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2010 Canada Basin seismic reflection and refraction survey, western Arctic Ocean: CCGS Louis S. St-Laurent expedition report

D.C. Mosher, J.W. Shimeld and C.B. Chapman

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CCGS Louis S. St-Laurent

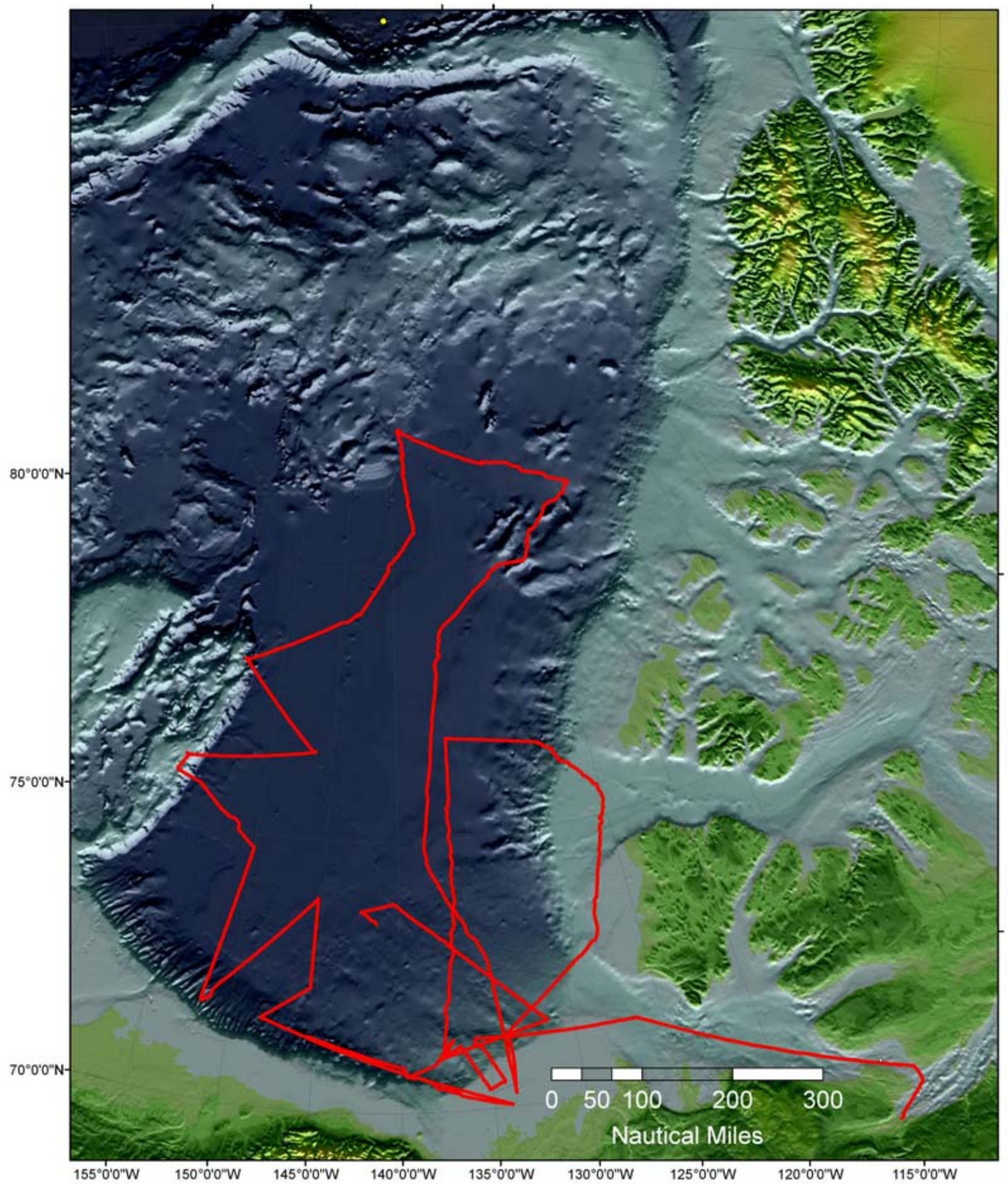

Photo by Bill Schmoker

Captain Andrew McNeill, Commanding Officer

Dr. David C. Mosher, Chief Scientist
Mr. John W. Shimeld, Second Scientist
Mr. C. Borden Chapman, Senior Technician

Executive Summary

The principal objective of the 2010 Canadian Polar Margin Seismic Reflection and Refraction Survey was to acquire multichannel seismic reflection and refraction data along positions that serve to establish sediment thicknesses and acquire bathymetric soundings 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 to the geoscience program, ice observations were acquired to groundtruth remotely sensed data. Seismic system calibration experiments were conducted to quantify sound signal intensity levels produced by the sound source. 3673 line-km of high quality multichannel seismic reflection data were acquired in addition to seismic refraction data recorded from 34 sonobuoy deployments. 9500 line-km of single beam bathymetry data were obtained plus 61 helicopter spot soundings. In collaboration the United States Coast Guard Cutter Healy, similar amounts of multibeam bathymetric and chirp subbottom profiler data were acquired.



CCGS LOUIS S. ST-LAURENT
AUGUST 4th - SEPTEMBER 15th, 2010

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D.C. Mosher, J. Shimeld, C.B.Chapman

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 2010 expedition represent the fifth 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 simultaneously in the ice-covered waters of the western Arctic. Programs on each vessel acquire complimentary data sets that will be shared and the vessels operate in tandem to ensure maximum data quality. For 2010, 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). They also collected five piston cores. LSSL collected seismic reflection and refraction data in addition to single beam bathymetry 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 LSSL2010 program were to, 1) acquire multichannel seismic reflection and refraction data to establish sediment thicknesses along Canadian and US western Arctic continental margins, and, 2) to acquire bathymetric sounding data at specific locations along this same margin in order to validate bathymetric data acquired by other means, for example by g. satellite altimetry or submarine, to establish baseline information such as the 2500 m contour and foot of slope positions. Strategic ship track lines were established to meet these criteria and to complement data acquired in earlier phases of this program or exist from legacy programs from national and international sources. Line orientations were also established to permit conducting scientific investigations regarding the origin of the Amerasian Basin and associated submarine land masses. Seismic system calibration experiments were also conducted to quantify sound signal intensity levels produced by the seismic system.

Personnel

Scientific Personnel

1. David Mosher, NRCan, Chief Scientist
2. Jon Biggar, DFO, Hydrographer in Charge
3. John Shimeld, NRCan, Second Scientist
4. Borden Chapman, NRCan, Chief Technician
5. Jim Weedon, DFO, Hydrographer, watch keeping
6. Marcus Beech, DFO, Hydrographer, watch keeping
7. Jon Childs, USGS Scientific Liaison
8. Peter Vass, contract, Machinist and Mechanical Technician
9. Ryan Pike, contract, MechanicalTechnician
10. Paul Girouard, contract, Navigation and Data Curation Technician
11. Jim Etter, contract, Electronics Technician, watch keeping
12. Dwight Reimer, contract, Electronics Technician, watch keeping
13. Jamison Etter, contract, Compressor Technician watch keeping
14. Rodger Oulton, contract, Compressor Technician, watch keeping
15. Nelson Ruben, contract, Mechanical Technician
16. Jonah Nakimayak, contract, Mammal Observer
17. Dale Ruben, contract, Mammal Observer
18. John Ruben, contract, Mammal Observer
19. Walta Rainey, NRCan, GIS Support

CCGS Louis S. St-Laurent Personnel

Commanding Officer	Andrew McNeill
Chief Officer	Kerry Evely
First Officer	Marian Punch
Second Officer	Reginald Prior
Third Officer	Adam Howell
Chief Engineer	Ronald Collier
Senior Engineer	Michael Willis
First Engineer	Joshua McInnis
Second Engineer	Wayne Barter
Third Engineer	Glen Nolan
Electrical Ofc	Stephen Tucker
Electrical Ofc	Anthony Engbers
Logistics Ofc	Tony Walters
Boatswain	Rico Amamio
Carpenter	Gary Morgan

Winchman	Edward Bridgeman
Leading Seaman	David Bartlett
Leading Seaman	Stephen Archibald
Leading Seaman	Michael Worth
Seaman	Daniel Dunlap
Seaman	Allan Snow
Seaman	Barney Noseworthy
Seaman	Al Jarvis
Seaman	Derrick Stone
E/R Tech	Justin Bishop (medevac)
E/R Tech	Jeff Doane
E/R Tech	Travis Tibbo
E/R Mechanic	Cyril O'Brien
E/R Mechanic	Jeff Simms
E/R Mechanic	Kody Critch
E/R Mechanic	Raine Jones
E/R Mechanic	Wallace Jackman
E/R Mechanic	Dean Kavanagh
E/R Mechanic	Paul Jenkins

Chief Cook	Randy Turner
Storekeeper	Jaimie Mizuik
Storekeeper	Joe Gurney
Second Cook	Daryl Tobin
Second Cook	Fred Skanes
Second Cook	Wanda Oram Canning
Steward	Lawrence Jesso
Steward	Darlene Bedard
Steward	Cory Simms
Steward	Larry Royea
Steward	Winston Brinson
Helicopter Pilot	Christopher Swannell
Helicopter Engin	William Duff
Electronics Tech	Stephen Wheeler
Ice Observer	Bruno Barrette
Ice Observer	Caryn Panowicz (Healy)
Medical Officer	Marcelle Collins

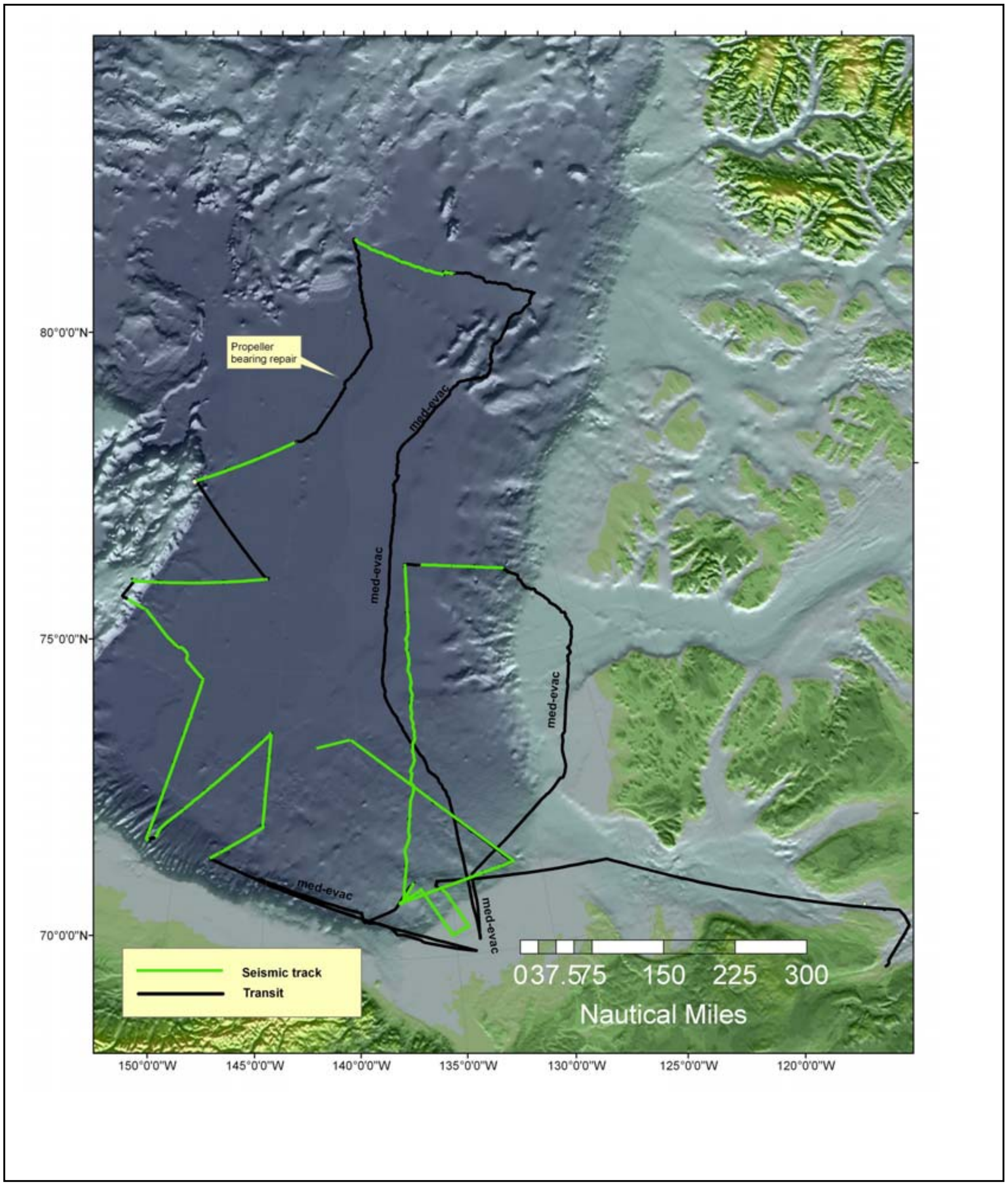

Figure 1-1. Total ship's track

Navigation, Record Keeping and Networking

The navigation and bathymetry 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 was 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. All seismic, gravity, sonobuoy, and Knudsen bathymetric and chirp data, as well as their related logfiles, were also backed up to DVD 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. This arrangement was changed during the last week of the cruise when a second sonobuoy antenna, looking forward, was installed. The GSCDIG computer was moved to the radio room and the coax cable normally used to carry the sonobuoy signal to the GSCDIG computer was used to carry the trigger pulse up to the GSCDIG computer. The navigation was sent to the GSCDIG computer via a dedicated fiber connection and two single port serial to fiber converters. The compressor monitoring was moved to the CHIRP logger as the system was not in use. The Knudsen 3.5Khz CHIRP system was a new addition for 2010.

All systems operated without any major problems. As in previous years, there were some problems with the extremely slow links between some of the cabins and the Seismic Lab. The problem was again traced to a duplex mismatch between the cabins' media converters and the port they were connected to on the network switch in the

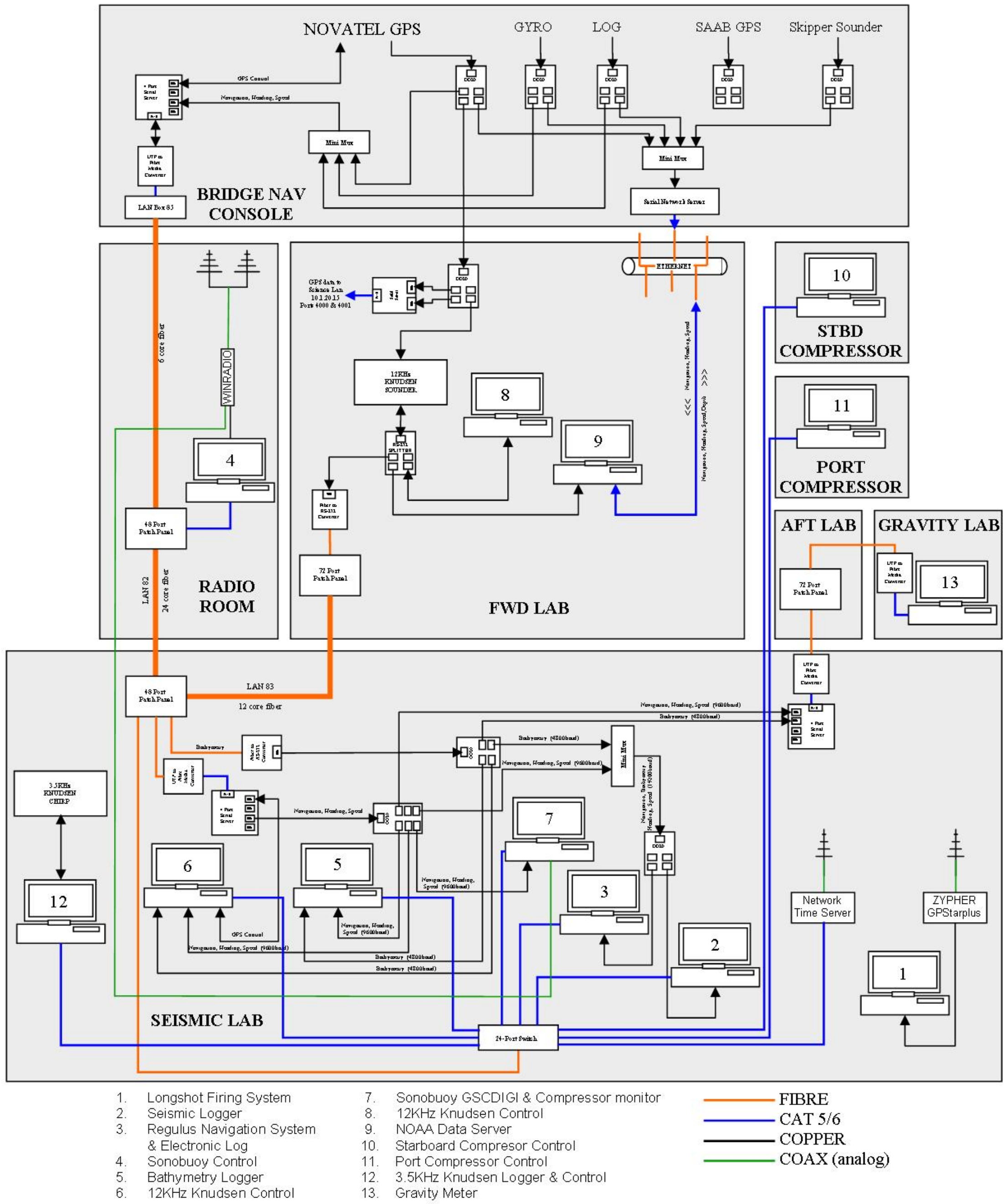

Figure 1-2 Science program wiring schematic, CCGS Louis S. St-Laurent 2010

LSL 2010 Data Summary

Line			Shotpoint		Sonobuoy			Knudsen		Gravity	SVP	XBT	XCTD
No.	Start	End	Start	End	No.	Start	End	3.5Khz	12Khz		Launch Time	Launch Time	Launch Time
	2191222	2191544						x		x			
	2191905	2201459						x		x			
	2201500	2222139						x	x	x			
LSL1001	2202130	2210826	1	4380				x	x	x			
LSL1002	2210826	2211256	4381	5995				x	x	x			
LSL1003	2211256	2220216	5996	10767				x	x	x			
LSL1004	2220216	2220821	19768	12951				x	x	x			
LSL1005	2220821	2221535	12952	15548				x	x x	x			2221741
									x				2211809
LSL1006	2242307	2251420	15449	18853	1	2250303	2251100		x	x			
LSL1007	2251420	2252210	18854	20509	2	2251509	2252210		x	x		2251513	
LSL1008	2260008	2261055	20510	22709					x	x		2260056	2260100
LSL1009	2261414	2262145	22710	24090	3	2261544	2262145		x	x		2261515	
LSL1010	2262149	2281431	24091	31809	4 5 6 7	2270042 2270854 2272010 2280412	2270836 2271701 2280406 2281100		x x x x	x		2270240 2271516 2280259	
									x			2281454	
LSL1011	2281811	2301417	31810	40513	8 9 10 11	2282105 2290637 2291500 2292310	2290500 2291430 2292300 2300715		x x x x	x		2290252 2291506 2300250	
LSL1012	2301417	2311932	40514	46023	12 13	2301428 2310110	2302330 2310916		x x	x		2301500	2311305 2311451
									x			2311952	
LSL1013	2320139	2320944	46024	47818	14	2320851			x x	x			2320304 2320311

LSL1014	2321052	2331509	47819	53039	14		2321718		x	x		2321953	2321454
					15	2330323	2331130		x				2330150
									xx				2331445
									x		2331704		2340255
LSL1015	2341142	2342221	53040	55102					x	x		2341943	2341505
LSL1016	2350052	2351830	55103	58293	16	2350109	2350905		x	x			2350253
					17	2350917	2351830		x				2351446
									x	x			2351837 2360255 2371751 2371943 2380140
LSL1017	2381140	2391333	58294	63759	18	2390233	2391017		x	x			2381454 2381458 2390023
									x	x	2391705		2391611
LSL1018	2391934	2392145	63814	64270	19	2392045	2392145		x	x			
									x	x			2401441
									x	x			2402343
									x	x			2411700
									x	x			2421451
									x	x			2422331
									x	x			2460128
LSL1019	2460152	2470416	64318	70233	20	2460935	2461056		x	x			2461453
					20a	2461056	2461735						2470255
LSL1020	2470421	2480230	70234	74696	21	2470455	2471255		x	x			2471450
					22	2471642	2480038						
									x	x			2480234
LSL1021	2480312	2500111	74697	84731	23	2480326	2481130		x	x			
					24	2481658	2490300						
					25	2490505	2491300						
					26	2491702	2500104						
LSL1022	2500114	2502310	84732	90176	27	2500117	2500919		x	x			
					28	2501327	2502130						
LSL1023	2502314	2520443	90180	97493	29	2511640	2520101		x	x			
LSL1024	2520450	2541019	97494	109683	30	2520754	2521613		x	x			

					31	2521751	2530304						
					32	2530717	2531517						
					33	2532037	2540406						
LSL1025	2541020	2541919	109684	111470	34	2541030	2541916		x	x			
									x	x	2542052		
									x	x			

Table 1-1. Data summary

LSL 2010 Data Archive Summary

Seismics

DVD No.	Line No.	Start	End	Shotpoint	
				Start	End
S1	LSL1001	2202130	2210826	1	4380
	LSL1002	2210826	2211256	4381	5995
	LSL1003	2211256	2220216	5996	10767
	LSL1004	2220216	2220821	19768	12951
	LSL1005	2220821	2221535	12952	15548
S2	LSL1006	2242307	2251420	15449	18853
	LSL1007	2251420	2252210	18854	20509
	LSL1008	2260008	2261055	20510	22709
	LSL1009	2261414	2262145	22710	24090
S3	LSL1010	2262149	2281431	24091	31809
S4	LSL1011	2281811	2301417	31810	40513
S5	LSL1012	2301417	2311932	40514	46023
	LSL1013	2320139	2320944	46024	47818
S6	LSL1014	2321052	2331509	47819	50749
	LSL1015	2341142	2342221	53040	55102
	LSL1016	2350052	2351830	55103	58293
S7	LSL1017	2381140	2391333	58294	63759
	LSL1018	2391934	2392145	63814	64270
	LSL1019	2460152	2470416	64318	70233
S8	LSL1020	2470421	2480230	70234	74696
S9	LSL1021	2480312	2500111	74697	84731
S10	LSL1022	2500114	2502310	84732	90176
S11	LSL1023	2502314	2520443	90180	97493
S12	LSL1024	2520450	2531600	97494	105899
S13	LSL1024	2531600	2541019	105900	109683
	LSL1025	2541020	2541919	109684	111470
	Source calibration files				

All other data

A	All Sonobuoys
	All SVP, XCTD, XBT
	Seastar DVD CTD
	Navigation
	Mammal observers logs
	Electonic Log
	Data and archive summaries

Gravity

DVD No.	Line No.	Start Day	End Day
G1		198	215
G2	LSL1001	216	221
	LSL1002		
	LSL1003		
G3	LSL1003	222	227
	LSL1004		
	LSL1005		
	LSL1006		
	LSL1007		
	LSL1008		
	LSL1009		
	LSL1010		
G4	LSL1010	228	233
	LSL1011		
	LSL1012		
	LSL1013		
	LSL1014		
G5	LSL1015	234	239
	LSL1016		
	LSL1017		
	LSL1018		
G6		240	245
G7	LSL1019	246	251
	LSL1020		
	LSL1021		
	LSL1022		
	LSL1023		
G8	LSL1024	252	258
	LSL1025		

Knudsen

DVD No.	Source	Start Day	End Day
K1	3.5Khz KEB & SGY	219	222
K2	12Khz KEB	220	257
	12Khz SGY	247	252 + 256

Table 1-2. Summary of data archives

forward lab. The only major problem was the loss of all navigation data during the second day. Although the seismic program had not yet started, this interruption in navigation data meant that the gravimeter could not function. The problem was traced to a malfunctioning serial to RJ45 converter in on the bridge. The exact cause of the malfunction was impossible to determine but the converter eventually started working and the problem did not recur.

A network radio link was again 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

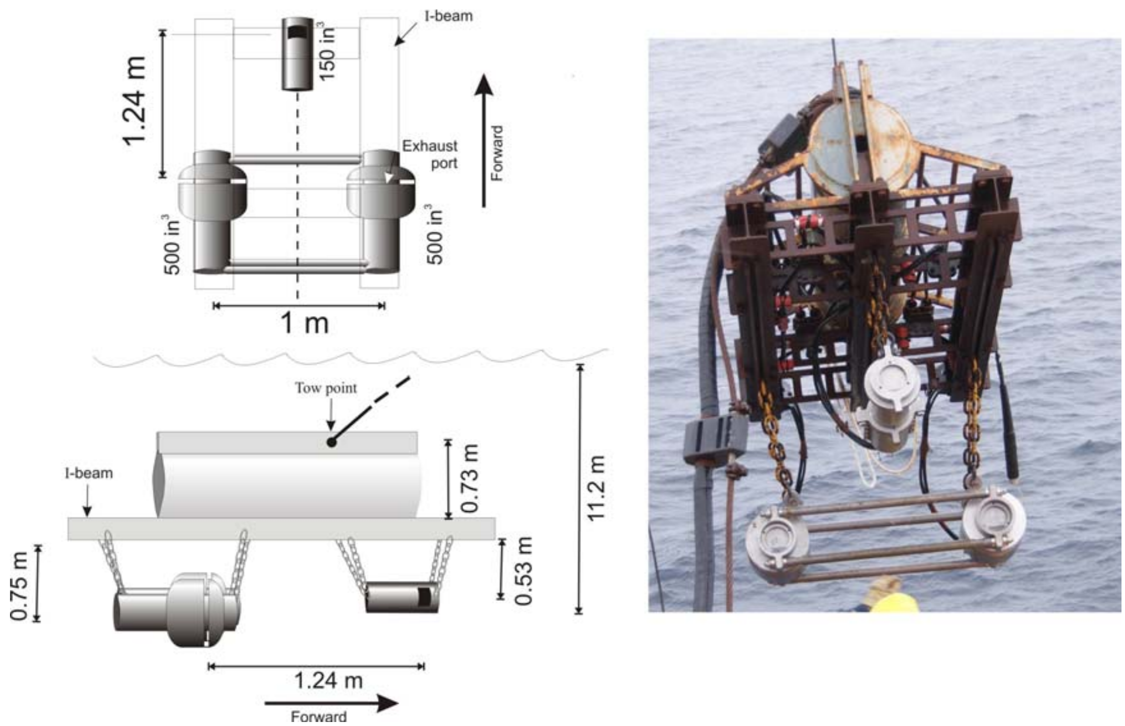

Figure 1-3. Deep tow G-gun array design and photo of it being deployed.

Full technical details of the systems can be read in Chapter 4 of the 2009 cruise report (Mosher et al., 2009).

Seismic Source

The seismic source was an 1150 in^3 pneumatically charged array (Fig. 1-3) of three Sercel G-guns arranged in two configurations, a shallow tow-configuration for open water (Fig. 1-4) and a deep tow configuration for ice operations (Fig. 1-3). For the deep tow arrangement, there were two arrays 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.

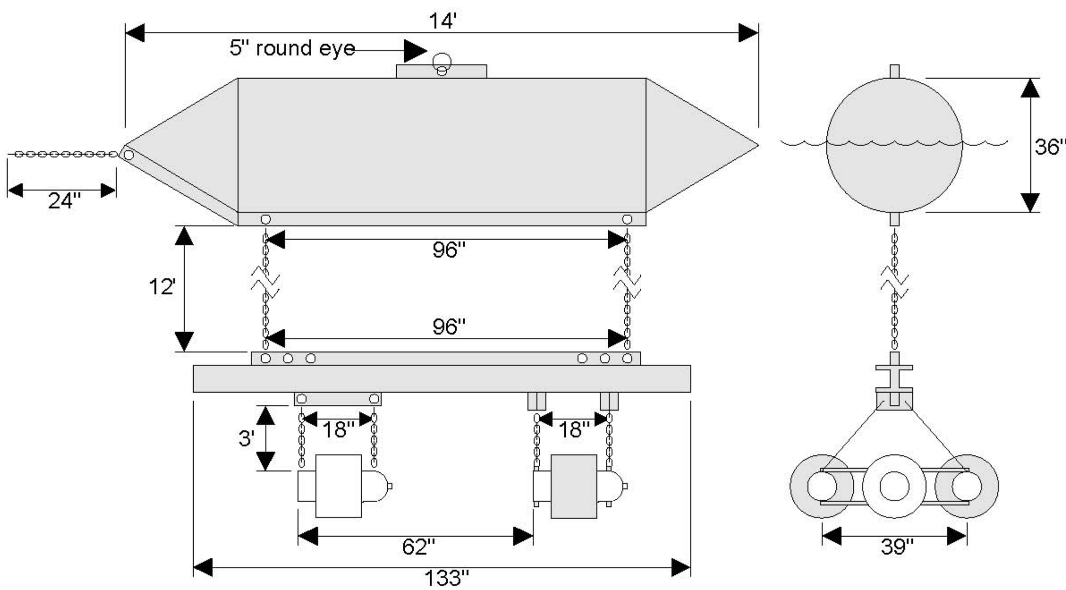

Figure 1-4. Seismic gun array configuration for shallow tow. The 150 in3 gun is in the lead and the two 500's astern.

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 2010 Louis program over the 2009 program. 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.

Unfortunately, these compressors have been plagued with mechanical problems requiring extensive in-field repairs and off-season maintenance and modifications. Due to poor "plumbing", most of the high pressure lines on both machines have required reworking to correct alignment issues at couplings and joints.

In 2010 there has been a decided decrease in the actual down time of both machines, mainly due to the many upgrades and corrective maintenance provided by NRCan and contract staff. In 2010 there was no lost survey time as a result of both compressors being out of service at the same time. Technicians were able to "keep ahead" of service issues, relying on one machine to be functional long enough to repair the other.

For the survey year 2010, a concerted effort was made to accumulate a maximum number of operational hours on the newer Hurricane Compressor, HC #2. Approximately 500 operational hours were added to the 250 hours already on this machine. By the end of the 2010 survey HC #2 had run a total of 750 hours while HC #1 had run 1740 hours.

Seismic acquisition required a watchkeeper in the seismic lab and another in the compressor container. The seismic lab watchkeepers (Etter 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, Nelson Ruben, Ryan Pike and Jamieson Etter) were required to watch over the compressor for any failures for emergency shut down and provide general maintenance that might be required during operations. During much of the program, the ambient air temperature was below zero degrees Celsius, and with the high air flow rate through the enclosure,

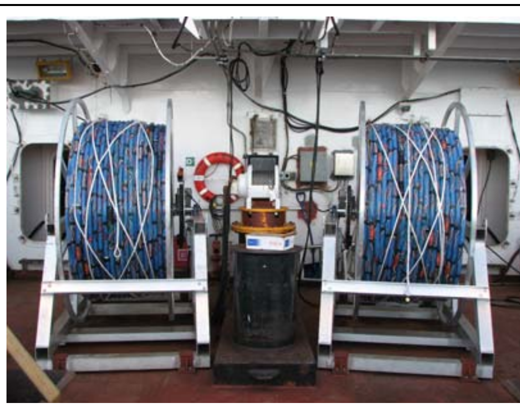

Figure 1-5. Two Geometrics GeoEEL Streamers on the quarter deck of the LSSL.

the working environment within the compressor container was extremely uncomfortable. Wind chill became a real issue and concern. As a result, watches were shortened to four hours and a third watchkeeper (Ryan Pike) was added to the schedule.

Geometrics GeoEel Digital Streamer

Two identical GeoEel streamers were assembled in July 2010 while the vessel was along side in St. John's, NL (Fig. 1-5). 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. On recovery, the streamer was pulled through a submerged shackle in order to weight the streamer and keep it at depth and vertical off the stern of the vessel.

No configuration changes were made for the 2010 Louis program. Please refer to the 2009 technical report (Mosher, 2009) for streamer "component placement".

In 2010, two streamer problems were carried forward from the previous year:

(1) The issue of the electro-mechanical coupling connectors between streamer sections working loose. While deployed, the connectors would loosen over time. This allowed sea water ingress into the connectors causing high leakage values to register on the deck equipment and eventually leading to an electrical short circuit, damaging the connectors and/ or streamer sections;

(2) Leaky pressure case and connectors on the repeater located immediately aft of the depressor, between the deck cable (or as it is referred to in the NRCan documents, the "bundle cable") and the float cable.

Steps taken to address issue #1:

In 2010 during the assembly process, an "O" ring was placed over the groove of each electro- mechanical connector, into the small gap between the connector collar and connector body. The "O" ring served to stabilize the collar and dampen the vibration which caused the collar to loosen during towing. With the "O" ring in place, approximately six wraps of electrical tape were wound around the connector collar to increase the outside diameter of the collar and hold the "O" ring in place. A #26 hose clamp was secured over top the electrical tape and carefully located in such a way as to span the connector collar, overtop the "O" ring and the connector body. Once securely tightened, the hose clamp forced the "O" ring into the tight groove between the connector collar and the connector body, further preventing the connector from loosening. This proved to be a successful technique preventing the connector loosening.

Steps taken to address issue #2;

The water ingress/ repeater issue was dealt with while at sea. This problem was a hold-over from previous years and once again arose early in the 2010 cruise.

Shortly after gear deployment, streamer leakage and soon after, streamer current increased. The problem was traced to the repeater immediately behind the tow sled. Upon removing the repeater, sea water was found in the electro- mechanical connectors. After several recoveries, sea water was also discovered inside the repeater pressure case. On one occasion the sea water had damaged the electronic circuit boards rendering this repeater unserviceable.

In 2009, an attempt was made to cure the ingress of sea water into the repeater/ connector using a clamp and support bracket system. The “on board” fabricated clamp secured the deck (bundle) cable to the back of the tow sled using a four point tow harness. The support bracket secured the deck (bundle) cable mould and the float cable mould while rigidly supporting the repeater. This helped address the issue immensely but again in 2010, the sea water was found inside the repeater pressure case and/ or the electro-mechanical connectors.

On careful examination it was observed that the outside diameter of the potted electrical moulds for the deck (bundle) cable and the three available float cables were quite different. Further, it was observed that there was a torque being applied to the repeater pressure case as it was secured to the support bracket. The support bracket was also only limiting movement of the repeater in one plane. To address these issues, a new bracket was fabricated from 2”x 2” x ¼” aluminium angle. The inner surface of the aluminium angle was machined on one end to allow for the difference in the outside diameter of the float cable which had a larger OD than the deck (bundle cable). Also specially fitted collars were fabricated to slide over the repeater body to fit the angle bracket securely. As with the other streamer sections, an “O” ring/ tape and hose clamp arrangement was used to prevent the connector collars from loosening. The entire assembly was secured to the aluminium angle bracket using seven- #36 hose clamps. By properly aligning the three components, deck cable, repeater and float cable, water ingress was stopped. Also the “L” shape of the aluminium angle offered structural support in both the vertical and horizontal plane, thus stopping any movement of the assembly.

As the OD on the port and starboard streamer float cable moulds were found to be different, two separate angle brackets had to be fabricated. Separate port and starboard repeater collars were also made to adapt the repeater to the different aluminium angle brackets.

The final step to reduce the water ingress into these repeaters involved disassembling the port bundle and increasing the layback of the deck (bundle) connector from 3 feet to 10 feet. This placed the deck (bundle) clamp approximately 10 feet behind the tow sled. The four legs of the pull cable bridle, which previously had been connected directly to the tow sled, were connected to a new seven foot single cable secured onto the back of the sled. This single cable served to reduce the “shock” transferred to the clamp and thus the deck (bundle) cable. With less movement on this new deck cable/ repeater/ tow cable assembly, there was no water ingress into the repeater pressure case or repeater connectors for the remainder of the program.

During an eight day tow, no streamer issues arose and streamer leakage remained at a minimum. On disassembly all connections over the streamer length remained comparatively tight and there was no observed water ingress at any of the connector joints.

The hardware performance of the Geometrics GeoEel system in 2010 was judged as "acceptable". A considerable portion of the 2010 program involved open water towing so the stress on the streamer would be similar to that of any open water seismic program. The modifications to the pulling arrangement as discussed above helped to eliminate some of the issues plaguing the seismic operation in previous years.

As stated, much of the program was in ice free or reduced ice filled waters. There was no incident where the streamer had to be deployed or recovered in rafting ice conditions or with sea ice under compression. Over the past years, these difficult environmental conditions proved significant to maintaining streamer functionality.

Modifications to improve stability of the connectors at the rear of the tow sleds and between streamer sections meant that less gear retrieval was necessary, reducing the chance of damage due to handling. There are a number of streamer components which will require Geometrics "factory service" before the 2011 season. These components will be grouped and inventoried before being sent to the manufacturer for repair.

Seismic Calibration

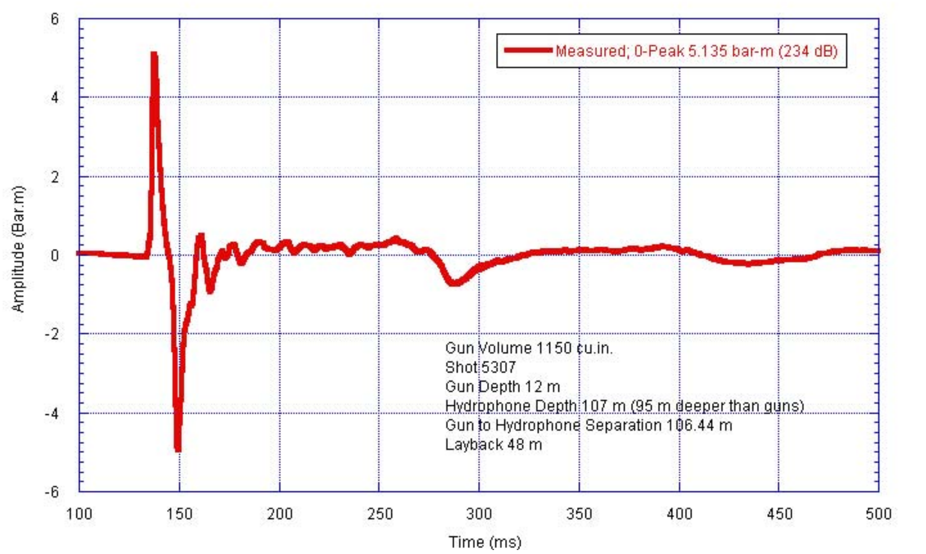

Figure 1-6. Deep tow configuration calibration test result, shot 5307. Top is a time domain shot signature showing a zero to peak amplitude of 5.135 bar-m or 234 dB re 1 μPa at 1 m. Bottom is the frequency spectrum plot for this trace, showing prominent power between 2 and 60 Hz with notching occurring at 65 Hz, caused by the bubble pulse period.

Two separate seismic calibration experiments were implemented during this program; one on the shallow tow arrangement and one on the deep tow arrangement. Most data were acquired throughout the program with the deep tow configuration. A full write up on these experiments is provided in Chapter 3. In both instances, 0-peak sound pressures were found to measure at 234dB re 1 μPa at 1 m and peak-to-peak pressures of 238 dB re 1 μPa at 1 m. A much improved signature was recorded over last years trials, indicating that there was indeed a problem with last year's experiment and results from that effort should be ignored.

In addition, an accurate time gap between trigger and fire points was recorded. The fire break point signal from the LongShot firing unit was recorded on a separate channel (channel 2) of the GSCDIG #4, along with the calibration trace on channel 1.

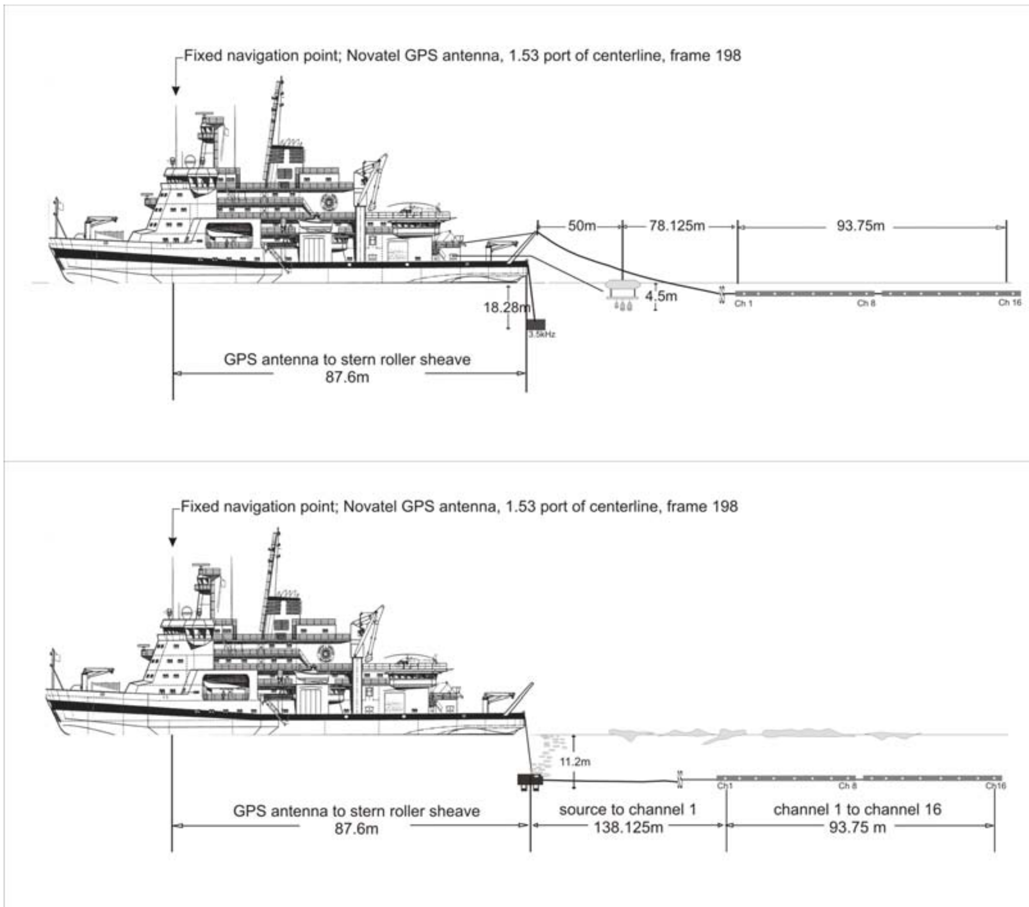

Figure 1-7. Geometric arrangement of the seismic reflection equipment. Top is the shallow tow configuration, bottom is the deep tow (in ice) configuration.

Seismic Reflection

Full details of the seismic reflection acquisition and processing component of the program are provided in Chapter 2. For most of the program the streamer was towed from the aft end of the G-gun tow sled at a depth of 11.2 m (see Fig. 1-7, deep tow configuration). For Lines 1 to 5, in open water, the shallow tow configuration was employed (Figs. 1-4 & 1-7). Two active 150 foot streamer sections were included in the overall streamer configuration. Total streamer length was approximately 300 m.

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. A Geometrics software program called Stratavisor provided streamer control, logging and display of the data. Stratavisor version 5.31 was implemented for most of the 2010 program and was found to be stable.

Figure 1-8. SeaStar mini CTD, About 2.5 cm in length.

Included in the Stratavisor software was a streamer depth monitoring option. Depth sensors were fitted inside the forward end of each active section. The active section tow depth was displayed on the Stratavisor monitoring software.

Wooden floats were added to cover the A/D and repeater modules (Fig. 1-9). These floats added significant buoyancy to the streamer and helped immensely in maintaining appropriate tow depths. Miniature SeaStar CTD's were mounted in the floats at the A/D converters and on the tail section of the streamer. These CTD's provided depth information after recovery of the streamer, permitting us to understand streamer dynamics during operation (Fig. 1-8). Temperature and salinity data were also acquired with these CTD's, showing salinity in the range of 27 to 28 psu and temperatures on the order of -1.2 to -1.5ºC. Full description of the CTD's are provided in the 2009 cruise report (Mosher et al., 2009) and in Chapter 2.

Seismic reflection data were post-processed using Claritas seismic processing software. Original SEG-D files were assembled into line segments and converted to SEG-Y format. Brute stacks were generated at sea and printed to verify the data quality. Final post-processing was also completed at sea and included : static shifts for recording delay, field time break, and firing delay ; debias ; design of wiggly line CMP bins at a 12.5 m interval ; matching and interpolation of receiver depths for each shot record ; bandpass filtering (3/8/140/240 Hz) ; F-K filtering ; T-squared amplitude scaling ; trace balancing ; trace editing based on frequency characteristics ; minimum phase conversion ; source signature deconvolution ; gapped deconvolution ; CMP stacking ; primary multiple suppression using an autoconvolution model with adaptive subtraction ; poststack coherency filtering ; finite

Figure 1-9. Cedar float that attaches over the repeater and A/D units. This one has been drilled to house the miniature CTD

difference migration using 2-D velocity models derived from previous sonobuoy results ; linear amplitude scaling (5 dB/s below seafloor) ; phase shift ; and time-varying lowpass filtering. Data quality was excellent for the most part. Heavy ice conditions requiring extra propeller revolutions and heavy sea states during several days of the open water surveying created most of the noise apparent on seismic data. See Figure 1-10 for a comparison of brute stack and processing seismic results and Chapter 2 for the full acquisition and processing report.

Very little time was lost this season due to seismic equipment failure; an estimated 18 hours total. The only significant problem was streamer leakage at the foremost repeater unit in the streamer. The most significant block of time lost was 14 hours on line 21/22 (Day 239) at the northernmost portion of the survey, due to streamer leakage. Ultimately, we finished the line in multibeam mode only while we effected streamer repairs. With redesign of the towing harness, the situation seems to have been resolved. Data quality were affected by bad sea states in open water conditions, particularly during days 227/228 on Line 10 and day 250 on Line 21. Data quality were also affected by excessive propeller wash in ice conditions. A streamer failure on August 27 (JD 239) between 0150 and 0630 and resulted in acquisition on only 8 active channels, which also affected data quality.

Reflection Results

25 seismic reflection lines totalling 111460 seismic shots and 3673 line-km of seismic reflection data were acquired over the course of 29.5 acquisition days (Figure 1-11; Table 1-3). Lines 1-5 were acquired on the Canadian Beaufort Shelf and uppermost slope to tie into existing industry data sets in this region (Fig. 1-11). The shallow tow configuration was used for these lines. The original intent was to acquire these data at the end of the program, but because of delays in obtaining permissions to acquire data in the US Exclusive Economic Zone (EEZ), this portion of the program was implemented first. By August 11th, US approvals were obtained and we proceeded to acquire data in the US EEZ.

Lines 6 to 11 were acquired within the US EEZ along the Alaska margin. By Day 230, at the end of Line 11, we were outside of the US EEZ, but continuing work for US interests with lines along Northwind Ridge. These included Lines 12-14 from NW Ridge to tie to the existing grid of seismic data in the central portion of the basin. These lines were modified to optimize ship time. Line 12 was oriented to attempt to tie into Grantz's 1993 lines (Grantz et al., 2004).

