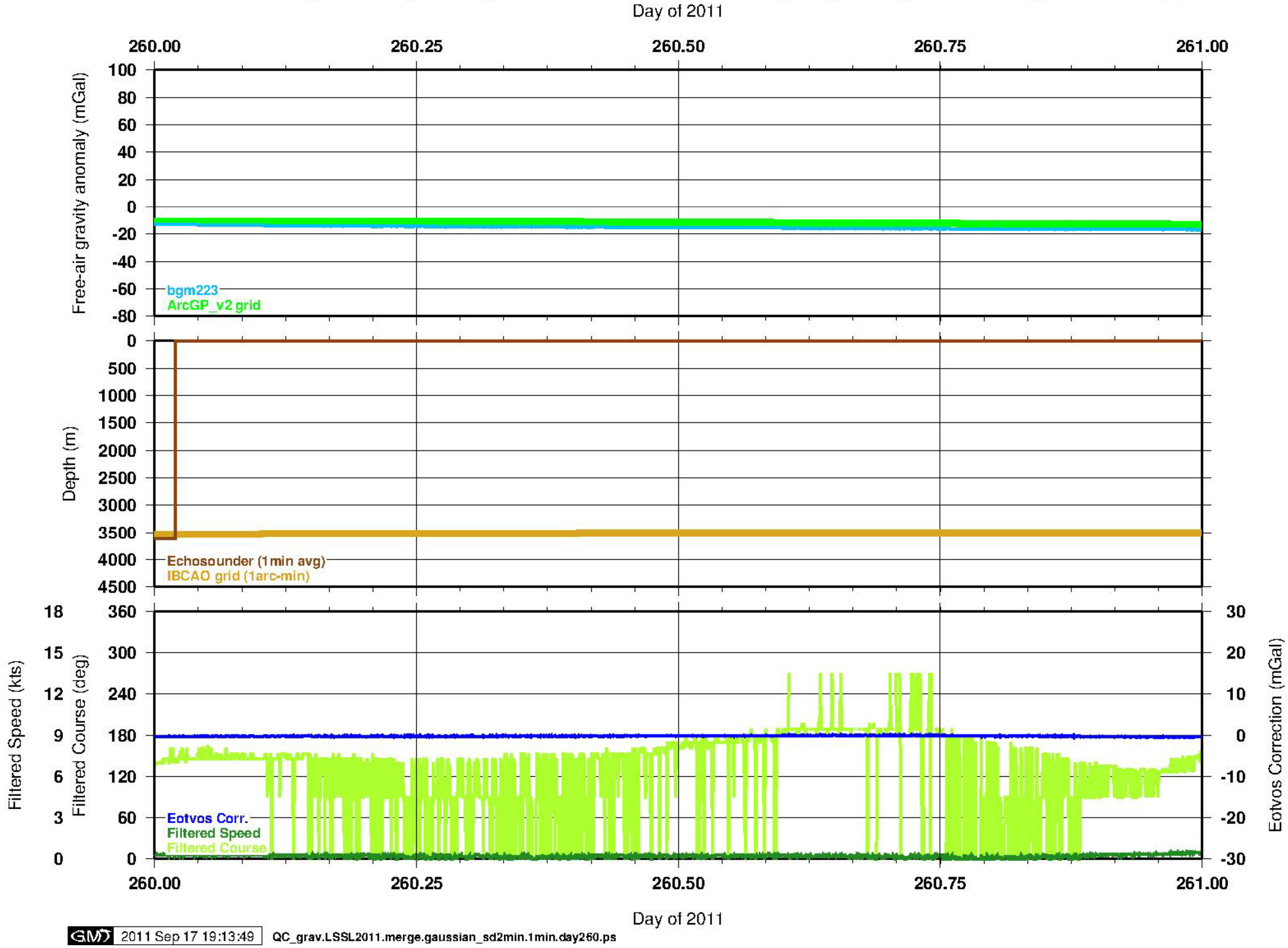


Notes:1400z Louis stop to let Healy lead and break ice; 1637z – SOL 8.