Line 15/16 runs from the north end of Northwind Ridge to the basin in a NE direction, in an attempt to cross a basement ridge and graben structure at an orthogonal angle (see Fig. 1-11). Once the crossing was made the line was terminated as northern objectives were a priority and shared time with the Healy was running out. It was hoped that we could tie in this line from the east as the two ships headed south again.

Line No.	Start Time	Lat	Long	End Time	Lat	Long	Shot Start	Shot End
LSL1001	2202130	71 09.5487	135 31.0039	2210826	70 29.4577	134 18.4119	1	4380
LSL1002	2210826	70 29.4577	134 18.4119	2211256	70 21.3779	135 08.7449	4381	5995
LSL1003	2211256	70 21.3779	135 08.7449	2220216	71 11.5090	136 36.4786	5996	10767
LSL1004	2220216	71 11.5090	136 36.4786'	2220821	70 59.0587	137 46.8283	19768	12951
LSL1005	2220821	70 59.0587	137 46.8283	2221535	71 18.8510	136 59.5461	12952	15548
LSL1006	2242307	71 39.3983	148 11.189	2251420	72 15.8884	145 24.4562	15449	18853
LSL1007	2251420	72 15.8884	145 24.4562	2252210	72 47.6661	145 22.7278	18854	20509
LSL1008	2260008	72 46.4979	145 22.2098	2261055	73 25.7201	145 20.275	20510	22709
LSL1009	2261414	73 25.4160	145 19.8999	2262145	73 55.0725'	145 18.2737	22710	24090
LSL1010	2262149	73 55.3428	145 19.1072	2281431	71 53.1010	151 22.3980	24091	31809
LSL1011	2281811	71 48.2714	151 43.5665	2301417	74 43.5333	150 02.8734	31810	40513
LSL1012	2301417	74 43.5333	150 02.8734	2311932	75 49.3355	156 10.8935	40514	46023
LSL1013	2320139	76 10.5362	156 12.6693	2320944	76 14.9631	154 06.2002	46024	47818
LSL1014	2321052	76 14.5613	154 09.2348	2331509	76 35.3846	146 24.1893	47819	53039
LSL1015	2341142	78 06.8297	153 16.3645	2342221	78 23.5169	150 47.7797	53040	55102
LSL1016	2350052	78 22.9335	150 43.3595'	2351830	78 59.5373	145 07.4122	55103	58293
LSL1017	2381140	82 32.6675	138 55.8290	2391333	81 45.6753	128 37.6587	58294	63759
LSL1018	2391934	81 47.34738	128 13.6112	2392145	81 43.3297	127 18.2167	63814	64270
LSL1019	2460152	76 32.3485	128 44.7508	2470416	76 51.6771	136 01.7003	64318	70233
LSL1020	2470421	76 51.5339	136 03.0370	2480230	75 22.4588	136 24.8971	70234	74696
LSL1021	2480312	75 21.6690	136 25.1744	2500111	72 25.4835	136 59.3035	74697	84731
LSL1022	2500114	72 25.2838	136 59.4271	2502310	70 59.8249	137 36.2238	84732	90176
LSL1023	2502314	70 59.5841	137 36.2321	2520443	71 29.7805	131 29.5214	90180	97493
LSL1024	2520450	71 30.3010	131 29.5314	2541019	73 50.8787	140 20.8305	97494	109683
LSL1025	2541020	73 50.9258	140 21.1254	2541919	73 42.0085	142 29.3098	109684	111470

Table 1-3. Line numbers and associated start and end times, locations and shot numbers.

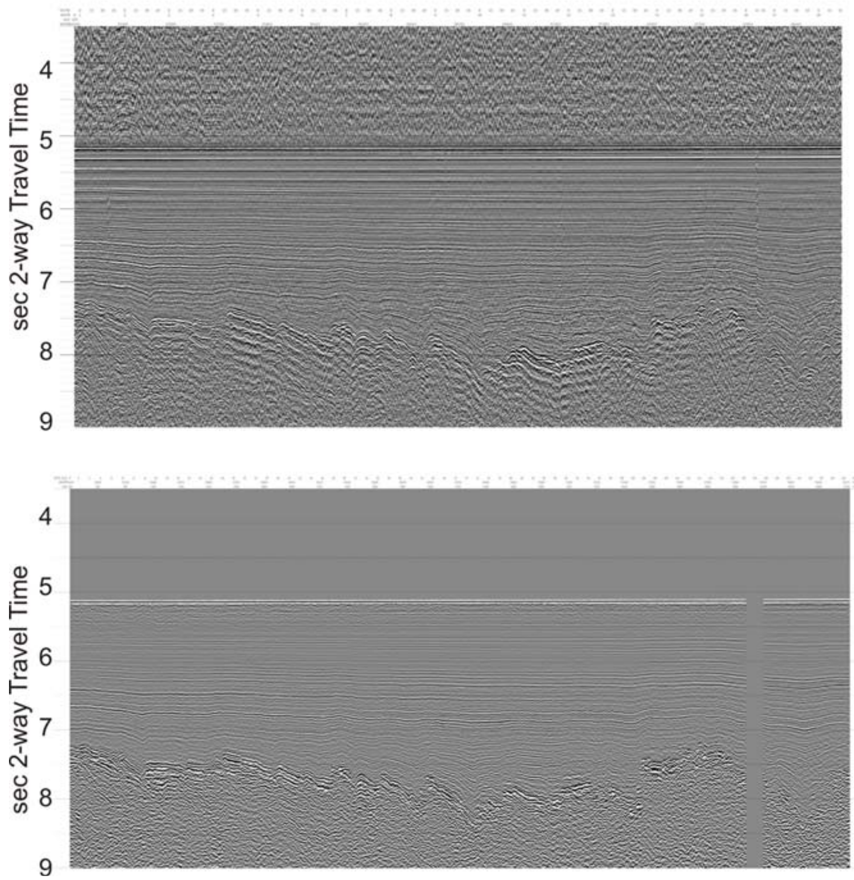

Figure 1-10. An example of seismic data acquired during this mission. Top is the brute stack and bottom is the final processed version of Line 16.

During transit to the north, LSSL developed propeller shaft problems which took ~36 hours to repair. This delay forced us to abandon plans to shoot a seismic line north through Stefansen Basin up to Alpha Ridge to 85ºN. We opted instead to start on Nautilus Spur and shoot Line 17 from west to east towards the north side of Sever Spur, and tie into the Borden Island spot sounding line. Ice conditions were heavy. The streamer failed about half way through this transect. We were able to tie into 2009 lines 20/21, but were not able to complete the transect. As a result, we completed the line and to tie to the spot sounding line with Healy multibeam only and LSSL broke ice for Healy. The intent was to tie the line up to the 2500 m contour, but at 1630, Day 240 (August 28), we broke the survey to go on a medical evacuation.

Following the med-evac, we had only 1.5 days left for joint operations with the Healy. To take advantage of this little remaining time, we ran a line (Line 19) from the north side of McClure Strait westward to tie into Line 09-31. This line forms the northernmost margin tie-line along the Canadian Archepelago margin; the other three being acquired in 2007. After tying to 09-31 we turned south on Line 20/21/S22 in order to make an eastern tie line between these margin perpendicular lines and to tie the grid in to the Beaufort margin, the FGP lines that exist there and our own few lines that were acquired at the start of the program. Healy was able to break ice for us until September 4th (Day 247) at 12:00h PST on line 20/21/22, after which we broke ice for ourselves. Ice conditions were relatively light, however.

From Line 21/22, we turned east on Line 23 to acquire a margin-parallel line along the upper portion of the Beaufort Slope. The original intent was to transit this line but weather did not permit recovery of the seismic equipment, so we continued surveying. We tied into FGP line 87-1 and turned northwest to acquire a dip line (Line 24) down the length of the MacKenzie fan delta and tie to the existing grid within the basin. We then turned SW on Line 25 to cross the gravity low in the central basin and terminated the line just after completing the crossing, thus terminating the seismic program at 1200h September 11, 2010.

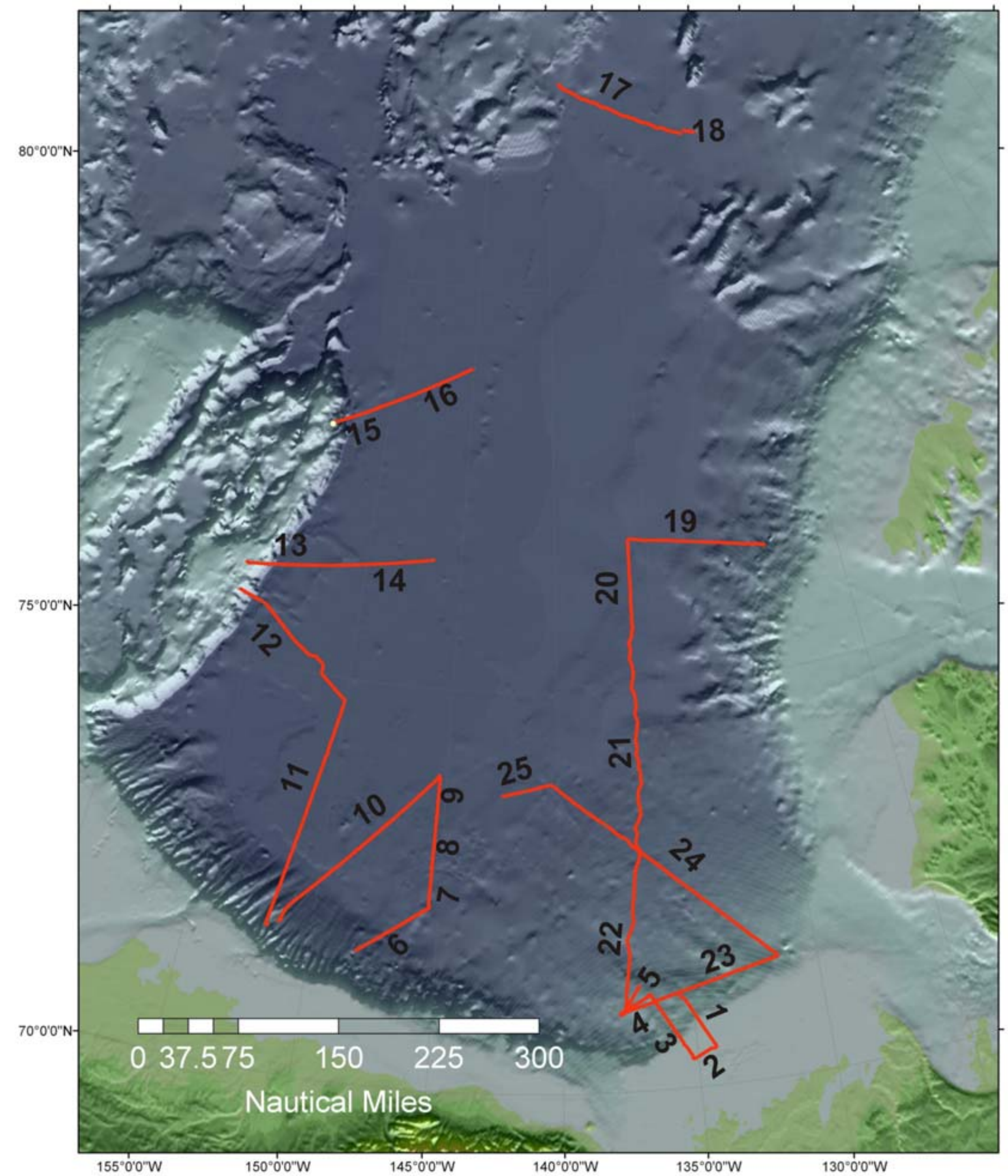

Figure 1-11. Map showing cruise track and line numbers.

Seismic Refraction

Figure 1-13. Sonobuoy being deployed off the quarter deck

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 15º 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. These signals were recorded on GSCDIG #4 as standard SEG-Y files. The seismic trigger pulse from the Zyfer clock was supplied to the digitizer to initiate recording. The record window length was only slightly shorter than the fire period. Several sonobuoys were deployed ahead of the vessel via helicopter drop in order to acquire approaching and departing refraction limbs. A single Yaggi array was mounted on the rail on Monkeys Island to receive the sonobuoy radio signals during the approach. This forward signal was recorded on a separate channel from the aft antenna of the GSCDIG, so two separate SEGY files were created for the one deployment (see Fig 13).

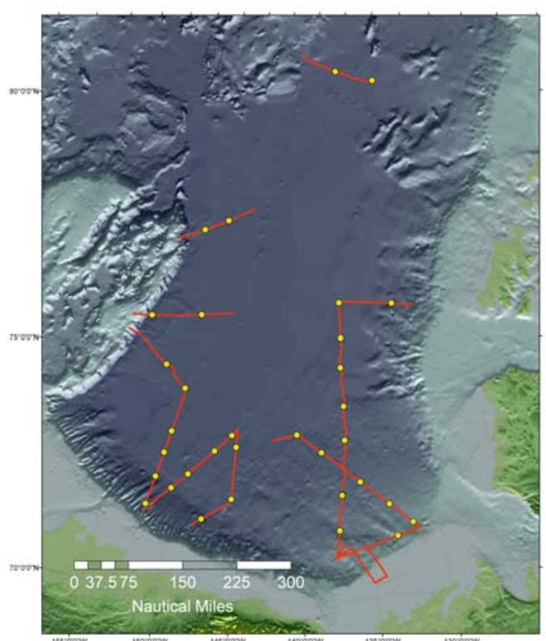

Figure 1-12. Location of sonobuoy deployments along track.

Refraction Results

34 sonobuoys were deployed with no complete failures (Fig. 1-12 and Table 1-4), although some had poor signal to noise issues. High quality records were obtained for the majority (Fig. 1-13). Helicopter and ship-to-ship communications resulted in HF intereference on digitized records, but this interference was not fatal. In addition, periodic bursts of noise of unknown source appear on the records.

SB#	Start			End		
	Time	Lat. N	Long. W	Time	Lat. N	Long. W
1	225030300	71 49.1747	147 26.6461	225110300	71 08.3785	146 00.2386
2	225150900	72 19.1675	145 24.5047	225221000	72 46.6661	145 22.7278
3	226154400	73 31.1373	145 19.7748	226214500	73 55.0725	145 18.2737
4	227004151	73 46.9449	145 44.8650	227083600	73 24.3061	146 58.8830
5	227085400	73 23.406 3	147 01.8250	227170055	72 59.8980	147 16.8283
6	227200400	72 47.9686	148 54.1545	228000406	72 26.1131	150 01.3067
7	228041212	72 25.7874	150 02.2801	228110000	72 04.6601	151 04.6995
8	228210508	71 58.6938	151 44.6130	229000500	72 31.6032	151 25.2516
9	229000637	72 38.1202	151 21.2573	229143000	73 10.5805	151 01.4895
10	229150000	73 12.6702	151 00.1861	229230000	73 42.5655	150 41.6940
11	229231000	73 43.2974	150 41.4246	230071500	74 16.2145	150 19.9271
12	230143824	74 44.3399	150 07.6549	230233000	75 10.8946	151 39.9034
13	231011028	75 12.6063	152 07.1913	231091600	75 32.1232	153 49.7580
14	232085125	76 14.3705	154 18.4270	232171837	76 19.3421	152 26.0675
15	233032249	76 26.9973	149 37.8642	233113000	76 33.0062	147 21.4272
16	235010900	78 23.4513	150 38.2894	235090500	78 39.9388	148 08.5123
17	235091712	78 40.3398	148 04.9256	235183000	78 59.5373	145 07.4122
18	239023320	82 06.0357	133 22.3962	239101700	81 51.8505	130 02.5758
19	239204501	81 45.2101	127 44.7812	239214443	81 43.3297	127 18.2167
20	246093532	76 39.7429	130 49.3772	246105601	76 40.8499	131 10.5827
20a	246105601	76 40.8499	131 10.5827	246173522	76 45.6914	133 05.0660
21	247045538	76 49.2360	136 01.9116	247125537	76 16.6892	136 06.0822
22	247164151	76 01.1420	136 08.8133	248003813	75 30.1987	136 20.5914
23	248032614	75 20.7535	136 23.7082	248113000	74 48.9657	136 17.1150
24	248165746	74 27.6277	136 22.1561	249030000	73 48.3134	136 19.7559
25	249050446	73 40.6054	136 29.8982	249130000	73 10.4438	136 41.5793
26	249170200	72 42.388	136 52.928	250010400	72 25.8665	136 59.0075
27	250011724	72 25.1613	136 59.5373	250091900	71 54.0124	137 21.8463
28	250132723	71 36.5063	137 20.4561	250213000	71 05.8280	137 33.2909
29	251164032	71 22.6800	133 11.2600	252010118	71 26.7680	132 12.8410
30	252075409	71 38.8588	131 58.1249	252161300	72 02.2545	131 12.9282
31	252175100	72 16.5750	134 02.0740	253030400	72 31.1848	134 54.4797
32	253071653	72 41.6563	135 31.9230	253151711	73 02.5191	136 53.5755
33	253203700	73 25.4150	138 26.9840	254040449	73 35.3218	139 11.5323
34	254102951	73 50.7931	140 23.7769	254191542	73 42.0175	142 29.2969

Table 1-4. Summary of sonobuoy deployments

Although it will take time to process and analyse the sonobuoy results, it is clear from a cursory look that there are distinct changes in the slopes and amplitudes of refracted arrivals from location to location. These differences are no doubt related to velocity and geologic changes. These data will provide a regional 3D model of crustal velocities and basement affinities, holding great promise to vastly extend the understanding of Canada Basin's geologic history. As a trial, we deployed a sonobuoy ahead of the Louis from the helicopter. In this way, we could receive both limbs of a refraction profile. We mounted a forward antenna on monkey's island to receive the signal ahead of the vessel. After several attempts, Sonobuoy 34 was successfully received (Fig. 1-14). The principal issue

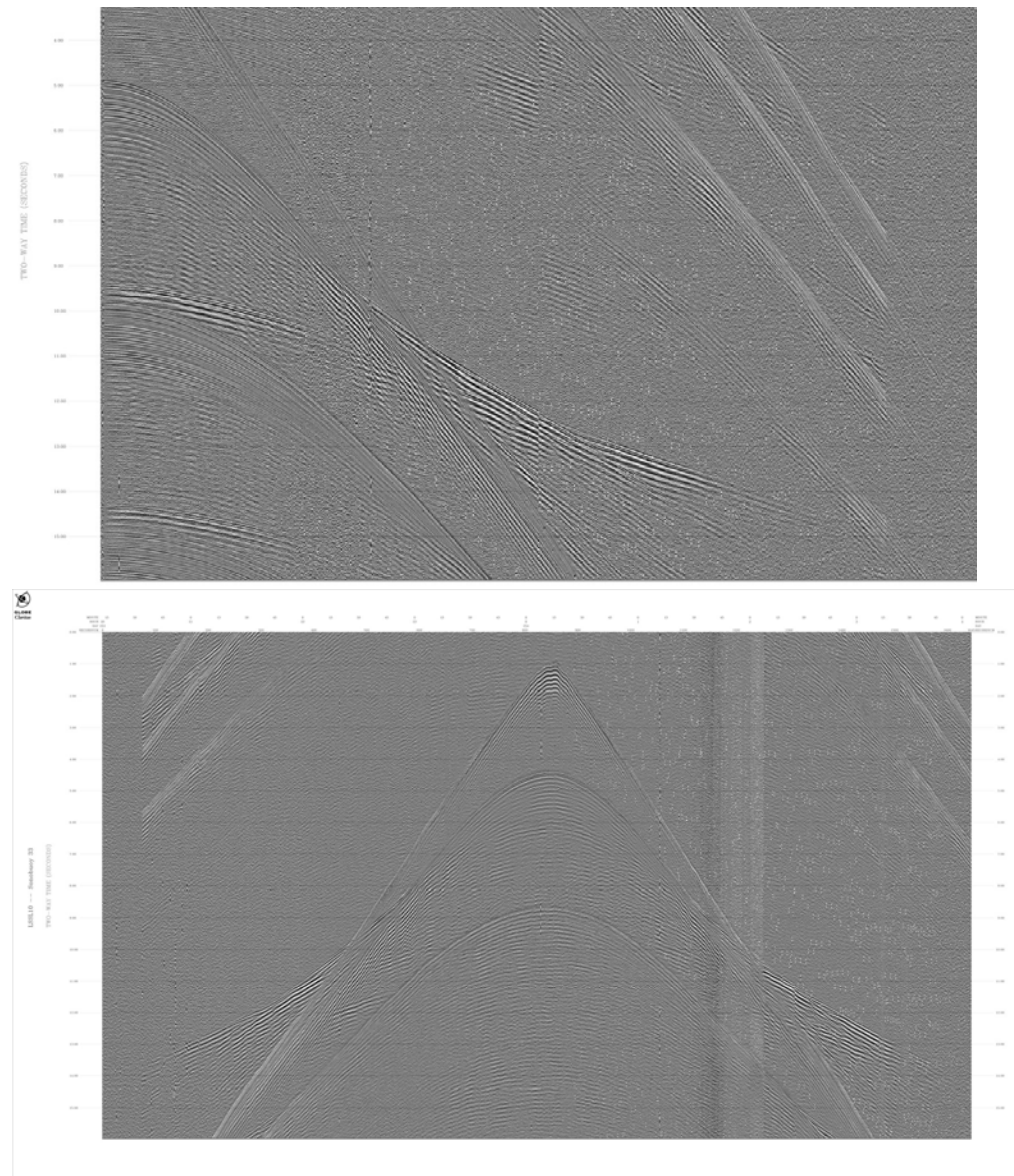

Figure 1-14. Top: an example of a sonobuoy record showing high data quality with easily identifiable refractions arriving before the direct wave. Bottom:Plot file results from deploying the sonobuoy ~17 nMi ahead of the vessel, so signals are received fore and aft.

was the the GSCDIG could not receive two channels for long record window lengths, without introducing errors in the digitized signal start time. The work-around was to record on only one channel but switch receivers when the vessel was beside the sonobuoy (see schematic below). The life span of the sonobuoys is too short (8 hours) to get the full range of refractors, but the trial was successful and perhaps for next year we can extend the life of the sonobuoys to allow this type of deployment.

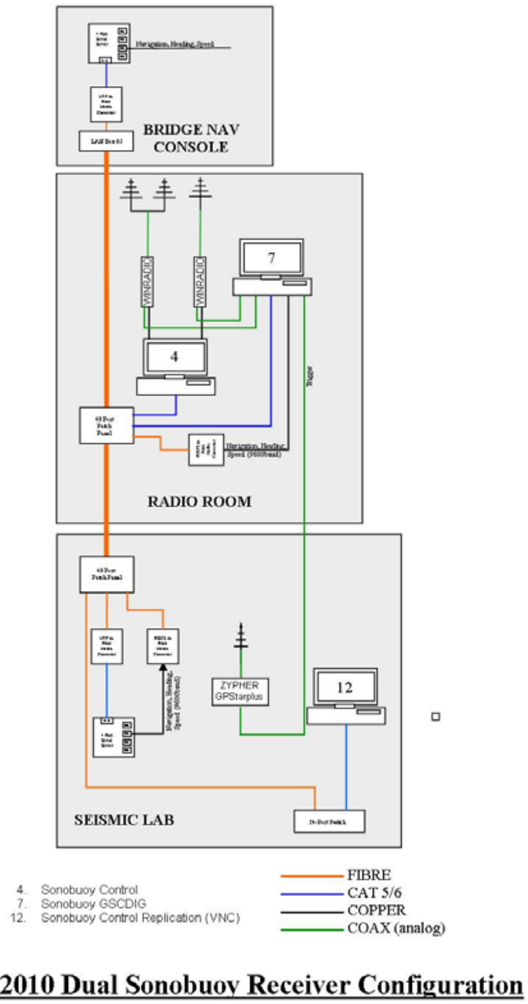

Figure 1-15. Wiring schematic for Forward and Aft sonobuoy, dual receivers

Chirp sonar

To provide sub-bottom sediment thickness measurements during parts of the 2010 CCGS Louis S. St. Laurent UNCLOS program, a chirp sonar system that could operate in ice was developed to tow from the stern of the vessel. Because of the configuration and requirement to tow it from the heel block on the stern of the vessel, it could be operated only concurrent with the shallow tow seismic configuration (see Fig. 1-7). Its use, therefore, was limited to open water tow only for this field season, thus was utilized on lines 1 to 5 (Table 1-5). Data quality was excellent, however, and ways will be studied in which the system may be able to be used for the entire program for next season.

A Knudsen 3260 transceiver and associated control computer were located in the Seismic Lab. Data were logged onto the PC's hard drive and off-loaded over the ship's science network. Navigation data were derived from the ship's navigation receivers over the science network.

The array consists of 12- Massa TCH1075 transducers in an electrically "parallel" arrangement, each with a nominal impedance of 250 ohms, a net transmitter load at 3.5 kHz, approx 27 ohms.

Array design Criteria: by Peter Simpkin

Beam Pattern Calculations for 12 transducer array of Massa TR1075 transducers:

Constants used:

- Active Diameter of individual transducer 7.0" = 17.8cm
- When formed into a 4 x 4 array with the four corner transducers missing, the active diameter is taken as 71.2 cm (28")

The half beamwidth for the main lobe pattern is estimated from the nomograms found in "Principles of Underwater Sound" by R.J. Urich.

The beamwidth information is extracted for Intensity Reductions of -3dB and -10dB from the on-axis intensity for frequencies of 2, 4 and 6 kHz .

Frequency	-3dB Half Angle	-10dB Half Angle
2 kHz	32º	60º
4 kHz	15º	27º
6 kHz	11.5º	18º

Figure 1-16: Sea Chest in Cradle

An aluminium sea chest was designed and constructed specifically to house the 12 transducer array and to bolt up directly under the depressor weight frame on the Port Tow sled. The sea chest was filled with approximately 150 gallons of NoTox II antifreeze. The electrical connection to the Knudsen 3260 Chirp transceiver was via electrical deck and lead-in cables and through a connector located on the top of the sea chest. Also fitted to the top of the sea chest were vent and fill piping and a pressure equalization bladder (See Fig. 1-16). A suitable cradle was constructed to hold the sea chest while in storage onboard the vessel and while in long term storage after use. Suitable zinc sacrificial anodes were fitted to help reduce affects of salt water corrosion on the aluminium components. All stainless steel 316 hardware was used in the construction and assembly. The overall weight of the sea chest, filled with antifreeze was 2250 pounds.

Inside the sea chest a chassis was fitted to accommodate the mating pair ends of the twelve electrical cables coming from the 12 transducers (Fig. 1-17). A single connector exited the same chassis and mated to the connector which passed through the lid of the sea chest. This electrical cable completed the connection to the umbilical cable from sea chest to the surface, then to the deck cable and into the Knudsen 3260 Chirp transceiver. The maximum cable length from the transceiver to the sea chest was 150 feet.

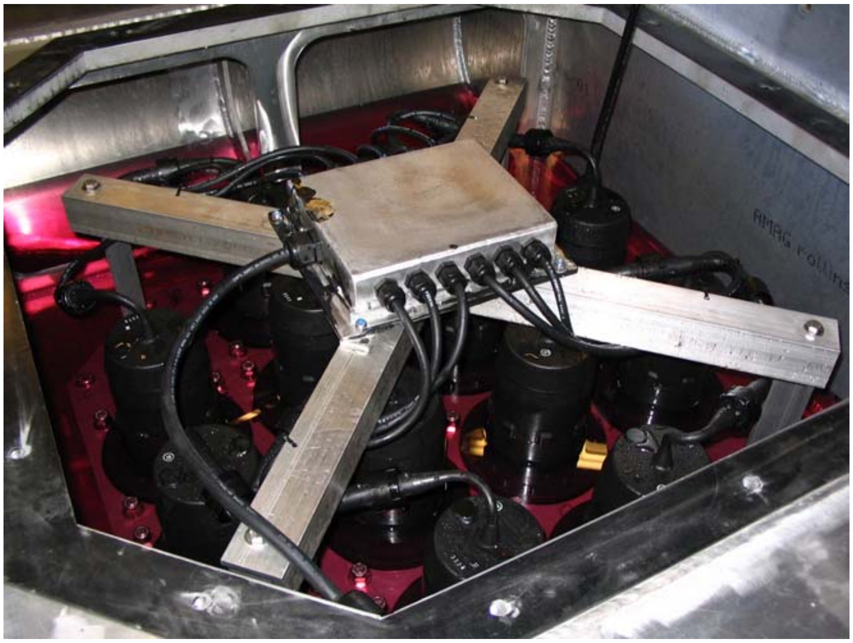

Figure 1-17: Interior of the chirp sonar sea chest showing transducer placement

A tow depth for the sea chest of 60 feet was fixed by a length of 1” steel cable fitted to the top of the tow sled depressor weight. The 1” cable was configured to be similar to the tow cable used to support the sled when towing air guns in ice, but was 30 feet longer. By fixing the tow cable to 60’ the inside pressure on the transducer array was set to 2 atmospheres allowing transmit power to operate up to 7.2 kWatts. To deploy the depressor weight and sea chest, the tugger winch located on the “tween” deck over the ship’s quarterdeck had to be changed. The combined weight of sea chest and depressor was 6900 pounds and a winch and cable was installed to safely carry the load.

The pull point location on the top of the tow sled depressor was moved aft to cause the sled to tow almost level at 4.5 kts. On the first deployment, a pitch and roll system was fitted to the sled to measure its orientation. This trial showed that the usual fixed tow point on the depressor was too far aft, causing the sled to tow nose down approximately 7- 9 degrees. By moving the point further aft, the sled pulled well with an angle of approximately 1 degree from horizontal.

Conclusions:

Data collected from the Chirp were judged to be of excellent quality (see Fig. 1-18). Unfortunately the program had some major changes and the opportunity to operate the Chirp system was brief. It is hoped that this tool could be adapted to operate in tandem with a second sled equipped with the air gun array.

Line no.	Start Time	Lat. N	Long. W	End time	Lat. N	Long. W
LSL1001	2202130	71 09.5487	135 31.0039	2210826	70 29.4577	134 18.4119
LSL1002	2210826	70 29.4577	134 18.4119	2211256	70 21.3779	135 08.7449
LSL1003	2211256	70 21.3779	135 08.7449	2220216	71 11.5090	136 36.4786
LSL1004	2220216	71 11.5090	136 36.4786'	2220821	70 59.0587	137 46.8283
LSL1005	2220821	70 59.0587	137 46.8283	2221535	71 18.8510	136 59.5461

Table 1-5. LSSL2010 Chirp Data

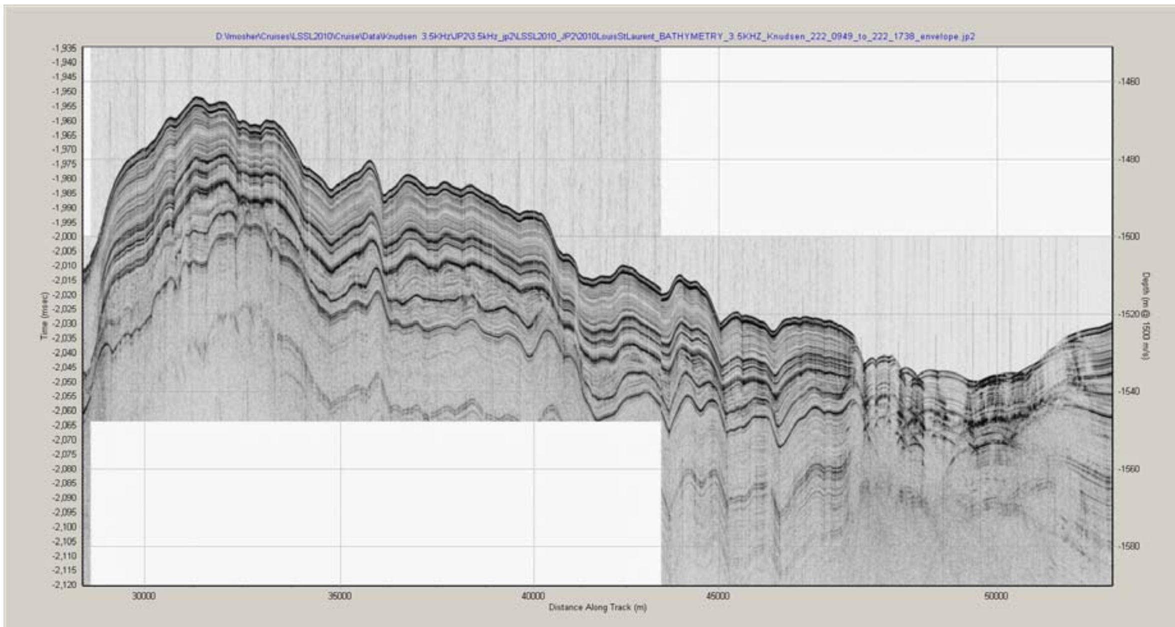

Figure 1-18. Example of LSSL2010 Chirp sonar profile, 1500 m water depth, showing >60m subseafloor penetration.

Bathymetry

As in the past four years of this program, the Canadian Hydrographic Service (CHS) performed bathymetric survey operations in conjunction with the NRCan seismic operations. Two sounding techniques were employed: conventional ship sonar and helicopter spot soundings. The ship navigated along pre-determined transects and the helicopter was deployed to collect spot sounding data between the survey lines. The ship logged 8355 line kilometres of bathymetry data and 61 spot soundings were acquired via helicopter (Fig. 1-19). Virtually the same equipment was used for both platforms. The USCGC HEALY joined the program on August 7th and departed September 4th, during which time additional hydrographic data were collected with their EM122 deep water multibeam and Knudsen Chirp profiler systems (Fig. 1-20).

The 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. The echo sounder performed well although the settings in deep water (>2500 metres) were set at maximum values to acquire the data. As is common when sounding in ice, bottom detection was sometimes lost due to interference from ice. Watchstanders (Weedon and Beach) 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.

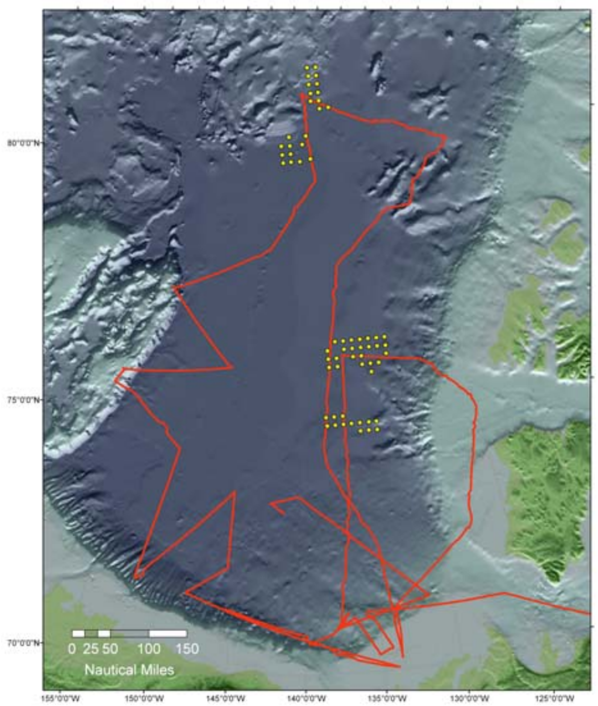

Figure 1-19. CHS spot soundings via helicopter

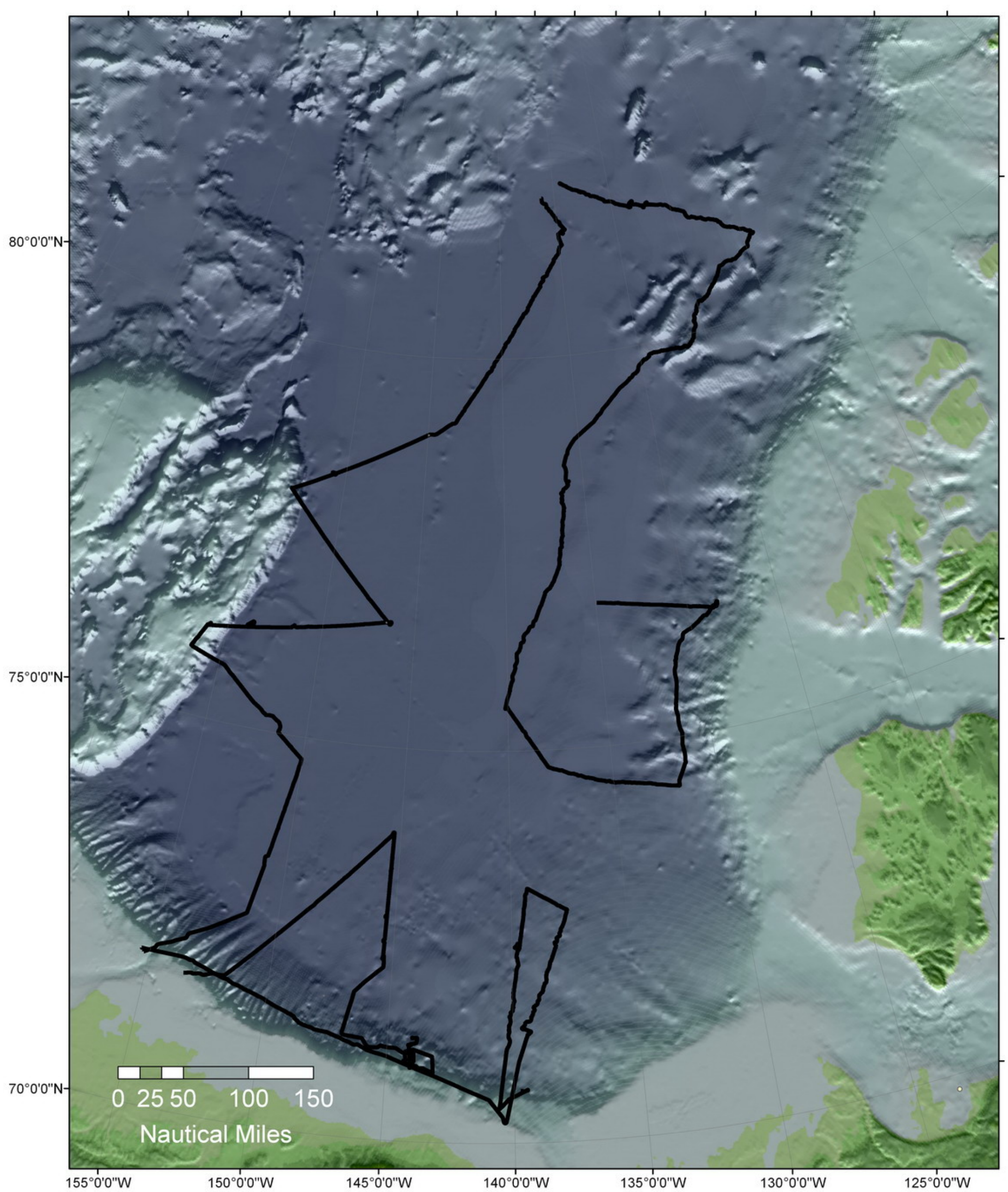

Figure 1-20. US Coast Guard Cutter Healy ship track during which multibeam bathymetric sonar and concurrent chirp subbottom profile data were acquired.

Gravity

A Bell Aerospace BGM-3 gravity meter, SN 223, was installed on the vessel in St. John's in July 2010. 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, 2010.

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)

The meter was installed in the ship's gravimeter compartment 615, as shown in Figures 1-21 and 1-22.

***Figure 1-22. BGM-3 Electronics and logging computers installed in Louis Gravimeter Compartment # 615*.**

Figure 1-21. BGM-3 sensor SN 223

Data were logged to a dedicated laptop computer installed with the gravimeter (shown in Fig. 1-1) 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 (Table 1-6).

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.

___

```
1   2          3            4          5     6
RGS 2010/08/01 00:00:00.547 982591.637 25367 1280620800.547
7          8          9    10   11   12   13   14
4.99004915 856009.060 BGM3 S223 GPS: -999 -999 1280620800.547
15   16   17   18   19   20     21     22              23
-999 -999 NONE -999 -999 DEPTH: 73.450 1280620800.3220 KNUD035
24   25      26             27           28             29
HDG: 287.700 1279386502.398 NO_DNV_ERROR 1280620800.547 -999
```

Table 1-6 *.rgs data record; fixed length 263 characters; space delimited ASCII; 29 record fields. (Note – need to add or replace table with description of the words in rgs string.)

Raw gravity readings data were filtered using a 4-minute Gaussian smoothing operator and plotted to monitor the performance of the meter and input streams (Fig. 1-23). Software for on-board processing and display was provided by Dr. Daniel Scheirer, USGS, Menlo Park. Plots of on-board processing were sent back to Menlo Park regularly for analysis, and no problems were noted. Data collected during periods when the vessel was in open water or light ice were characterized by very well-behaved measurements. Periods of heavy ice when *Louis* was being escorted by *Healy* were similarly smooth and generally free of spurious noise. Only when *Louis* was breaking heavy ice were the data noticeably degraded by the constant jarring and abrupt accelerations caused by contact with ice, backing and ramming, and short-period turns (e.g. Fig. 1-23).

Preliminary data are available in a 1-minute data file containing the following 16 words of data:

Date_Time(1) | Year(2) | DOY(3) | Lon(4) | Lat(5) | Dist_inc_1min(km,6) | Dist_1min(km,7) | Course(deg,8) | Speed(kts,9) | Gravity_bgm223(mGal,10) | PredGravity(mGal,11) | Eotvos Corr(mGal,12) | FAA_bgm223(mGal,13) | Echosounder_depth(m,14) | ArcticGPv2.0_FAA(mGal,15) | IBCAO_depth(m,16)

The appendix contains preliminary (not edited or drift-corrected) daily plots of free-air gravity anomalies, compared with the Arctic Gravity Project model (Kenyon and Forsberg, 2008).

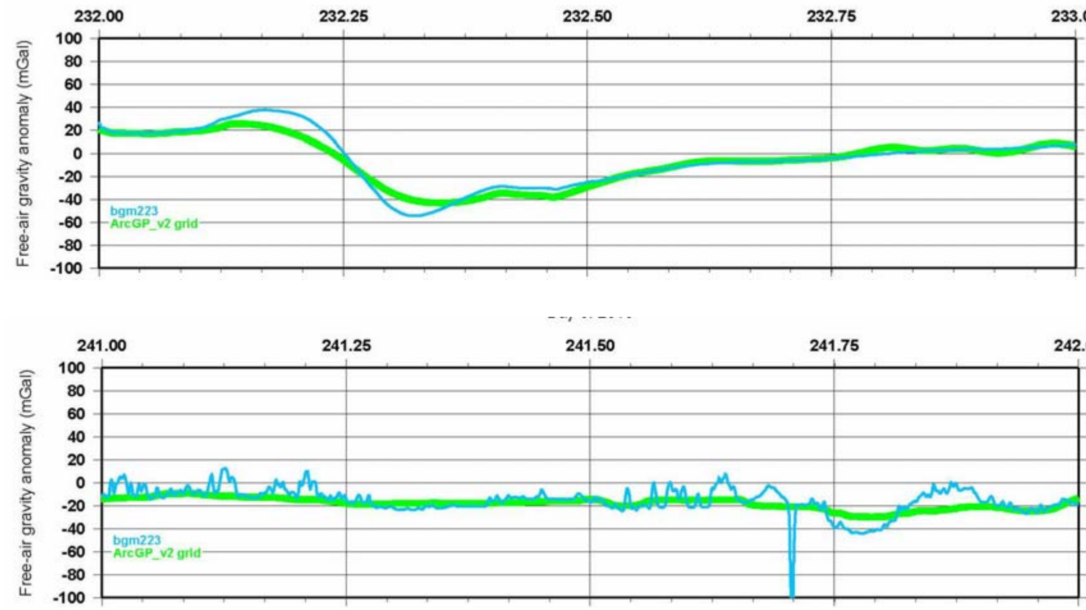

Figure 1-23. Top image shows gravity signal(blue line) with Healy breaking ice ahead of LSSL. Notice the goodness of fit with the ArcGP grid (green line), with some finer detail added. Bottom image shows gravity signal while LSSL breaks ice. Notice the addition high frequency noise due to accelerations of ice contact.