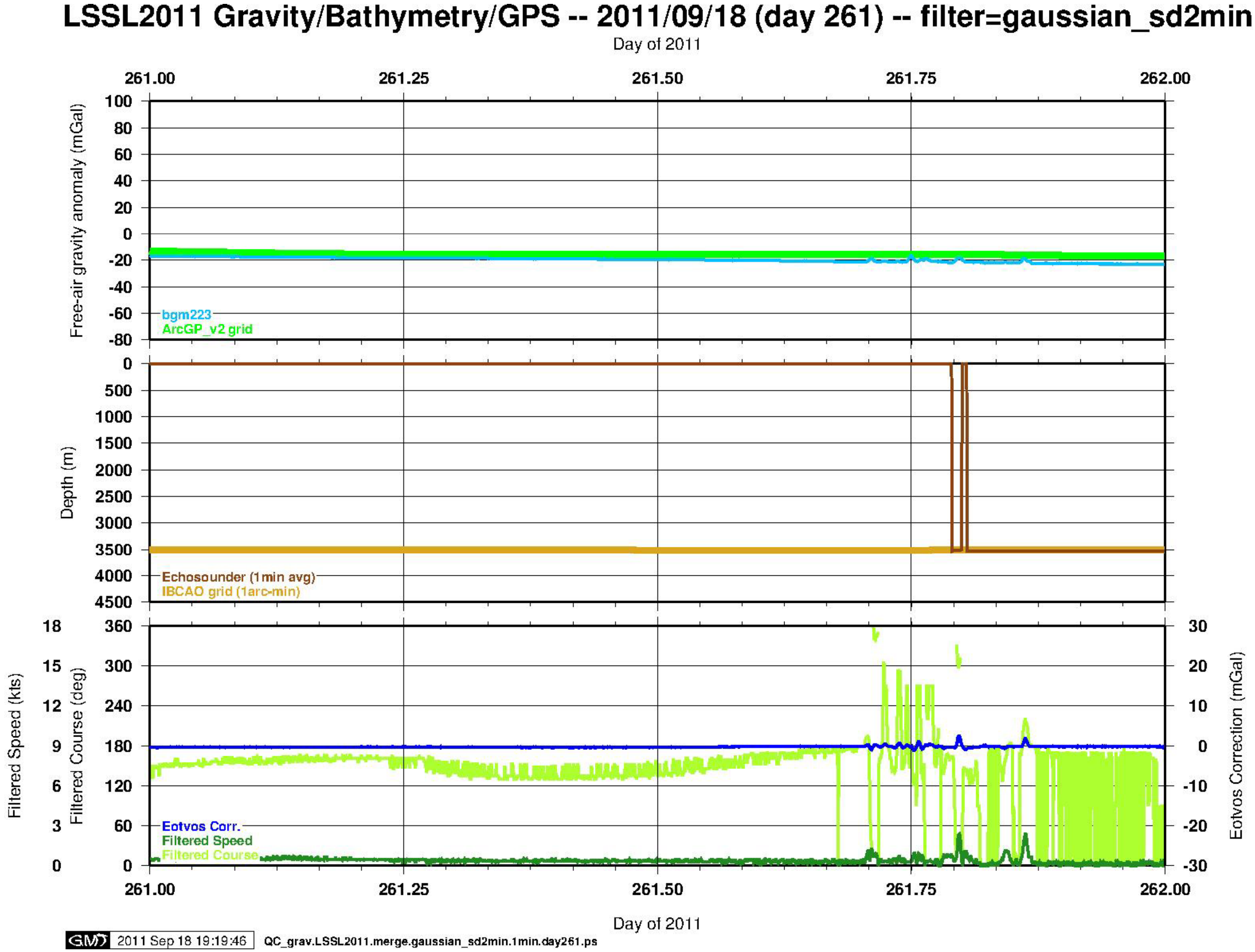


Notes:0443z EOL 8, 0500z Louis begin breaking ice for Healy; 1521z, Louis stopped for engine work; 1600z resume; 1938z stopped in ice pool for AUV ops.

LSSL2011 Gravity/Bathymetry/GPS -- 2011/09/17 (day 260) -- filter=gaussian_sd2min