Physical Oceanography

Vertical Casts

SVP, XCTD and XBT

3 Deep water Sound Velocity Probes, 33 XCTD (eXpendable Conductivity – Temperature – Depth profiler, Tsurumi-Seiki Co., Ltd.) probes and 14 XBT (eXpendable Bathy Thermograph) Probes were launched to measure the vertical profiles of water sound velocity, temperature and salinity (Table 1-7 and Fig. 1-24). The three sound velocity profiles were made to a maximum depth of 3640 m. 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 1-7 Physical Oceanographic vertical casts

Description	Lat (N)	Long (W)	Time (GMT)	Date
SVP	76.60547432	146.4039403	17:04:17	08/21/2010
SVP	81.78446433	128.3080373	17:05:45	08/27/2010
SVP	73.69433343	142.4791223	20:51:46	09/11/2010
XBT t-6 Cast	72.49452942	149.8479296	02:59:47	08/16/2010
XBT t-6 Cast	72.80393344	145.3777611	00:58:09	08/14/2010
XBT t-6 Cast	73.48392518	145.3299964	15:15:10	08/14/2010
XBT t-6 Cast	73.68737273	146.0613606	02:40:04	08/15/2010
XBT t-6 Cast	73.08942998	147.9963329	15:16:07	08/15/2010
XBT t-6 Cast	71.86156149	151.4219537	14:54:30	08/16/2010
XBT t-6 Cast	72.37567827	151.5182689	02:52:32	08/17/2010
XBT t-6 Cast	73.21891421	151.0047909	15:06:42	08/17/2010
XBT t-6 Cast	73.98265644	150.528036	02:49:48	08/18/2010
XBT t-6 Cast	74.75634477	150.2065465	14:59:32	08/18/2010
XBT t-6 Cast	75.82747286	156.2985592	19:51:46	08/19/2010
XBT t-6 Cast	76.3551426	151.7013769	19:52:18	08/20/2010
XBT t-6 Cast	78.34531618	151.0152545	19:42:15	08/22/2010
XCDT-1 Cast	77.36920653	136.8824349	23:29:50	08/30/2010
XCDT-1 Cast	78.44767927	150.1248238	02:52:10	08/23/2010
XCDT-1 Cast	72.80959117	145.3781132	01:03:48	08/14/2010
XCDT-1 Cast	76.44220963	149.7870321	02:49:55	08/21/2010
XCDT-1 Cast	76.58788134	146.4722688	14:44:44	08/21/2010
XCDT-1 Cast	75.28337329	152.5611381	03:04:11	08/19/2010
XCDT-1 Cast	75.73620642	155.0069708	14:50:27	08/19/2010
XCDT-1 Cast	76.84922247	135.6228151	02:54:25	09/04/2010
XCDT-1 Cast	76.16179506	156.0590055	03:03:35	08/20/2010
XCDT-1 Cast	76.16401291	156.0256725	03:10:21	08/20/2010
XCDT-1 Cast	81.78215612	128.3377107	16:10:41	08/27/2010
XCDT-1 Cast	76.52691438	128.7429682	01:26:50	09/03/2010
XCDT-1 Cast	77.39086233	149.948386	02:54:24	08/22/2010
XCDT-1 Cast	81.74850222	138.5565437	01:38:56	08/26/2010
XCDT-1 Cast	80.48954386	123.6819825	16:57:27	08/29/2010
XCDT-1 Cast	76.2904055	153.1458159	14:53:37	08/20/2010
XCDT-1 Cast	78.19679833	152.336743	15:04:47	08/22/2010
XCDT-1 Cast	78.85768809	146.3820608	14:45:05	08/23/2010
XCDT-1 Cast	78.99502011	145.0988597	18:36:06	08/23/2010
XCDT-1 Cast	79.72293589	141.3447493	02:54:46	08/24/2010
XCDT-1 Cast	80.88969615	137.8203499	17:50:14	08/25/2010
XCDT-1 Cast	81.07770128	137.9498721	19:33:47	08/25/2010
XCDT-1 Cast	82.44679823	137.9702476	14:53:21	08/26/2010
XCDT-1 Cast	82.44698137	137.9667473	14:57:42	08/26/2010
XCDT-1 Cast	82.18497857	134.2891866	00:22:24	08/27/2010
XCDT-1 Cast	81.34126666	122.4675228	14:42:07	08/28/2010

XCDT-1 Cast	80.98233202	118.9964465	23:43:07	08/28/2010
XCDT-1 Cast	78.85999037	135.5767434	14:49:56	08/30/2010
XCDT-1 Cast	76.72770615	132.2877867	14:52:02	09/03/2010
XCDT-1 Cast	76.78676639	133.6491919	19:34:14	09/03/2010
XCDT-1 Cast	76.14843125	136.1245698	14:48:59	09/04/2010
XCDT-1 Cast	75.37207312	136.4116547	02:35:49	09/05/2010
XCDT-2 Cast	71.28860186	137.0798967	17:50:05	08/10/2010
XCDT-2 Cast	71.28307866	137.0984348	18:10:08	08/10/2010

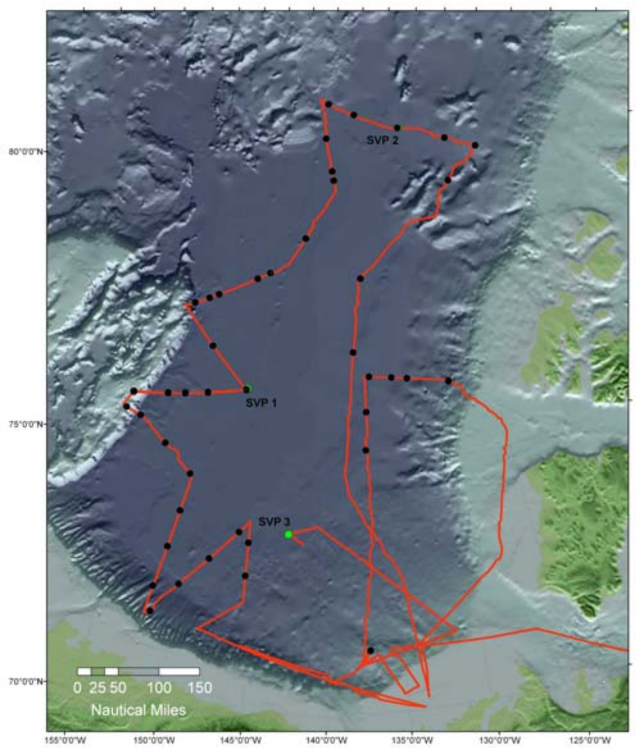

Figure 1-24. Vertical oceanographic profile data. Black dots are XCTD and XBT locations and the green dots are full ocean depth Sound Velocity Probe locations.

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 1-25 and 1-26 show a summary of results of salinity and temperature measurements taken through this underway system.

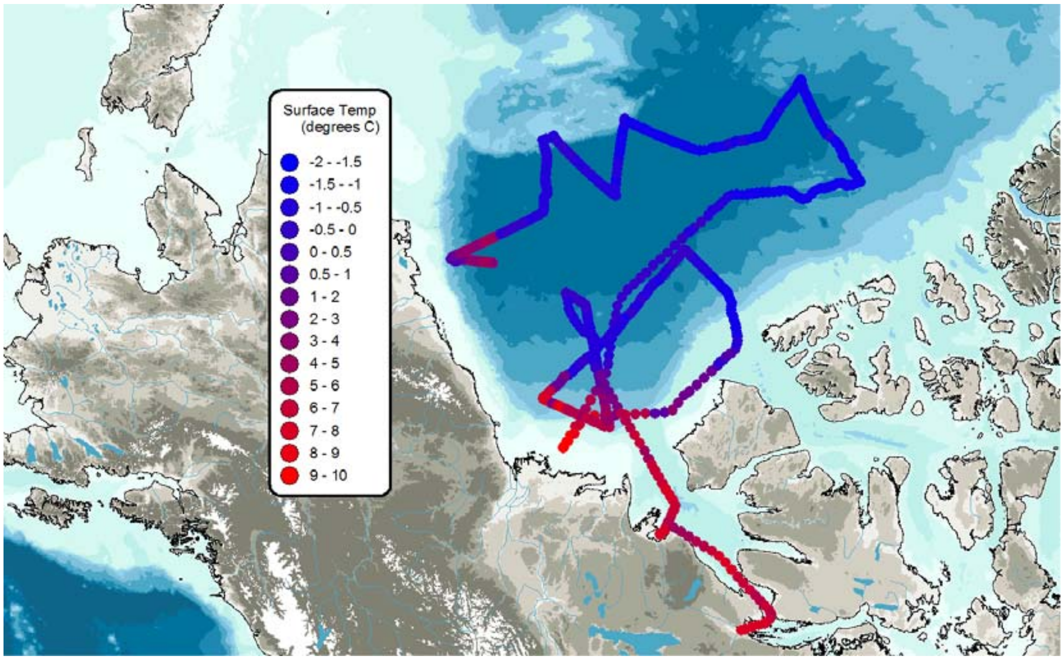

Figure 1-25: TSG inlet temperature

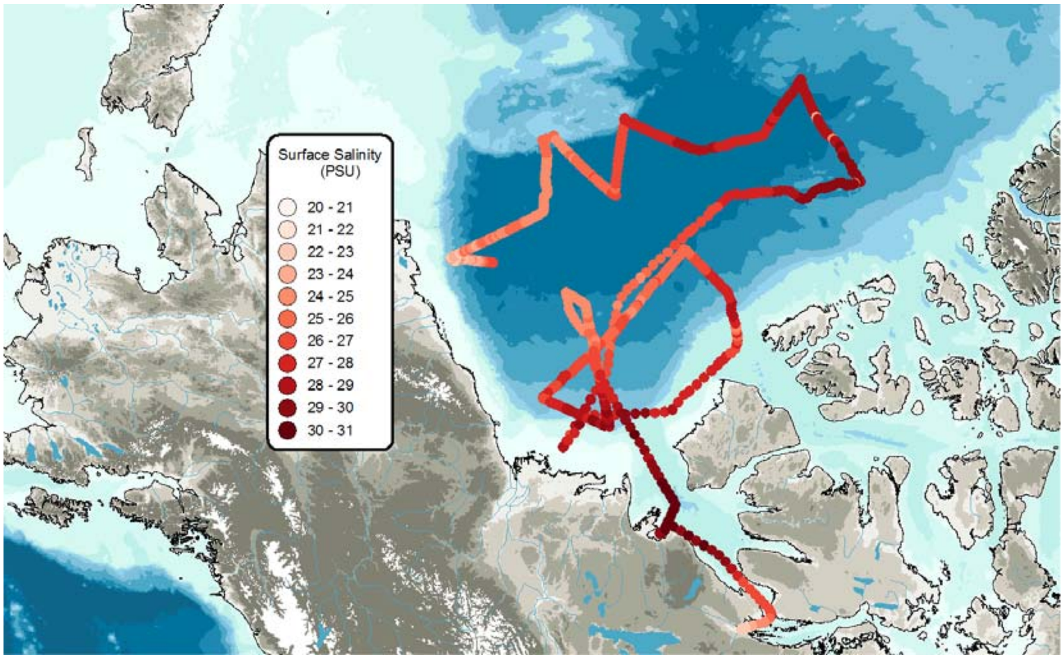

Figure 1-26: TSG salinity

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. These measures differed for operations within the US EEZ versus areas outside of the US EEZ (Canadian and international waters).

US EEZ regulations

Within the US EEZ, five mammal observers were required, thus two were transferred from the Healy to the LSSL during this phase of the program. Mitigative operations included:

1) 2 mammal observers for 30 minutes prior to start up of seismic operations. 2.5 km of visibility was required. Maintaining a small airgun operation (power down) prevented need for the full start up procedure during periods of repair.

2) Ramp up procedures as per normal over a 10 minute time span

3) Power down (one small pneumatic gun remain operational) vs shut down (all seismic sources off) depending upon radius of interaction.

3) Summary of radii of interaction and appropriate action:

Spouting whales (bowhead, gray, humpback)
- Powerdown at 2500 m or if behaviour changes are observed
- Shutdown at 1000 m

Narwhals
- Powerdown at 2500 m or if behaviour changes are observed
- Shutdown at 1000 m

Beluga
- Powerdown at 500 m
- Shutdown at 75 m

Seals (ringed, bearded)
- Powerdown at 100 m
- Shutdown at 30 m

Walrus and Polar Bear
- Do not approach closer than 800 m

Bear on the ice, seemingly unfettered by passing of an 11,000 tonne ice breaker or two. (Photo Bill Schmoker)

Canadian regulations

Details of mitigative requirements for the CBSRRS2010 program can be seen in the 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. If spotted within this 1000 m radius,

Table 1-8. Mammal sightings

DAY	TIME	LINE #	LAT,	LONG.	MAMMAL
221	616	lsl1001	70.628769	134.528285	ring seal
221	1711	lsl1003	70.605344	135.56863	ring seal
226	717	lsl1008	73.218959	145.348597	ring seal
227	945	lsl1010	73.35017	147.152028	ring seal
230	843	lsl1011	74.359943	150.275165	ring seal
230	1128	lsl1011	74.536948	150.160933	ring seal
230	1356	lsl1011	74.700054	150.06249	polar bear
231	225	lsl1012	75.258107	152.406534	polar bear
234	1135		78.118357	153.309496	ring seal
234	1154	lsl1015	78.108689	153.229376	ring seal
234	1201	lsl1015	78.104431	153.206354	ring seal
234	1205	lsl1015	78.102224	153.191607	ring seal
234	1223	lsl1015	78.108588	153.103666	ring seal
234	1328	lsl1015	78.14373	152.792354	ring seal
234	1434	lsl1015	78.180155	152.472966	ring seal
235	344	lsl1016	78.477521	149.83533	ring seal
235	508	lsl1016	78.528315	149.381084	ring seal
239	656	lsl1017	81.96747	131.514092	ring seal
246	128		76.527392	128.74161	polar bear
246	1621	lsl1019	76.747391	132.72258	ring seal
246	1758	lsl1019	76.766025	133.191497	ring seal
254	121	lsl1024	73.473858	138.668374	polar bear

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 native observers. During seismic operations there were 4 polar bear sightings and 18 seals observed (Table 1-8; Fig. 1-27). Other than seabirds, no other animals were encountered.

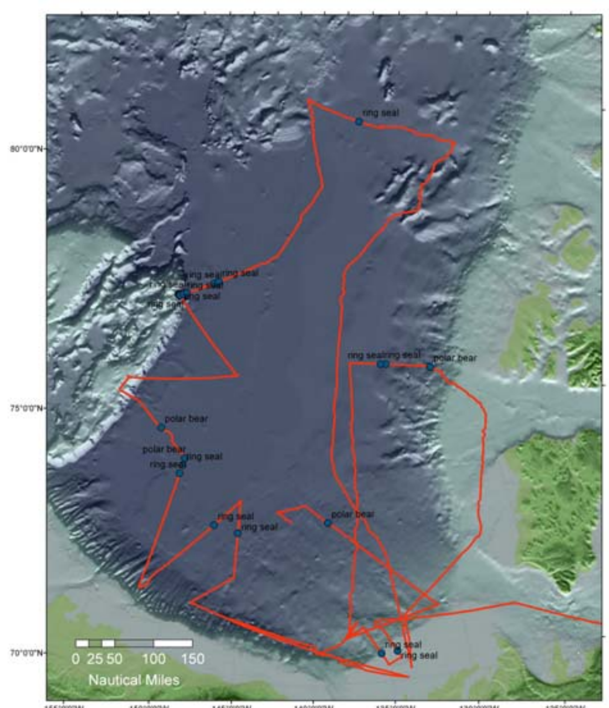

Figure 1-27. Locations of mammal sightings.

Sea Ice

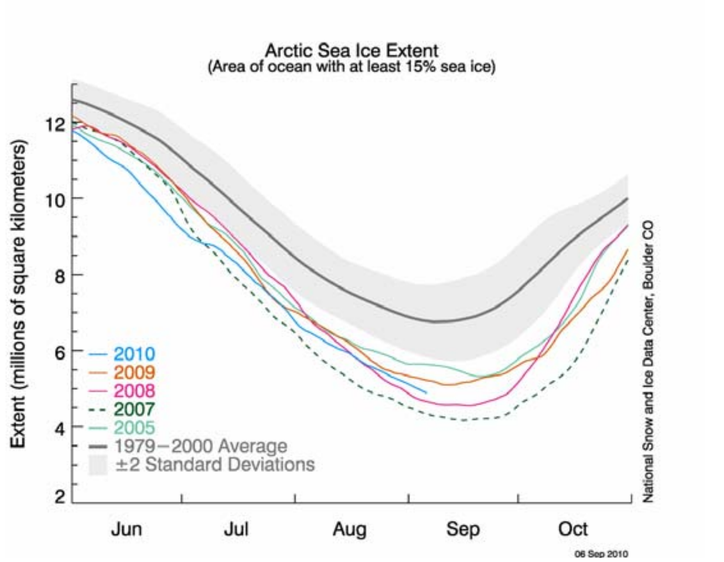

Figure 1-28. Daily Arctic sea ice extent as of September 6, 2010, along with daily ice extents for years with the four lowest minimum extents. The solid light blue line indicates 2010.

A daily documentary of ice conditions is provided in Chapter 5. This August, ice extent was the second lowest in the satellite record, after 2007. On September 3, ice extent dropped below the seasonal minimum for 2009 to become the third lowest in the satellite record (see Figs. 1-28 and 1-29). Average ice extent for August was 5.98 million square kilometres (2.31 million square miles), 1.69 million square kilometres (653,000 square miles) below the 1979 to 2000 average, but 620,000 square kilometres (240,000 square miles) above the average for August 2007, the lowest August in the satellite record. At the end of August, ice extent had fallen to the fourth lowest in the satellite record, behind the seasonal minima recorded for 2007, 2008, and 2009. The daily rate of decline for August was 55,000 square kilometers (21,000 square miles) per day, close to the 1979 to 2000 average of 54,000 square kilometers (21,000 square miles). (reference National Snow and Ice Data Center: http://nsidc.org/arcticseaicenews/2010/090710.html).

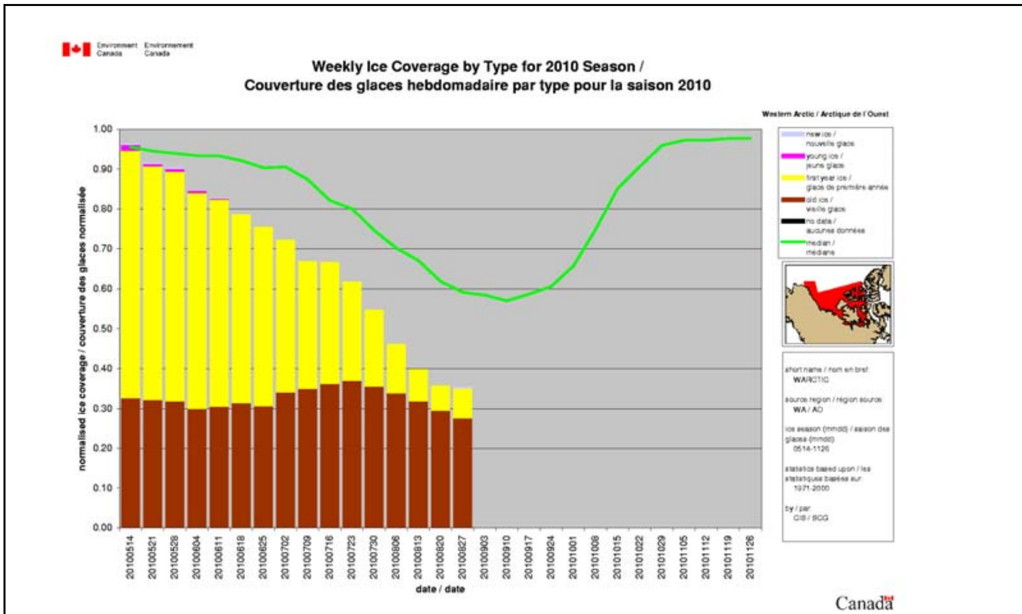

Figure 1-29. 2010 Weekly ice coverage, Southern Canada Basin

Aerial photograph showing ice conditions, taken during the expedition from the helicopter. *Photo by Bruno Barrette*

As a result of these conditions, combined with the fact that winds were light for the majority of the expedition. Sea ice conditions were favourable for two-ship seismic operations, and even single ship operations in southern extremities. The pack did not extend as far south this year as it did last, permitting single ship operations in this area (see Fig. 1-30).

Significant flows of second and multiyear ice were encountered, but in general there were significant open water polynas indicating no ice pressure. Significant ice cover and thicknesses were not experienced except in the northern region of the study area. On line 17, for example, ice breaking became difficult and ridges were encountered that required several attempts to break through. By the easternmost extent of the line, north of Sever Spur, where a tie was made to a spot sounding line from the 2010 spring program, ice was heaviest. During the following med-evac, our route took us across Sever Spur from north to south. Initial ice breaking was heavy and the two ice breakers worked in tandem. By the southern half of Sever Spur, however, conditions lightened somewhat and open water was observed. This is remarkable, given the difficulty in attempts to acquire data here in 2008. Heavy ice breaking was again required off of McClure Strait during transit to meet up with the Healy and commence Line 19.

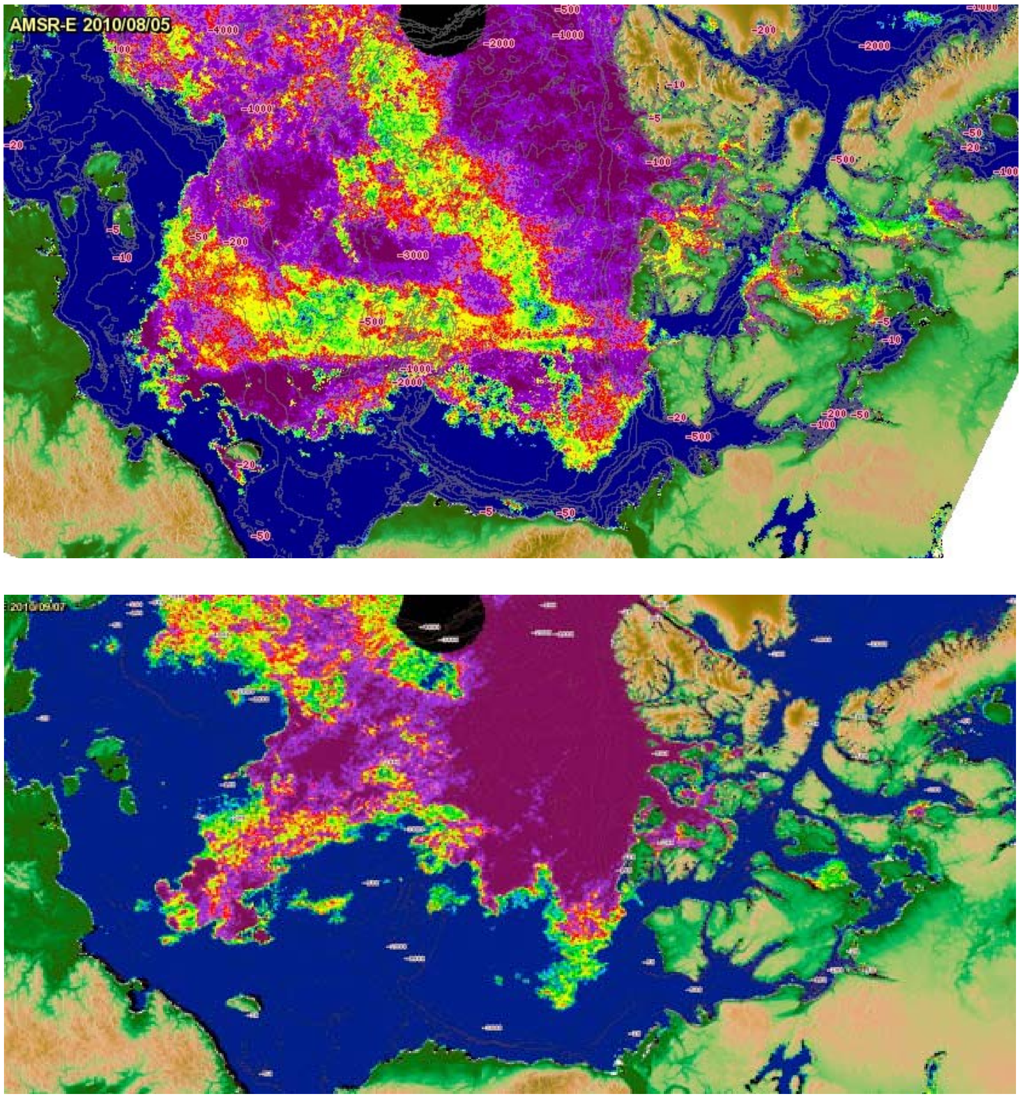

Figure 1-30. Advanced Microwave Scanning Radiometer - Earth Observing System (*AMSR-E*) images: Top is August 5, 2010 and bottom September 7, 2010, showing differences in ice edge positions and approximate percent ice cover, as interpreted from the imagery data. The white boxes outline our survey area.

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 (15K or less) characterised the dominant wind patterns, with a few exceptions: on our transit to Beaufort Sea, winds blew first from the SE at 20K on August 6th and then from the NE at 20-25K with gusts up to 35K 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 knots 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 25K with gusts up to 35K. 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 -4C and the daily maxima near +4C. The maximum temperature registered in Beaufort Sea was +7.8C on September 7th, when the southerly flow described above brought milder air to the region. The minimum temperature was -5C recorded on September 5th, near 75N and 135W.

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.
- A hazard / general alarm light needs to be installed within the compressor containers.

- 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.
- Replace hard drives on seismic digital acquisition and firing units. Carry spares.
- 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 next season 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 next season, 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.

Acknowledgements:

The scientific party wishes to thank Captain McNeill 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 its Commanding Officer, Capt. William Rall and his Officers, Crew and the Scientific Staff of expedition HLY1002. Their assistance went well above and beyond ice breaking in an effort to ensure success of this mission.
The authors would like to express our highest appreciation, respect and admiration for the technical crew of the scientific party. The program would definitely have not achieved success without the long hours of commitment and their innovative solutions to unique problems that arise from working in the harsh environment of the Arctic.

Mr. Jamison Etter, Mechanical trainee, air gun maintenance and repair
Mr. Jim Etter: Hydraulics, electronics and watch keeping
Mr. Paul Girouard: Navigation, network, and data curation
Mr. Rodger Oulton: Compressor and diesel mechanical and watch keeping
Mr. Dwight Reimer: GeoEel system, air gun control and watch keeping
Mr. Ryan Pike: Inventory control, air gun mechanical, watch keeping
Mr. Nelson Ruben: Compressor watch keeper
Mr. Peter Vass: Machinery fabrication and equipment maintenance

And of course, our Mammal Observers, for endlessly keeping watch in the frigid and inhuman climatic conditions on Monkey's Island: Jonah Nakimayak, John Ruben and Dale Ruben. Kevin DesRoches has our gratitude for reviewing this lengthy manuscript.

References:

Grantz, A., Hart, P.E. and May, S.D., 2004. Seismic reflection and refraction data acquired in Canada Basin, Northwind Ridge and Northwind Basin, Arctic Ocean in 1988, 1992 and 1993. U.S. Geological Survey Open-File Report 2004-1243. Online http://pubs.usgs.gov/of/2004/1243/index.html. Accessed January 7, 2011.

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Chapter 2: Acquisition and Processing of the Seismic Reflection Data

John Shimeld

Introduction:

Seismic operations were conducted between August 8th and September 11th with interruptions for equipment repairs, transits between lines, and two medical evacuations. A total of 3763.3 line km of 16-channel, short-offset, 2D seismic reflection data were acquired during the cruise. The seismic profiles extend across continental shelf, continental slope, and abyssal plain regions of Canada Basin, Northwind Ridge, and Alpha Ridge in the Arctic Ocean (Figure 2-31). Water depths ranged from a minimum of 58 m across portions of the Beaufort shelf, to a maximum of 3898 m over central Canada Basin. Start and end points of each line are summarized in Table 2-8.

The survey was conducted under a wide range of sea conditions including calm open water, rough open water with 3–4 m swells and, for roughly 50% of the surveyed distance, within the perennially frozen Arctic icepack. Across most of this region there was 6 to 9 tenths first year ice cover ; pans of multiyear ice rarely comprised more than 4 tenths of the total. Ice ridges were sparse except along portions of LSL1017 and LSL1018 where ridges up to about 1.5 m in height were encountered. Winds were light to moderate, rarely exceeding 25 knots, and the ice was not under significant compression during the seismic operations. From preliminary satellite record analyses, the U.S. National Ice Centre reports that the areal extent of the summer icepack this year was the third smallest on record since the beginning of satellite imagery in the late 1970s. Relative to previous field seasons, the general ice conditions this season were noticeably lighter and, accordingly, there is significantly less ambient noise on the seismic records from icebreaking operations.

Seismic profiles were collected along lines that were planned in advance of the program. However, as anticipated, variable ice conditions and operational constraints caused the shiptrack to deviate, sometimes significantly, from the original plan. The bridge crew of both vessels worked together to plot and maintain the straightest possible course through the ice within ±5 nautical miles of planned lines, although some exceptions were unavoidable. To save time and to cover the maximum survey distance possible, no overlaps between lines were made. Transitions between lines were made with simple turns using a radius of ½ nautical mile or greater. The seismic lines are named LSL1001 through LSL1025. New lines were started at each redeployment of the gear and also at significant changes in line heading.

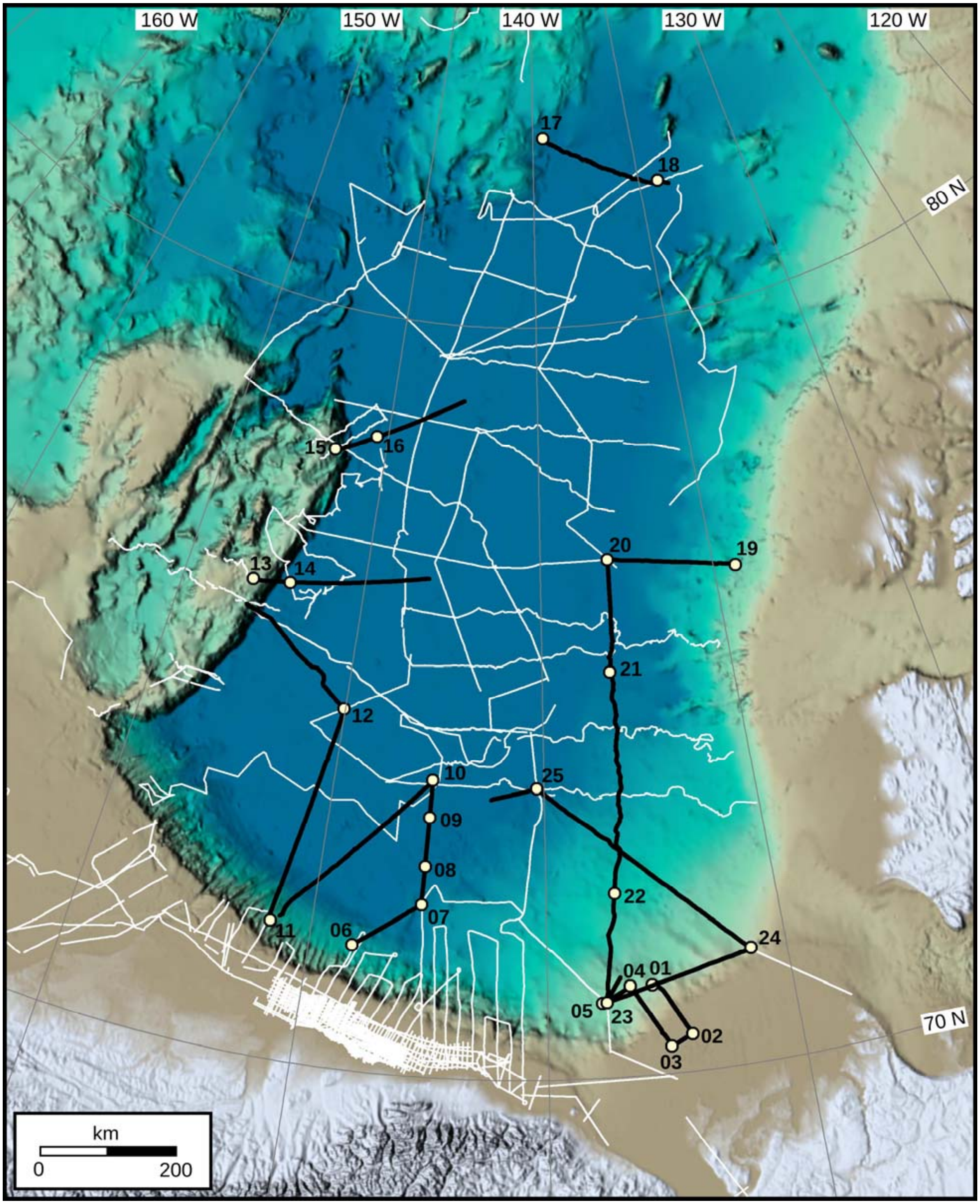


Figure 2- 31. Location map of the survey area. In total, 3763.3 line km of 16-channel, short-offset seismic data were acquired during the Louis S. St-Laurent 2010 cruise. The seismic lines are shown in black. The start of each line is numbered and indicated with a white dot. Pre-existing seismic data are plotted with thin white lines.

Table 2-8: Shot and trace statistics for seismic reflection line segments collected during this cruise.

Line	First Shot	Last Shot	# of Traces (actual/nom.)	Start Coord.	End Coord.	Line km	Average Shotpoint Spacing (m)	Bathymetric Range (m)	Start Date (UTC)	End Date (UTC)
LSL1001	1	4380	68480/68480	71.181437, -135.711082	70.490628, -134.306715	96.1	21.9	59 1096	20:13:40 08/08/2010	08:26:40 09/08/2010
LSL1002	4381	5995	25840/25840	70.489834, -134.306112	70.356261, -135.147182	36.2	22.4	55 73	08:27:20 09/08/2010	12:56:20 09/08/2010
LSL1003	5996	10767	76352/76352	70.356314, -135.162049	71.191241, -136.606276	108.6	22.8	58 1331	13:00:30 09/08/2010	02:15:40 10/08/2010
LSL1004	10768	12951	34944/34944	71.192268, -136.609363	70.984560, -137.779364	49.1	22.5	1301 1609	02:16:50 10/08/2010	08:20:40 10/08/2010
LS1005	12952	15548	41552/41552	70.984013, -137.782076	71.313990, -136.993008	51.9	20.0	1466 1612	08:21:30 10/08/2010	15:35:00 10/08/2010
LS1006	15549	18853	52880/52880	71.649670, -148.182597	72.264513, -145.408145	119.1	36.0	2864 3562	22:55:02 12/08/2010	14:20:10 13/08/2010
LSL1007	18854	20509	26496/26496	72.265346, -145.406365	72.794077, -145.378622	59.4	35.9	3472 3585	14:21:01 13/08/2010	22:09:55 13/08/2010
LSL1008	20510	22709	35200/35200	72.775034, -145.370076	73.428322, -145.342553	75.6	34.4	3560 3705	00:08:04 14/08/2010	10:53:03 14/08/2010
LSL1009	22710	24090	22096/22096	73.423545, -145.331658	73.917445, -145.303738	56.1	40.6	3661 3778	14:16:11 14/08/2010	21:44:41 14/08/2010
LSL1010	24091	31809	123504/123504	73.922324, -145.31806	71.885529, -151.372006	308.1	39.9	2489 3785	21:49:53 14/08/2010	14:30:25 16/08/2010
LSL1011	31810	40513	139264/139264	71.804533, -151.725993	74.725078, -150.047607	333.7	38.3	1774 3893	18:11:18 16/08/2010	14:17:20 18/08/2010
LSL1012	40514	46023	88160/88160	74.727155, -150.050525	75.823048, -156.190547	222.1	40.3	1516 3898	14:19:17 18/08/2010	19:34:08 19/08/2010
LSL1013	46024	47818	28720/28720	76.175691, -156.211394	76.249155, -154.104978	58.3	32.5	875 3894	01:39:03 20/08/2010	09:43:24 20/08/2010
LSL1014	47819	53039	83536/83536	76.242675, -154.15410	76.589597, -146.403825	210.2	40.3	3834 3896	10:52:18 20/08/2010	15:08:48 21/08/2010
LSL1015	53040	55102	32976/33008	78.113765, -153.272554	78.392021, -150.795565	68.8	33.3	2076 3882	11:43:49 22/08/2010	22:20:45 22/08/2010
LSL1016	55103	58293	51056/51056	78.382297, -150.721739	78.992636, -145.119424	140.7	44.1	3860 3883	00:52:32 23/08/2010	18:31:03 23/08/2010
LSL1017	58294	63759	81792/87456	82.546172, -138.948401	81.761080, -128.626175	188.3	34.4	3354 3728	11:37:28 26/08/2010	13:33:46 27/08/2010
LSL1018	63814	64270	7312/7312	81.788899, -128.225476	81.722137 -127.304905	17.4	38.1	3564 3620	19:34:24 27/08/2010	21:43:35 27/08/2010
LSL1019	64318	70233	94656/94656	76.539330, -128.747008	76.861302, -136.025837	191.4	32.3	2159 3679	01:52:10 03/09/2010	04:15:15 04/09/2010
LSL1020	70234	74696	71408/71408	76.858814, -136.051187	75.374560, -136.415813	170.6	38.2	3565 3679	04:21:12 04/09/2010	02:29:33 05/09/2010

LSL1021	74697	84731	160560/160560	75.361204, -136.419908	72.425185, -136.988291	347.4	34.6	2574 3595	03:11:51 05/09/2010	01:10:10 07/09/2010
LSL1022	84732	90176	87120/87120	72.421465, -136.990578	70.997368, -137.604067	162.9	29.9	1460 2573	01:14:31 07/09/2010	23:10:09 07/09/2010
LSL1023	0	97493	117072/117072	70.992837, -137.603924	71.495977, -131.493389	226.9	31.0	517 1550	23:14:59 07/09/2010	04:43:01 09/09/2010
LSL1024	97494	109683	195040/195040	71.505001, -131.491848	73.847738, -140.345755	395.4	32.4	684 3548	04:49:47 09/09/2010	10:18:24 11/09/2010
LSL1025	109684	111470	28592/28592	73.848794, -140.352026	73.700255, -142.488482	69.0	38.6	3547 3671	10:20:12 11/09/2010	19:16:00 11/09/2010

Source Parameters

Airgun Configuration and Firing Delays

A cluster of 3 Sercel G-guns comprised the seismic source for this survey (*c.f.* Chapter 1). Two of the airguns each had a volume of 500 in³, and the third a volume of 150 in³, so the total volume of the seismic source was 1150 in³.

As described in Chapter 1, two different towing arrangements were used. In open water, the airgun cluster was suspended from a float at a depth of 5.5 m and towed 50 m aft of the stern roller sheave. In the icepack, the cluster was attached to a weighted sled suspended immediately below the stern roller sheave at a depth of 11.2 m.

The three airguns were fired simultaneously with a field time break of 46 ms. There was an additional mechanical delay of 10 ms, measured using an oscilloscope. Thus the total delay between time zero of the shot records and actual firing of the airguns was 56 ms.

Shot Interval

The source was fired at regular time intervals chosen in relation to the water depth as follows :

- 10 s for < 3 s of water ;
- 14 s for 3–4 s ;
- 17 s for 4.0–4.8 s ;
- 18 s for 4.8–5.0 s ; and
- 19.5 s for > 5 s.

The distance between shotpoints varied during the survey as a function of these shot intervals and also the vessel speed over the ground, which fluctuated especially during periods of heavy icebreaking. The bridge crew tried to maintain an average speed over the ground of 4.0–4.5 knots and a speed through the water of no greater than 5.5 knots. At a 19.5 s shot interval, the distance between shots was ≤44 m, and at a 14.5 s shot interval the distance between shots was ≤23 m. The average over the entire survey was 33 m.

Source Wavelet

As described in Chapter 4, far-field recordings of the source were made for the open-water towing configuration during August 10th, and for the icepack towing configuration during September 4th. Average source wavelets were derived by aligning and stacking traces from shot records of each airgun combination. These are plotted on Figures 2-32 through 2-35.

The power spectra of the G-guns, in both the open-water and icepack towing configurations, manifest serious notches across a number of frequency ranges within the practical seismic bandwidth of roughly 3 to 70 Hz (Figures 2-33 and 2-35). These notches are caused by destructive interference between the primary and the bubble pulses and they have a significant negative impact on both the depth of penetration and resolution of the seismic data. Although the spectra are not calibrated, it appears that the 150 in^3 G-gun adds power that partially offsets the low-frequency notches (*e.g.* at 10 and 20 Hz), but it does not add significantly to the upper frequencies of the seismic bandwidth.

With the airguns at 5.5 m in the open-water towing configuration, destructive interference between the primary and source ghost should create a distinct notch at about 131 Hz. However the power spectra diminish rapidly above 70 Hz (Figure 2-33) and there is surprising little power in the 70 to 125 Hz band. This does not significantly impact the primary objective of imaging the base of sediments, but it does reduce the vertical resolution that can be achieved for shallow targets.

With the airguns at 11.2 m in the icepack towing configuration, the source notch should be apparent at about 64 Hz, and significant drop in power does occur at that frequency (Figure 2-35). However, the 1150 in^3 spectrum exhibits power above 64 Hz that is not apparent for the other source volumes. This suggests that the calibrated measurements of the 1150 in^3 source might be contaminated with high frequency noise although it was not noted during the measurements.

Power spectra of the raw data show obvious similarities with the calibrated source measurements including the strong bubble pulse notches (Figure 2-36). The practical seismic bandwidth of data acquired with the open-water towing configuration is comparable to that of the calibrated source measurement. This is because the receiver depths are generally equal to or shallower than the source depth so the receiver ghost suppresses power in frequency bands at or above the source ghost notch (Figure 36A). However, during icebreaking the receiver depths frequently exceed the source depth. Often the receiver ghost notch occurs between about 30 and 60 Hz (Figure 36B), and can sometimes suppress frequencies in the 20 Hz range.

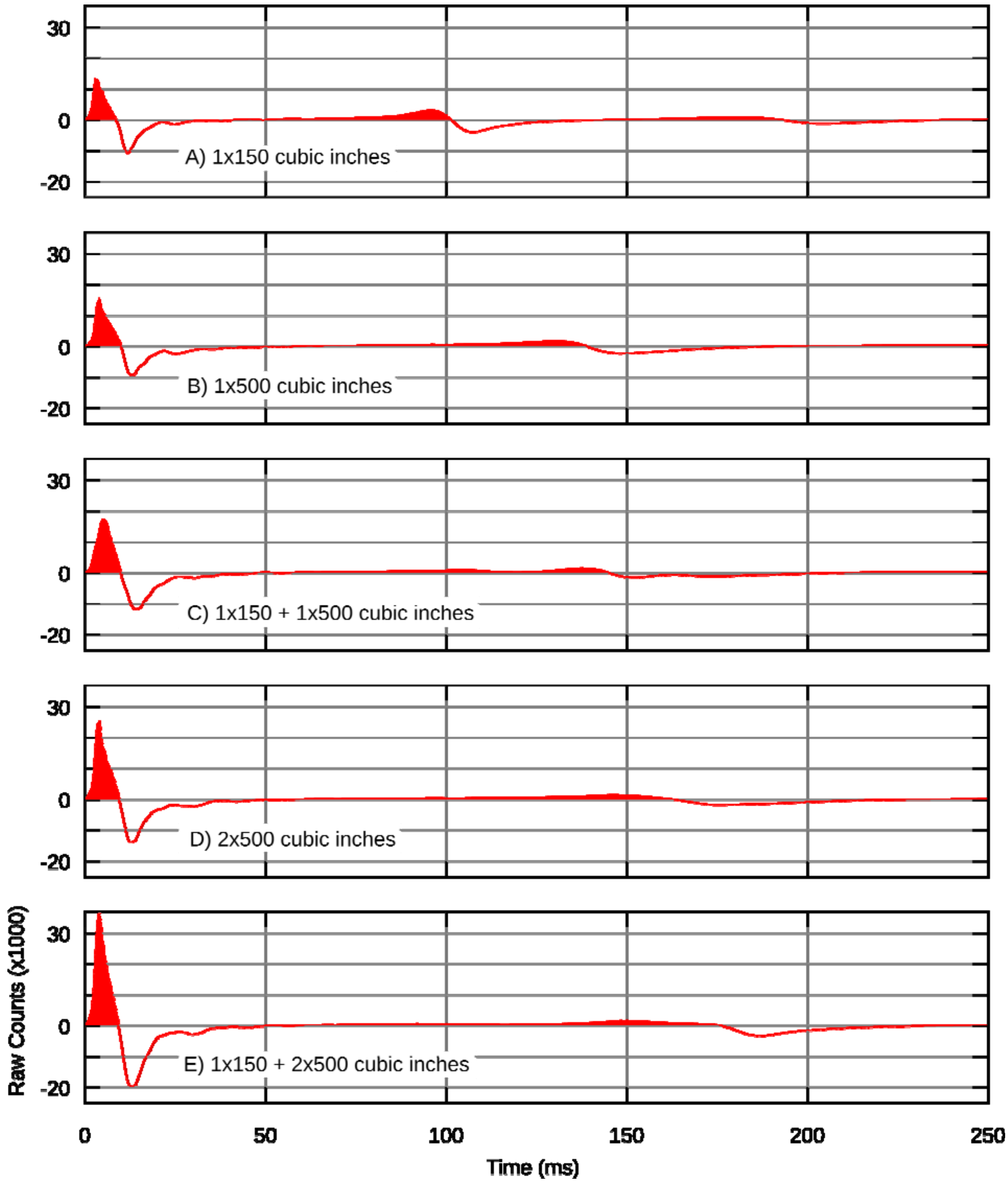


Figure 2-32: Source wavelets for the open-water towing configuration (source depth = 5.5 m). The time series were derived by aligning and stacking the traces recorded for various G-gun combinations during the August 10th calibrated hydrophone measurements (cf. Chapter 4). Total source volumes are as follows : A) 150 in³ ; B) 500 in³ ; C) 650 in³ ; D) 1000 in³ ; E) 1150 in³.

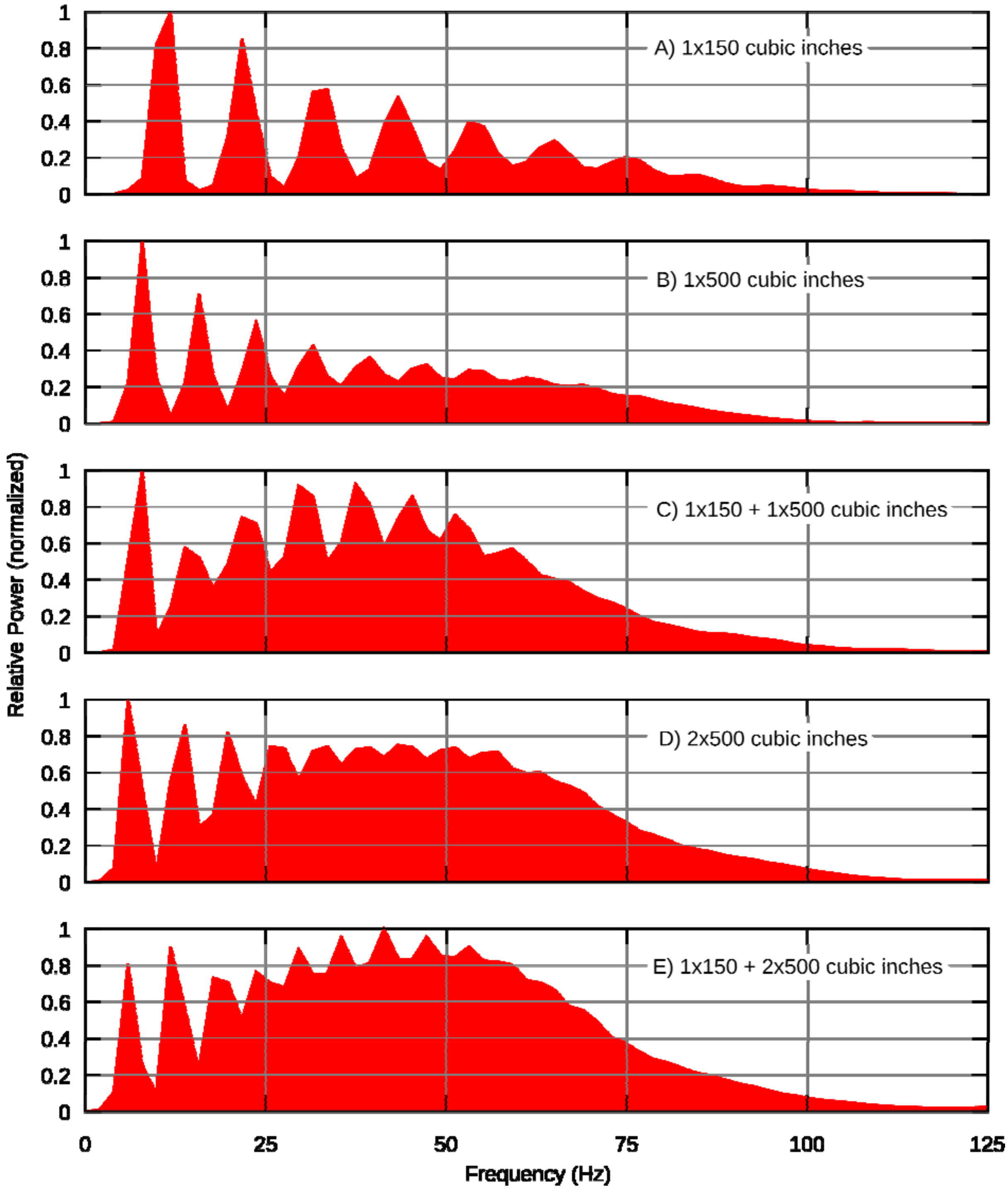


Figure 2-33: Relative power spectra for the open-water towing configuration (source depth = 5.5 m). The various G-gun combinations were recorded during the August 10th calibrated hydrophone measurements (cf. Chapter 4). Total source volumes are as follows : A) 150 in^3 ; B) 500 in^3 ; C) 650 in^3 ; D) 1000 in^3 ; E) 1150 in^3.