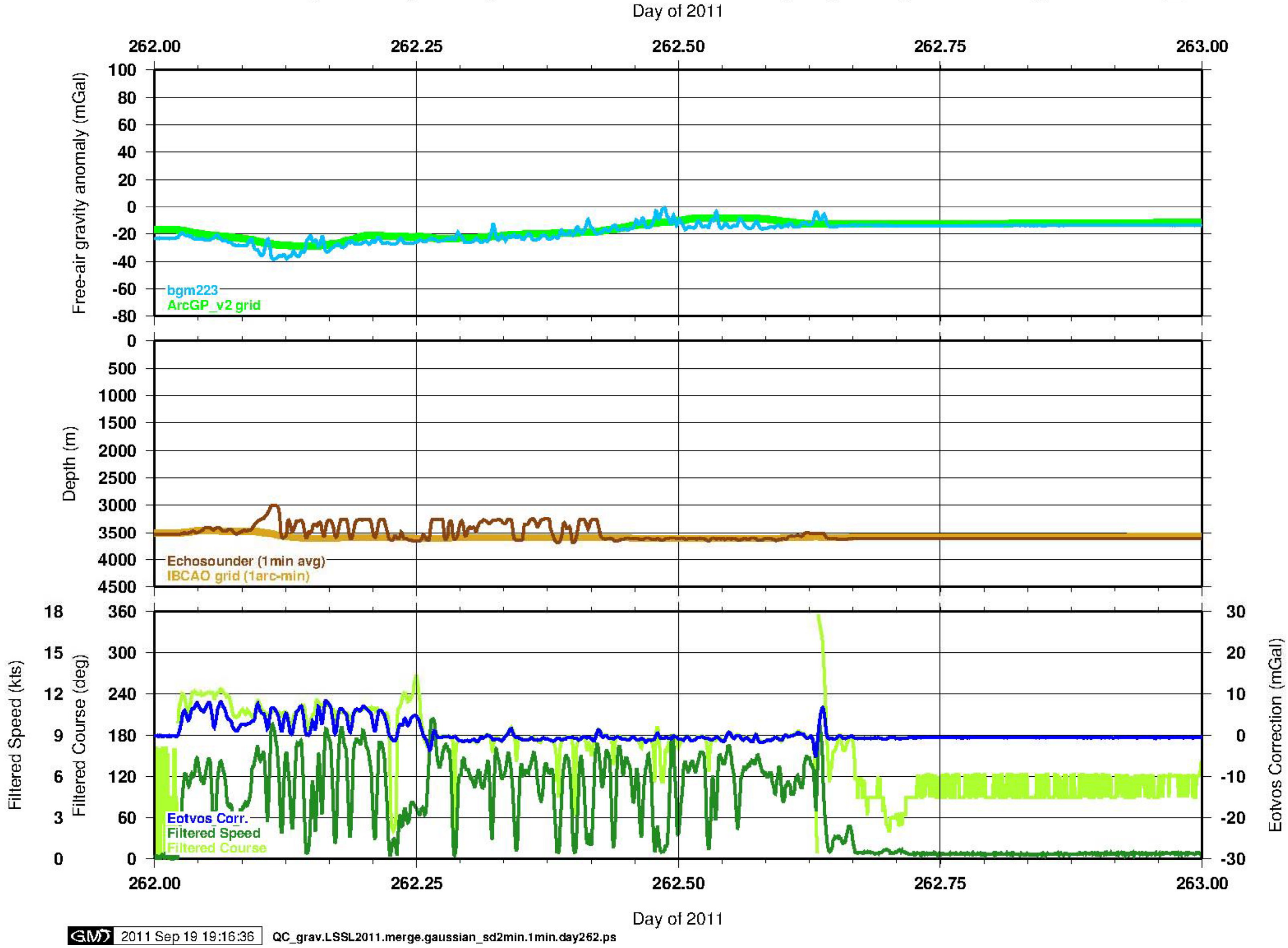


Notes: Engines shut down, hove to in open pool for AUV ops.

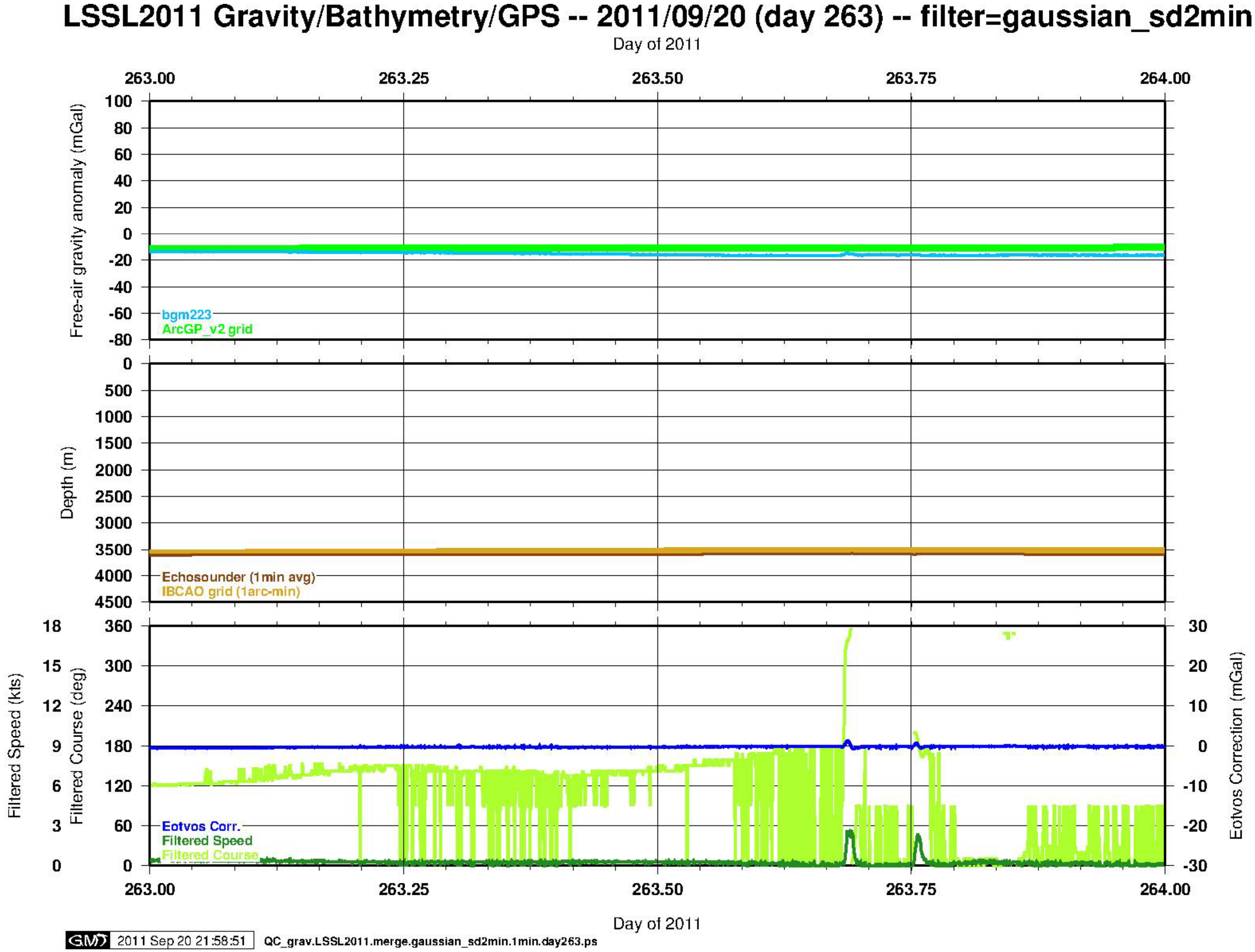


Notes: AUV ops continued, then recover AUV in the pond, and recover Raven UAV from the ice