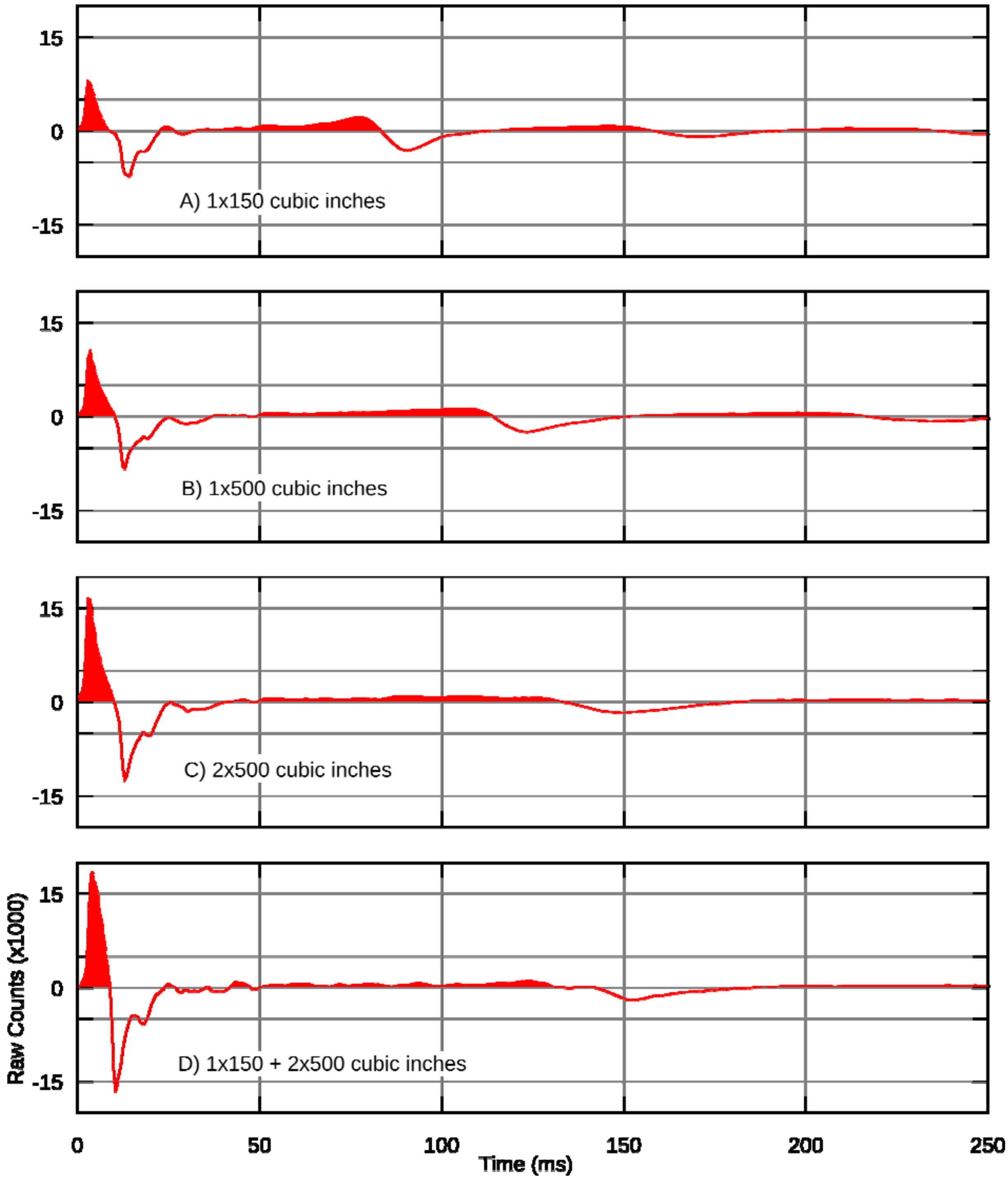


Figure 2-34: Source wavelets for the icepack towing configuration (source depth = 11.2 m). The time series were derived by aligning and stacking the traces recorded for various G-gun combinations during the September 4th calibrated hydrophone measurements (cf. Chapter 3). Total source volumes are as follows : A) 150 in3 ; B) 500 in3 ; C) 1000 in3 ; D) 1150 in3.

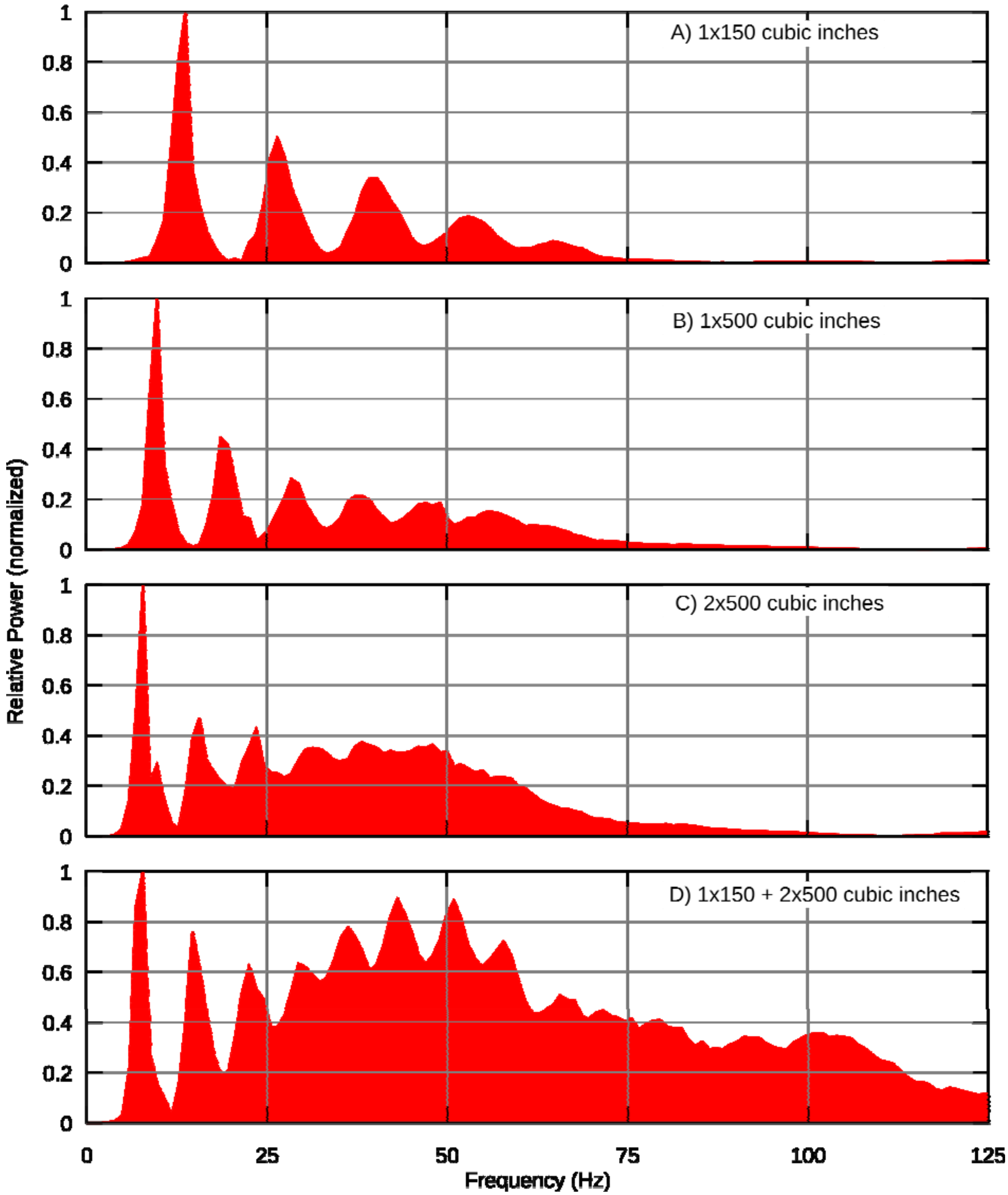


Figure 2-35: Relative power spectra for the icepack towing configuration (source depth = 5.5 m). The various G-gun combinations were recorded during the September 4th calibrated hydrophone measurements (cf. Chapter XX). Total source volumes are as follows : A) 150 in3 ; B) 500 in3 ; C) 1000 in3 ; D) 1150 in3.

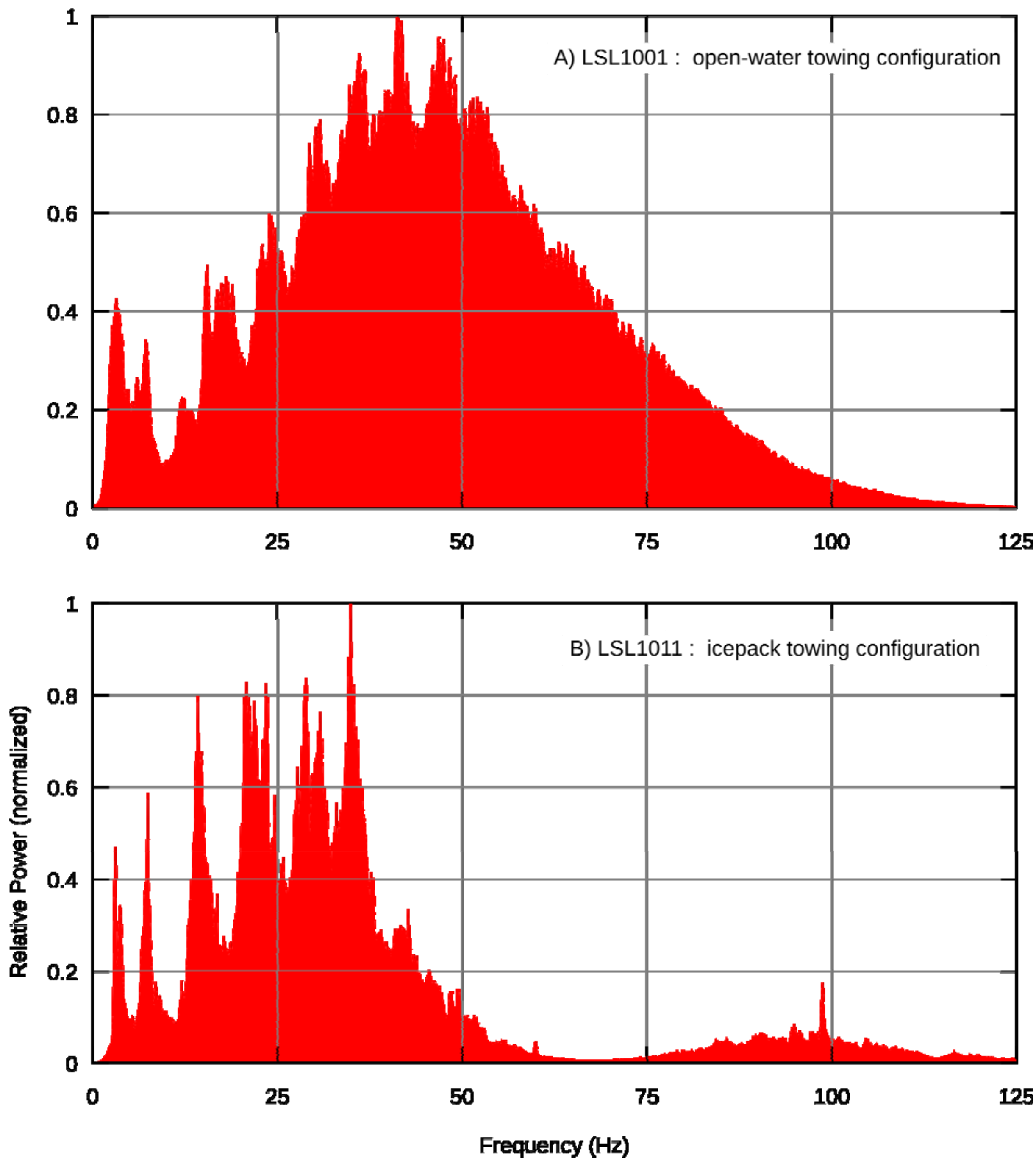


Figure 2-36: Relative power spectra for samples of the unprocessed data. Traces within each shot record were stacked and then sets of 5 adjacent shots were summed. The power spectra were computed over a 6.5 s window for A) LSL1001, representing the open-water towing configuration with the 1150 in3 source, and B) LSL1011 which was acquired with the icepack towing configuration with the 1150 in3 source. Receiver depths for LSL1011 ranged between 14 and 21 m in this example, which noticeably suppresses power in the 35 to 50 Hz band.

Receiver Parameters

The receiver array consisted of two active sections, each 50 m long, with 64 equally spaced hydrophones. These were configured into 8 channels per active section with 8 hydrophones per group. Accordingly, there were a total of 16 active channels with a group interval of 6.25 m.

Icebreaking operations lead to frequent course deviations, changes in speed, and even complete stops. Also there can be significant water temperature and salinity changes around the icepack, meaning that correct balancing of the streamer is not possible over the duration of the survey. Active control of the streamer is not feasible because of the risk of damage or loss should a streamer bird become caught in the ice. As a result of these factors, receiver depths can vary significantly along the length of the streamer and also from one shot to the next. Differences of several metres between the inboard and outboard receiver groups are common, and the average depth along the streamer can change by 20 m in the space of 10 minutes when the ship encounters difficult patches of ice.

Receiver depths were measured in two ways : 1) with ODDI SeaStar mini-CTD sensors installed in wooden floats near receiver groups 1, 9, and 16 as was done during the 2009 program (Mosher et al, 2009); and 2) using pressure transducers that are built into the GeoEel streamer at receiver groups 1 and 16. The SeaStar CTDs were programmed to measure depth, temperature, and salinity at 10 s intervals and the data were downloaded after each gear recovery. These CTDs were used whenever possible since they are considered more accurate than the GeoEel depth sensors, and also because the GeoEel sensors in the starboard streamer were inoperative for the duration of the survey. Comparison of the depths reported by the SeaStar and GeoEel sensors reveals systematic errors in the GeoEel sensors which were corrected during data processing using the linear regression equations shown on Figure 2-37.

Fluctuations in receiver depth change the way in which energy reflected downwards from the sea surface (the receiver ghost) interacts with upward travelling energy and can effectively suppress a broad range of frequencies between about 30 and 60 Hz. The fluctuations can also cause travel time shifts of 20 ms or more, leading to inaccuracies in the seismic datum and misties between intersecting lines. These issues can be largely corrected using traces shifts and source signature deconvolution if the receiver depths are known with reasonable accuracy.

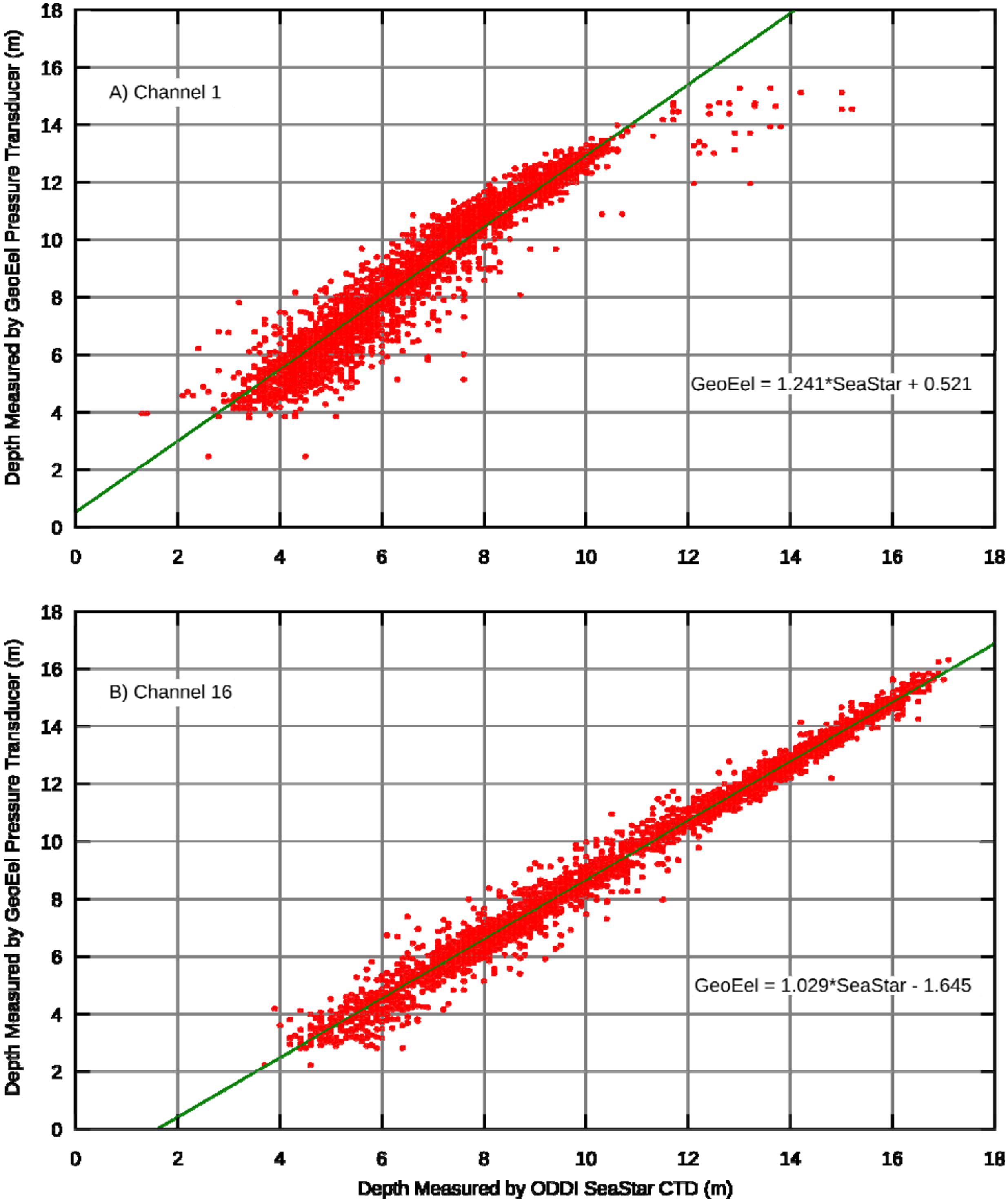


Figure 2-37: Comparison of receiver depth measurements obtained using the ODDI SeaStar mini-CTD sensors with the GeoEel depth sensors on A) channel 1, and B) channel 16. For the seismic data processing, measurements from the GeoEel sensors were corrected to more closely match those of the SeaStar sensors by applying the linear regression equations shown on the figure.

Source-to-Receiver Offsets

The Novatel Global Positioning Satellite (GPS) antenna located above the wheelhouse top at frame 198 of the ship was used as the fixed navigation point for the survey. The source and receiver offsets relative to the fixed navigation point are shown on Figure 2-38 for the open-water and also the icepack towing configurations.

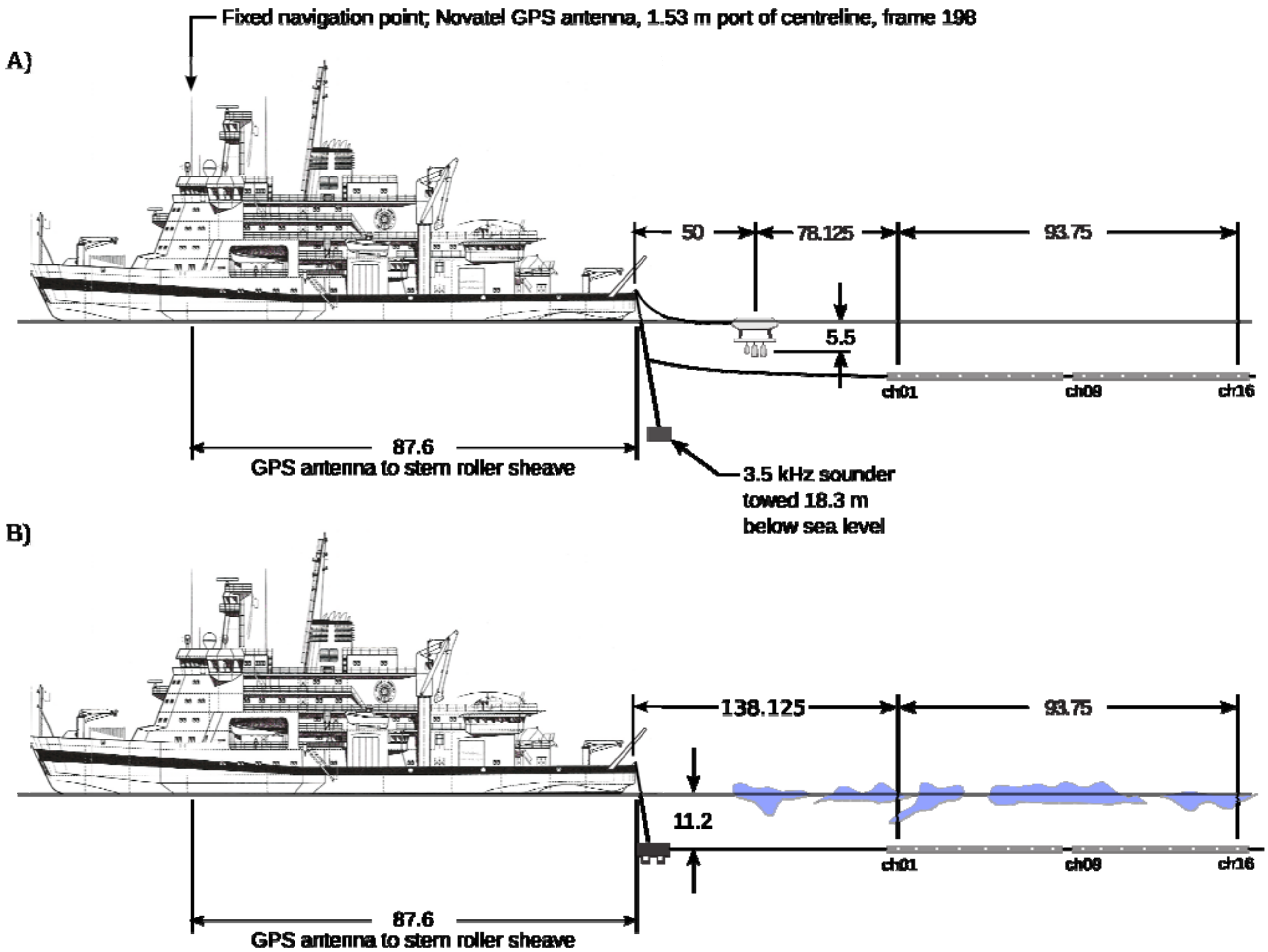


Figure 2-38: Source to receiver offsets for A) the open-water towing configuration and B) the icepack towing configuration. All distances are in metres.

Data Recording

CNT-2 Software Parameters

The seismic reflection data were recorded using the Geometrics GeoEel system described in Chapter XX. With this system, analog hydrophone signals are converted to 24-bit digital traces by analog-to-digital converters in the streamer and are automatically summed for each receiver group. The trace data from each receiver group are broadcast, via ethernet connection in the streamer, to the multithreaded CNT-2 software (version 5.36) running under the Windows NT operating system on a personal computer in the seismic lab.

The CNT-2 software provides a user interface for configuring the GeoEel system, for monitoring the data quality during acquisition, for testing the receiver array, and for recording the data to magnetic disk drive and/or magnetic tape. Additional data such as geographic position or source signature information can also be logged by the CNT-2 software through a serial communications port. The recording parameters that were used during the survey are listed in Table 2-9.

Table 2-9: Recording parameters used with the Geometrics CNT-2 software during the survey.

Parameter	**Value**
Sample interval	2 ms
Recording window	LSL1001 through LSL1005 :8.0 s All other lines : 12.0 s
Recording delay	LSL1001 through LSL1005 : none All other lines : 0.5 s
Recording format	SEG-D 8058 revision 1
Active channels	1 through 16 (near trace = 1; far trace = 16)
AC coupling	disabled
Shot/file number comparison	disabled
Preamp gains	+18 dB on all channels
Transconductance	20 Volt/bar

Data Storage

Digital shot records were stored on magnetic disk drive, one file per shot record, in the Society of Exploration Geophysicists SEG-D 8058 Revision 1 format. Included in each SEG-D file is an variable-sized external header containing GPS navigation strings including date (UTC), geographic position in degrees and decimal minutes (reference ellipsoid: World Geodetic System, 1984), water depth from the 12 kHz sounder, speed through the water, heading, speed over ground, and course over ground.

The SEG-D files were copied every half-hour onto a separate magnetic disk drive installed on the recording computer. Upon completion of each line, all associated shot records and log files were copied onto two additional hard drives and a set of DVDs for archival.

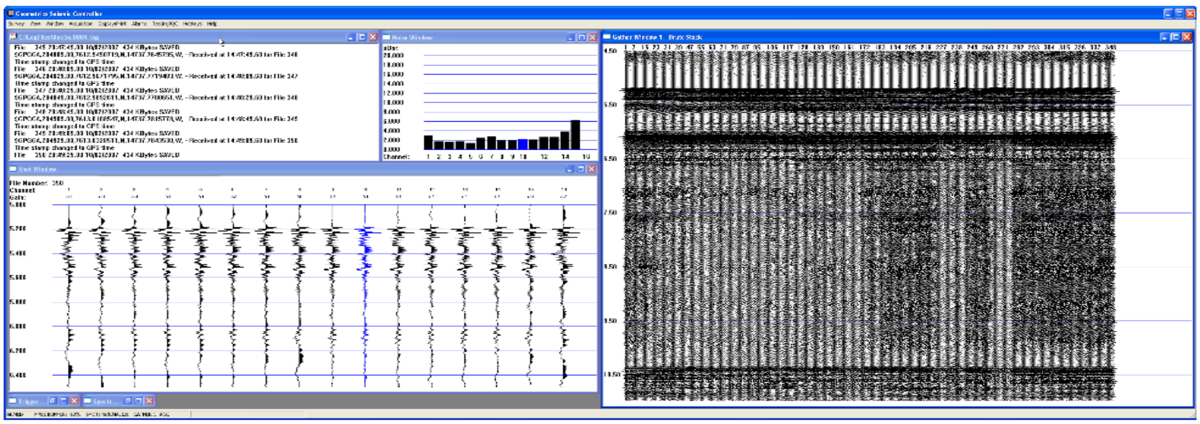


Figure 2-39: Screen capture of the CNT-2 graphical user interface showing a message log (top left), RMS noise chart (top middle), shot record (bottom left), and brute stack (right). The software also allows the frequency spectra of each trace to be monitored (not shown).

Data Quality Monitoring and Seismic Watchkeeping

During acquisition the CNT-2 user interface was used to automatically plot each shot record, the amplitude spectra of each trace, a log of diagnostic messages, and a simple brute-stack record section. An example monitor display is shown on Figure 2-39. This provided immediate, shot-by-shot feedback on the GeoEel system performance and confirmation that the data were of acceptable quality. The software is capable of displaying a bar graph of root-mean-squared (RMS) noise levels within a user-defined window for each shot record, but this function appeared to cause the software to crash and so this function was abandoned.

Watchkeepers kept a half-hourly log of the following system parameters: calendar day, UTC time, latitude, longitude, line segment, water depth, course over ground, heading, speed over ground, speed through water, ship's bubbler (on/off), streamer system (port/starboard), streamer leakage, streamer current, streamer voltage, streamer depth (inboard/outboard), seismic source system (port/starboard/tow depth), shot number, total source volume, number of airguns, firing rate, record length and recording delay. An electronic copy of the watchkeepers' log is included with the cruise documentation.

Data Processing

The Globe Claritas commercial software package (version 5.4) developed by the New Zealand Institute of Geological and Nuclear Sciences was used to process the seismic data during the cruise. The software was installed on a dual-processor laptop running the Fedora Linux operating system (release 11). An external 500 gigabyte, universal serial bus hard-drive was used to store copies of the raw and processed datasets. The processing workflow is listed below, and a summary of CMP range, shot range, fold, and line length is given in Table 2-10.

Processing Workflow

1. **Read SEG-D**

   Read individual shot records in SEG-D format ; apply static shifts to account for recording delay (+500ms), field time break (-46 ms), and firing delay (-10 ms).
2. **Navigation and Geometry**

   Extract navigation information from SEG-D trace headers, including : longitude, latitude, water depth, speed through water, speed over ground, and date ; design CMP bins at 12.5m intervals along track assuming streamer directly behind vessel.
3. **Receiver Depths**

   Interpolate the depth of each receiver group at each shotpoint by matching shot times with a 30 s (3-point) average of depth measurements from the ODDI SeaStar mini-CTDs. When these measurements are unavailable, interpolate the receiver depths using corrected measurements from the GeoEel depth sensors (c.f. Figure 2-37). Apply source/receiver static corrections to each trace using a surface water velocity of 1440 m/s to shift each trace to sea level datum.
   Receiver depths range between 0.1 and 63.9 m, with an average of 10.7 m for the entire survey. The depth at channel 1 is typically 1−3 m shallower than at channel 16, but this varies as a function of speed through the water and also the water column properties. Static corrections for the average source and receiver depths range between 3 and 52 ms.
4. **Swell Noise, Strumming, and Geometrical Spreading**

   Bandpass filter (3/8/140/240 Hz) ; F-K filter (>4ms per trace) ; T^2 amplitude scaling ; balance.
5. **Trace Editing**

   edit erroneous traces ; calculate integrated instantaneous frequency 0−5 s beneath seafloor to identify noisy traces ; low-cut filter (8/12 Hz) applied to noisiest 5% of all traces in the survey ; low-cut filter (10/14 Hz) applied to noisiest 1% of all traces in the survey ; balance.
   Since there is no opportunity for data re-acquisition, it is desirable to retain even very noisy traces in the processing stream unless they truly contain no usable signal. During icebreaking operations the noise can vary significantly from channel to channel, but manual editing of every shot record would be time-consuming and highly subjective. To characterize the noise efficiently, and in a

quantitative manner, instantaneous frequency was integrated over a 5 s window beneath the seafloor. Traces with high noise levels from swell, cable strum, and propwash have abnormally low values of integrated instantaneous frequency and can be reliably identified using this attribute. Thresholds of 5% and 1% were chosen for low-cut filtering.

6. **Minimum Phase Conversion, Source Signature Deconvolution, and CMP Stack**

   minimum phase conversion ; source signature deconvolution ; gapped deconvolution (300 ms, gap at 2nd zero crossing); sort traces to CMP gathers ; calculate CMP static shifts (≤ 8 ms) to maximize stacking power ; balance ; stack. A matching filter designed on the measured source wavelet was applied to convert the data to minimum phase. To include the effects of the receiver ghost, the source signature was convolved with two spikes : +1.0 at time-zero and -0.7 at the calculated travel time to the interpolated receiver depth of each trace. Suppression of the bubble pulse was achieved with prestack gapped deconvolution using the 2nd zero crossing of each trace as the gap length.

7. **Primary Multiple Suppression**

   A forward model of the seismic record was constructed by convolving the source wavelet with the deconvolved stack obtained in step 6 (after removal of NMO corrections). The resulting traces were then autoconvolved to generate an estimate of the first primary multiples. These were removed from the deconvolved stack of step 6 using the adaptive subtraction routine described by Monk ("Wave-equation multiple suppression using constrained gross-equalization" in Geophysical Prospecting, v. 41, p. 725−736, 1993). Poststack F-K filtering was applied to further suppress energy parallel to the first seafloor multiple.

8. **2-D Velocity Models**

   The following linear model of sediment velocity was derived from analyses of the 2007−2009 sonobuoy records : $V(t) = 2067 + 727*t$, where t is the one-way travel time beneath the seafloor. A constant average velocity of 1480 m/s was used for the water column.

9. **Poststack Filtering**

   *despike ; balance ; gapped deconvolution (800/80 ms, 51 trace mix) ; F-X running mix coherency filter (5 traces) ; finite difference migration using velocity model derived in step 8 (0.95*V(t)) ; singular value decomposition coherency filter ; linear amplitude scaling (5 dB/s beneath seafloor) ; phase shift (270˚) ; time-varying lowpass filter (60/80 Hz at 0−2 s below seafloor, 30/40 Hz at 2.5−3.5 s, 25/35 Hz at >4 s) ; 5 trace running mix (weighted at 0.05, 0.2, 0.5, 0.2, and 0.05).*

10. **SEG-Y Output**

    insert missing CMPs ; interpolate shotpoints ; antialias filter; resample (4 ms) ; SEG-Y output with CMP latitude/longitude as arcsec (x100) in byte locations 81 and 85.

Table 2-10: Summary of deconvolved CMP stacks derived from the 16-channel, short-offset seismic data acquired during the Louis S. St-Laurent 2010 program.

Line	First CMP	Last CMP	First Shot	Last Shot	Average CMP fold	Line km
001	114	7740	4372	65	18	95.3
002	114	3016	5987	4381	18	36.3
003	100	8792	5996	10760	17	108.7
004	114	4049	12944	10768	18	49.2
005	100	4262	12952	15540	19	52.0
006	100	9638	15549	18849	12	119.2
007	100	4860	18854	20505	12	59.5
008	100	6166	20510	22688	12	75.8
009	100	4590	22710	24087	10	56.1
010	112	24744	31804	24091	8	307.9
011	100	26826	31810	40509	8	334.1
012	100	17912	40514	46018	8	222.7
013	100	4772	46024	47813	13	58.4
014	100	16778	47864	53028	11	208.5
015	100	5619	53040	55089	11	69.0
016	100	11355	55103	58288	8	140.7
017	100	15116	58294	63754	8	187.7
018	100	1502	63814	64261	10	17.5
019	112	0	0	64318	13	191.9
020	112	13761	74688	0	12	107.6
021	112	27826	84726	0	12	346.4
022	112	13148	0	84732	14	163.0
023	0	18253	0	0	13	226.9
024	0	31761	97494	0	13	395.8
025	112	5645	111462	0	10	69.2

Comments

1. **LSL1001 through LSL1005**

The ODDI SeaStar mini-CTDs were not installed on the streamer during acquisition of these lines. Receiver depths were obtained by applying the corrections shown on Figure 2-37 to the GeoEel depths sensors at channels 1 and 16. Depths for the remaining channels were linearly interpolated.

2. **LSL1009**

The ODDI SeaStar mini-CTD was inadvertently not installed at receiver group 16 during deployment of the starboard streamer for this line. Since the GeoEel depth sensors are not functional for the starboard streamer, no receiver depth measurements are available for channel 16. Therefore, for processing, the depths for channels 10 through 16 were assigned the same depths as were measured for channel 9.

3. LSL1010

Swells of up to 3 m increased noise levels along this line between shotpoints 30000 and 31809.

4. LSL1015 and LSL1017

Recording errors occurred for a number of shot records on these lines. The Geometrics software reported problems and timeouts with serial and ethernet communications and this caused SEG-D files to be written with only channels 9–16. The problems were found to be caused by damaged cables in the bundle cable.

5. LSL1019

This line is contaminated by primary multiple energy from strong reflectors in the upper sedimentary sequence, including the seafloor.

6. LSL1022 and LSL1023

Swell noise was high along these lines because of 25-30 knot ENE winds over open waters which created waves in excess of 3 m.

Recommendations

1. An accurate description needs to be obtained from Geometrics regarding the amplitude and phase characteristics of the analog 3 Hz low-cut filter that is implemented by AC coupling of the streamer. Application of a pre-digitization analog filter is desirable since it greatly expands the dynamic range of the recorded signal, but our tests indicated that AC coupling negatively affects signal across the 1-20 Hz band.
2. Re-evaluate the design of the source array. The cluster of 2x500 in^3 G-guns plus 1x150 in^3 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.
3. 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 next season 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.
4. Before the start of acquisition next season, 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.
5. 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.
6. 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.

Chapter 3: Canada Basin 2010 Canadian Hydrographic Service

Jon Biggar, CHS

Background

The Canadian Hydrographic Service (CHS) is responsible for a number of conditions under Article 76 of the United Nations Convention on the Law of the Sea (UNCLOS) to delineate/survey/establish the continental shelf for Canada's territorial submission:

- mapping baselines from which the extent of the territorial sea is measured;
- mapping the 2500 metre isobath and the Foot of the Slope;
- Optimising the location of boundary lines at calculated distances. (60, 100, 200 and 350 nautical miles);
- Populating data bases with the above data and outputting in the form of charts, maps and diagrams

Summary

As in the past four years of this program the CHS component was conducted in conjunction with the NRCan seismic operations. The program again was 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 ops 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 consisted of Jon Biggar, Jim Weedon and Marcus Beach (Central and Arctic Region). Dave Street (Newfoundland Region) was the CHS representative onboard the USCGC Healy. 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 10,070 line kilometers (Figure1) and the helicopter collected 61 spot soundings (Figure 2). In addition a 3.5 KHZ Knudsen sounder was deployed in open water when the seismic gear was not configured for navigating in ice. The USCGC Healy joined the program on August 10th and departed September 4th, during which time additional hydrographic data was collected including deep water multibeam and 3.5 kHz single beam by USCGC Healy. In addition to our regular responsibility CHS deployed Expendable Conductivity, Temperature and Density Probes (XCTD) / Expendable Bathythermograph probes (XBT) daily and monitored the continuous underway sampling of near-surface seawater as part of the study of the oceanography of the Beaufort Gyre and Canada Basin.
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.

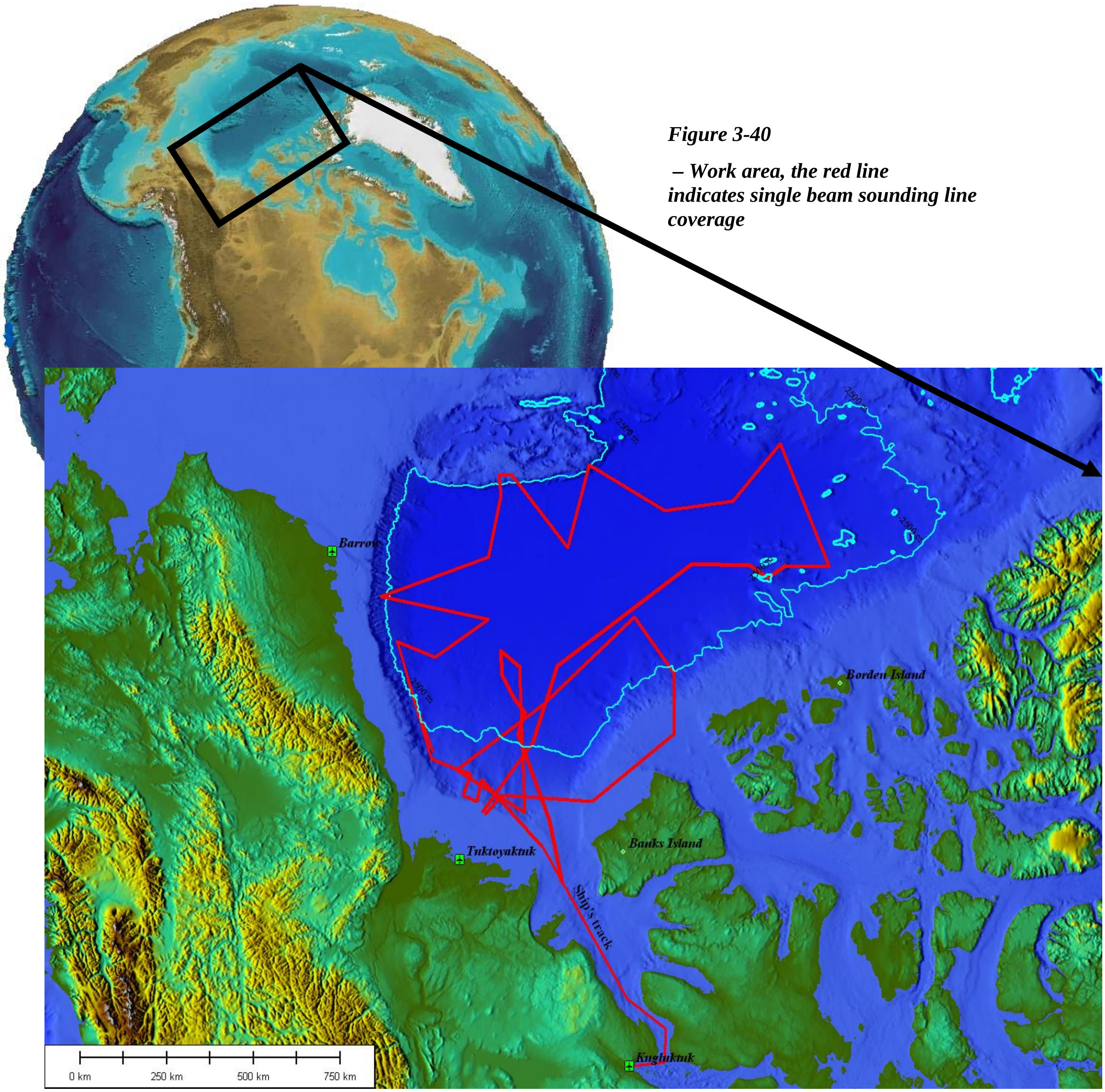


Figure 3-40

– Work 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 and helicopter spot sounding. (Figure 4) The helicopter, a Messerschmitt MBB BO105, was used to maximize the area covered and to collect data inaccessible to the ship because of ice conditions.

Figure 3-41. *Knudsen 320B/R Plus sounder and PC interface was located in the Oceanographic lab on the 300 level. The sounder is a dual frequency configuration with the high frequency set to 12 kHz and low frequency reserved for a 3.5 kHz transducer which is not installed.*

The ship collected depths using the Knudsen 320B/R Plus sounder attached to a 12 kHz transducer. The system used Chirp pulse generation technology. The system was operated remotely using Knudsen Echo Control Client and Echo Control Server software via a network connection in the aft seismic lab. When sounding with an icebreaker, bottom detection was lost due to interference from ice/ship's bubbler system and sea state. (Figure 3) The echo sounder preformed well with the exception of logging extra files. Normally the keb and kea format files are logged and when sgy format files were added to the logging sequence the Knudsen files became corrupt, computer crashes and poor performance were experienced. Knudsen Echo Control Client v1.47 and Echo Control Server v1.74 software were used for acquisition and PostSurvey v2.24 software was used for viewing during post processing of the data. The 3.5 kHz Knudsen was deployed during open water opportunities. The system was is use for 4 days and preformed well.

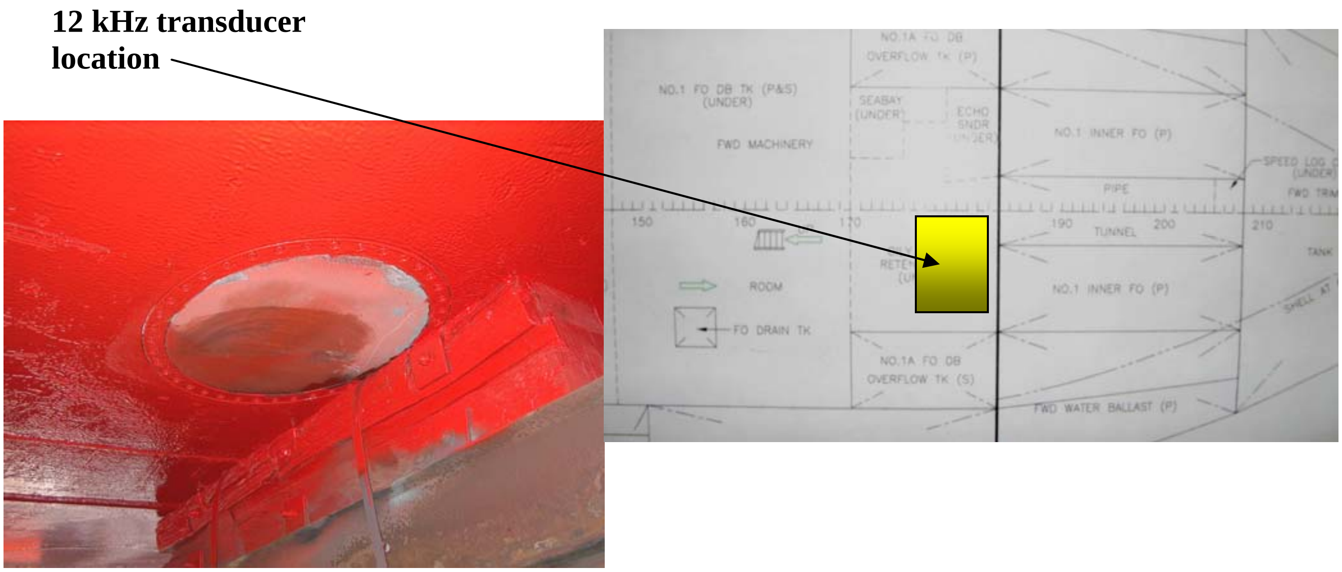


Figure 3-42. *12 kHz transducer acoustic window in hull.*

Figure 3-43. *transducer below landing on deck*

Similar to 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 performed in open water. The open water technique was achieved by Helicopter with slinging the transducer below the helicopter and placing into the water while in a hover. Two models of Knudsen echo sounders using a fixed frequency of 12 kHz were used, 320A and 320M. The Knudsen 320M was prone to HF radio transmissions and simply *required a ground wire to the aircraft frame to rectify the problem.*

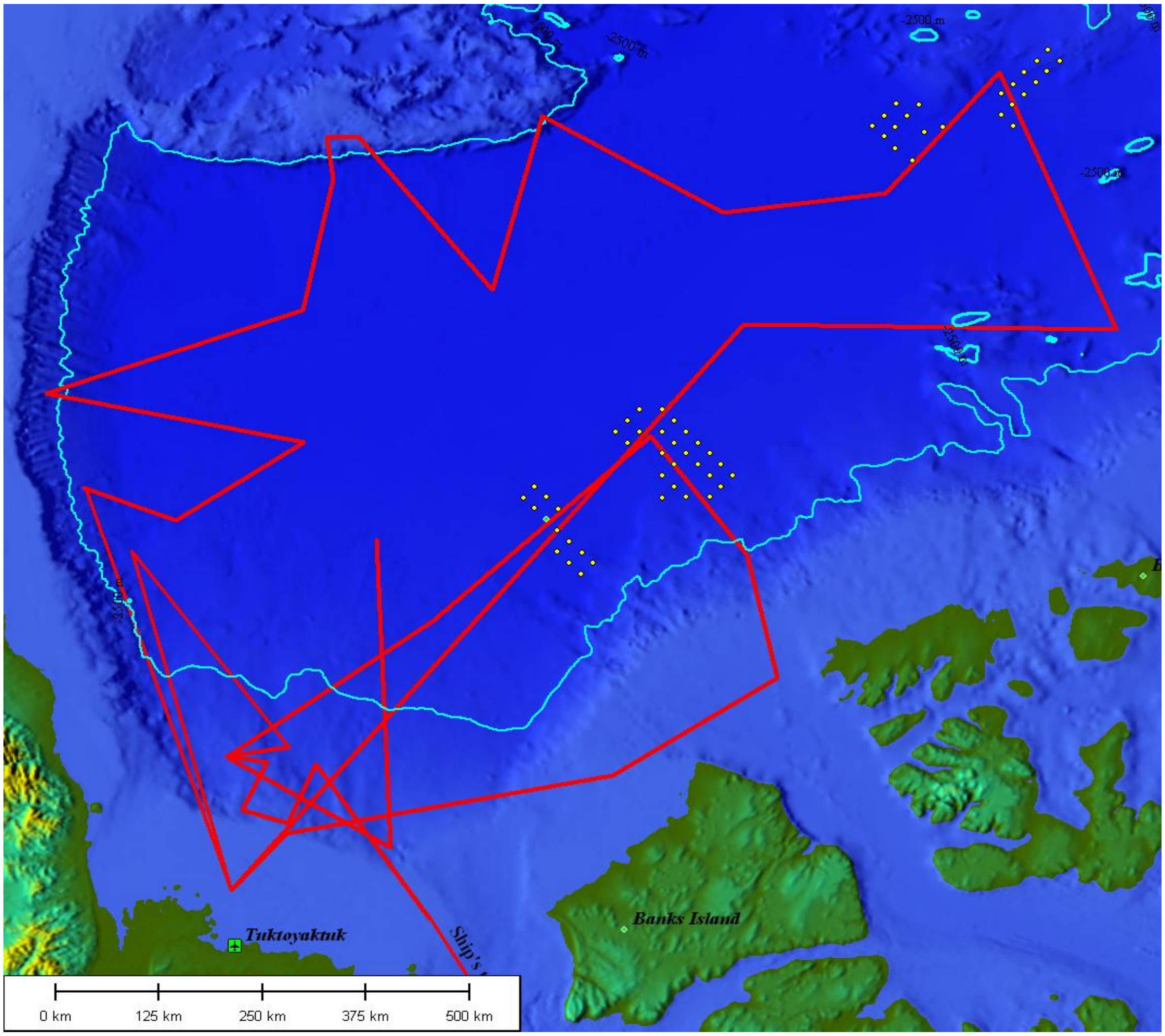


Figure 3-44. *Helicopter spot soundings (yellow dots) collected during program.*

Figure 3-45. *Spot sounding in open water, showing 12 kHz transducer slung below helicopter*

The sounders were set to a fixed velocity of 1500 m/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 condition in most cases was lighter than previous years. The data was logged to a laptop and post processed in Excel. The helicopter logged 11.5 hours of flight time to collect 61 spot soundings. This season weather hampered the operations and only four days of the scheduled 12 days spot sounding was achieved. The remaining part of the cruise was further south or in United States waters where spot soundings were not required.

Figure 3-46. *Knudsen sounder and laptop*

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 electrical connection to the transducer point was also incorporated for emergency use. The laptop was not connected to helicopter power but ran on its internal batteries to elimate any problems with static electicity.

Figure 3-47. *As recommended from previous year a permanent GPS antenna mount was attached on the dash of the B105*

Figure 3-48.

3.5 KHz transducer mounted to seismic air gun sled (left) and Knudsen Chirp 3260 sounder (right).

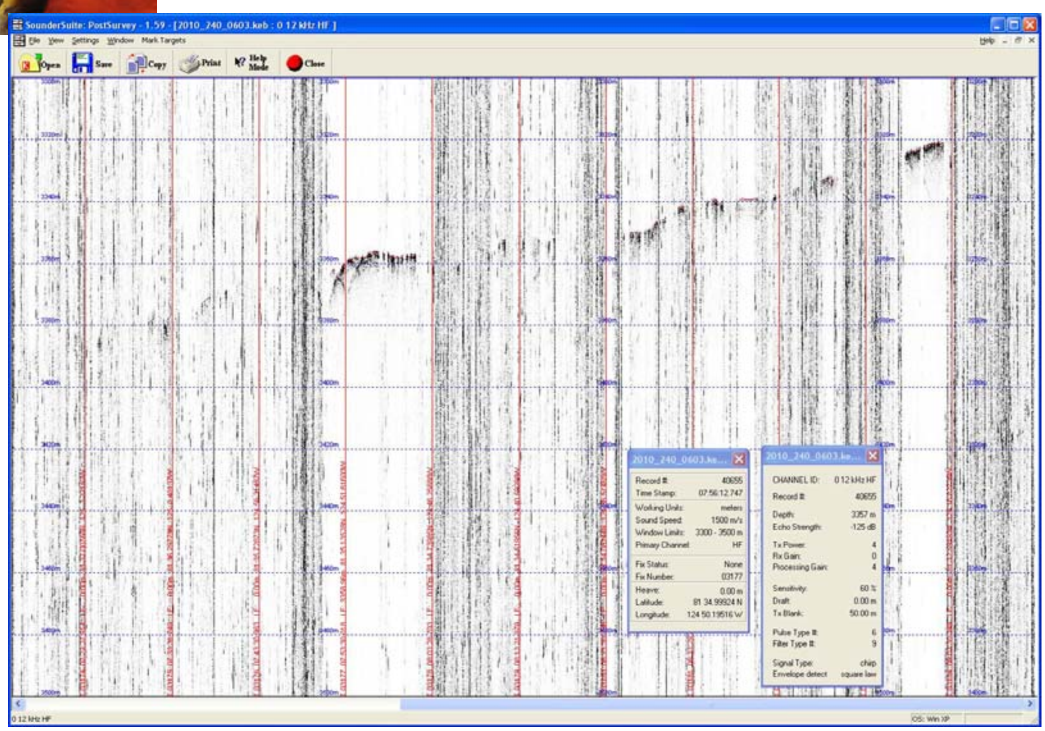


Figure 3-49. Typical echo traces (Echo Control window) when travelling in heavy ice conditions

Positioning Methods

Figure 3-50. MSat coverage map for CDGPS corrections

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 CDGPS service by means of MSAT satellite communications. The correction data is based on algorithms developed by Natural Resources Canada (NRCan) and real-time positioning data from Canadian reference stations. The estimated positional accuracy was less than 2.0 metres in static mode. Differential corrections were received for most of the voyage. The estimated positional accuracy without corrections was less than 5.0 metres. All equipment performed well overall.

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

Figure 3-51. NovAtel DL V3 GPS receiver in the equipment rack located on the bridge of the ship. Positions were fed directly to seismic lab for distribution to various computers/navigation programs.

Figure 3-52. NovAtel software interface used to configure and monitor NovAtel GPS receiver

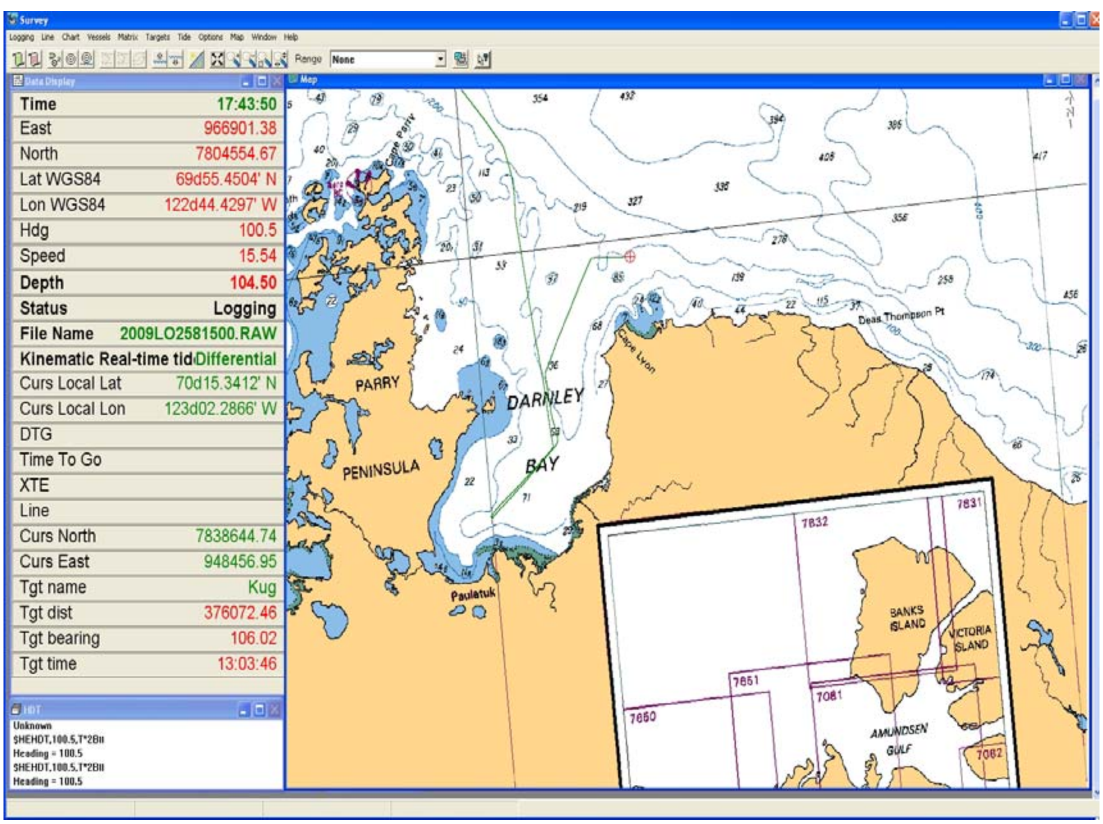


Figure 3-53. *HyPack logging software*

Data Collection

For navigation and planning, HyPack v7.0 (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. 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). Three profiles casts were taken with maximum depth of 3850m. (Figure 5) Additional profiles were obtained and compared to with XCTDs and XBTs.

Figure 3-54. Science winch with SV Plus v2 (sound velocity meter) depth range 5000 metres (SVP) mounted.

Figure 3-55. The data were downloaded from SV Plus v2 using Smartalk v2.27 software.

Figure 3-56. The setup used for downloading XCTD/XBT using the MK21 USB DAQ – Surface ship. Bathythermograph Data Acquisition system and LM-3A Hand-Held Launcher (Lockheed Martin Sippican)

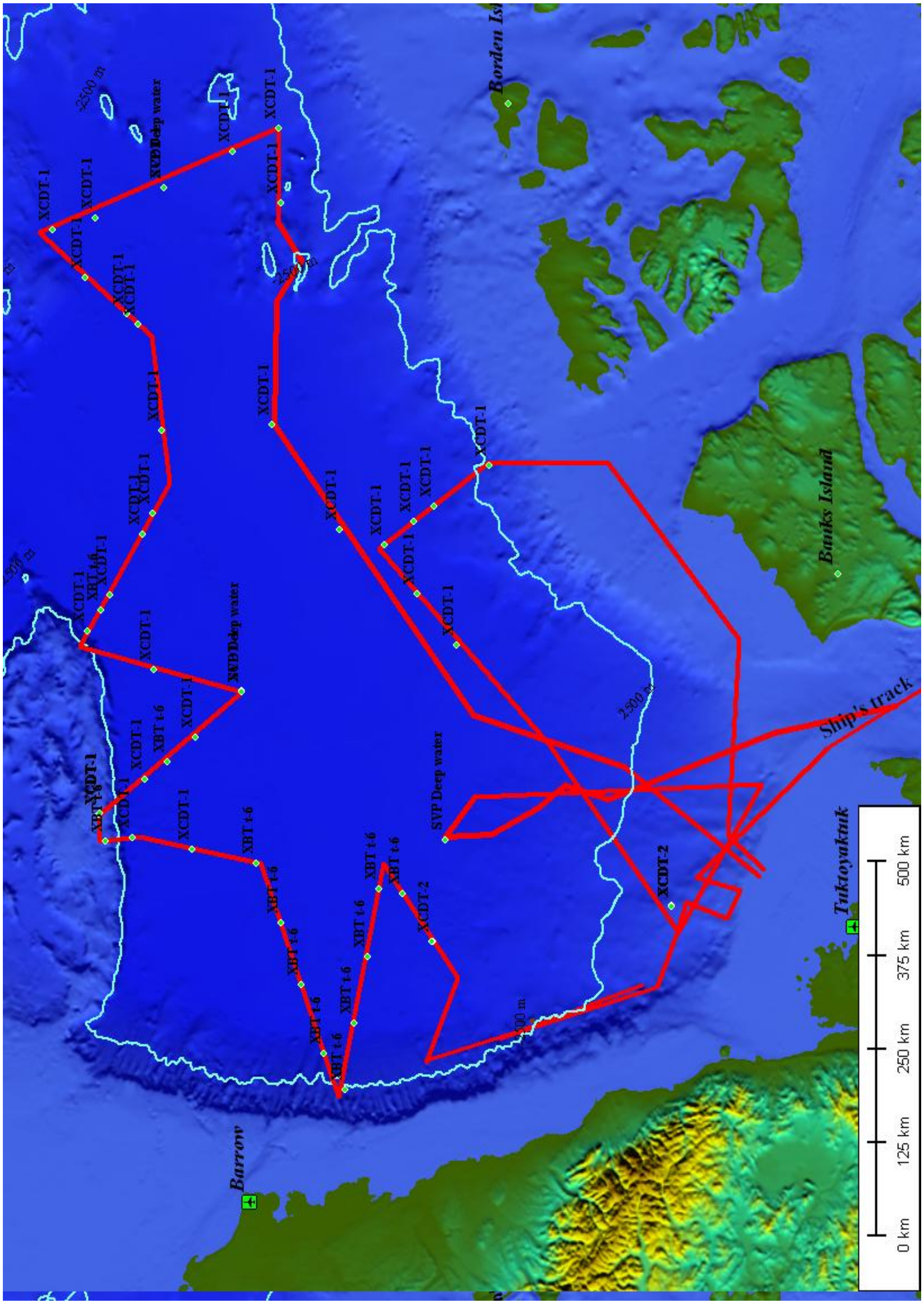


Figure 3-57. Locations of Sound Velocity casts in survey area.

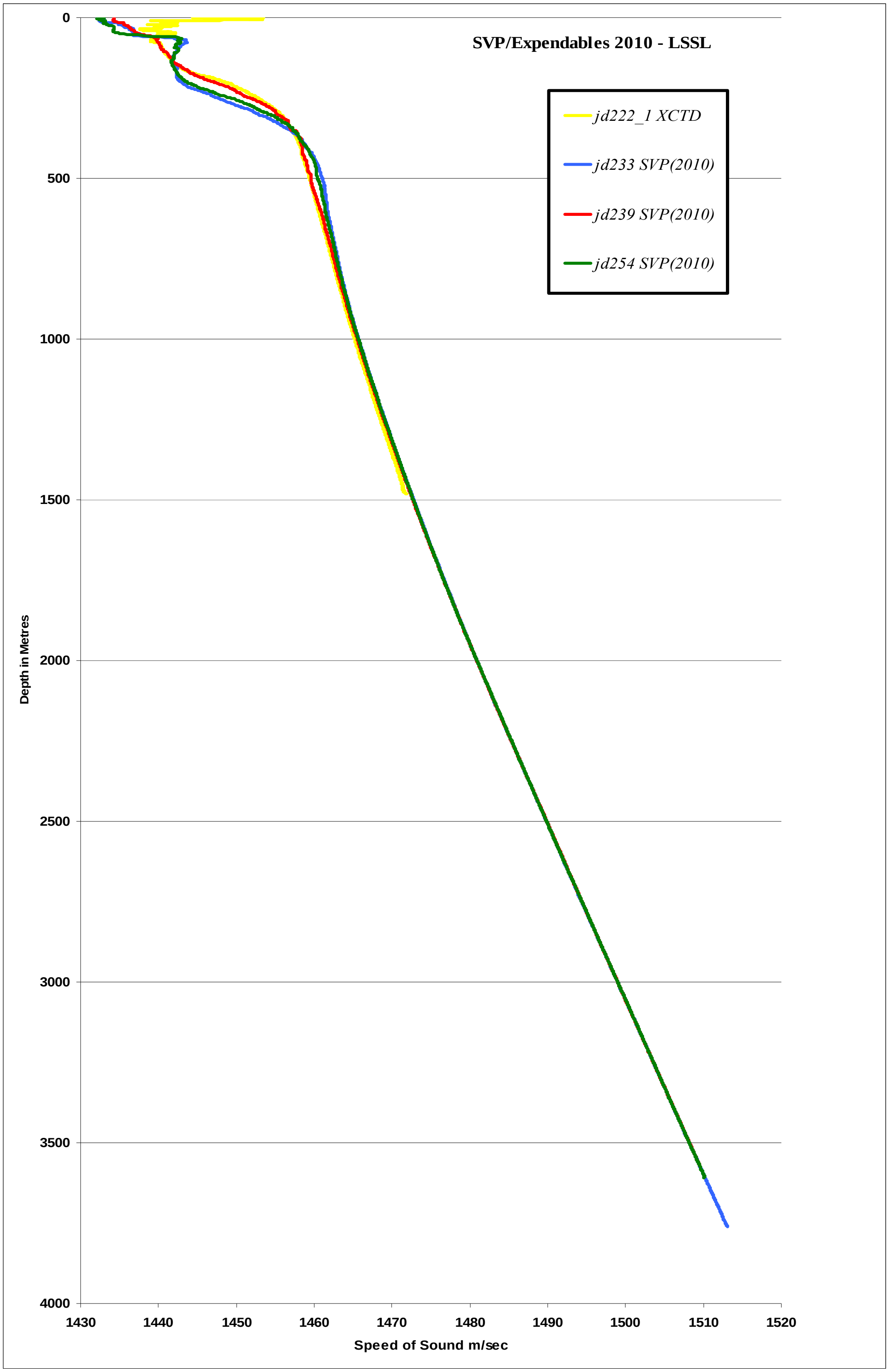


Figure 3-58. Figure 5 - SVP / XCTD graph/profiles

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.

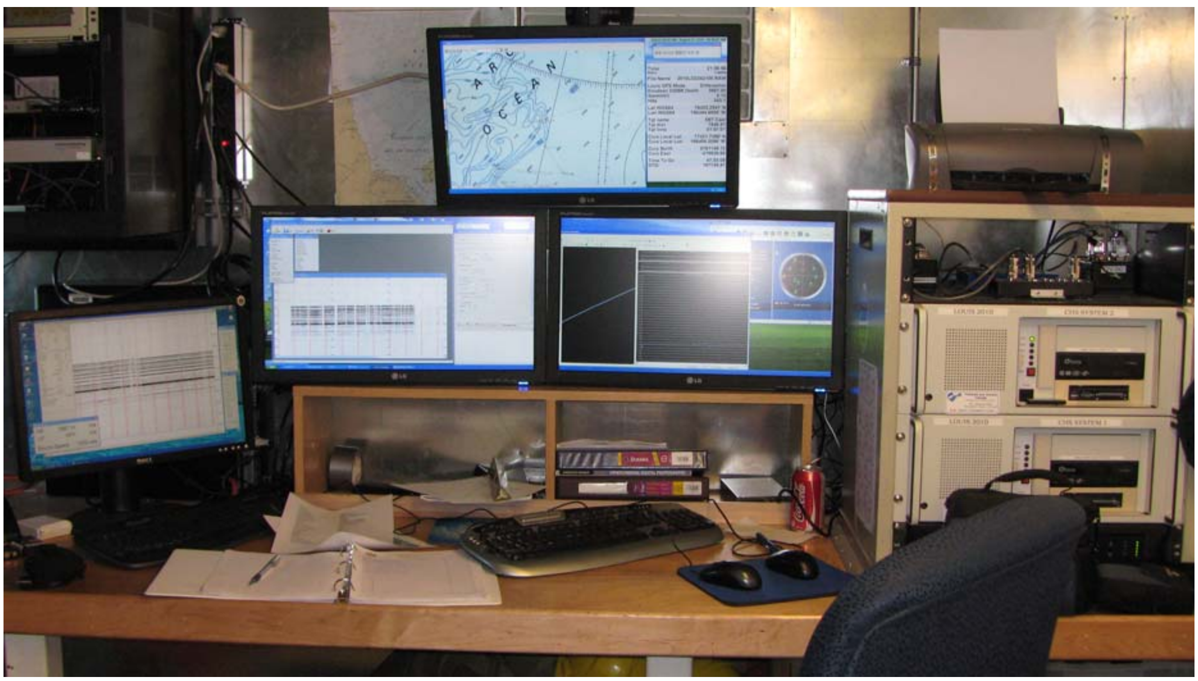


Figure 3-59. NRCan Seismic lab onboard CCGS LSSL showing Navigation (collection) Knudsen sounder control and processing station

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 confirmed by deploying small launch to read the draft marks.

Science

Physical Oceanographic Program for DFO -IOS (Institute of Ocean Sciences)
CHS monitored the continuous underway sampling of near-surface seawater temperature, salinity and phytoplankton (fluorescence), and dissolved gases. The ship's seawater loop system draws seawater from below the ship's hull at approximately 9m, to the main lab ("aft lab"). This system allows measurements to be made of the sea surface water without having to stop the ship for sampling. Physical seawater samples were taken at frequent regular intervals above 75N.

Expendable Deployments

XCTD (eXpendable Conductivity – Temperature – Depth) and XBT (eXpendable Bathythermograph probes) probes were launched by a hand launcher LM-3A from the stern of the ship to measure the physical seawater properties to depths of 460 m to 1870 m (depending on the unit). The data is communicated back to a digital data converter (MK-21 USB DAQ) and a computer onboard the ship by a fine wire which breaks when the probe reaches its maximum designed depth. Profiles were collected at 47 stations along the ship's track. (34 XCTD, 14 XBT, 3 deep-water SVP cast)

Recommendations and Conclusions

As stated in the previous years reports the ship should be outfitted with another 12 or 3 kHz transducer for redundancy. If for some reason the existing system fails there is no alternate method for bathymetry collection in deep water. All hydrographic computers were replaced this year and all functioned without problems. A racked mounted uninterrupted power supply (UPS) was also installed. The SV Plus v2 (sound velocity meter) was recalibrated but required software updates to function properly. 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). The software should be upgraded to the newest version for the 12 kHz Knudsen sounder, this might provide a more stable logging environment. 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.

Table 3-11. Major Equipment and Software Programs

CCGS Louis S St Laurent
Knudsen 320B/R Plus sounder
12 kHz transducer

NovAtel DL V3 GPS receiver / NovAtel L Band antenna

1 Desk top and 2 rack mounted computers running Windows XP

SV Plus v2 (sound velocity meter) depth range 5000 metres (SVP)
NovAtel CDU v3.2.1.3

MK21 USB DAQ – Surface ship Bathythermograph Data Acquisition system and LM-3A Hand-Held Launcher (Lockheed Martin Sippican)
XSV02 (Expendable Sound Velocity Probe)
XCTD -1-2 (Expendable Conductivity, Temperature and Density Probes)
XBT T-6 (Expendable Bathythermograph probes – 460 m)

CCG Helicopter 363 (B105)
Knudsen 320A sounder (variable frequency capacity)
Knudsen 320M sounder 12 kHz
12 kHz Knudsen transducer

NovAtel Propak V3-RT2 GPS receiver / NovAtel L Band antenna

GoBook XR-1 laptop / HyPack software / Knudsen software
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

Table 3-12. Locations of XCTD (eXpendable Conductivity – Temperature – Depth) and XBT (eXpendable Bathythermograph probes) and SVP (Sound Velocity Probe)

Description	Latitude (N)	Longitude (W)	Time (GMT)	Date
SVP Deep water cast	**73.69433343**	**142.47912**	**20:51:46**	**09/11/2010**
SVP Deep water cast	**76.60547432**	**146.40394**	**17:04:17**	**08/21/2010**
SVP Deep water cast	**81.78446433**	**128.30804**	**17:05:45**	**08/27/2010**
XBT t-6 Cast	**72.0.323221**	**145.40831**	**15:12:41**	**08/13/2010**
XBT t-6 Cast	**72.80393344**	**145.37776**	**0:58:09**	**08/14/2010**
XBT t-6 Cast	**73.48392518**	**145.33000**	**15:15:10**	**08/14/2010**
XBT t-6 Cast	**73.68737273**	**146.06136**	**2:40:04**	**08/15/2010**
XBT t-6 Cast	**73.08942998**	**147.99633**	**15:16:07**	**08/15/2010**
XBT t-6 Cast	**72.49452942**	**149.84793**	**2:59:47**	**08/16/2010**
XBT t-6 Cast	**71.86156149**	**151.42195**	**14:54:30**	**08/16/2010**
XBT t-6 Cast	**72.37567827**	**151.51827**	**2:52:32**	**08/17/2010**
XBT t-6 Cast	**73.21891421**	**151.00479**	**15:06:42**	**08/17/2010**
XBT t-6 Cast	**73.98265644**	**150.52804**	**2:49:48**	**08/18/2010**
XBT t-6 Cast	**74.75634477**	**150.20655**	**14:59:32**	**08/18/2010**
XBT t-6 Cast	**75.82747286**	**156.29856**	**19:51:46**	**08/19/2010**
XBT t-6 Cast	**76.3551426**	**151.70138**	**19:52:18**	**08/20/2010**
XBT t-6 Cast	**78.34531618**	**151.01525**	**19:42:15**	**08/22/2010**
XCDT-1 Cast	**76.52691438**	**128.74297**	**01:26:50**	**09/03/2010**
XCDT-1 Cast	**76.72770615**	**132.28779**	**14:52:02**	**09/03/2010**
XCDT-1 Cast	**76.78676639**	**133.64919**	**19:34:14**	**09/03/2010**
XCDT-1 Cast	**76.84922247**	**135.62282**	**2:54:25**	**09/04/2010**
XCDT-1 Cast	**76.14843125**	**136.12457**	**14:48:59**	**09/04/2010**
XCDT-1 Cast	**75.37207312**	**136.41165**	**02:35:49**	**09/05/2010**
XCDT-1 Cast	**75.28337329**	**152.56114**	**03:04:11**	**08/19/2010**
XCDT-1 Cast	**75.73620642**	**155.00697**	**14:50:27**	**08/19/2010**
XCDT-1 Cast	**76.16179506**	**156.05901**	**03:03:35**	**08/20/2010**
XCDT-1 Cast	**76.16401291**	**156.02567**	**03:10:21**	**08/20/2010**
XCDT-1 Cast	**76.2904055**	**153.14582**	**14:53:37**	**08/20/2010**
XCDT-1 Cast	**76.44220963**	**149.78703**	**02:49:55**	**08/21/2010**
XCDT-1 Cast	**76.58788134**	**146.47227**	**14:44:44**	**08/21/2010**
XCDT-1 Cast	**7.39086233**	**149.94839**	**02:54:24**	**08/22/2010**
XCDT-1 Cast	**78.19679833**	**152.33674**	**15:04:47**	**08/22/2010**
XCDT-1 Cast	**78.44767927**	**150.12482**	**02:52:10**	**08/23/2010**
XCDT-1 Cast	**78.85768809**	**146.38206**	**14:45:05**	**08/23/2010**
XCDT-1 Cast	**78.99502011**	**145.09886**	**18:36:06**	**08/23/2010**
XCDT-1 Cast	**79.72293589**	**141.34475**	**02:54:46**	**08/24/2010**
XCDT-1 Cast	**80.88969615**	**137.82035**	**17:50:14**	**08/25/2010**
XCDT-1 Cast	**81.07770128**	**137.94987**	**19:33:47**	**08/25/2010**
XCDT-1 Cast	**81.74850222**	**138.55654**	**01:38:56**	**08/26/2010**
XCDT-1 Cast	**82.44679823**	**137.97025**	**14:53:21**	**08/26/2010**
XCDT-1 Cast	**82.44698137**	**137.96675**	**14:57:42**	**08/26/2010**
XCDT-1 Cast	**81.78215612**	**128.33771**	**16:10:41**	**08/27/2010**

Description	Latitude (N)	Longitude (W)	Time (GMT)	Date
XCDT-1 Cast	**82.18497857**	**134.28919**	**00:22:24**	**08/27/2010**
XCDT-1 Cast	**81.34126666**	**122.46752**	**14:42:07**	**08/28/2010**
XCDT-1 Cast	**80.98233202**	**118.99645**	**23:43:07**	**08/28/2010**
XCDT-1 Cast	**80.48954386**	**123.68198**	**16:57:27**	**08/29/2010**
XCDT-1 Cast	**77.36920653**	**136.88243**	**23:29:50**	**08/30/2010**
XCDT-1 Cast	**78.85999037**	**135.57674**	**14:49:56**	**08/30/2010**
XCDT-2 Cast	**71.28860186**	**137.0799**	**17:50:05**	**08/10/2010**
XCDT-2 Cast	**71.28307866**	**137.09843**	**18:10:08**	**08/10/2010**
XCDT-2 Cast	**72.80959117**	**145.37811**	**01:03:48**	**08/14/2010**

Table 3-13. Ship Activity Log

Date	JD	Time (UTC)	Activity	SVP	3
4-Aug	**216**	**1700**	**Board Ship**		
5-Aug	**217**	**0000**	**Attended orientation**		
6-Aug	**218**	**1720**	**Started travelling**		
8-Aug	**220**	**1500**	**Started Logging - HyPack, Sounder 12kHz**		
		1615	**Started Logging - Sounder 3.5 kHz**		
		1900	**Seismic guys testing/fixing gear**		
		1925	**Test SVP - Still not right config file**		
		2000	**Seismic gear up and running**		
9-Aug	**221**	**0500**	**12 kHz sounder crashed**		
		0525	**3.5 kHz sounder windows error (4-5 runtime errors during night - restart)**		
		0826	**start line segment 2 (shallow water ~50-60m)**		
		1256	**start line segment 3 (start shallow head north)**		
		1800	**Heading down slope past a few pingos**		
		1900	**Start Processing**		
10-Aug	**222**	**0000**	**Start Processing JD220 and part of JD221**		
		0200	**Backed up RAW and KEB/A files to External drive for JD220, JD221**		
		0215	**Commenced turn for line segment 4**		
		0909	**Started line segment 5**		
		1107	**Backed up RAW data ('c:\Preprocess') to sounding pc**		
		1535	**End work on line 5 - breaking off to pull gear and heads towards Healy**		
		1702	**3.5 kHz sounder shut down - pull gear out of water**		
		1750	**XCTD-2 cast _1 71°17'19"N 137°04'48"W**	**1**	
		1810	**XCTD-2 Cast _2 71°16'59"N 137°05'54"W**	**2**	
		1815	**Seismic gear out of water - steaming to meet with Healy**		
11-Aug	**223**	**0000**	**meet Healy**		
		0000	**Lost bottom due to ship maneuvers**		
		0051	**Bottom found again - image poor**		
		0935	**Losing bottom due to rapid changed in depth - increased range to 500m**		
		1320	**Weak return due speed increase to 17kt (back tracking) Medavac to Tuk**		
		1807	**bottom digitizing poor (16.5 knots)**		
		2230	**Test New SVP instructions - appears to be working**		
12-Aug	**224**	**0247**	**Single Beam Edit process JD221, most JD 222**		
		0411	**Reached medavac drop off point**		
		xxxx	**Processing JD222, 223**		
		2142	**Stop/Start logging for start of selected line #1**		
		2150	**deploying gear**		
13-Aug	**225**	**1330**	**bits and pieces of ice starting**		
		1420	**start of new line (7)**		
		1507	**XBT Cast_1 72°19'10"N 145°24'30"W**	**1**	
		2212	**Streamer dead**		
		2309	**Small Gun in Water**		
		2317	**Retrieve Gear**		
		2355	**Gear Back In Water**		

14-Aug	226	0052	Back ON Line	
		0058	XBT Cast_2 72°48'14"N 145°22'40"W	2
		0103	XCTD-2 cast_3 72°48'35"N 145°22'41"W	3
		0105	passing through some ice flows	
		1040	stopped in ice - still logging - maneuver out	
		1445	resuming course	
		1515	XBT Cast_3 73°29'02"N 145°19'48"W	3
		1545	Buoy in water	
15-Aug	227	0035	passing through ice / blanking sounder	
		0041	Buoy in Water	
		0109	HIPS 2010 backup to Sounder computer	
		0240	XBT Cast_4 73°41'15"N 146°03'41"W	4
		0435	Lost bottom	
		0440	found bottom	
		1516	XBT Cast_5 73°05'22"N 147°59'47"W	5
		1848	around large ice flow	
		2236	waves on beam - hard to pick up bottom	
16-Aug	228	0259	XBT Cast_6 72°29'40"N 149°50'53"W	6
		0443	lost bottom	
		1330	heading off course	
		1350	regain bottom	
		1454	XBT Cast_7 71°51'42"N 151°25'19"W	7
		1800	Eel back in water	
		1838	Start of line north	
		2200	restart HyPack to sync time	
17-Aug	229	0252	XBT Cast_8 72°22'32"N 151°31'06"W	8
		1506	XBT Cast_9 73°13'08"N 151°00'17"W	9
		1900	entering moderate ice	
18-Aug	230	0001	Stopped logging GPS data - wrong receiver type to collect the data requested by Terese	
		0014	lost bottom reading (air/ice under hull?)	
		0139	regain bottom (right where we left it)	
		0225	HIPS\UNCLOS2010 backup to External Drive	
		0249	XBT Cast_10 73°58'58"N 150°31'41"W	10
		0250	Crossed to outer side of EEZ	
		1459	XBT Cast_11 74°45'23"N 150°12'24"W	11
		1506	Stop/start Survey/ reload line	
		1800	Lost bottom	
		1813	Regained Bottom	
		1900	lost bottom	
		1919	regained bottom	
		2020	start divert around ice flow - off line	
19-Aug	231	0207	Back on line after divert around ice	
		0315	XCTD-1 Cast_1 75°17'00"N 152°33'40"W	1
		1450	XCTD-1 Cast_2 75°44'10"N 155°00'25"W	2
		1951	XBT Cast_12 75°49'38"N 156°17'55W	12
20-Aug	232	0303	XCTD-1 Cast_3 76°09'42"N 156°03'32"W	3
		0313	XCTD-1 Cast_4 76°09'50"N 156°01'32"W	4
		0320	lost bottom	
		0515	regain bottom	
		1453	XCTD-1 Cast_5 76°17'25"N 153°08'45"W	5
		1952	XBT Cast_13 76°21'19"N 151°42'	13
21-Aug	233	0045	Jon trial run in Helicopter w/ transducer	
		0249	XCTD-1 Cast_6 76°26'32"N 149°47'13"W	6
		1444	XCTD-1 Cast_7 76°35'16"N 146°28'19"W	7
		1510	Shut down gear/guns/streamer	
		1600	Start SVP cast to 3800m	
		1704	SVP cast down to 3800m 76°36'20"N 146°24'14"W	1
		1800	Draft 8.75m & 8.65m keep 8.7m in file	

		1820	completed SVP cast	
22-Aug	234	0254	XCTD-1 Cast_8 77°23'27"N 149°56'54"W	8
		1504	XCTD-1 Cast_9 78°11'49"N 152°19'57"W	9
		1942	XBT Cast_14 78°20'43"N 151°01'	14
23-Aug	235	0111	HIPS 2010 backup to External Drive	
		0252	XCTD-1 Cast_10 78°26'52"N 150°07'24"W	10
		1445	XCTD-1 Cast_11 78°51'28"N 146°22'52"W (recording ended early ~200m due to ice flow)	11
		1830	XCTD-1 Cast_12 78°59'42"N 145°05'56"W (recording ended early ~400m due to ice flow)	12
		1830	pulled gear to transit north/ break for Healy	
		~2030	Jon out on heli run - sounder/transducer not working properly - came back	
24-Aug	236	0254	XCTD-1 Cast_13 79°43'23"N 141°20'41"W (recording ended early ~300m due to ice flow)	13
		0410	ship engine/shaft problems - stopped	
		0440	ship going again	
		0500	ship engine/shaft problems - stopped again - long term - in 9/10 ice cover	
		0750	stopped logging HyPack & Knudsen files due to engine repair ongoing	
25-Aug	237	0540	ship now moving again	
		1600	change of course - head to point 28 (line 28-29)	
		1750	XCTD-1 Cast_14 80°53'23"N 137°49'13"W (recording ended early ~200m due to ice flow)	14
		1933	XCTD-1 Cast_15 81°04'40"N 137°57'00"W	15
		2025	Jon out on heli run	
		2240	Jon back from heli run	
26-Aug	238	0138	XCTD-1 Cast_16 81°44'55"N 138°33'24"W	16
		1127	gear in water for line 28>29	
		1145	started line 28	
		1453	XCTD-1 Cast_17 82°26'48"N 137°58'13"W (recording ended early ~200m due to ice flow)	17
		1457	XCTD-1 Cast_18 82°26'49"N 137°58'00"W (recording ended early ~400m due to ice flow)	18
		~1930	Jon Leave on Heli Run	
		2222	Jon return from Heli Run	
		2230	problems with water sampler in wet lab - hose got loose - water on floor (different one than last time)	
27-Aug	239	0022	XCTD-1 Cast_19 82°11'06"N 134°17'21"W (recording ended early ~375m)	19
		0115	Backed up HIPS\UNCLOS2010 to external drive	
		1410	Move to open water to retrieve gear	
		1512	recover gear	
		1600	SVP in water	
		1610	XCTD-1 cast_20 81°46'56"N 128°20'16"W	20
		1705	SVP cast down to 3572.22m 81°47'04"N 128°18'29"W (3600 counter/ 3617 sounder)	2
		1815	SVP operations complete	
		2145	Problems with gear - gear out/in twice	
28-Aug	240	0000	Shut down and Restart both Survey Computers	
		0230	Gear out - change over to Breaking for Healy	
		1442	XCTD-1 Cast_21 81°20'29"N 122°28'05"W	21
		2343	XCTD-1 Cast_22 80°58'56"N 118°59'56"W	22
		2355	Break off Line - Heading to Tuk	
29-Aug	241	0157	soundings difficult to get - see notes for times/depth recordings.	
		1657	XCTD-1 Cast_23 80°29'22"N 123°40'56"W	23
		1754	soundings difficult to get - see notes for times/depth recordings.	
30-Aug	242	0015	soundings difficult to get - see notes for times/depth recordings.	
		1449	XCTD-1 Cast_24 78°51'36"N 135°34'36"W	24
		2329	XCTD-1 Cast_25 77°22'09"N 136°52'57"W	25
31-Aug	243	1200	Reloaded Survey to sync time	
1-Sep	244	0500	Stopped outside of Tuk - Heli Back from drop off	
		0845	Turn Around to head north	
2-Sep	245	0100	Fire & Boat drill	

		0140	Fire & Boat Drill completed	
		0200	Backed up HIPS\UNCLOS2010 to external drive	
3-Sep	246	0110	Gear going back in water	
		0126	XCTD-1 Cast_26 76°31'37"N 128°44'35"W (recording ended early ~950m)	26
		1452	XCTD-1 Cast_27 76°43'40"N 132°17'16"W (recording ended early ~260m)	27
		1628	Jon Leave on Heli Run	
		1830	Jon return from Heli Run	
		1934	XCTD-1 Cast_28 76°47'12"N 133°38'57"W	28
		2247	Jon Leave on Heli Run	
4-Sep	247	0106	Jon return from Heli Run	
		0254	XCTD-1 Cast_29 76°50'57"N 135°37'22"W	29
		0415	Made turn to the south	
		1448	XCTD-1 Cast_30 76°08'54"N 136°07'28"W	30
		2135	Started Logging .SGY files on Knudsen 12kHz	
		2326	Jon Leave on Heli Run	
		2330	Jon return from Heli Run - problems	
		2335	Jon Leave on Heli Run	
5-Sep	248	0220	Jon return from heli Run	
		0235	XCTD-1 Cast_30 75°22'19"N 136°24'42"W	31
		1405	Echocontrol crash/ KEB, SGY files stopped recording - HyPack continued ok	
		1420	Echocontrol back up	
6-Sep	249	0126	Reloaded Survey to sync time	
7-Sep	250	1350	lost bottom	
		1530	restart Knudsen computer	
		1725	restart Knudsen computer	
		1825	restart Knudsen computer	
		1917	restart Knudsen computer - stopped logging SGY during repeated starts and lost bottom	
		2000	restart Knudsen computer	
		2318	bottom return - changed course	
		2319	restart Knudsen computer	
		2329	restart Knudsen computer	
8-Sep	251	0012	logging SGY files again	
		2130	Pump in science lab shut down - restart 2200 - system back up JD252 0500	
9-Sep	252	1510	DAS computer freeze while processing NAV in HIPS - data lost ~ 1 min	
		1528	DAS computer freeze while processing NAV in HIPS - data lost ~ 1 min	
		1723	Reboot Knudsen computer (main) and local	
		1732	Start record KEB and SGY again	
		1952	Restart Echocontrol client - seemed to run slow	
		1956	SGY files slowing down KEB display recording	
		2005	Stop recording SGY files due to slowing down recording of KEB file	
10-Sep	253	0117	Backed up HIPS Processed Data + UNCLOS2010 directory (processed data in main HIPS dir)	
		2354	Reset DAS computer power (mistake)	
11-Sep	254	1950	SVP operation begin	
		2051	SVP reach max depth 3607.58m 73°41'39.6"N 142°28'44.8"W	3
			(3620 counter/3665 sounder- touched bottom)	
		2150	SVP operations complete	
12-Sep	255	1812	DAS computer freeze while processing NAV in HIPS - data lost ~ 3 min	
		2130	Merged and exported all lines to date (JD255_1200)	
13-Sep	256	1724	Restart Echocontrol client - error - reconnect - restart sounder computer in lab	
14-Sep	257	1605	At Kugluktuk - End Logging	

Chapter 4: Seismic Source Calibration

David C. Mosher

Questionable results from 2009 calibration trials required another attempt to be made this year. All possible factors are accounted including complete recalibration of hydrophones, signal conditioning unit, digitial acquisition system and cabling. In addition, water velocities were measured and, in the deep tow experiment, a depth sensor was used on the hydrophone. Two separate trials were conducted; one for the shallow tow configuration and one for the deep tow configuration. The full 1150 in^3 array was recorded as well as each gun individually and the 2x500 in^3 guns together. Only data for the full array have been analysed for this report.

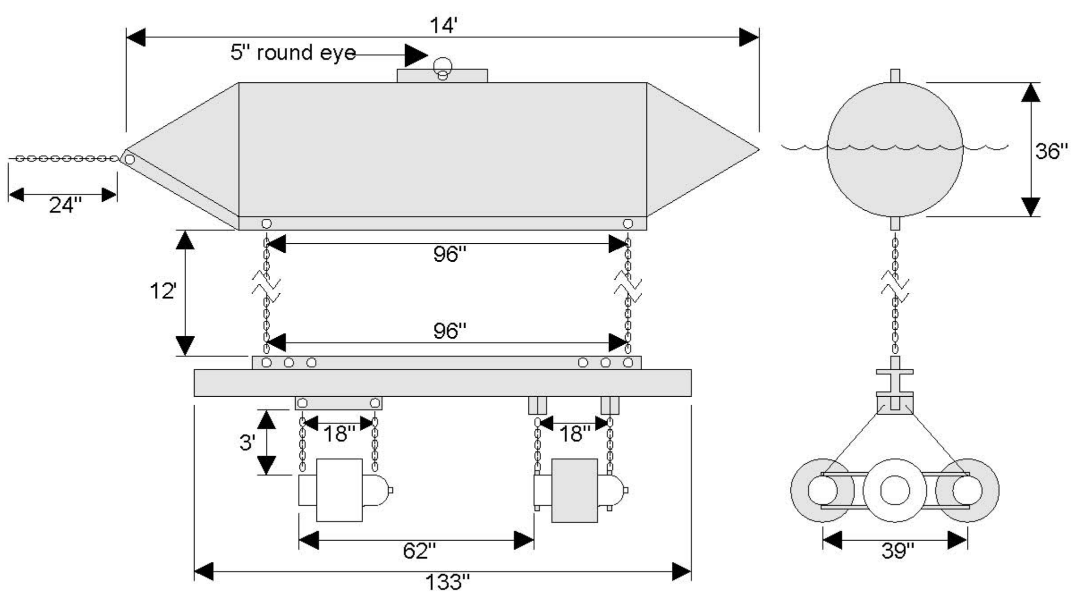


Figure 4-60. Seismic gun array configuration for shallow tow. The 150 in^3 gun is in the lead and the two 500's astern.