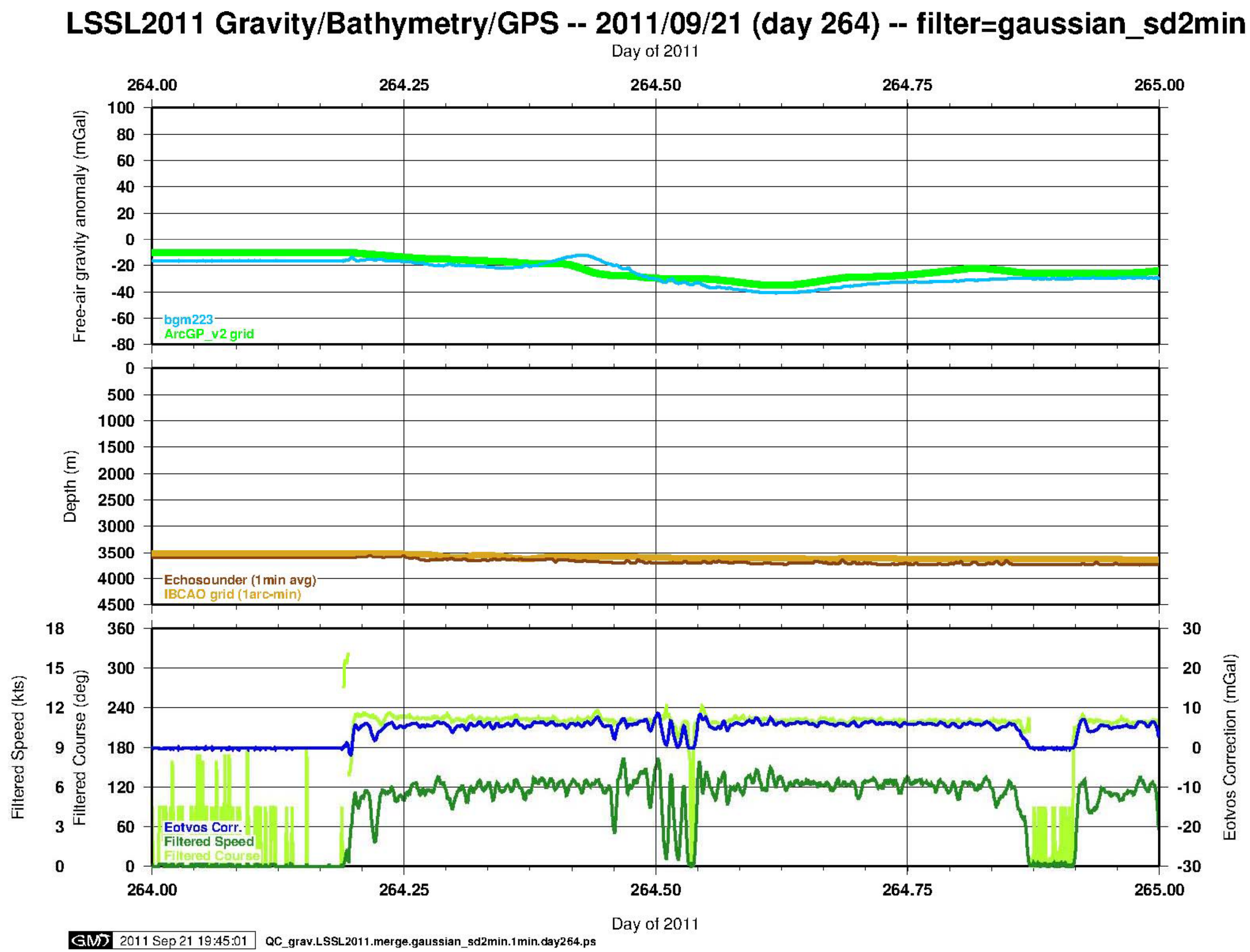
LSSL2011 Gravity/Bathymetry/GPS -- 2011/09/19 (day 262) -- filter=gaussian_sd2min



Notes: 0100z, finish AUV ops; ~2:30-1500z, breaking ice ahead of Healy (two brief periods behind Healy); 1520z - stop after realizing there is a prop problem.