Source Signature Test: Shallow Tow Array Configuration

JD 222
Ship Position: 71.3058º -136.9920º

Equipment and configuration
Hydrophone: NRCan #22;

Calibration (June 11, 2010), -200.3 dB//V/uPa (low gain) on SCU #6
GSCDig #4 Channel 1
0.9794 = calibration factor of GSCDig 4 Ch 1 (June 11, 2010)
SCU-6 s/n 025
Realtime Systems LongShot firing system

SCU 6 settings
Input: Seistec J1
Output = input A
dc power
no gain (low) switch setting

Configuration
Hydrophone Cable out 300 ft (91.44 m), deployed from stern
Gun Array 33 m from stern
Gun array depth = 6 m
Trigger/Fire delays = 58 ms

Digitizer Settings
Sample Interval 50 µs
Sample Frequency 20 kHz
Number Samples 9216
Record Length 460.8 ms

Test 1
filename: caltestlsl2010_2010_222_16_10_23.sgy
full array = 2x500 cu.in. G guns and 1x150 cu.in. G gun
Pressure = 1950 psi
31 shots

Test 2
filename: caltestlsl2010_2010_222_16_15_37.sgy
array= 1x 150 cu.in. g gun
pressure 1950 psi
14 shots

Test 3
filename: caltestlsl2010_2010_222_16_18_05.sgy
1x500 cu.in. G gun
pressure 1950 psi
10 shots

Test 4
filename: caltestlsl2010_2010_222_16_19_50.sgy
2x500 cu.in. G guns
pressure 1950 psi

18 shots

Test 5
filename: caltestlsl2010_2010_222_16_22_50.sgy
1x500 cu.in. G gun and 1x150 cu.in. G gun
pressure 1950 psi
14 shots

Source Signature Test: Deep Tow Array Configuration
JD 248

Equipment

Hydrophone: NRCan #22;
Calibration (June 11, 2010), -200.3 dB//V/uPa (low gain) on SCU #6
GSCDig #4
Channel 1 = Shot record; naming convention = LSSL2010_Deep_towNRC-H022_"time stamp".sgy; 0.9794 = calibration factor of GSCDig 4 Ch 1 (June 11, 2010)
Channel 2 = Fire break Point, naming convention - LSSL2010_Deep_towRTS_AngFTB_"time stamp".sgy

SCU-6 s/n 025
Realtime Systems LongShot firing system

SeaStar mini-CTD (attached to hydrophone to provide depth for second set of filenames provided below), Filename= 1S5274.DAT

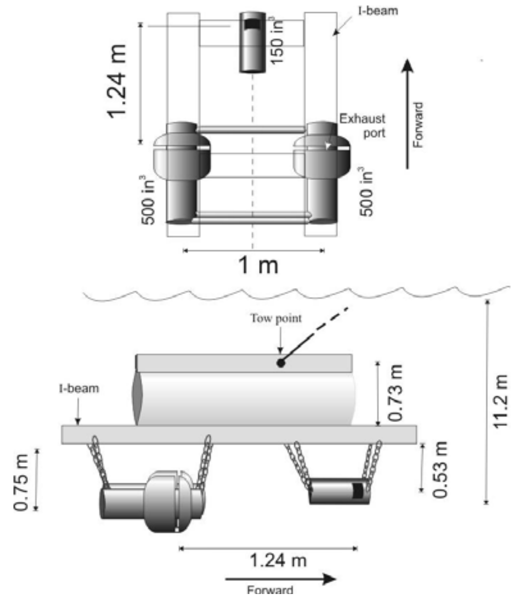


Figure 4-61. Design and measurement parameters of the Sercel G-gun array for CPMSRRS 2010

SCU 6 settings
Input: Seistec J1
Output = input A
dc power
no gain (low) switch setting

Configuration
Hydrophone Cable out 400 ft (121.92 m), deployed from stern
Gun Array 0 m from stern
Gun array depth = 12 m
Trigger/Fire delays = 56.7 ms (determined from GSCDig Chan 2 data

Digitizer Settings
Sample Interval 20 µs
Sample Frequency 50 kHz
Number Samples 50000
Record Length 1000.33 ms

Test 1
filename: LSSL2010_Deep_towNRC-H022_2010_248_02_38_47.sgy
filename: LSSL2010_Deep_towNRC-H022_2010_248_02_55_42.sgy
full array = 2x500 cu.in. G guns and 1x150 cu.in. G gun
Pressure = 1950 psi
11 shots

Test 2
filename: LSSL2010_Deep_towNRC-H022_2010_248_02_47_14.sgy
filename: LSSL2010_Deep_towNRC-H022_2010_248_02_59_00.sgy
array= 1x 150 cu.in. g gun
pressure 1950 psi
10 shots

Test 3
filename: LSSL2010_Deep_towNRC-H022_2010_248_02_43_24.sgy
filename: LSSL2010_Deep_towNRC-H022_2010_248_03_00_40.sgy
2x500 cu.in. G gun
pressure 1950 psi
10 shots

Test 4
filename: LSSL2010_Deep_towNRC-H022_2010_248_02_46_06.sgy
filename: LSSL2010_Deep_towNRC-H022_2010_248_03_02_18.sgy
1x500 cu.in. G guns
pressure 1950 psi
10 shots

Results

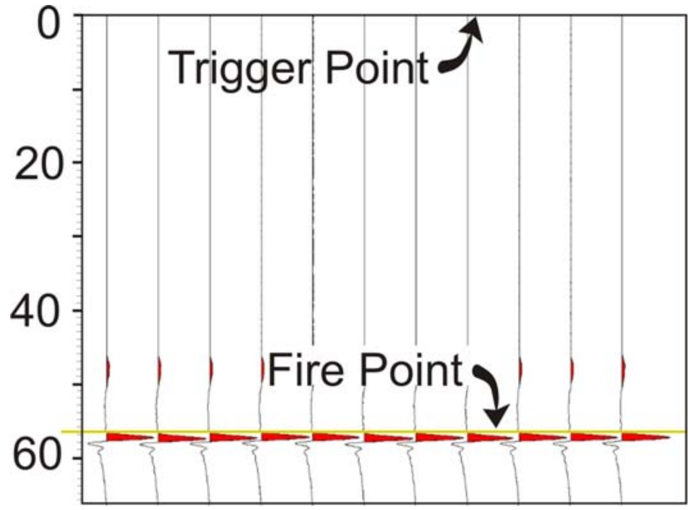


Figure 4-62. Fire point signal digitized from the LongShot fire unit.

For this report, only results for the full array (1150 in^3) are presented. Other configurations, such as single gun and pairs of guns are logged and archived but not analysed. Measured results are compared with modeled results from GUNDALF version 6.1 software (Oakwood Computing). For each test, and XCTD deployment was used to determine sound velocity in the water column. Since the experiment takes place within the top 100 m water depth, the velocities over the interval from 0 to 100 m were averaged. Time difference between the trigger point and the fire point was recorded on the GSCDig from the analog output of the LongShot firing unit, showing a 56.8 ms delay between the two.

Shallow Tow configuration

Measured

Table 4-14. Average amplitudes (0-peak and peak-peak) for calibration trials with the shallow tow configuration.

Trace	Distance (m)	Amplitude (Bar)	Amplitude (Bar.m)	0-Peak Amp (dB)	0-Peak Amp dB re 1 m
93	68.832	0.084935	5.84626096	198.5817562	235.3375639
94	68.5368	0.087244	5.979452718	198.8147523	235.5332287
95	68.61168	0.086779	5.954036627	198.768269	235.49623
96	67.00896	0.084346	5.651919597	198.5212619	235.0439195
97	67.464	0.083983	5.665832746	198.4838333	235.065275
98	67.7736	0.08419	5.705837785	198.5051773	235.1263884
99	66.456	0.088852	5.904752985	198.9733507	235.4240347
100	64.9728	0.084495	5.489904441	198.536664	234.7912957
101	63.97056	0.086067	5.50575545	198.6967353	234.8163383
102	64.91376	0.091033	5.909316147	199.1840092	235.4307445
103	64.944	0.082689	5.370159657	198.3489633	234.599744
104	64.512	0.085073	5.488251836	198.5958705	234.7886806
105	64.512	0.083606	5.393566762	198.4447111	234.6375212

106	64.35072	0.077917	5.014024291	197.8326605	234.0037287
107	64.35072	0.080162	5.158462706	198.0793377	234.2504059
108	64.11024	0.083376	5.345276318	198.4208552	234.5594032
109	63.40752	0.086845	5.506625525	198.7748955	234.8177109
110	64.152	0.077805	4.991323516	197.8201104	233.9643144
111	64.19088	0.077697	4.987418295	197.8080493	233.9575159
112	64.44	0.084906	5.471340031	198.5787635	234.7618741
113	64.008	0.083475	5.34306721	198.4311276	234.5558127
114	64.43136	0.083461	5.377486505	198.4296406	234.6115866
115	64.008	0.080466	5.150487233	198.1122812	234.2369663
116	64.89648	0.076361	4.955587835	197.6574807	233.9019036
117	64.728	0.08182	5.296069787	198.2572302	234.479074
118	64.89936	0.080468	5.222299999	198.1124281	234.3572363
119	66.56976	0.076727	5.107716482	197.6989958	234.1645357
120	66.84336	0.080714	5.395178828	198.1389514	234.6401169
121	67.16448	0.079537	5.342034021	198.0113399	234.554133
122	67.968	0.076308	5.186479873	197.6513641	234.2974539
123	68.20992	0.070959	4.840104135	197.0201433	233.6970941
				AVERAGE	**234.6419945**

Trace	Distance (m)	Amplitude (Bar)	Amplitude (Bar.m)	Peak-Peak Amp (dB)	Peak-Peak Amp dB re 1 m
93	68.832	0.126513	8.708153164	202.0427134	238.7985212
94	68.5368	0.129758	8.893194642	202.2626795	238.981156
95	68.61168	0.128586	8.822517207	202.1838892	238.9118503
96	67.00896	0.134015	8.980222263	202.5430842	239.0657417
97	67.464	0.134019	9.04146469	202.5433341	239.1247758
98	67.7736	0.136586	9.256921847	202.7081208	239.3293319
99	66.456	0.134314	8.925998667	202.5624524	239.0131364
100	64.9728	0.133559	8.677724947	202.5134859	238.7681176
101	63.97056	0.138963	8.88956764	202.8580097	238.9776128
102	64.91376	0.137394	8.91878186	202.7593755	239.0061108
103	64.944	0.135887	8.825039753	202.6635527	238.9143334
104	64.512	0.135832	8.762824874	202.6600725	238.8528826
105	64.512	0.127801	8.244698081	202.130685	238.3234951
106	64.35072	0.125348	8.066219935	201.962333	238.1334012
107	64.35072	0.127878	8.229063448	202.13594	238.3070082
108	64.11024	0.136501	8.751090874	202.7026958	238.8412439
109	63.40752	0.129474	8.209652655	202.2436803	238.2864957
110	64.152	0.127924	8.206605228	202.1390668	238.2832709
111	64.19088	0.124839	8.013542211	201.927024	238.0764906
112	64.44	0.126005	8.119753207	202.007746	238.1908566
113	64.008	0.126888	8.121822784	202.068385	238.1930702
114	64.43136	0.13089	8.433404658	202.3381128	238.5200588
115	64.008	0.127976	8.191465162	202.1425466	238.2672318
116	64.89648	0.120305	7.807358109	201.6056592	237.850082
117	64.728	0.128248	8.30125444	202.1610307	238.3828745

118	64.89936	0.128229	8.321979858	202.1597249	238.4045332
119	66.56976	0.119822	7.976500973	201.5707086	238.0362485
120	66.84336	0.127718	8.537129615	202.1250721	238.6262375
121	67.16448	0.131413	8.826256046	202.3727373	238.9155304
122	67.968	0.12285	8.349876022	201.7875107	238.4336005
123	68.20992	0.116722	7.961617095	201.3430749	238.0200257
				AVERAGE	**238.5753331**

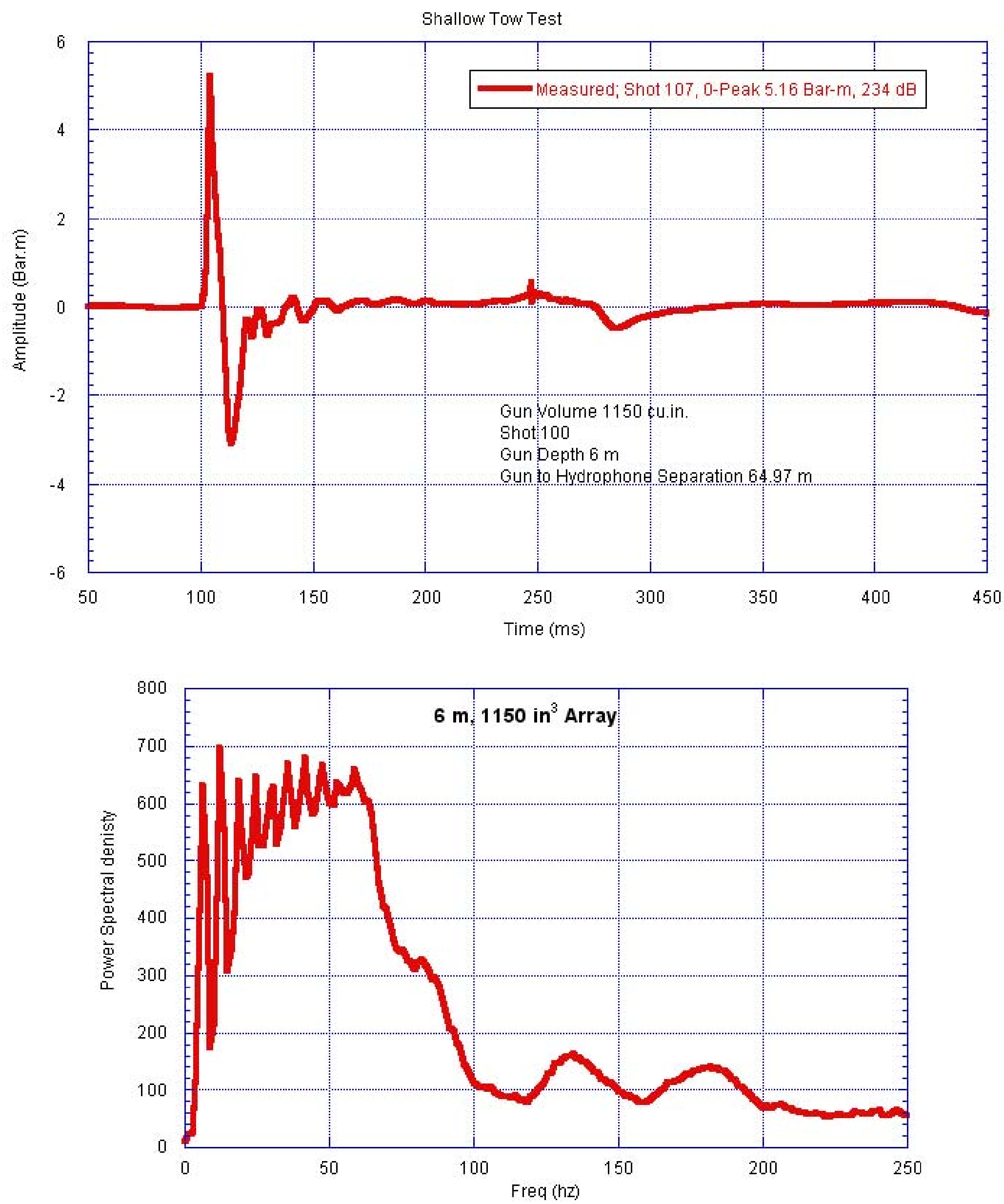


Figure 4-63. Shallow tow configuration calibration test result, shot 107. Top is a time domain shot signature showing a zero to peak amplitude of 5.16 bar-m or 234 dB re 1 μPa at 1 m. Bottom is the frequency spectrum plot for this trace, showing significant power between 2 and 60 Hz with notching occurring at 100 to 120 Hz, caused by the bubble pulse period.

Model

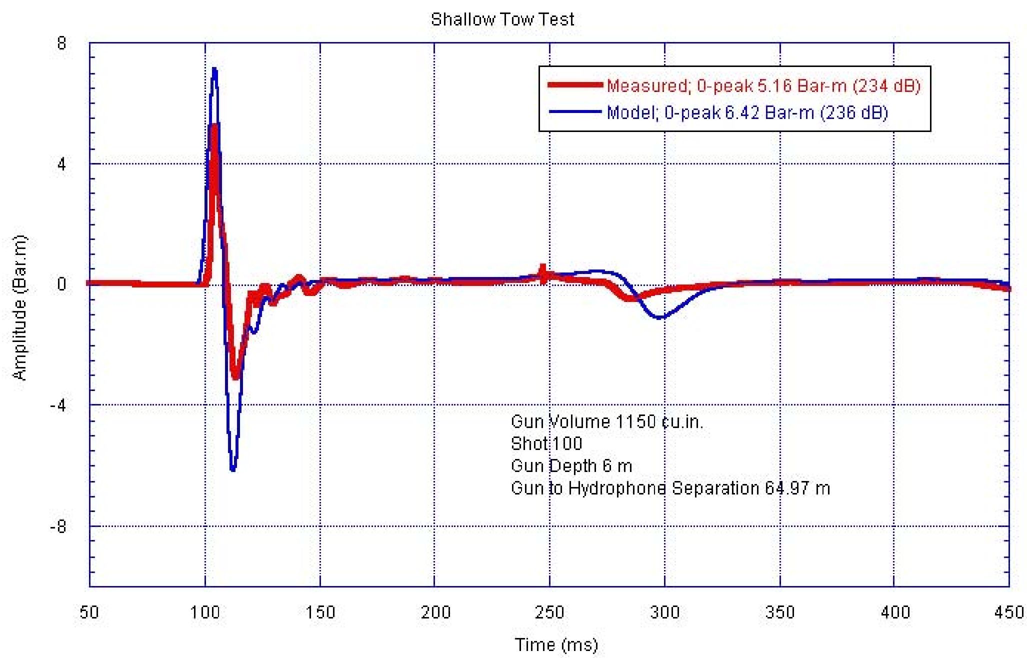


Figure 4-64. Comparison of the measured and modeled time-signature results. Note the 0-Peak amplitude of the model suggests 6.42 Bar-m (236 dB re 1 mPa @ 1 m), while the measured result is 5.16 Bar-m (234 dB re 1 mPa @ 1 m). This difference is consistent but unexplained. See Appendix C for modeling results details.

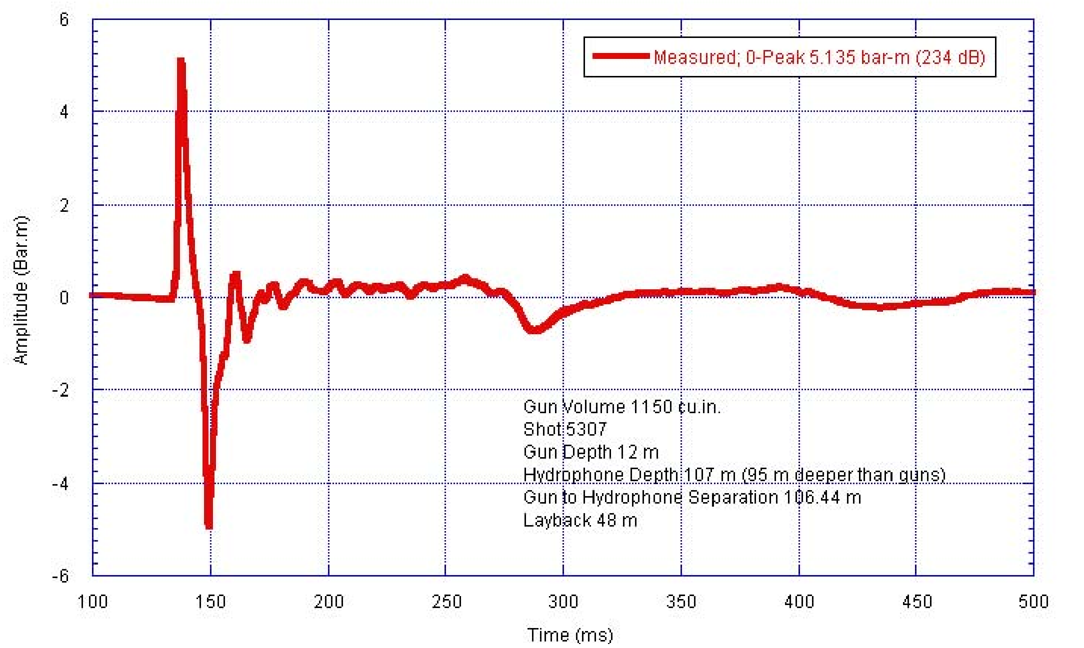
	Model/Measure Bar-m	Model/Measure MPa	Model/Measure db re 1 μPa@1m
Peak to peak in bar-m.	12.9 / 8.50	1.29 / 0.850	242 / 238.6
Zero to peak in bar-m.	6.33 / 5.40	0.633 / 0.540	236 / 234.6
RMS pressure in bar-m.	4.48 / 2.375	0.448 / 0.237	233 / 227

Table 4-15. Table of amplitude values reported from the model compared with the field measurement (RMS was calculated for the initial positive and negative peaks of the signatures - a duration of 20 ms).

Hydro-phone Depth (m)	Trace	Distance (m)	Amp (Bar)	Amp (Bar.m)	0-Peak Amp (dB)	0-Peak Amp dB re 1 μPa@1m
107	5307	106.44	0.049692425	5.289	193.93	234.5
104.2	5308	107.60	0.04803056	5.168	193.63	234.3
101.85	5309	108.11	0.04695705	5.076	193.43	234.1
98.86	5310	108.58	0.047067735	5.111	193.45	234.2
96.3	5311	109.18	0.047847748	5.224	193.60	234.4
94.2	5312	109.44	0.046665367	5.107	193.38	234.2
92	5313	109.65	0.046593013	5.109	193.37	234.2
90.2	5314	110.49	0.047146439	5.209	193.47	234.3
88.08	5315	110.72	0.045459398	5.033	193.15	234.0
86.4	5316	111.44	0.045696872	5.092	193.20	234.1
84.9	5317	111.79	0.045353476	5.070	193.13	234.1
			Average	**5.135**		**234.2**

Hydro-phone Depth (m)	Trace	Distance (m)	Amplitude (Bar)	Amplitude (Bar.m)	Peak-Peak Amp (dB)	Peak-Peak Amp dB re 1 m
107	5307	106.44	0.090562924	9.640	199.14	239.7
104.2	5308	107.60	0.094785972	10.199	199.53	240.2
101.85	5309	108.11	0.092606064	10.011	199.33	240.0
98.86	5310	108.58	0.093101652	10.109	199.38	240.1
96.3	5311	109.18	0.095314902	10.406	199.58	240.3
94.2	5312	109.44	0.090167815	9.868	199.10	239.9
92	5313	109.65	0.093468864	10.249	199.41	240.2
90.2	5314	110.49	0.09026285	9.973	199.11	240.0
88.08	5315	110.72	0.086167498	9.541	198.71	239.6
86.4	5316	111.44	0.090268747	10.059	199.11	240.1
84.9	5317	111.79	0.088463308	9.890	198.94	239.9
			Average	**9.995**		**240.0**

Table 4-16. Average amplitudes (0-peak and peak-peak) for calibration trials with the deep tow configuration.



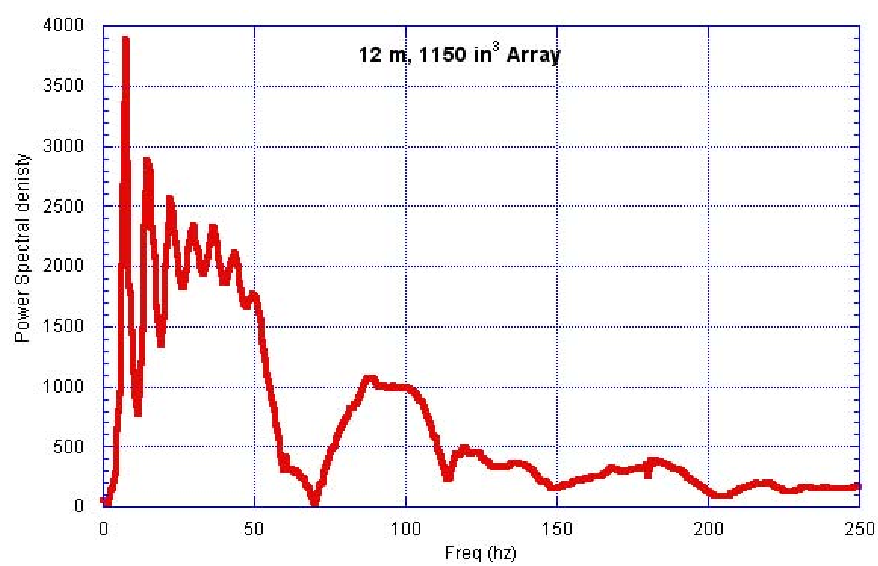


Figure 4-65. Deep tow configuration calibration test result, shot 5307. Top is a time domain shot signature showing a zero to peak amplitude of 5.135 bar-m or 234 dB re 1 µPa at 1 m. Bottom is the frequency spectrum plot for this trace, showing prominent power between 2 and 60 Hz with notching occurring at 65 Hz, caused by the bubble pulse period.

Model

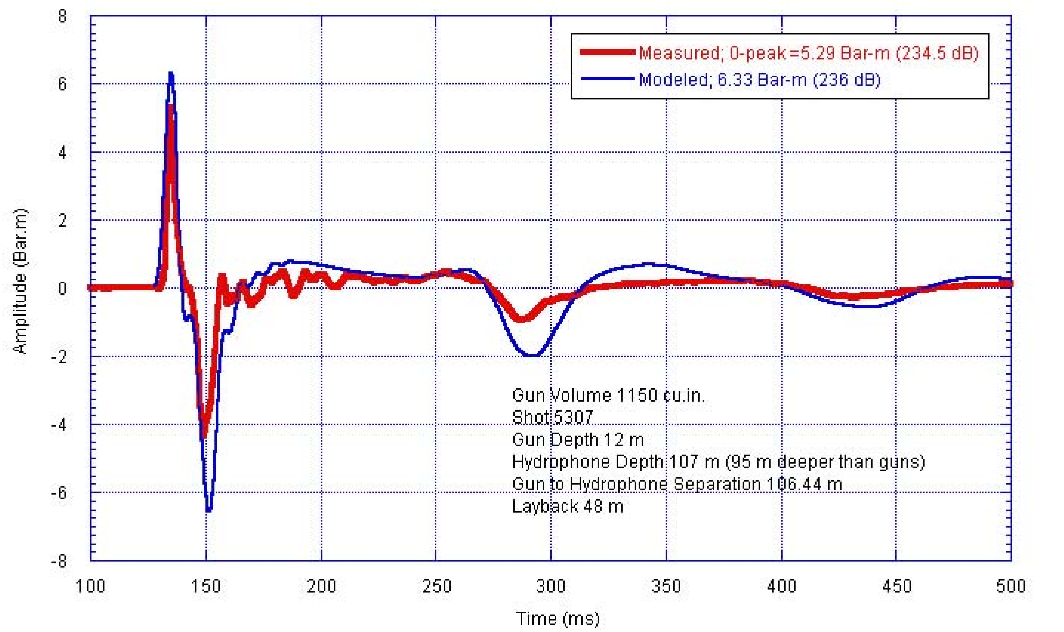


Figure4- 66. Comparison of the measured and modeled time-signature results. Note the 0-Peak amplitude of the model suggests 6.33 Bar-m (236 dB re 1 mPa @ 1 m), while the measured result is 5.29 Bar-m (234.5 dB re 1 mPa @ 1 m). This difference is consistent but unexplained. See Appendix C for modeling results details.

	Model/Measure Bar-m	Model/Measure MPa	Model/Measure db re 1 µPa@1m
Peak to peak in bar-m.	12.9 / 10.0	1.29 / 1.00	242 / 240.0
Zero to peak in bar-m.	6.33 / 5.29	0.633 / 0.529	236 / 234.5
RMS pressure in bar-m.	4.48 / 2.49	0.448 / 0.249	233 / 228

Table 4-17. amplitude values reported from the model compared with the field measurement

(RMS was calculated for the initial positive and negative peaks of the signatures - a duration of 20 ms).

2009 Result

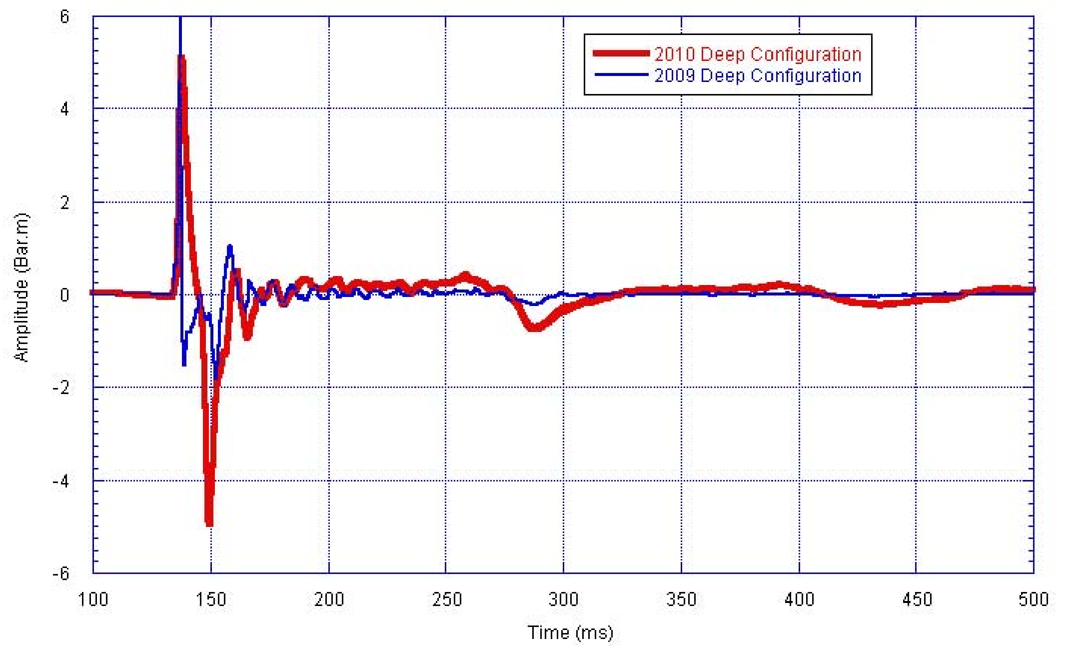


Figure 4-67. A comparison of measurements made in 2009 with those of 2010.

Discussion

Results of the 2010 calibration experiments are considered quality results. All known variables are accounted for, including complete calibration of the hydrophone and digitizing systems. The shape of the impulsive pressure response of the pneumatic array is consistent from shot to shot and agrees well with the shape of predicted results from the Gundalf 6.1 model, including pulse width and bubble oscillation period. Absolute peak values however, are less, by 2 dB on average. This discrepancy cannot be readily explained, but results are consistent amongst all shots and for the two separate experiments. Given these measured results, assuming a 20LogR loss in the water column, a zero-to-peak source level of 180 dB is reached at 500 m. This radius agrees with attenuation results made in 2009 (see Mosher et al., 2009). In 2009 measurements, however, the shape of the impulsive response was particularly unusual and could not be explained. A fault in the calibrated hydrophone was found and clearly this had an impact, if not on the amplitude level, then at least on the shape of the pulse recorded. As a result, 2009 results are considered invalid and for all further analytical and processing endeavours, the 2010 results should be employed.

Application of a mini-CTD on the hydrophone allowed the depth of the hydrophone during the course of the experiment to be recorded. The depth clearly varied significantly (see Table 2), but source levels are consistent. This result indicates the source is omni-directional over the range of measurements made.

Chapter 5: Ice and Weather Observations

Bruno Barrette

Introduction

I joined the CCGS Louis S. St-Laurent with the crew change, in Kugluktuk, Nunavut, on August 4th, 2010 at 2100Z. I replaced ISS Erin Clark that had been with the ship from St John's to Kugluktuk. Erin would stay on board until August 10th, date at which she transferred to the USCGC Healy to perform ISS duties on the American Ship

I completed my assignment on the CGBN on September 15th, date of the crew change. ISS Erick Thibault will be replacing me.

Daily Log: Beaufort Sea Unclos Operations 2010

BREAK-DOWN OF LOUIS S. ST-LAURENT UNCLOS OPERATIONS (including ice conditions along the way)

This part of the report summarizes, in chronological order, ship operations from August 4th to September 15th
2010. It also describes the ice conditions encountered along our way

August 4th :
ISS Bruno Barrette arrives on board at 14h00 PDT. In the evening, Erin Clark (ISS being relieved) briefs me on the ISS duties and operational particularities of the work on CGBN (familiarization).

It is to be noted that, during the whole UNCLOS survey mission, the USCGC Healy was taking the CGBN under ice escort for the greatest portion of the voyage with the exceptions of transit legs from one to another waypoint (science gear not deployed). During those transits, the CGBN was the leading ship.

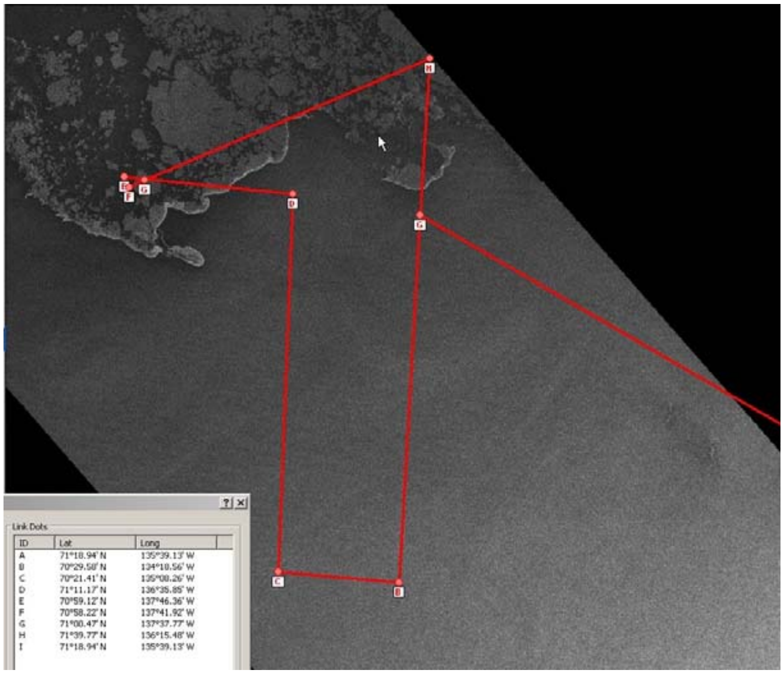
August 5th :
The ship remains in Kugluktuk. During that time, the new crew members are given the usual shipboard security briefings (ship and helicopter). I also verify all ISS equipment in preparation for ice operations. Most of the time is spent with Erin training on the IceNav system. Operation on this system was entirely new to me. I received a one-day course, in Montreal, two years ago and I had read the user's manual prior to boarding. Erin did a great training job.

August 6th:
Departure around noon. We were in Dolphin Union Strait at 17h30 PDT. Ice free waters.

August 7th:
Transit through Amundsen Gulf. Ice free waters.

August 8th:

We arrive at the first deployment station. The routing of the test run had been chosen in mostly open water so that the seismic gear can be verified and calibrated. The testing took place overnight. Refer to the image on the next page for details of the route taken.



Take note that a diagram of the entire UNCLOS Mission Tracks has been inserted at the end of the present document

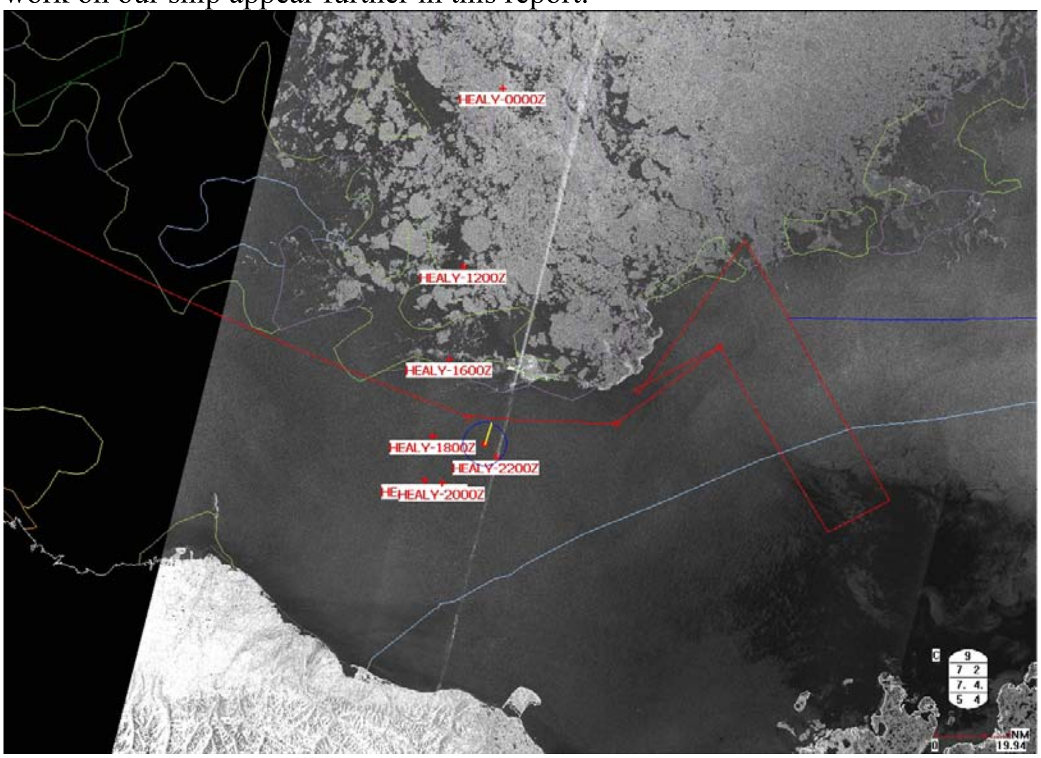
August 9th:
Testing and verification of seismic equipment is well under way. The whole leg took place in open water (see picture on the next page) since the ice edge had been drifting with winds north of our travel line.

Erin and I discuss the routine that we will use to ensure good communication while she is on the Healy.

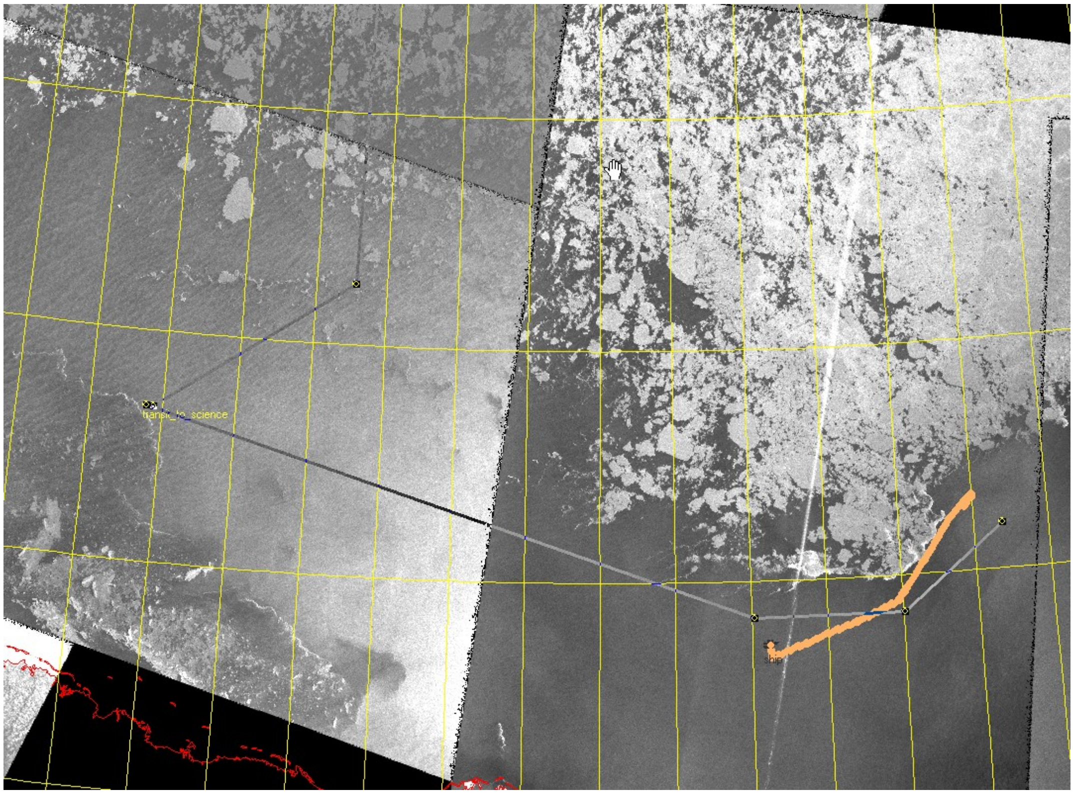
That is:
(1) Set times for daily weather and ice briefing preparations to ensure consistency and accuracy,
(2) Determination of which ice chart will be sent to CIS Ottawa daily
(3) Identify the means that will be used to transfer data (imagery and ice information) between the two ships.

It is to be noted that our routine worked very efficiently and that the line of communication was excellent between the two of us. Also note that the ice charts produced on CGBN, most of the time, were sent to Ottawa rather than the one produced on the NEPP. When airborne reccos were performed, the CGBN chart was always the one sent out.

August 10th:
The science gear is brought back on board. We begin the transit to 141W, point where we will rendez-vous with the USCGC Healy. The two ships meet, in open water, at 17H30 PDT (see image on the next page). Erin Clark transfers on the Healy and Caryn Panowicz (Ice analyst with the NIC, in Washington) boards the CGBN at 18h30 PDT. I meet her on the flight deck and, later on that night, give her a tour of the vessel. Comments on her work on our ship appear further in this report.



August 11th:
The course set to reach the first leg of the UNCLOS program track lines must be altered. A medevac trip was to be done to Tuktoyaktuk to ensure the safe return to land of one of our crew members. The medevac course took us through open waters to within helicopter range of Tuktuyaktuk.. The transfer was made late in the evening. The transit back to the base leg of UNCLOS started overnight. The image on the next page shows the transit route to the base of the first leg of science work. It shows the entire first line of seismic surveying. The southern portion of Leg 01 was near the ice edge of sparsely distributed TFY decayed ice that exceptionally lingered near 147W.



August 12th:
We arrive at the base leg 01 at 15h00 PDT. The science seismic gear is deployed right away. Science surveying work begins along a route to the NNE in direction of the main ice edge. We attain the edge at about 1 AM on the 13th.

August 13th:
The first technical problems arise with the scientific equipment. Tests are done in open water and we are back on course at 16h00 PDT. Ice conditions: Very low concentrations of old ice in small floes (1 to 2/10) except at 7210N 14530W where a two nautical miles wide band of ice shows 9/10 old ice.

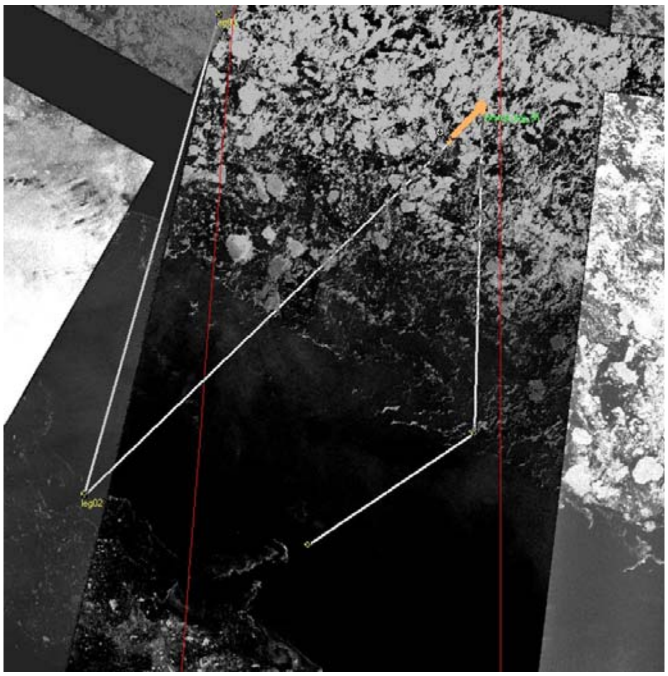
August 14th:
The second portion of Leg 01 is completed by 15h00 PDT. The first part of Leg 02 in a SW direction is undertaken. See the depiction of Leg 02 on the next page. Ice conditions: the entire leg took place in generally easy to moderate ice conditions with 6 to 7/10 total concentration with 4 to 5/10 of multi year ice (MYI) and 2 to 3/10 of decayed TFY.

August 15th:
The Leg 02, started yesterday, brings us back out to the ice edge at around 13h00 PDT (7250N). Before reaching the edge, the ship was in light ice conditions showing 4/10 total concentration with 3/10 old ice and 1/10 TFY. Past the edge we were in open water to the end of the leg.

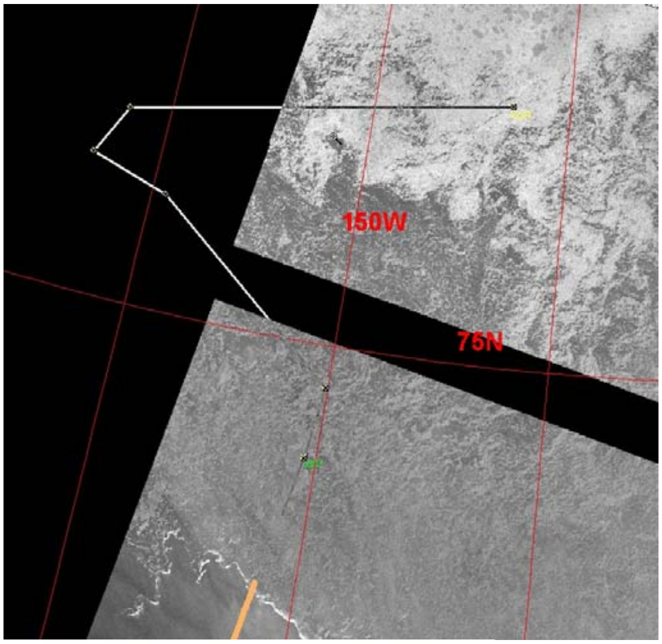
We had to navigate through strong easterly winds blowing at a sustained 30K. The winds continued overnight.

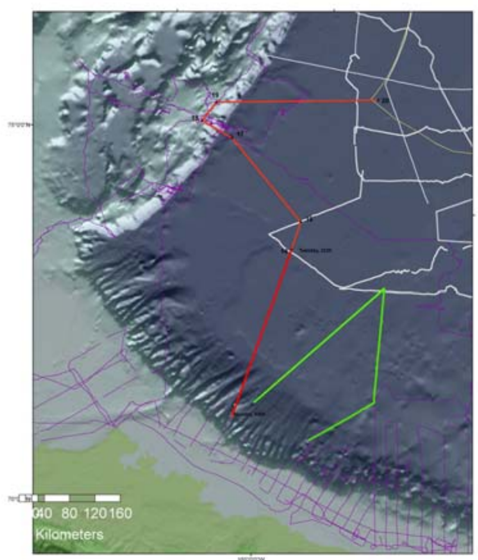
August16th:
Leg 02 was completed by mid-afternoon and we were on our way on Leg 03. We started in open water. At the end of Leg 02, we encountered very light decaying old and TFY ice (2/10 or less). We see an illustration showing legs 01, 02 and 03 on next page. Leg 03 is the latter portion of the segments.

The picture below shows Leg 01, 02, and 03



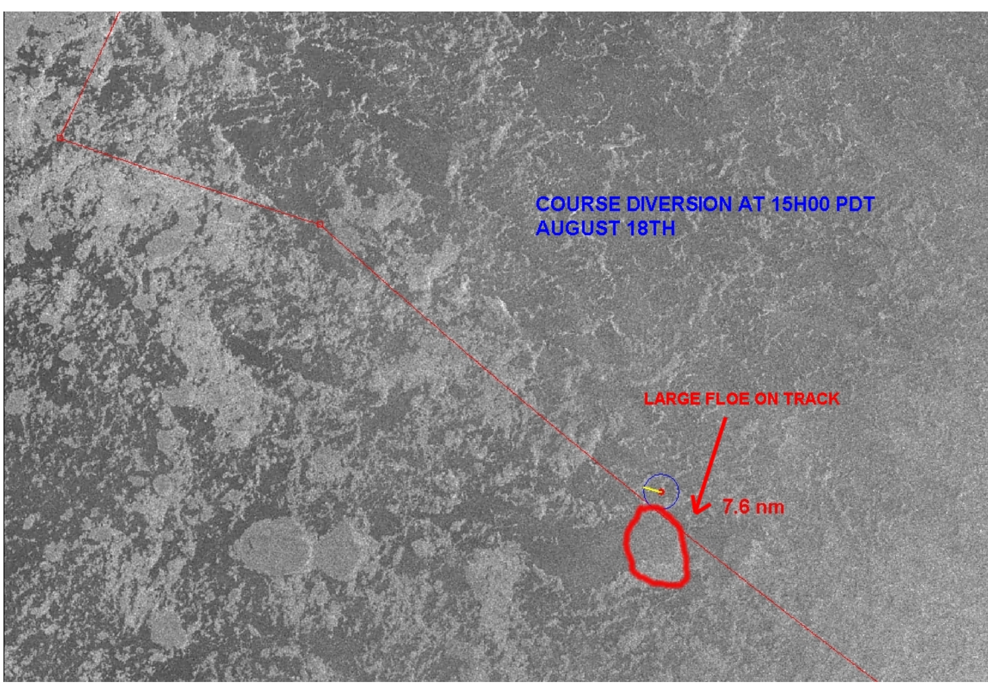
The picture below shows waypoints of the fourth surveying leg (WP16 to 20). On the next page, we see the diagram used by the science team.





August 17th:
We are progressing along Leg 03. We rendez-vous with the USCGC Healy returning from Barrow AK. The American ship picked up the replacement of the person evacuated on medevac and equipment parts. A first helicopter recco was performed to the end of leg 03 . Ice conditions: southern portion to 74N: 3 to 4/10 ice with 90% old ice and 10% decayed TFY – northern portion: 6/10 total concentration with 5/10 MYI (few thaw holes) and 1/10 TFY. The picture below illustrates the ice conditions encountered

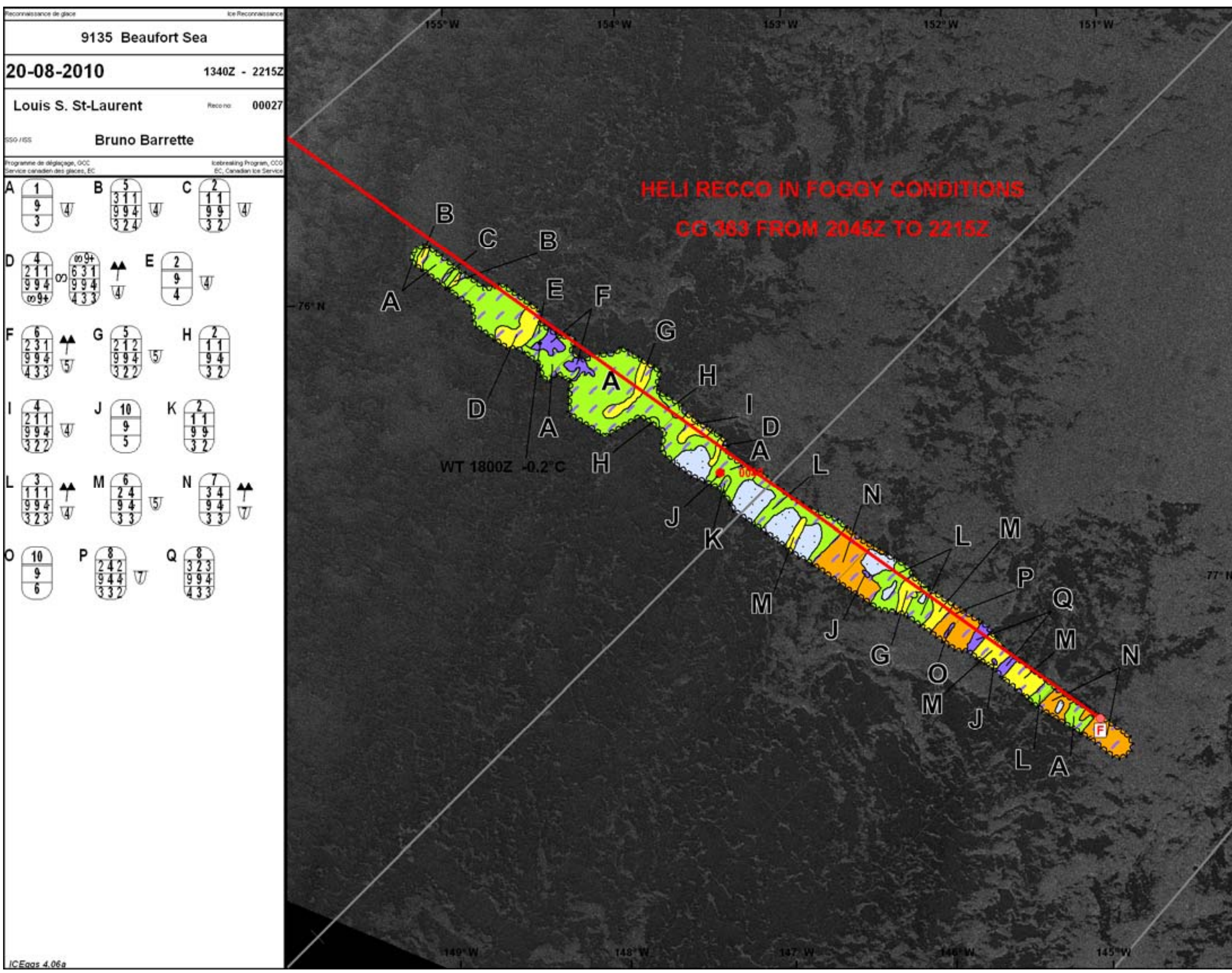
August 18th:
The ship starts to make its way along Leg 04. A helicopter recco is done along the track (to approx 100 NM ahead). A giant floe blocks our way at 75N 152W. It forces a diversion of the course around 15H00 PDT (see image below). The science team is upset to get off track. It seems that their data is greatly affected when the ship moves off track. Notwithstanding, the easiest line of progression comes first. The floe was more than 10 NM across of solid MYI. The rest of the track presented 7/10 total concentration made of 5/10 MYI and 2/10 TFY with few ridges and thaw holes.



pro

August 19th:
The first portion of the 4th leg is completed. Maintenance has to be done on the seismic equipment. To put it back in the water, we need to travel to open water. It is decided that a transit without measurements would be done to WP 18 (NW corner on the picture above). The latter portion of leg 04 (142NM) is to the east (see track picture of preceding page.). At the beginning of Leg 04, we found total concentrations between 6 and 9/10 of ice with 85% old ice and 15% decayed TFY.

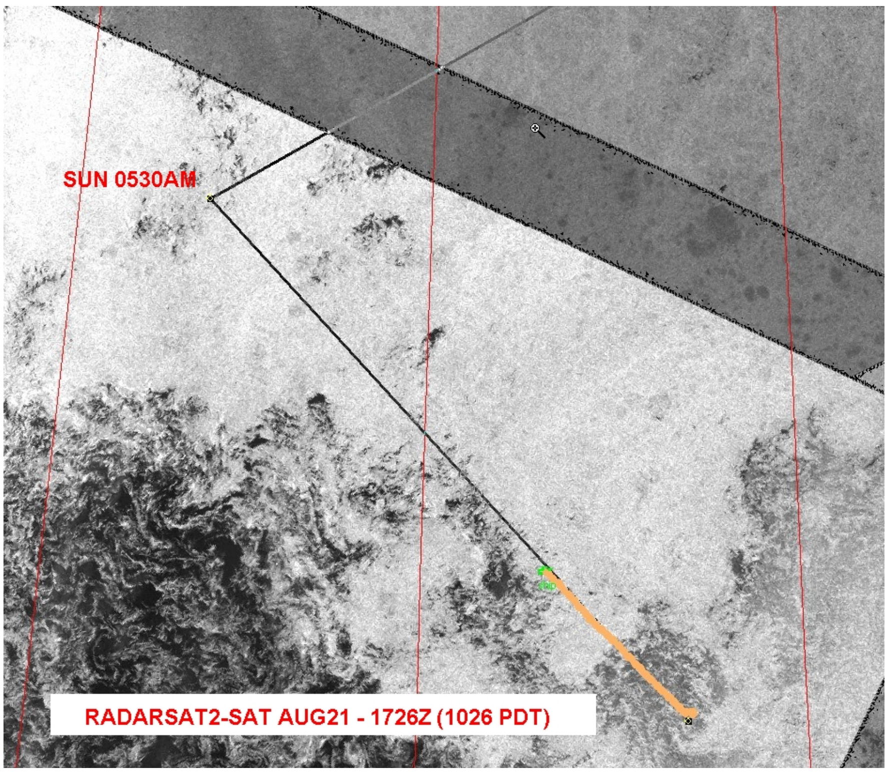
August 20th:
We continue our route to the last WP on route 04. A helicopter recco is done along our track at very low altitude and foggy conditions.. Erin and Josh (US Ice Specialist) accompany us. See recco results below. Note that the chart is NOT set North up.



August 21st

Leg 05 is started (see picture next page). Seismic equipment continues to work without problems. Pictures of ice conditions are sent to the Canadian Ice Service in Ottawa to confirm the predominance of thick first year ice on our track. This information was used to adjust the daily ice analysis chart (justifying photo next page). Reported ice conditions were: 8 to 9/10 total concentration with 2 to 4/10 of MYI and 5 to 6/10 of decayed TFY. With the cold temperatures, 1/10 of newly formed nilas was also reported (air temp was -3C and water temp -0.4C). Very few large floes of MYI were encountered.

August 21st - Leg 05:



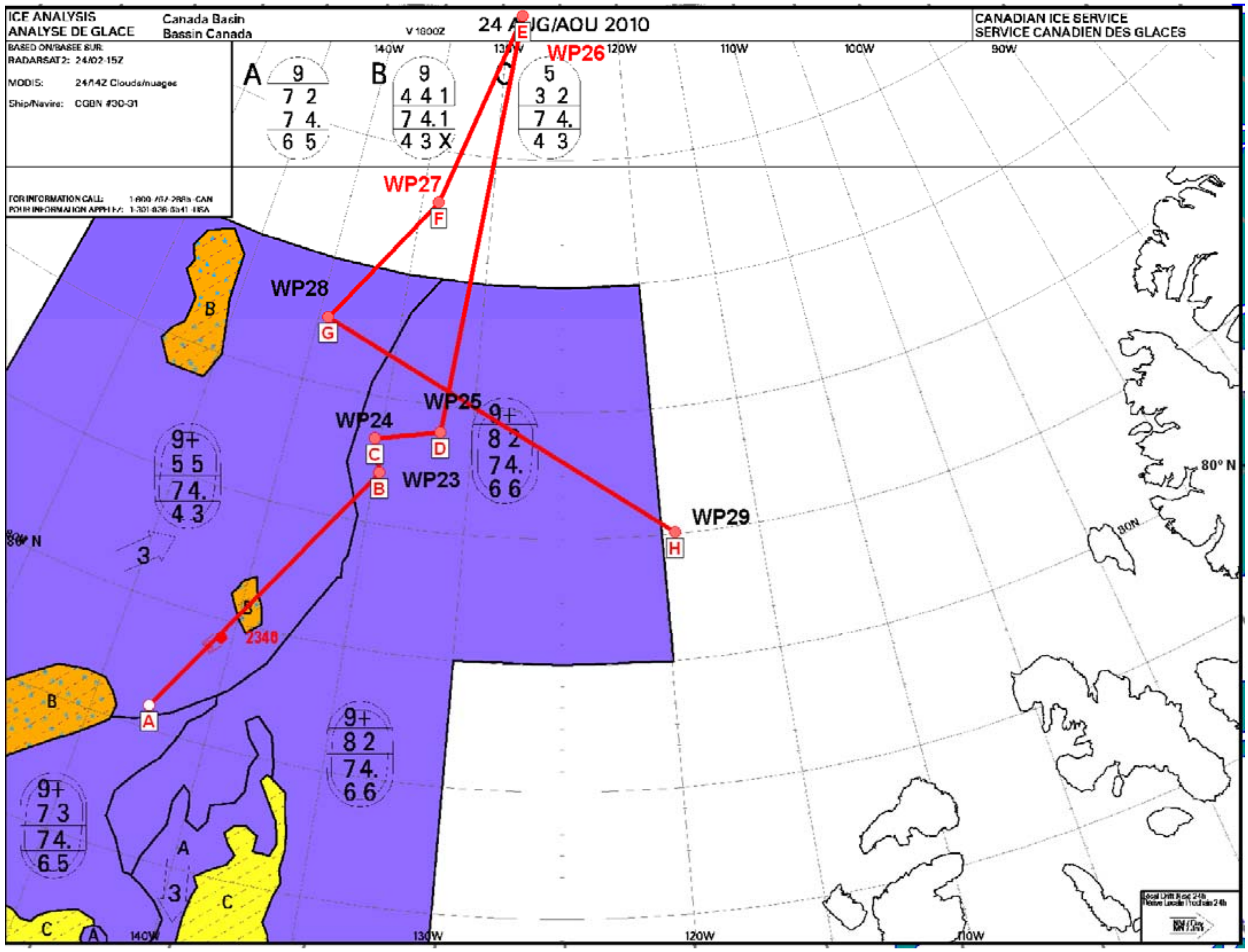
August 21st: Predominance of thick first year on first portion of leg 05:

August 22nd:
We continue our way on the second portion of Leg 05. A helicopter recco was done to the end of the leg. Many pictures were taken. They were sent to CIS Ottawa and Sarnia Ice Office. They depicted the predominance of TFY ice (or second year ice) in its late melting stage and decayed old ice floes (proportion 6/10 TFY-SYI and 4/10 MYI). The northeast portion of the leg (north of 79N) had a predominance of old ice. The picture below is representative of these conditions.

August 23rd:
The planned tracks into the northern portion of the UNCLOS program (north of 80N) are been mapped out. We start on the first portion today. To WP 23 (see chart on next page). A helicopter recco is done ahead of ship. Ice conditions become clearly with a

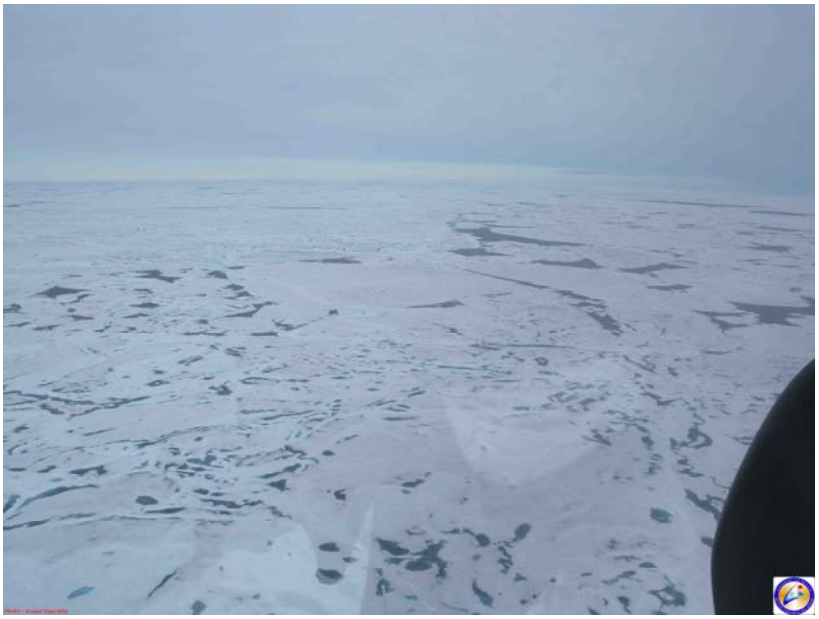
predominance of MYI and the floe sizes increase very significantly. However, ice is not under pressure due to the absence wind. (see the picture below depicting ice conditions).

August 24th:
Last night, a serious mechanical problem arose with a shaft. It brought the ship to a halt so the repairs could be done. The day was spent at 7950N 141W. Repairs were finished late in the evening and the ship was on its way. The planned northern leg was modified to include a dogleg of surveying over a newly discovered seamount (shown by WP23, 24 and 25). Waypoints 26 and 27 were established well to the north (up to 85N). See the Canada Basin ice chart below showing the original planned track (WP23 to 29) along with ice information.



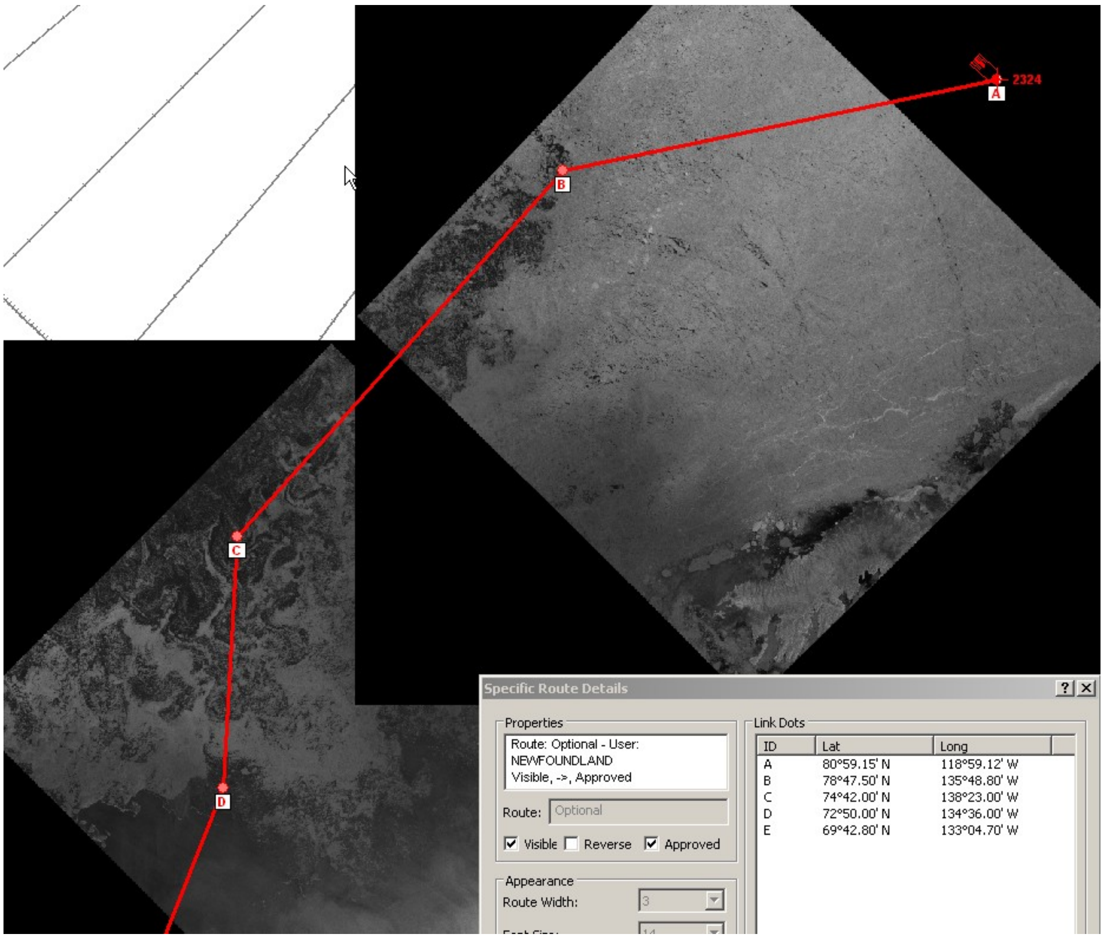
August 25th:
In light of the accumulated delays since the beginning of the mission, the members of the science team decide to eliminate the northern legs of the originally planned track lines (see above WP23 to WP28). The track was modified to become a direct survey line from WP23 to WP 28. From there, the segment between WP28 and WP29 will be sounded. A helicopter recco was done along the track between WP23 and WP28. As this point, there was definite predominance of thick MYI. Conditions are now: 9/10 total concentration with 8/10 MYI and 1/10 TFY. Many floes 2 to 5 NM across were seen. Progression of our ships becomes more challenging.

August 26th:
Early in the morning, we are well on our way to WP29 (NW to SE portion of the track, see illustration on the preceding page). A heli recco is done and shows the observe the roughest ice conditions encountered so far on our trip (see pictures below). We observe mostly thick MYI with many thaw holes. We found numerous vast and giant floes on our track. All were reported on the chart. Significant ridge lines up to 15 feet in height barred the track.



August 27th:
Little progress was made today. Multiple adjustments needed to be made to the seismic equipment. It was taken out and back into the water a few times. It was decided that the back-up gear needed to be put in place. A CTD (Conductivity, Temperature, and Density) was done along with expendable CTD's. At 20h00 PDT, the seismic equipment is pulled out for good, the CGBN then commence leading icebreaking duty taking along with the USCGC Healy surveying on Multibeam. We are in direction WP29. Ice conditions: 8 to 9/10 mostly old ice (1/10 TFY) in large and very large floes.

August 28th:
The ship almost reached WP29 when a medevac was declared. The evacuation would take place in Tuktoyaktuk. The shortest ice route to the ice edge was chosen and the ship redirected. The illustration below shows ice conditions along the medevac transit (illustration is NOT north up). Ice conditions remain as yesterday, mostly MYI.

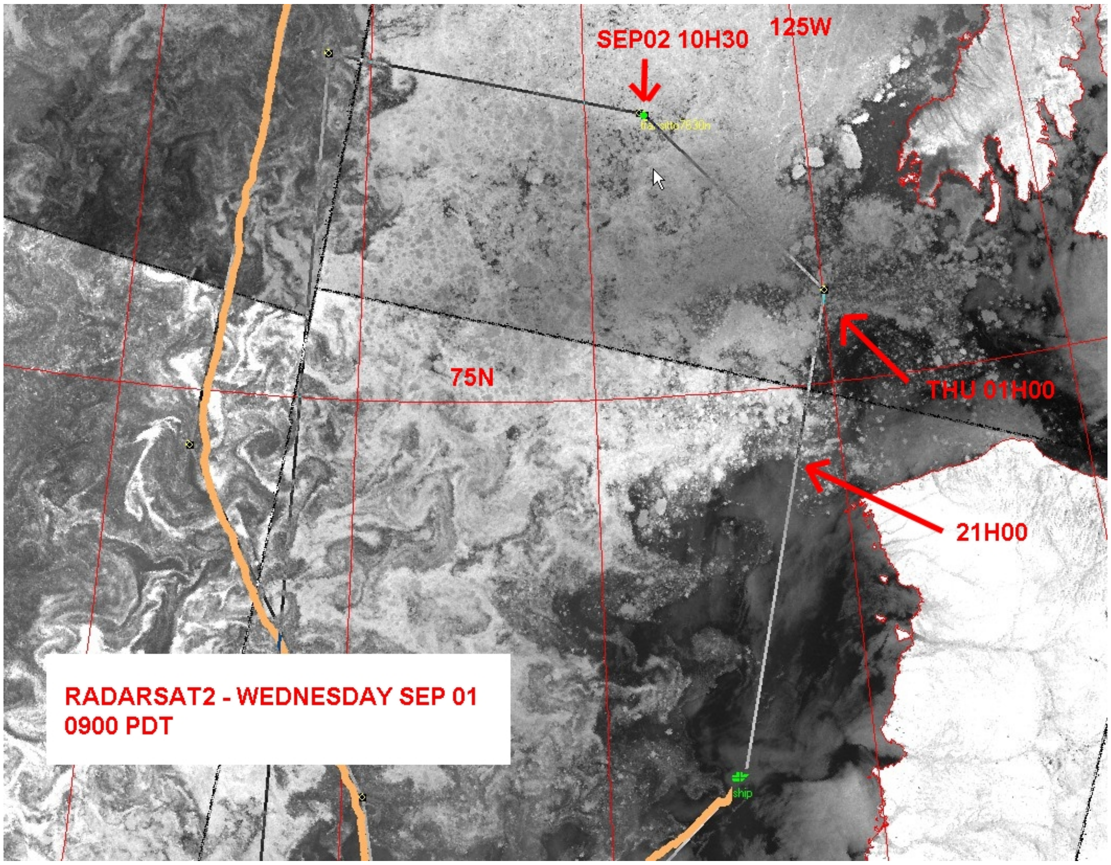


August 29th:
Pursuing on the medevac route, NEPP is the leading ship through ice. Conditions remain in very closed pack of MYI with 1 to 2/10 TFY. There is presence of vast floes (2 to 10K across).

August 30th:
Continuing our way south, we are out of the main MYI ice pack in the morning at 78N. Concentrations diminish to 6 to 8/10 with predominance of MYI.

August 31st:
We attained the southern portion of the medevac route in late afternoon. The helicopter is dispatched to Tuktoyaktuk at 18h30 PDT. The routing to reach the next science leg is

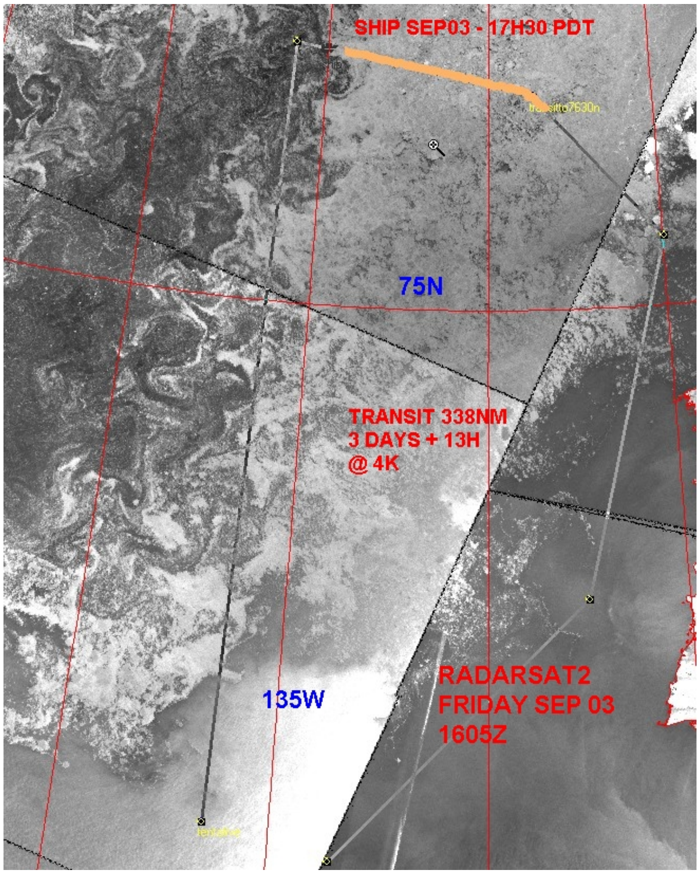
established. The route was chosen as the longest possible distance in open water to reach the ice pack NW of Banks Island (see picture below)..



September 1st:
Enroute in direction of the next science survey leg. Mostly in open water.

September 2nd:
A heli recco is done up to the starting WP (7630N) of the next science leg. Unfortunately, the latter portion of it was performed with very limited visibility. Ice conditions were difficult with 9/10 total concentration made of mostly MYI in mostly large or very large floes. There was presence of ridging. WP 7630N is reached at 18h30 PDT. The seismic surveying equipment is submerged and work is started. NEPP is leading for icebreaking.

September 3rd:
Surveying is continued in direction of the western end of the track. The illustration on the next page shows the ship's position at 17h30 PDT. Separation with the USCGC Healy takes place at that time. Erin Clark returns on board and Caryn Panowicz returns to her ship. Conditions on this leg change to an equal distribution between old and TFY ice.



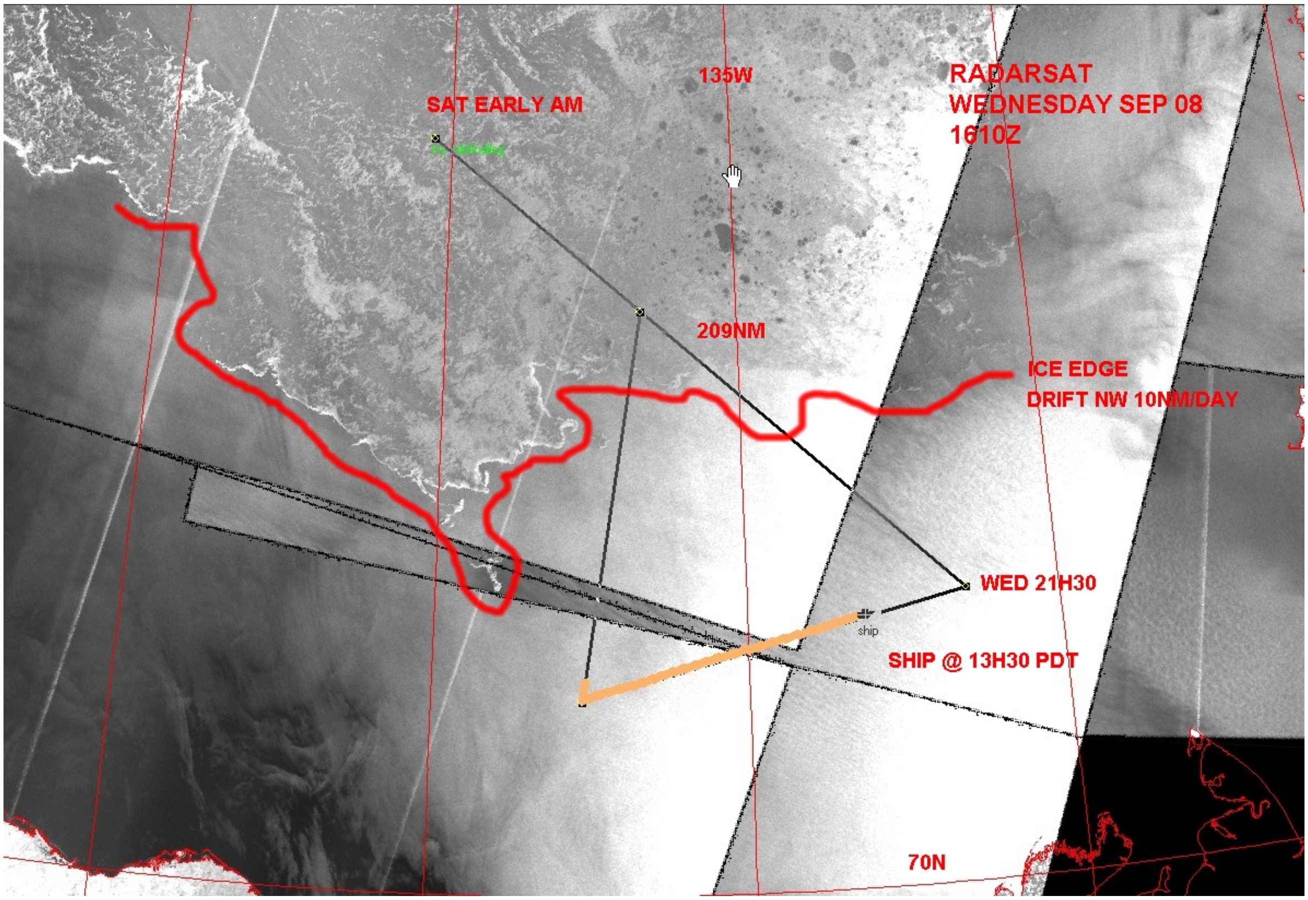
September 4th:
The ship is now on the southern portion of the leg. Ice conditions improve at 76N (lower concentrations – 6 to 8/10). It is to be noted that significant concentrations (3 to 4/10) of decayed second year ice were reported from 77N and south.

September 5th:
Continuation of the southern leg. Ice conditions: 8 to 9/10 total concentration with 4 to 5/10 MYI, 3 to 4/10 SYI and 1/10 TFY.

September 6th:
Open water is reached at approximately 72N. Continuation of the southern portion of the leg.

September 7th:
The southernmost point of this leg is attained. The ship will now transit in open water to the SE base of the last UNCLOS science leg to be done on this trip.

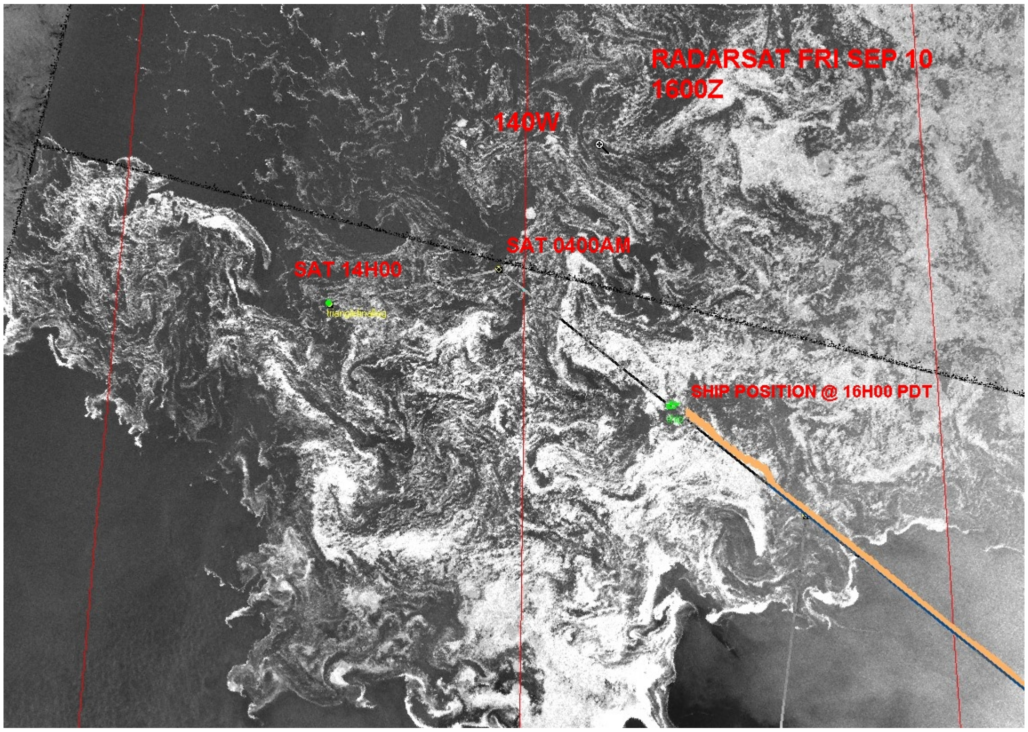
September 8th:
We transit to the beginning point of last science leg. The figure on the next page indicates the ship's position in the afternoon.



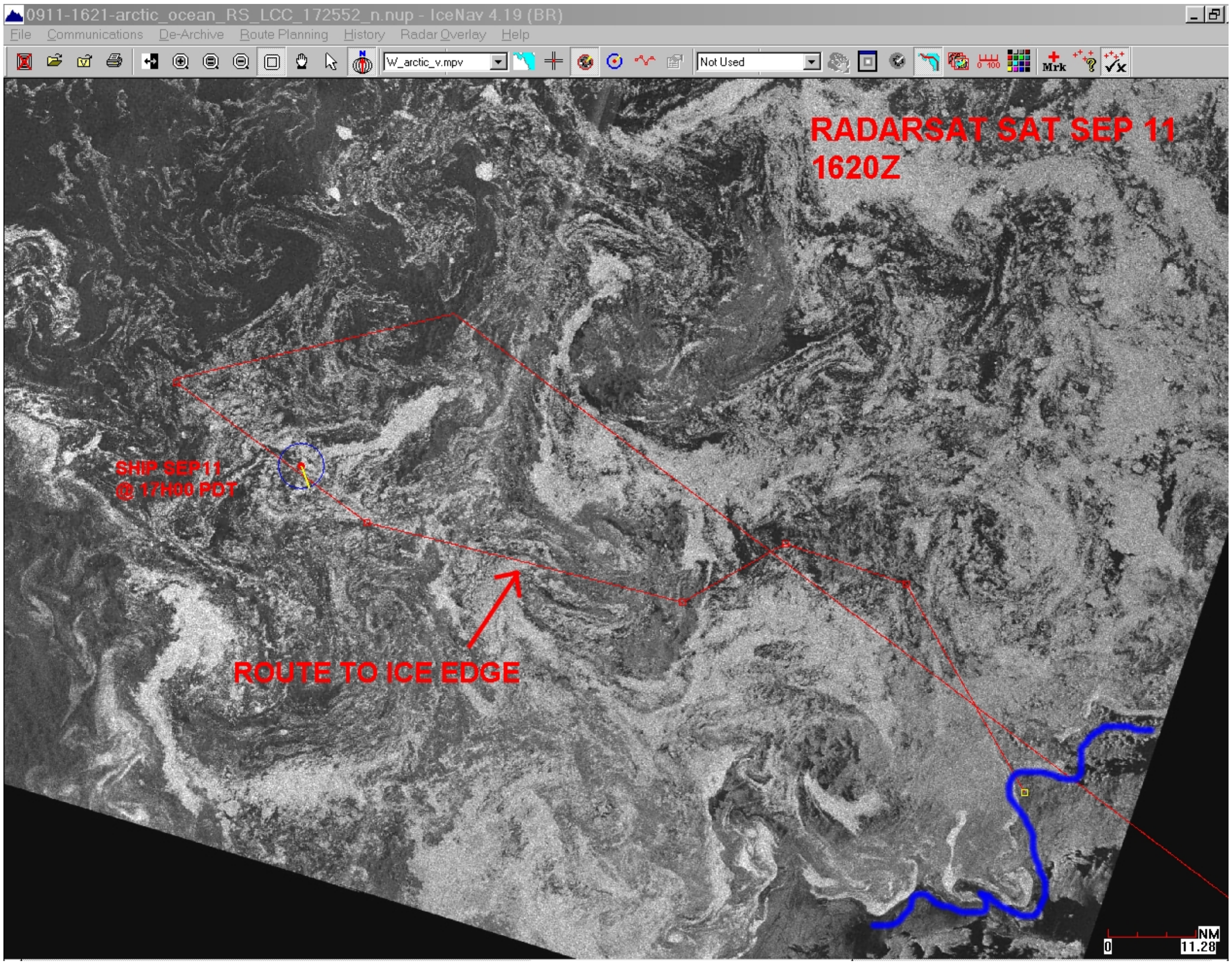
to

September 9th:
The day is spent in open water in a NW direction to the end point of the last seismic survey line.

September 10th:
The ship is close to completion of the survey line. An additional short portion of leg is added to the original plan. The image on the next page shows the new planned route. The ship reentered ice at 72N. Ice conditions to the end of the line were generally 3 to 6/10 total concentration with 85% old ice (MYI and second year) and 15% decayed TFY. A section around 73N had higher concentrations closer to 9 to 9+/10.



September 11th:
The very last portion of survey line for the 2010 UNCLOS project is completed at noon time. The science gear is taken out of the water. An ice route is established to take the path of least resistance out of the ice pack. The exit travel route begins at 14h00 PDT. The picture on the next page shows the route chosen. The ice concentrations were never more than 70% ice cover (25% of the time) and much lower around 3 to 5/10 (75% of the time) mostly decayed MYI and SYI.



finsi

September 12th:
The ship comes out at the ice edge at approximately 5h30 PDT. We take the open water route in direction of Paulatuk where we will drop off our three marine mammal observers.

September 13th:
We arrive in Darnley Bay (Paulatuk) early in the morning. The marine mammal observers are airlifted back home. The ship is on its way for our crew change destination, Kugluktuk, at 10h00 PDT. Open and ice free water from then on.

September 14th:
We arrive at destination, Kugluktuk, at in the morning. Crew change preparations are undertaken.

September 15th:
Last day on board. Crew change operations are started at XXHXX PDT. It is the conclusion of my ISS duties.

Forty-one (41) daily ice observation charts (charts #12 to #52) were produced during this trip. They were all, without exception, sent to the Canadian Ice Service in Ottawa. Among these charts, eight (8) had, embedded in them, ice conditions determined by helicopter reconnaissance flights. Flights were generally done ahead of the ship to a distance of approximately 100 NM unless weather conditions warranted an early return. Whenever required, draft charts were sent before at 1745Z daily, ahead of the final version. This procedure ensures that the ice forecaster in CIS has preliminary ice information to use in the production of the CIS daily ice charts.

Weather Conditions

Unsurprisingly, weather conditions during our entire Arctic trip were typical of the Beaufort Sea summer season. I had heard of it, now I have seen it!!

For a month and a half (!), Beaufort Sea was under the influence of a stationary high pressure system. From the day of our arrival in the region on August 9th to the day of departure, September 12th, the Beaufort Sea was, for 34 days, in the anticyclonic flow. Only two exceptions to that rule: on August 30th and on September 9th, where 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. Being in the anticyclone signifies that the colder air (cooled by the presence of the ice pack) is trapped under an ever lasting inversion. When moisture from the surrounding open water is added to the mix along with generally light winds (or even absence of circulation); you have the perfect recipe for ever lasting FOG! It was a shallow layer of fog (extending from surface to a few hundred feet upward) but fog nevertheless.

Indeed, we had, count them, twenty-five days with 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.

Consequently, we were did not see sunshine for the longest time. The sun truly shined on only six (count them!) days during our whole trip on the 17th and 18th of August, on the 22nd and 23rd of August and on the 8th and 9th of September. We saw the sun peak through the fog on five other days (August 15, 24, 26 and September 3 and 4), that is when the fog dissipated enough late in the day.

As for the wind patterns, we will easily understand that the circulation was invariably characterized by light winds (15K or less). A few exceptions to the rule: on our transit to Beaufort Sea, winds blew first from the SE at 20K on August 6th and then from the NE at 20-25K with gusts up to 35K on August 7th and 8th. The wind was attained gale force on the 8th generating significant waves and swell (up to 4.5 meters). We had a windy day on August 15th, with easterlies at 25KG30K due to a trof line, on the Alaskan North Slope shoreline, pushing and tightening the western high pressuregradient. The same phenomenon repeated itself on the 7thand 8th of September when winds blew from the SE at 25K with gusts up to 35K.

As for air temperature, if we make exception of the periods when we approached the coastline, temperatures were absolutely stable, as expected in a anticyclonic regime. They remained in a range such that daily minima were near -4C and the daily maxima near +4C. The maximum temperature registered in Beaufort Sea was +7.8C on September 7th, when the southerly flow described above brought milder air to the region. The minimum temperature was -5C recorded on September 5th, near 75N and 135W.

For the first time in my life (!) I did not see the barograph chart indicate a pressure of less than 1006 hPA for a period of more than 30 days (almost six weeks, in fact). The maximum recorded was of near 1033 hpa.

Finally, the winds revived as soon as we left the Beaufort Sea when transiting to Paulatuk and Kugluktuk. We had a steady northwesterly flow at 25K in Dolphin and Union Strait. 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.

Avos Equipment Operation and Malfunctions

The CGBN AVOS station has worked very well and is fully reliable. Comparisons were made for the following parameters: air temperature, wind speed and direction, dew point and corrected barometric pressure. All parameters values were well within limits when compared with traditional instruments measurements.

The water temperature was obtained from the a functional sea water intake in the aft science lab. It was favorably compared with sea bucket measurements.

Two problems will be brought to the attention of the Port Meteorological Officer (Andre Dwyer). I will e-mail him as soon as this report is filed. First, the battery back-up of the UPS unit (Uninterrupted Power Supply) is not functioning (battery is dead). When it went down, the AVOS station stopped all measurements and transmissions. It had to be reset. In order to do so, we have to reset the main breaker in the outside control box. The station restarted normal function after the adjustment

Secondly, the readings for the H-3 average course of the ship (direction and speed – DsVs parameter) is always indicating SE at 5K. Erin Clark and my self tried everything we could think of including (1) ensuring that the ship Gyro was connected properly to the station and (2) verifying the configuration preset station parameters without success. This problem is easily “worked-around” by entering the values manually for each transmission.

Lastly, this year, we began to use an American weather software called UGRIB (installed in the Icevu Computer). It has been put to the test at the beginning of my assignment. It was compared with two long range forecast models. The model is significantly unreliable east of Point Barrow and for the whole of Beaufort Sea region. Understandable when one thinks that it was developed for mid-latitudes. This do not constitute a problem given all other very reliable Canadian and American products available to us for the Arctic regions.

A weather watch was carried out during the whole trip. Four main and intermediate messages were transmitted every day including manually entered-observed parameters. The observations were made at 15Z, 18Z, 21Z and 00Z (day+1). I also kept the barograph running and a complete record of the observations in the old Meteorological Log (I'm an old timer, what can I say!)

Ice Specialist Work Station and Equipment

The Icevu computer at the Ice Specialist work station has been working exceptionally well throughout our trip. The Icevu platform has been working at excellent processing speed. All installed software worked perfectly well, as expected.
Only one strange occurrence to report: every time a session begins after a long period with the monitor in sleep mode, the monitor turns itself OFF once or twice when reactivated. The shut-off last only a few seconds, the it turns back on. After that, it works perfectly fine! I will bring this problem to the attention of our IT specialist in CIS Ottawa on Friday.

The printer also works very well. However, in normal printing mode, it uses up ink cartridges at a very high rate, unless they are of the XL type (extended life). A work-around procedure is to use the printer as often as possible in the draft printing mode.

The Ice Nav station performed perfectly as well. I was surprised at the versatility and efficiency of the system, particularly when compared to the performance of the IceVu system when using Polar Stereoscopic Projection imagery. I have outlined the advantages and disadvantages of the system in our Procedures Manual.

GPS signal feeds to Icevu, Icegg and Ice Nav worked without problems. The Icevu computer is connected to a UPS which prevents problems when a power failure occurs.

In regards to meteorological equipment and supplies, note the following points:

- The barograph works properly and accurately. The clockwork is in good order. Its felt pen is in good condition and many replacements are found in the meteorological supplies drawer of the AVOS station desk. There is a sufficient supply of barograph charts for many months of operation.

- There are multiple ordinary and SST thermometers in stock. Two working shipboard psychrometers are found outside, between bridge level and the observation deck along the stairways both on starboard and port sides (Marine Stevenson screens). Note that there is a good supply rayon tubing and muslins (below zero operation). The water reservoirs are stored in the AVOS station desk drawer.
- There is an operational sea bucket at the quarter-deck, starboard side and a spare in the AVOS station desk drawer.

All ice charts were produced directly from the special work table installed on the port side of the bridge windows. It is an ideal work place for ship recco's. Our new pen computer (Elite Book) was used both from the bridge and during helicopter patrols. As usual, I experienced a few crashes of the Icegg software, nothing that could not be solved quickly. When used on the bridge, our new GPS unit works very well when placed on the window sill. Erin and I ran into one problem with the Icegg software loaded into our new computers. We had error messages issued when finalizing patrols with certain line features. The problem was brought to the attention of our IT specialist, in Ottawa. A fix was found quickly. We only had to reload the Icegg Software sent to us via FTP to solve the problem for good. I used my pen computer plugged into the AC inverter of the helicopter on each flight. It worked perfectly. I did not try the pen with solely the battery pack, but there will be plenty of other occasions to do so.

The new camera provided by EC works like a charm. It is to be noted that the GPS function on the camera does not work in Beaufort Sea probably due to the weakness of GPS satellite signals. Numerous pictures were taken during our trip. Many were used operationally, others to depict ship activities. Some pictures were sent to Sarnia for the "Monday morning operational briefings". Many were sent to CIS Ottawa to illustrate ice conditions in various locations while in operation. All pictures taken during our trip were "burnt" onto a DVD and left with the captain. They were also transferred to the X:\Crew McNeil\Marian\Post-Arctic Ship Public Drive.

The Icegg software displayed all daily CIS ice charts correctly and they were georeferenced.

Most of my idle work time on board gave me a chance to pursue a significant project: I produced a hopefully useful document intended to regroup all procedures the ISS needs to be familiar with when on duty on board CGBN. It was produced, finalized, proof-read and corrected: it has been called the "CGBN ISS Procedures Manual. Such documents do NOT exist on most of the CCGS ships where ISS personnel are assigned. This procedural manual contains ISS procedures common to most CG icebreakers, and others that are very specific to the CGBN. I believe the manual to be exhaustive, concise and useful. In fact, I am proud of the final product. It has been developed using the framework established for both the Quebec and St John's Ice offices by ISS Lucie Thériault and ISS Éric Vaillant. I also need to mention the invaluable support received from ISS Erin Clark in the proof-reading and improvements to the manual from a technical writing point of view. It will be tool for any ISS with limited experience coming to the CGBN. The core of the manual was developed when I wrote equivalent documents on the CCGS Des Groseilliers and CCGS Sir Wilfrid Laurier, last year. It will be presented at the next semi-annual ISS meeting in November. It will also be an essential instrument to abide by the audit rules dictated by the ISO9000 program which EC CIS come under

Satellite Imagery and Quality of Cis Ice Charts and Analysis

We received numerous satellite images (Radarsat 1-2, Modis and NOAA images) issued by CIS in Ottawa. We also received (thanks to the work of Caryn Panowicz) the evening ascending passes from the National Ice Centre in Washington. This is one of the definite advantages of working in collaboration with US agencies. The area coverage was absolutely adequate and timely to meet our operational needs. This is an exceptional and commendable performance by CIS Ottawa!