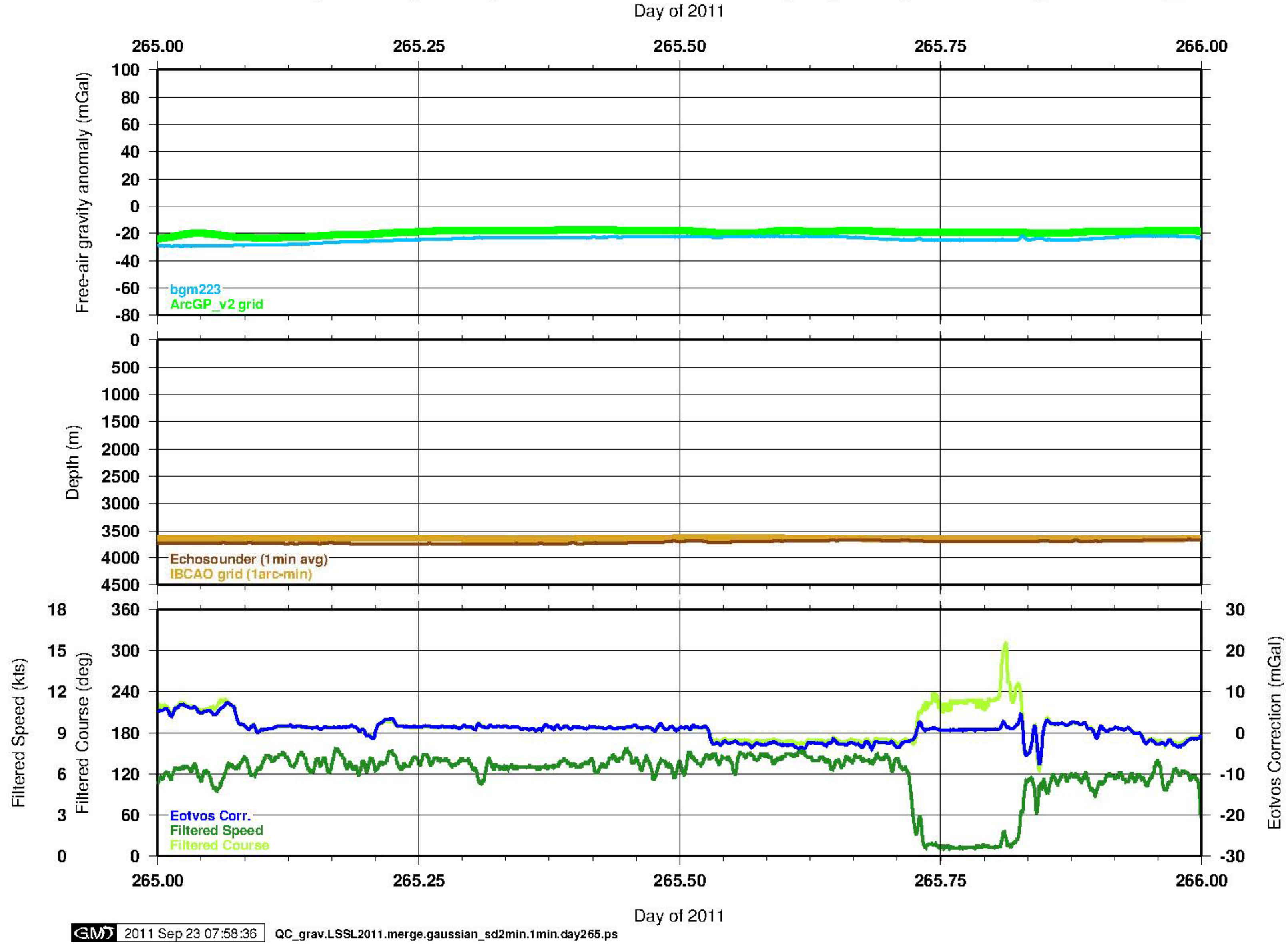


Notes: Stopped for prop assessment and Healy rafting.



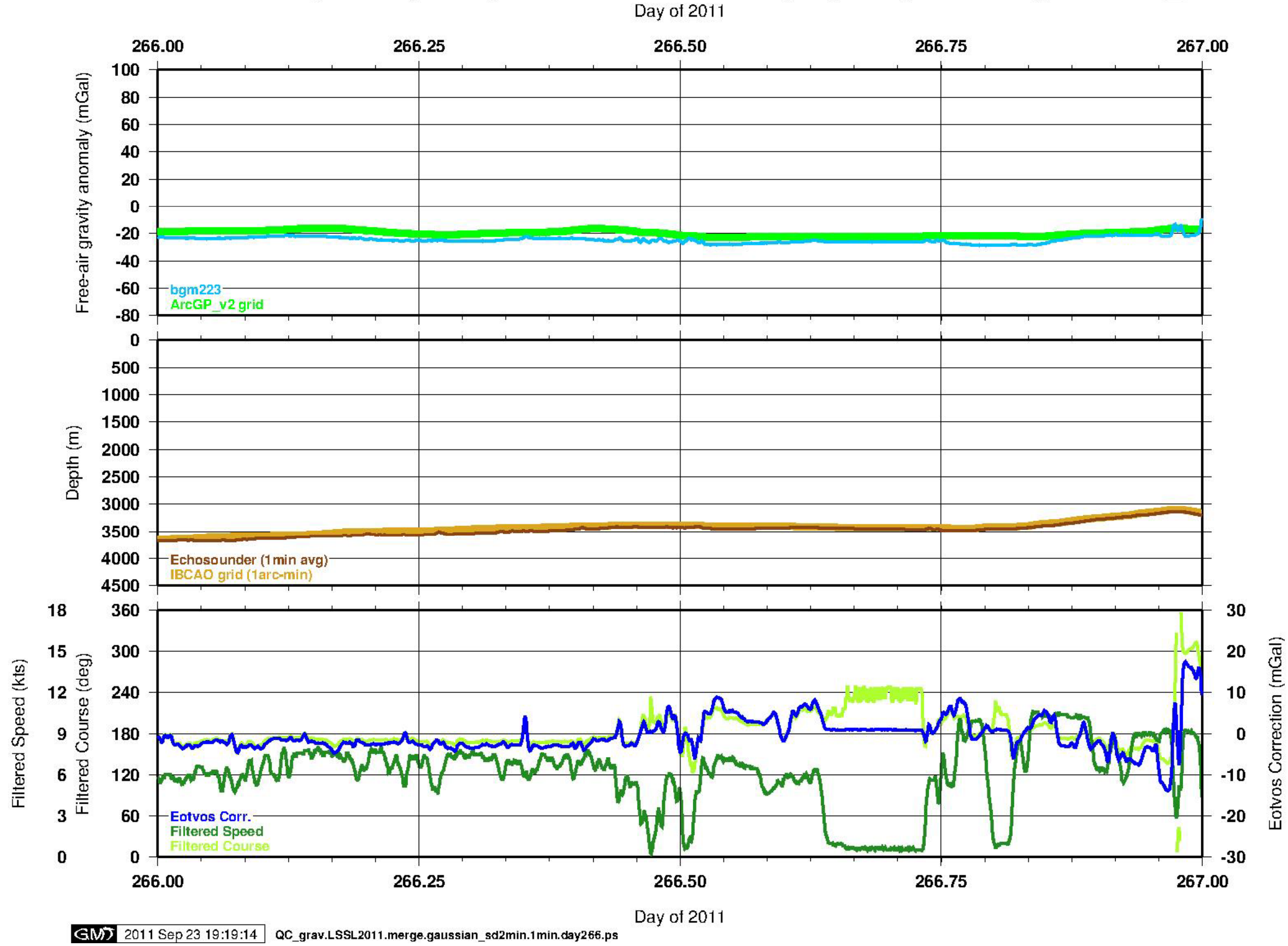
Notes:0430z end raft and follow Healy through the ice; 2100z stop for ROV inspection of the center shaft and propellor.

LSSL2011 Gravity/Bathymetry/GPS -- 2011/09/22 (day 265) -- filter=gaussian_sd2min

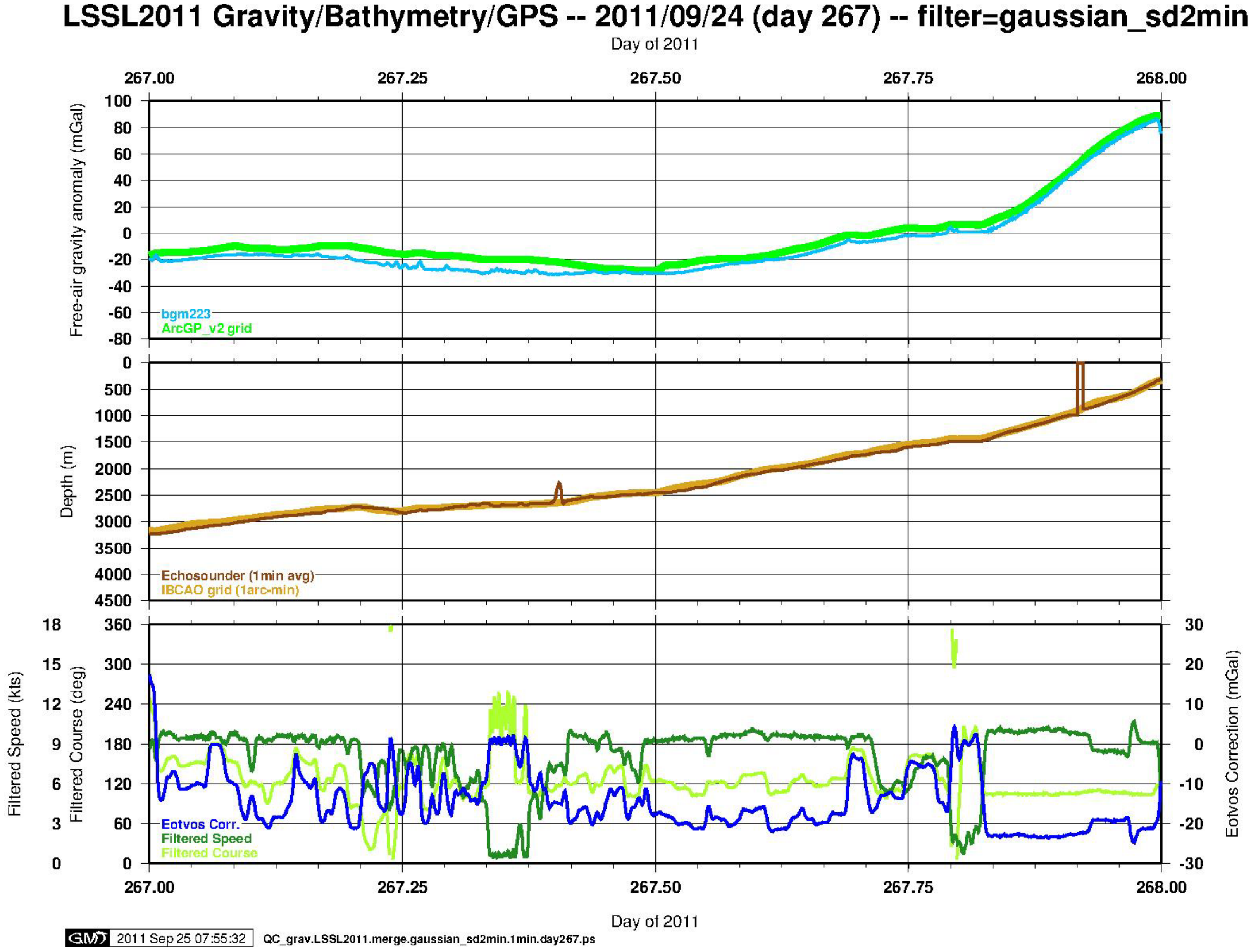


Notes:

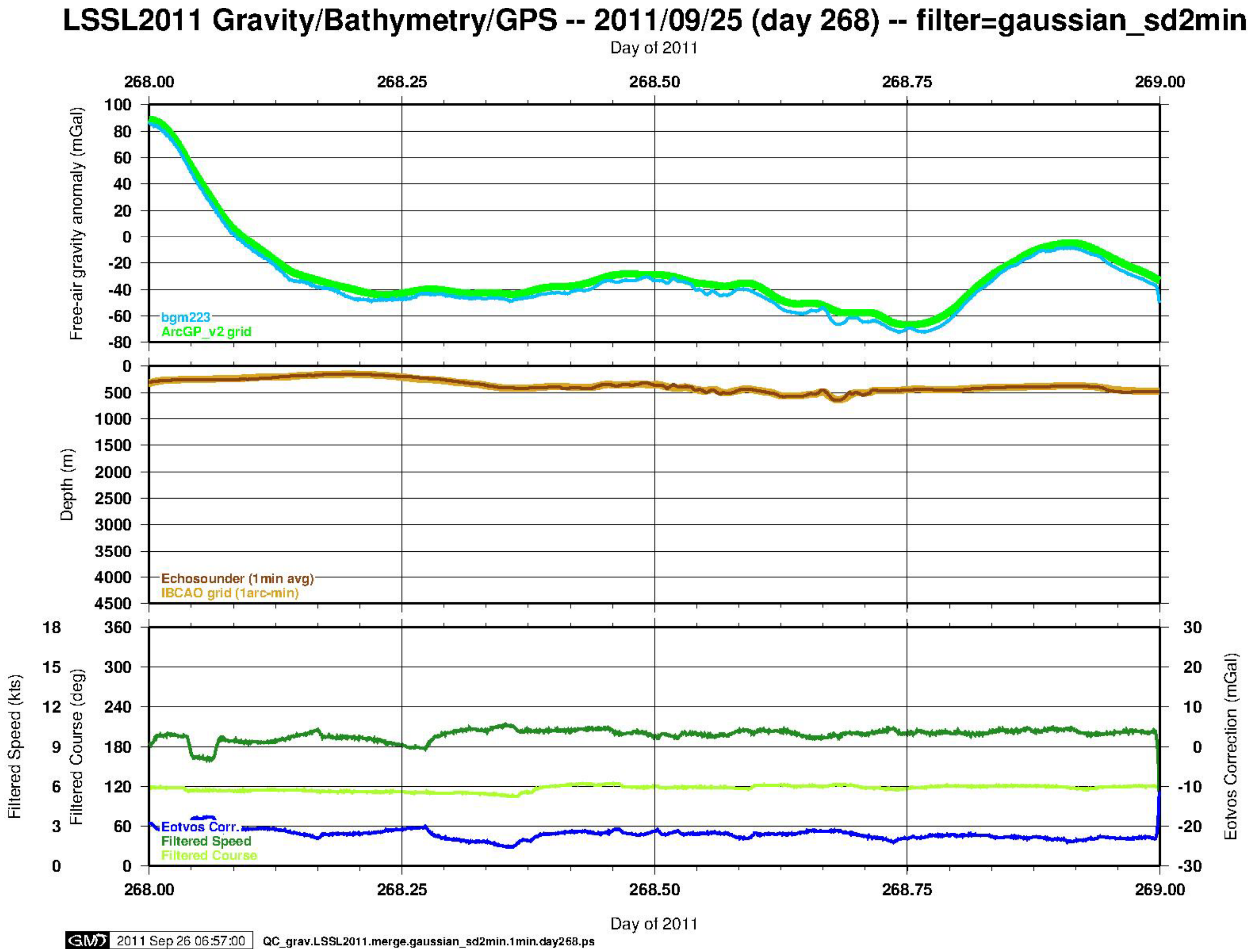
LSSL2011 Gravity/Bathymetry/GPS -- 2011/09/23 (day 266) -- filter=gaussian_sd2min



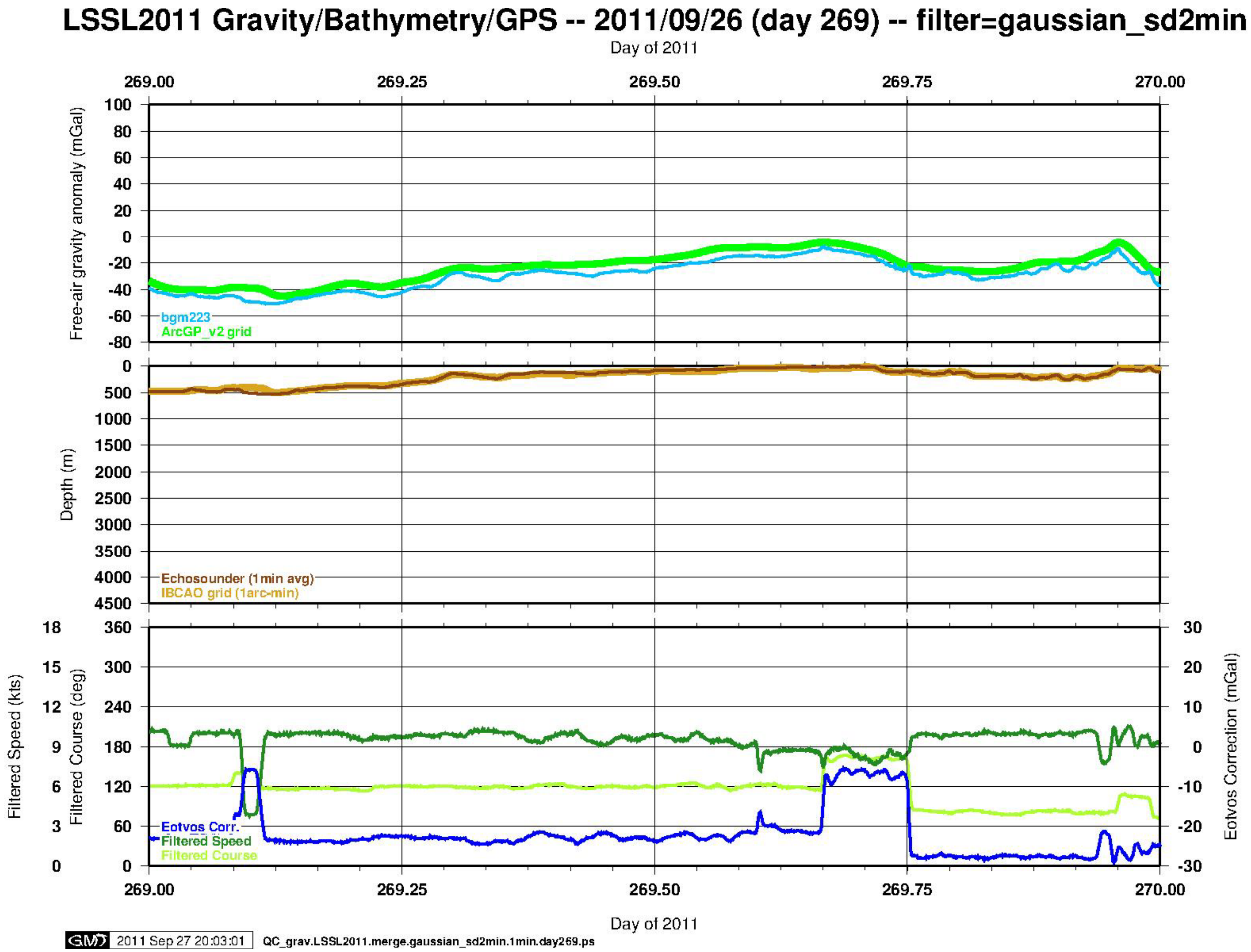
Notes: 15:30z Stop for ROV inspection of prop; 2000z – final pass by Healy and depart for Cambridge Bay port call



Notes: Transit south in Canada Basin, up Mackenzie Delta

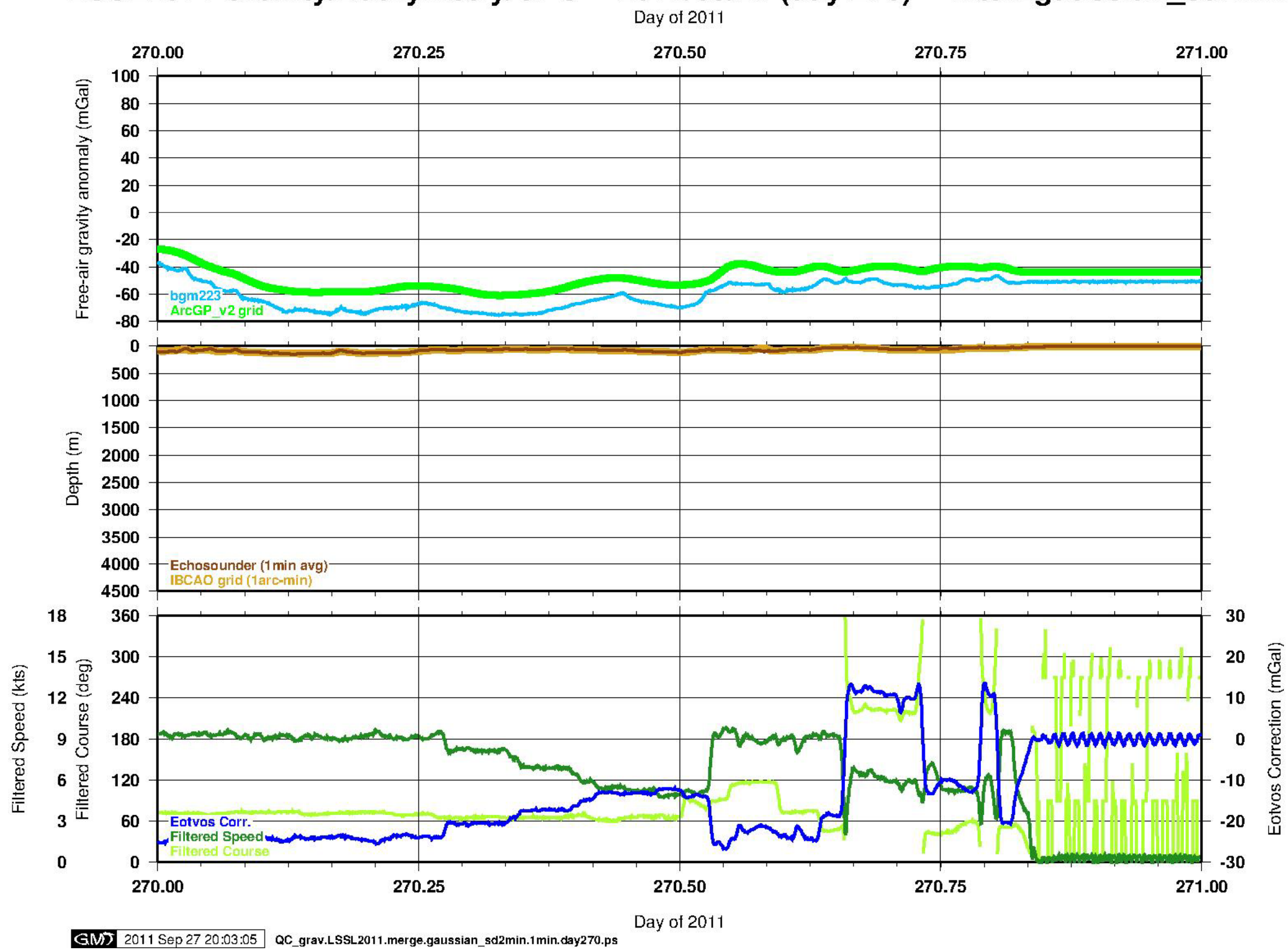


Notes: Transit south and east through Amundsen Sound



Notes: Transit in Northwest Passage to Cambridge Bay, Nunavut

LSSL2011 Gravity/Bathymetry/GPS -- 2011/09/27 (day 270) -- filter=gaussian_sd2min



Notes: Arrive in Cambridge Bay