The RSAT-2 images were of particularly good quality. I need to mention the excellent planning work done by ISS Erin Clark and Darlene Langlois from the CIS, to prepare the imagery orders for the UNCLOS voyage. There has been only TWO missing passes, due to the long imagery processing delays at the Alaskan Receiving station. These delays were also due to lower priority assigned to some image orders. None of these factors negatively impacted operations.

I want to mention the collaboration provided by the people of the CIS in regards to adjustments made to ice products (daily ice charts) in accordance with our observations and for the promptitude with which our FTP standing order adjustments were made when requested. Lastly, we found the special bulletin FICN00 produced specifically for the CGBN Beaufort Sea operations to be useful when outside of marine forecast regions.

Communications

The Telesat Internet service has worked very well throughout our trip (Username : iceobserver, password : iceobs). In a few instances, the signal was interrupted because of ship course, but this was never truly detrimental to operations.

Access to this type of communication significantly simplifies the work of the ISS. The Internet heavy use during peak periods slows data access significantly. However, all the major downloads were done outside peak hours (ie. very early in the morning or mid-afternoon).

I only had to turn to SAT-B communications on twice during the trip and it worked well in both instances. The procedure to follow in case it has to be used is in Appendix S of the CGBN Procedure Manual.

When the ship passed north of 78N, the Iridium signal replaced the weakened Telesat signal. Iridium communications worked beautifully.

Phone communications and the Wireless link between CGBN and NEPP worked very well whenever the CGBN and USCGC Healy were within the 2 NM range.

Accomodations

I was assigned the cabin normally used by the ISS located on the "boat and flight deck". The CCGS Louis S. St-Laurent is one of the most comfortable ships when it comes to life on board. The cabin is very spacious with sufficient storage space. The furniture is in very good condition. Washroom and laundry facilities are close by. It is also very well appreciated to have Internet hook-up in the cabin. Only one element has not been working: the TV set died on the first few days I was on board! Not a problem, because both the officer's and crew lounges have top notch TV systems.

Support of Bridge Officers and Crew Personnel

Firstly, I must emphasize the excellent collaboration obtained from all CCGS Louis S. St-Laurent bridge officers and ship personnel during my stay on board. They all and always demonstrated a high level of professionalism. All of them contributed to the success of my work on board. My stay on your ship enabled me to add-on to my own experience and knowledge as an ISS. In addition, all exchanges were always upbeat and friendly.

Secondly, I want to express my most sincere appreciation and thankfulness to the CCGS Louis S St-Laurent crew and the admiration I have for their exemplary teamwork approach. Every member of the crew seems to be very conscious that he/she is part of a larger team that must work with as few problems as possible so that and efficient operation of the ship is possible. I respectfully ask you, the captain, to extend my most sincere thanks to all crew members. They made my integration to the team easy and, in many instances, were of great help to facilitate my work on board.

The weather and ice briefings were informally made in accordance with the needs of the commanding officer or any other navigation officer. Aviation briefings were also given to the helicopter pilot every time a flight was planned or whenever flight operations were carried out. Every night at 19h00, a complete ice and weather briefing was given to the science team in the ship's boardroom. Other briefings were given informally whenever requested. My work practices ensure that all necessary information is made available immediately, on demand, and at all times up-to-date when requested. I am absolutely conscious that Ice Service Specialists are at the service of the CCG, and, consequently, must maintain the highest standards of efficiency at work to support the ship's operations.

Recommendations and Actions

As mentioned above, concerns about the operation of the AVOS station will be brought to the attention of the NF Port Meteorological Officer

The AVOS UPS (uninterrupted Power Supply).unit batteries must be replaced (PMO will be informed).
A DVD to be left with the captain was prepared. It contains: (1) all pictures taken by the ISS during the trip, (2) the climatology data regarding the Beaufort Sea and Western Arctic for the current year, (3) the ISS trip report and (4) the ISS Procedures Manual.
All the ice and weather information used for briefing purposes to the science team was left with the science team leader, Dave Mosher, in its electronic form.

- All the data burned onto the DVD was also placed in X:\Crew McNeil\Marian\Post-Arctic Ship Public Drive under the file folder CIS ISS Summer 2010.
- I produced the “CCGS Louis S. St-Laurent – ISS Operational Document – Procedures Manual”; a comprehensive procedures manual to be used as a reference for all ISS duties performed onboard. The M is subject to the approval of François Choquet (AWIR - Chief – Exterior Services) and André Pelland – Marine Operations Manager
- Erin Clark was responsible to submit recommendations to improve the working environment in the ISS office. In addition to her suggestions, I would like to mention two important elements: (1) The lighting in the room constantly reflects on the computer keyboard which is annoying and (2) there should be more free space between the ISS work position chair and surrounding desks to ensure easy movement in and out of the work position.
- I would also recommend that, in future voyages, the representative of the NIC (US Ice Specialist) would be a person that manifests motivation and participation in the familiarization activities related to the work and tasks devolved to the ISS on board a CCG ship. It was not the case with the person assigned to the task this year.

Acknowledgements

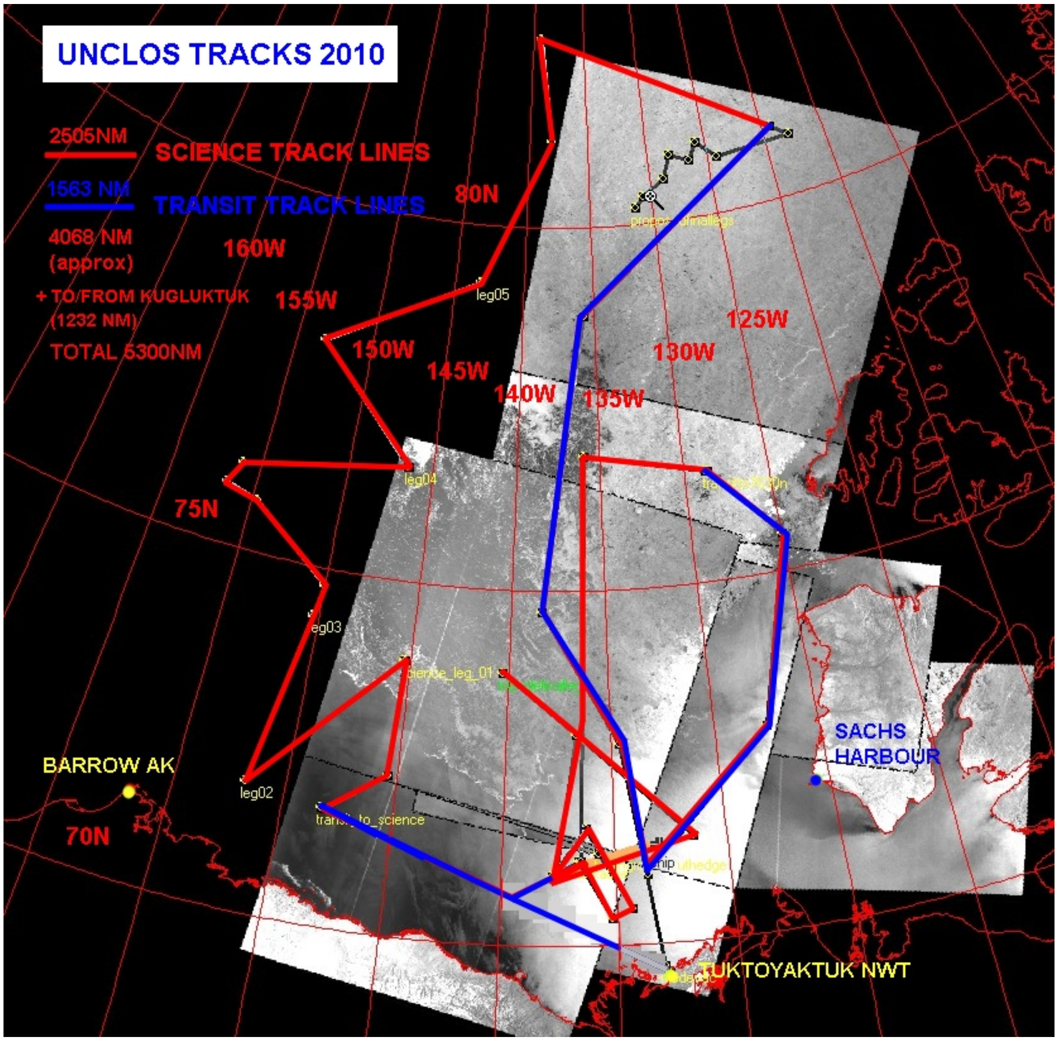
My stay on board the CCGS Louis S. St-Laurent has definitely been very enjoyable. I would like to extend my most sincere thanks to all crew members and more particularly to the captain. It has been very easy to become a member of the ship’s team and my work has consequently been made that much easier. I truly enjoyed my assignment on the “Louis” and hope to be able to return for duty in the near future.

Very respectfully,

Bruno Barrette
Ice Service Specialist
Canadian Ice Service

Ottawa

CC : François Choquet – AWIR - Chief – Exterior Services
André Pelland – Marine Operations Manager
Canadian Ice Service
Ottawa



Appendix A

Daily and Weekly Logs

Chief Scientist Daily Log

August 4th. (Wednesday) (JD 216)
Charter flight St. John's to Kugluktuk via Iqaluit.
Met Jon Childs and MMO's in Kugluktuk....all scientific personnel on board by late afternoon.

August 5th (Thursday) (JD 217)
Kugluktuk. Ship's Captain decides to spend the day at anchor for crew familiarization (30 new ship staff members).

August 6th (Friday) (JD 218)
Weigh anchor at 12:30 Central Time and steam towards Beaufort Sea. Delays in US permissions to survey in the US EEZ have forced us to modify our plan and to conduct surveying in Canadian waters first. The only open areas where we can conduct single ship seismic operations is in the shallower portion of the Beaufort Sea - at our planned FGP tie lines. 2 days steam to arrive at survey area.

August 7th (Saturday) (JD 219)
Steaming
Preparation of equipment
Clocks went back 1 hour to Mountain Time zone.

August 8th (Sunday). (JD 220)
Planned for early morning arrival for commencement of survey. Captain would not permit CG crew to commence until 08:00. Commenced deployment by 0830. 3.5 kHz tow body and streamer deployed. Significant rigging involved in getting the shallow tow version of the airgun array - very time consuming.
- Late morning (1130) ready to commence. Streamer not functioning and Long Shot firing unit not working. Swapped out the firing unit and brought the streamer on board. Replaced repeater unit and deck cable and redeployed. By mid-afternoon, all functioning and commence surveying.
2200h Port compressor fails (same one that always fails!). Replace with Stbd compressor and back operational.

August 9th (Monday) (JD 221)
Continued surveying Canadian Beaufort shelf to slope region throughout the day and night. Compressor 1 repaired but still leaking fluid. Still running on #2.

August 10th (JD 222)

- Ceased survey on Line 3 at 0830. Conducted signature test of shallow tow array and then pulled gear on board. Switching over from shallow tow array to ice array before US EEZ work. Gear on board by about 11:00
- -Steamed to meet up with Healy. We met up at 17:00 local. Captain, Jon Childs and I flew over to meet with Brian Edwards, Captain Rall, Dale Chayes etc.
- -Flew back to LSSL by 2000h
- Still no US IHA approvals which means we cannot start surveying in US EEZ.
- Personnel transferred including Captain Bourdeau, Erin Clarke and David Street over to Healy. Sarah, kwasi (US MMOs) and Caryn Panwicz (US ice observer) came over to Louis from Healy.

August 11th (Wednesday) (JD 223)

- At 6:20 am (Pacific time) discovered that a crewman had injured his hand and we are heading to Tuktoyuktuk to send him ashore for medical attention. The cut is deep and requires stitches. Steam all day to Tuk. At 1745h, helicopter deployed to take him to Tuk. Helicopter returned at 2015 and heading back to US EEZ
- Ironically, US IHA approval arrived this afternoon, at about 1500h
- Gang has rebuilt the ice seismic airgun arrays and are ready to deploy as soon as we are back on station
- Comparison of measured source signatures and those of the Gundalf model are excellent.

August 12 (JD 224)

- Steaming 17 knots most of the day towards first line in the US EEZ. Arrived at 1430 and began deploying seismics. Gear in the water and firing by 1600h. Ice configuration. Start of line 6 shortly after. Fog nearly prevented startup of array. Response to marine mammal observation is significantly more complex in US waters. In addition, startup requires 30 minutes of 2.5 km visual.
- Guns and streamer working well and deployed first sonobuoy at 2000h.

August 13 (JD 225)

- 2nd deployment of a Sonobuoy. Noticed interference on the sonobuoy records. It seems as though we are picking up the shots from the Bos Atlantic - last position was 79 29N and 139 35W at 1600UTC on August 12...about 170 nMi from us.
- Streamer started to show water egress through the day...finally about 1500h she shorted out. Rigged a 150 cu in gun to deploy to keep shots firing in the water in order to avoid shut down and start up procedures in US waters. Brought the gun sled aboard and replaced the first repeater unit at the tow point...that fixed the problem and we redeployed...took a couple of hours. Back operational by about 1700h.
- 2000h first teleconference call with Healy on voice-over IP.
- Monster bash that evening... Polar Bear sighting - mother and cub long way off.

August 14 (JD 226)

- 0400 got called from Borden...streamer died again. Seems we were stuck in ice and screws were revved for over 20 minutes...might have caused the leakage. We roused the crew and brought in the sled and streamer (deployed the small 150 gun first). Hand-hauled the streamer and got it up to the helideck. Attached the stbd streamer to the port gun sled and redeployed. Back operational by 0730.
- Operating with port guns and stbd streamer running all down. completed first US EEZ line and turned to head south on the second line. Data quality is excellent. Still trying to discern source of interference on the sonobuoy records, but the quality of the data is still excellent.

August 15 (JD 227)

- Heading south on 2nd US EEZ line. making good progress. Position is 73º 08.04759N, 147º 51.12136W at 0730h Pacific time
- Fog and low surface fog with brighter skies overhead.
- Weather worsened as the day progressed. High winds and seas as we got out of the ice front - affecting data quality
- Healy forged ahead to pick up our crewman and fuel filters from Barrow. They acquired bathy and chirp during their transit along the same line.
- ~2100h #2 compressor, radiator failed...switched back to number 1. No more spare radiators. Not sure why they are failing

August 16 (JD 228)

- Rough night - heavy sea swell hitting us broad side. Woke in the morning to find us 5 miles off track and heading in the wrong direction. During the night, Captain ordered to alter course to head more into the sea. That is fine, but I, nor the watch, was notified. We terminated the line in the morning without completion, since we were so far off line by then anyway. Our stbd compressor had a shaft on the belt wheel loosen. Pulled in the seismic gear at 0800 PST to also take a look at the streamer...for some reason it is giving negative readings on the current.
- Blue skies and swell diminished as we got closer inboard and ice dampened the sea swell. Scattered multiyear ice pieces all around. Nice and calm actually
- Healy in Barrow, have taken our man aboard but are waiting for the fuel filters in the morning flight - they did not arrive last night.
- Started line at the south to head north (westwardmost line of the US EEZ survey) at 1100 PST = line 11. Deployed Sonobuoy 8.
- As we proceeded north, we encountered long heavy swells again.
- Late in the day the seas continued to drop.
- Learned at about 2200h that the Healy had picked up our fuel filters and is now proceeeding to intersect us at speed

August 17 (JD 229)

- Swells continued to die down through the night. Morning fog burned off to be a beautiful day. Seismic system working wonderfully and guys fired up the Port compressor to test their patch job on the radiator.

- Healy reached us just as we entered the ice pack at 1200h, just in time. Once through the edge, the ice is scatter 3-4/10ths of mostly old multi-year. Winds calm and seas calm.
- helicopter effected transfer of crewman and filters from Healy to Louis and took the ice pik up for a recon flight.
- Great Day

August 18 (JD 230)

- Turned on to line 12 heading to NW towards Northwind ridge at about 0700h - and eventually picks up Art Grantz' old line 93-11
- US Mammal observers returned to Healy
- Helo went on a recon flight
- Bruno (Ice Pik) spotted a large flow along line and advised Captains to veer around the flow....took us >5 miles out of our way - Without telling me - I was quite upset about it. Talked to the Captain that I should be involved in these debriefings from the ice pik.
- Issue arose with respect to speed in water vs speed over land. Captain upset that John S. spoke directly to the mates, which is absurd - our watchkeepers have to be able to speak to the mates about these issues. I think I've sorted that out with the Captain.
- Repairs to the port compressor continue - trying to rig up a water cooled heat exchanger.
- Dale and Johnny want to split their shifts to 4 and 4...

August 19 (JD 231)

- Continued surveying line 11 - 12 but 4 miles prior to end of line (~1500h), the stbd compressor blew a seal on an oil line and oil sprayed everywhere. Had to shut down and clean up and repair. Streamer was also acting up with spikes in the leakage display values. We pulled the gear and steamed for waypoint 19 to 20 that brings us east out of Northwind ridge...large pool of open water there to deploy. We broke ice for the Healy for the transit. 1830h we are back in operation on Line 13, due west off of Northwind Ridge.
- Spoke to Jacob w.r.t. priority lines. His priorities are the far north lines, so we will transit to get to those. Only ~13 days left of Healy and Louis joint time. Drafted a plan to get us up to there and back by Sept. 3.
- I took two of the mates (Adam and Albert) on tour of the quarterdeck so they could see what we are dealing with and why the need for speed in water.
- Polar bear sighting ~1700h
- evening science meeting at 1900h as per usual
- evening telecom with Healy at 2000h as per usual

August 20 (JD 232)

- 0200h PST, gear had to come in because of leakage into the streamer. We cannot seem to solve the issue of leakage at the first repeater behind the sled. We reconfigured the bracket a bit, put it back in the water and will think about more drastic changes during the next transit. Back in the water and operational by 0400h.

- Helo ops in afternoon. Walli and Jon Childs over to Healy. Ice observation with Bruno, Erin and Jason (latter 2 from the Healy).
- Jon Biggar tried out his instrumentation from the Helo after supper.
- Ryan tells me about a near fire in the compressor...yikes!
- Equipment working well...significant amount of low fog, generally light ice conditions to open water.

August 21 (Sat) (JD 233)

- Completed line 14 about 0730 - continued line until 0800h, then brought all gear on board and took an SVP station - Healy did a CTD station nearby
- Transit for the rest of the day - mostly through decayed first year ice... lots of fog but little wind.

August 22 (Sunday) (JD 234)

- Arrived at Waypoint 21 on Northeastern portion of Northwind Ridge at 0330h. Deployed gear to run Line 15 and were underway by 0430h. Ice light and rotten but freeze up appears to be starting - beautiful clear day.
- Ice cover nearly continuous through day, although apparently thin.
- At ~1430h, ice pack appeared to start to move and track behind Healy closed in quickly. Louis wasn't close enough and pack closed until we got stuck. Helo operations on personnel transfer - Healy pulls ahead and stops to take on Helo - too far ahead and stopped too long. Louis had to slow and lost momentum. Beautiful sunny day with no wind.
- 1800h all gear back in the water and continuing line (now line 16).

August 23 (JD 235)

- 10/10 ice cover - clear morning with some surface fog. All gear worked throughout the night.
- #1 Compressor (stbd) stopped working at 0930h. Don't know why...fired up #2 but it took some time as the engine room had to supply fresh water to the jury-rigged heat exchanger. Lost ~10 - 15 minutes of shots...
- Pull gear at 1130h; 1230, on our way north...
- John Shimeld gave a talk on seismics
- 2115h Ship's port propeller problem...shaft bearings went dry (no oil) and wore out, as well as pads . Captain estimates 2 days minimum to repair. I sent the Healy on to the Seamount to core and we will reassess the situation in the morning. 79º 52.17N, 140º53.10'W

August 24 (JD 236)

- Awaiting repairs to port propeller shaft bearings
- ~2100h testing underway

August 25 (JD 237)
0100h started transit

- Decided to cancel northern survey line (south to north) up onto Alpha Ridge.
- Proceeding to east side of Nautilus Ridge to survey west to east, across to north side of Sever Spur to tie in to bathymetry point soundings.
- Occasional stops to clear filters on propeller shaft oil

August 26 (JD 238)

- 0300h met up with Healy at Waypoint 28 (east side of Nautilus Spur). Engine room cleared filters again, then gear in the water and operational by 0440h. SOL 17.
- Stuck twice within the first couple of hours! We did not get stuck once last year.
- Gradually, the bridge(s) seem to be realizing what needs to be done to maintain headway. Unfortunately, they used the centre shaft a few times, and now the seismic sled has a few twists in it. We've been stuck only once more since this morning.
- Continue to survey in relatively heavy ice conditions, however. Made about 50 nMi since start of line to midnight.

August 27 (JD 239)

- 0150h got a call from John S...seems only 8 channels are being acquired. Perhaps one of the A/D modules. John rebooted and it seemed to recover all 16 channels, but then failed shortly after. Continued surveying anyway, acquiring only the 8 aft channels.
- 0630h, decided to pull in the gear as there was a large open pond nearby. Made ties to seismic lines LSL09-21 and 23
- 0830h gear on board with the streamer wrapped around the tow sled...
  Position 81º 46.90'N, 128º 20.55'W; 98 nMi along line.
- Took SVP and Healy took a CTD.
- Changed tow sleds...Ready to redeploy gear at 1115h; Captain orders to wait until 1200h, after lunch.
- Gear redeployed at 1230h - Line 18
- Streamer lasted only about 2 hours when it shorted out and we brought it back up ... changed out the fore repeater unit and redeployed.
- No success...streamer still giving high current....recovered entire array and swapped streamers
- Redeployed at about 1800h. Again, streamer read fine on the deck and for a few minutes in the water, then leakage went through the roof!
- Recovered gear about 2000h and finished line as a multibeam/chirp line - so we broke ice for the Healy

August 28 (JD 240)

- Breaking ice all day for Healy - heading to tie in Borden Island spot sounding profile. Making about 4-5 knots only. Heavy ice but not unmanageable.

- 1530h Captain informs me that we may have a med-evac situation!
- 1630h Captain informs me that we are on med-evac

August 29 (JD 241)

- Continue transit on med-evac - only made about 45 nMi last night, through heavy ice.
- Still on Sever Spur heading almost due south...not sure why we didn't back track and head west to easier ice.
- Ice conditions improved through the day.

August 30 (JD 242)

- Transit to Tuk
- A Healy person injured their hand and was transferred to the Louis for med-evac to Tuk.
- Transit alone - Healy split off to go to core sites.
- Our patient (Winston) is doing well. Will go home out of this and not to hospital or Dr.'s care!

August 31 (JD 243)

- Out of ice by mid-morning
- Helicopter departed for Tuk with patients at 17:30, LSSL continued steaming toward Tuk
- Helicopter back on board at 21:30
- Engine Room needed some time to change filters etc on propeller shaft bearings
- Underway for McClure Sound Waypoint 37 at 0145h PST (sept 1)...why the delay?

September 1 (JD 244)

- Underway to Waypoint 37 off of McClure Sound at 0145h, Travel around ice margin up along Banks Island

September 2 (JD 245)

- Transit still to Waypoint 37. Busting through nasty ice this morning...much improved by afternoon.
- Arrived WP at 1730h; streamer deployed and operational @1900h; line 19
- Fly-over from US Coast Guard Aurora

September 3 (JD 246)

- Completed line 19 at 2130h and turned south on line 20
- John informed me we have 3rd multiple interference on Line 19 data - ouch!....so much effort to get here.

September 4 (JD 247)

- Continue Line 20
- Healy breaks off at 1200h

September 5 (JD 248) Sunday

- Continuing line 20, all working well (knock on wood)
- Weather clear, some fog. Ice - 9/10s but old and rotten. Some difficult spots but OK for one ship.

September 6 (JD 249)

- Continuing south on line 20. 2nd year and multiyear ice, rotten and lots of holes and no pressure. Bridge still steering around the ice flows as much as possible.
- ~1003h PST Flew out in chopper and deployed a sonobuoy ahead of the ship to get both refraction limbs. Requested vessel steer a straight course for the position and deviate as little as possible.
- Reviewed these sonobuoy data - unfortunately, the antenna does not look forward very well, so data quality is poor on the approaching limb, but fantastic on the sail-away limb.
- Shut down and started new line in order to dump cache on seismic acquisition system. Line no. 21, but still line heading south.
- Weather worsening through the night. Winds up to 25 knots

September 7 (JD 250)

- Continuation of line 21/22
- Winds 25 knots gusting to 30 under gloomy skies. Wave height probably 2 m. Lots of noise on seismic records. Skies improve in pm but still rough seas.
- Turn eastwards ~1530h PST to tie to FGP line to the east. Leaving gear in the water because of significant wave height ???? Captain wanted us to pull gear early, I said it was fine to be left out.

September 8 (JD 251)

- Continuing Line 23 eastward. Wave height down in the am...supposed to continue to drop. Nice blue sky.
- Significant wave heights still by late pm, no sign that wind is abating.
- Conducted a helicopter sonobuoy drop (#29) ahead of the vessel along this line. We mounted a forward looking antenna and at 0930h went out with a sonobuoy and deployed. We digitized the forward and aft antennas as separate channels on the GSCDig. Seems to be working although the GSCDIG is having problems keeping up with the sample rate??? Looks like a trigger jitter....ugh!
- tied to FGP line 87-1B, ~2300h Turned on to Line 24 heading to NW...

September 9 (JD 252)

- Deployed sonobuoy 30 ~ 0100h,
- Continuing line 24 to NW, deployed a sonobuoy ahead of the ship with the helo at 10:53
- Spotted sonobuoy to the port at 14:30
- GSCDig was not able to record 2 channels with such long record lengths.
- Late evening - fog encountered, a sign that we are approaching the ice edge.

September 10 (JD 253)

- Started to encounter light ice in very early morning
- Gun number 1 acting up a bit - perhaps water or crude in the firing chamber? Clears and then acts up again - firing on manual when it acts up.
- After lunch, deployed a sonobuoy from the helo (John S and me) - lots of fog. First sonobuoy didn't come up (maybe under ice), second one worked. deployed at 1337h PST
- Passed Sonobuoy about 1700h PST
- Ice thickening up a bit as we proceed NW...rotten and still feasible by one ice breaker.

September 11 (JD 254)

- Final day of seismic operations.
- Gear continues to work - on to Day 9 for this deployment - incredible.
- very light ice this far to the west.
- 1210h seismics off; 1230h all gear on board, 111460 shots in total
- SVP station
- 1500h All Science Operations complete and we're heading to Paulatuk.

September 12 (JD 255) Sunday

- Steaming to Paulatuk

September 13 (JD 256)

- Dropped Jonal Nakimiyak, Dale Ruben, John Ruben and Nelson Ruben off in Paulatuk via helicopter 0830h PST

NRCan Weekly Reports

Weekly Report, August 9, 2010

August 4th. (Wednesday)
Charter flight St. John's to Kugluktuk via Iqaluit.
Met Jon Childs and MMO's in Kugluktuk....all scientific personnel on board by late afternoon.

August 5th (Thursday)
Kugluktuk. Ship's Captain decides to spend the day at anchor for crew familiarization (30 new ship staff members).

August 6th (Friday)
Weigh anchor at 12:30 Central Time and steam towards Beaufort Sea. Delays in US permissions to survey in the US EEZ have forced us to modify our plan and to conduct surveying in Canadian waters first. The only open areas where we can conduct single ship seismic operations is in the shallower portion of the Beaufort Sea - at our planned FGP tie lines. 2 days steam to arrive at survey area.

August 7th (Saturday)
Steaming
Preparation of equipment
Clocks went back 1 hour to Mountain Time zone.

August 8th (Sunday).
Planned for early morning arrival for commencement of survey. Captain would not permit CG crew to commence until 08:00. Commenced deployment by 0830. 3.5 kHz tow body and streamer deployed. Significant rigging involved in getting the shallow tow version of the airgun array - very time consuming.
- Late morning (1130) ready to commence. Streamer not functioning and Long Shot firing unit not working. Swapped out the firing unit and brought the streamer on board. Replaced repeater unit and deck cable and redeployed. By mid-afternoon, all functioning and commence surveying.
2200h Port compressor fails (same one that always fails!). Replace with Stbd compressor and back operational.

Weekly Report   August 15, Day 11

At 1515h, our position is 72º 44.67N,   149º04.38W.

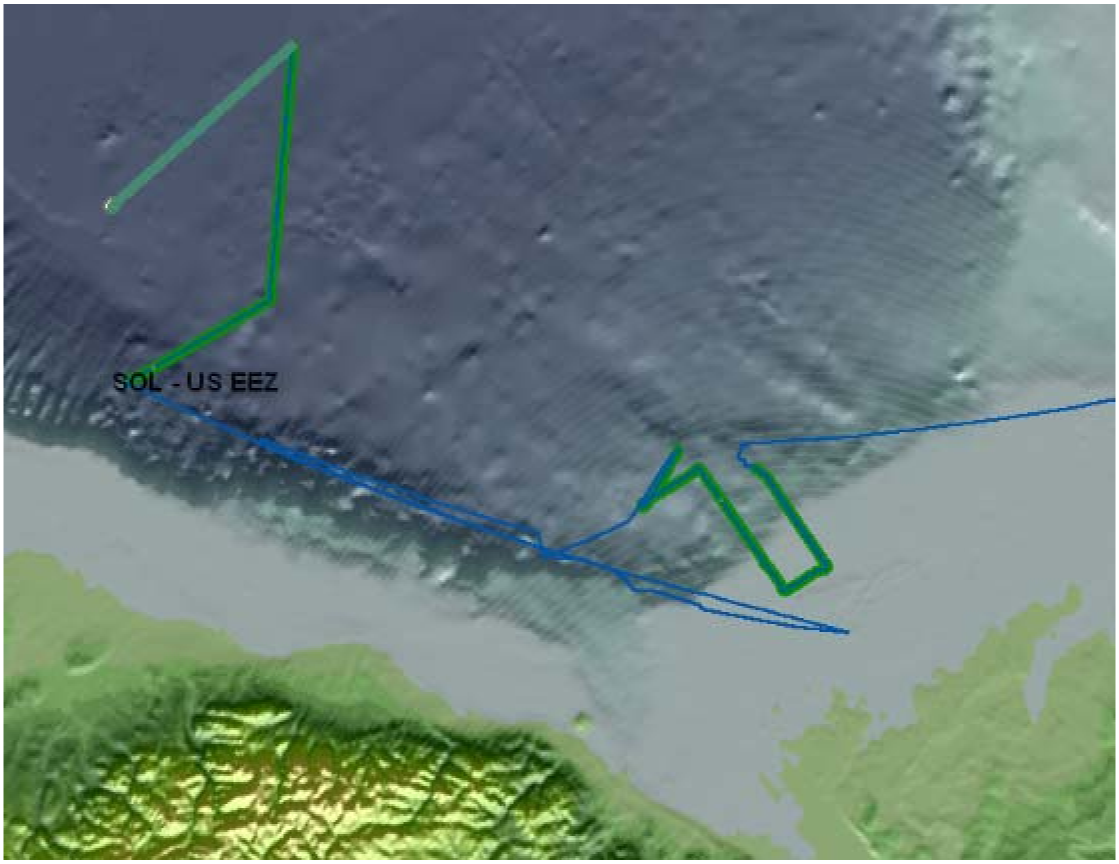
August 8th, Commenced surveying on the Canadian Beaufort Slope and outer shelf with open water tow configuration and Chirp system. After start up problems we conducted the survey until 0830 on August 10th. Rendezvous with Healy on August 10th (evening) for face-to-face meetings between Chief Scientists and Captains on the Healy. Transferred personnel. Steamed toward first waypoint in the US EEZ, despite awaiting US approvals. August 11, 0620h learned of an injured engine room crew member. We steamed back to Tuktoyuktuk to take him to shore via helicopter. US approvals came in at 1500h. Helicopter returns to LSSL at 2030 that evening and we head back to US EEZ. Because of significant ice, we switched the seismic system back to the ice-tow array. It was a major effort to change over.

1430, August 12, arrive at first waypoint in US EEZ and immediately commence seismic operations. Some difficulty in startup because of fog and US requirements for mammal observation (2.5 km for 30 min. prior to startup). Eventually manage to start seismic operations and survey northwards on first leg of Line 4. No ice until northern half of the line, with increasing density northwards. Significant amounts of old ice around the edges of the pack. Two incidents of water egress into the first repeater unit of the streamer requiring recovery and causing delays. One incident resulting from LSSL stuck in ice and needing to increase prop revs. Now heading south on second leg of the US EEZ survey pattern. All working well and data quality is generally excellent. We are now in open water with significant swell, however.

We are significantly behind schedule on our initial survey plan. Modifications are being considered to lines off Northwind Ridge and to remaining survey patterns.

TOTALS
805 line km seismic data (325 km with open water configuration in Canadian waters)
22319 shots
6 sonobuoy deployments

Healy completed multibeam survey pattern in the disputed zone


SOL - US EEZ

Weekly Report   August 16 - 22, Day 12-18

At 1800h (PST), LSSL position is 78º 23.42N 150º 45.26N

Completed the lines in the US EEZ by August 17. Some weather issues causing noisy data and off track positions on one line, but otherwise, data quality is excellent. After completing all planned lines exiting the US EEZ, we deployed the US mammal observers back to Healy. After significant delays due to customs in Anchorage, Healy picked up our crewman and ship's fuel filters in Barrow and delivered them to us on August 17 - caught up with us just as we entered the ice pack. Very light ice conditions initially, mostly scattered decaying multiyear ice. Completed two "modified" dip lines into and out of Northwind Ridge. Excellent data quality. Some issues with streamer leakage - all focussed on the foremost repeater unit - where it attaches to the sled. Port compressor blew a second first stage heat exchanger and is inoperable (no further spares), although the guys eventually came up with a fix using one of the ship's water cooled heat exchangers. It is not ideal as the ship has to use her fire pumps in order to run sea water through it...so it is an "emergency" spare only. On August 19, the starboard compressor blew an oil seal and needed repair, terminating one of the NW Ridge lines just before end of line. The port compressor was not yet functional, so while repairs were effected we transited to second line on NW ridge. We are now on the third line in the north of NW Ridge. Ice is continuous but not thick. We managed to get stuck in the ice and had to pull gear. Presently shut down for helicopter operations and supper!

Totals

4,400 ship's track (bathymetry)
1,785 line km seismics
56000 shots
16 sonobuoy deployments
1 SVP station
15 xctds

August 22nd - August 29th. Louis S. St-Laurent Weekly Report

August 22nd, working on a line running NE off of Northwind Ridge toward the centre of the basin, ice became thicker and started closing in, causing us to get stuck a couple of times. By Monday, we pulled the gear to head to the northern extremity of the survey area to accomplish our objectives there. 36 hours were lost due to propeller bearing problems on the port shaft of the Louis. Healy went ahead and cored on the Seamount - recovering 4.93 m of core. By Tuesday, August 25th at 0100h we were in transit again toward the north, but this delay cost us the northern line. Frequent stops to clean oil filters on the propeller shaft. By Thursday, August 26th, we met up with the Healy and by 0440h we started surveying from Nautilus Spur towards the east to intersect the north side of Sever Spur. Heavy ice, Louis got stuck a couple of times as well bridge applied the centre shaft which causes our towed seismic gear to tangle. It still was operational, so we left it deployed. Eventually, however, the streamer failed - first acquiring only 8 channels, then complete loss of data - upon recover it was wrapped around the gun array. Ongoing issues with the streamer caused us to switch streamers, but it would not work either. After numerous deployments and recoveries, we decided to pull in the seismic gear and multibeam the remainder of the line while we figured out the issues with the gear. We broke ice for Healy. We made the first sounding point north of Sever Spur (spot soundings from this spring's ice camp), when the Captain informed me that we had a med-evac situation (1520h PST, August 28th). All scientific operations ceased and we are presently on transit to Tuk to deploy Coast Guard crewman.

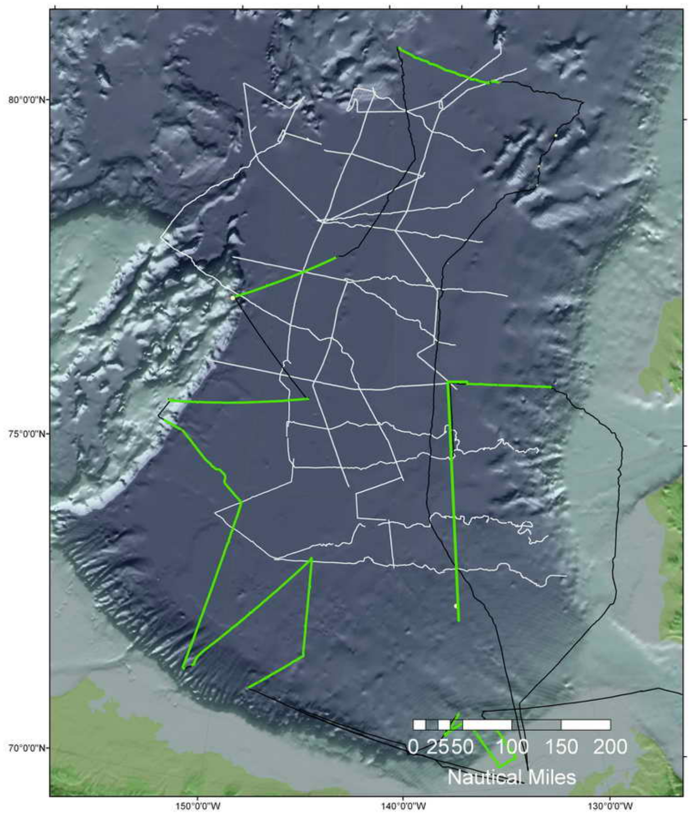
Total navigation track	5.223.30 km
Total seismic	2,206.40 km
furthest north	82º 33'

August 30th to September 05 Louis S. St-Laurent Weekly Report

Took on an injured engine room tech from Healy (hurt hand) on August 30 as part of our med-evac to Tuktoyuktuk. Healy then broke off to go to a basin core site. Completed med-evac to Tuktoyuktuk on August 31. Helicopter was back aboard by 2130h PST but engine room needed to conduct work until 0145h PST on Sept. 1. Then proceeded to a way point on the north side of McClure Sound, travelling around the ice margin next to Banks Island. Operational again on Sept. 2nd @1900h PST; US Coast Guard Aurora aircraft did a fly-over that evening. September 3rd we completed the westward line out of McClure Sound to tie into line 2009-31 and turned south to complete an easterly transect line through the 2007 margin lines. Some compressor problems but nothing debilitating. Healy broke off to head back to Barrow on August 4th. She completed one core in the basin and surveying the 2500 m contour off McClure Sound while we were on the med-evac run. Still on this southward line that will tie into MacKenzie lines acquired at the start of the survey by Tuesday morning.

Position at 14:23:08Z 73º 04.81'N, 136º 45.68'W

Total navigation track	8,354 km
Total seismic	2,551 km
Number shots	82041

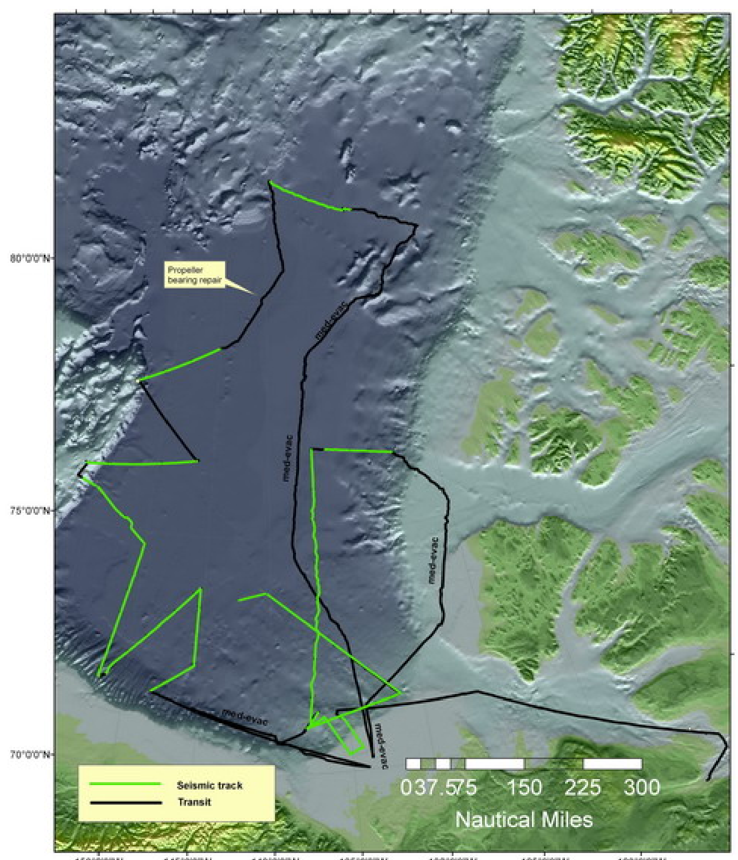


Green = 2010 Seismic tracks, White = previous seismic tracks
Black = Ship track

Weekly Report, Sept 6-Sept 12, 2010

Completed the southward line to tie into Beaufort shelf lines from the start of the program, and to FGP line 87-3. The weather and sea state got rather nasty so we elected to leave the gear in the water and conducted a transect line to the east across the front of the delta. By Sept 8th, the weather was down a bit. We started a line heading northwest that ties from FGP line 8701B out to our main grid in the center of the basin. At the northern half of this line, we were back in ice, but light enough to work through with one ice-breaker. We completed this line on September 11 and ran a short line to the SW that crossed the gravity low structure. By 1210h PST on September 11, all seismic gear was brought in to end the program. This deployment lasted 9 days - a new record. We completed an SVP station and then started making way to Kugluktuk by 1500h.

28 days on task
9600 km track
3673 line-km of MCS data
111460 shots
34 sonobuoy deployments
33 XCTD stations
14 XBT stations
3 SVP casts
61 Spot soundings



Canadian Hydrographic Services Weekly Report

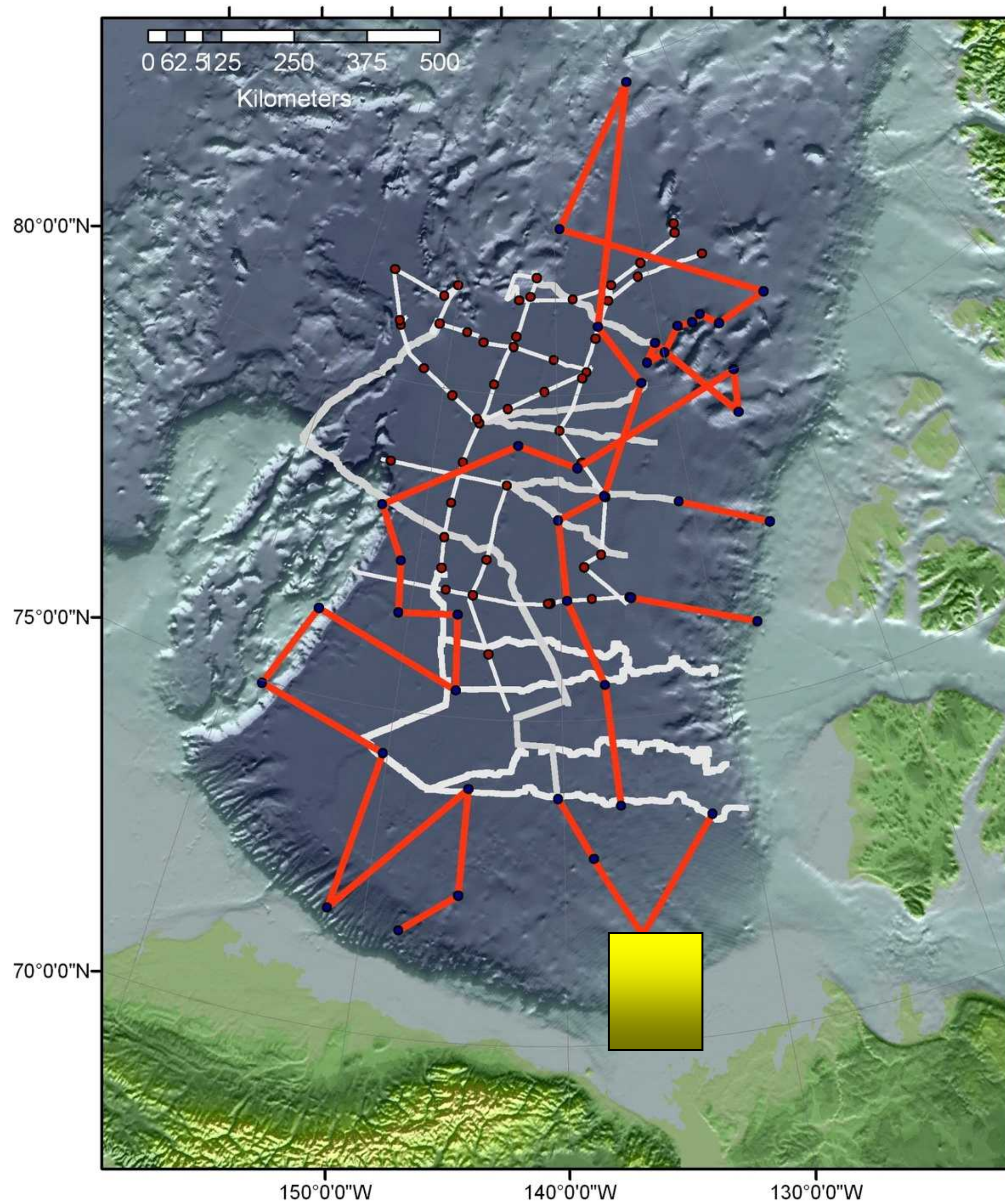
Jon Biggar

UNCLOS – CCGS Louis S. St Laurent 2010
Highlights: departed Burlington, bathymetry/seismic program started

Weekly Summary: Aug 3 to 8
Aug 3 Tuesday – staff traveled to St John's, overnight for crew change flight next day
Aug 4 Wednesday –staff departed on crew change flight to Kugluktuk, departed shortly after 7 AM, 6 hour flight with stop over in Iqualuit (1 hour) for flight crew change and fuel, arrive at Kugluktuk midday
Aug 5 Thursday – started computers, training, ship orientation for staff
Aug 6 Friday – boat and fire drill, departed Kugluktuk, problems with deep water SVP (sound velocity probe). Seems a wrong config file was sent with the unit after company service and calibration, the unit will works HyperTerminal, Tony has been a great help with this problem
Aug 7 Saturday – started setting up helicopter equipment, problems with Novatel communications over ship network, problems with NovAtel GPS receiver /BackPack communications also, both were resolved
Aug 8 Sunday – sound operations began (24/7), seismic operations had equipment problems but were repaired and operations began

Plans: Continue seismic / bathymetry survey operations 24/7 and rendezvous with Healy mid week

The Plan: red lines – proposed survey lines (highlighted area is the present work location)
white lines – previous year's survey lines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140°0'0"W
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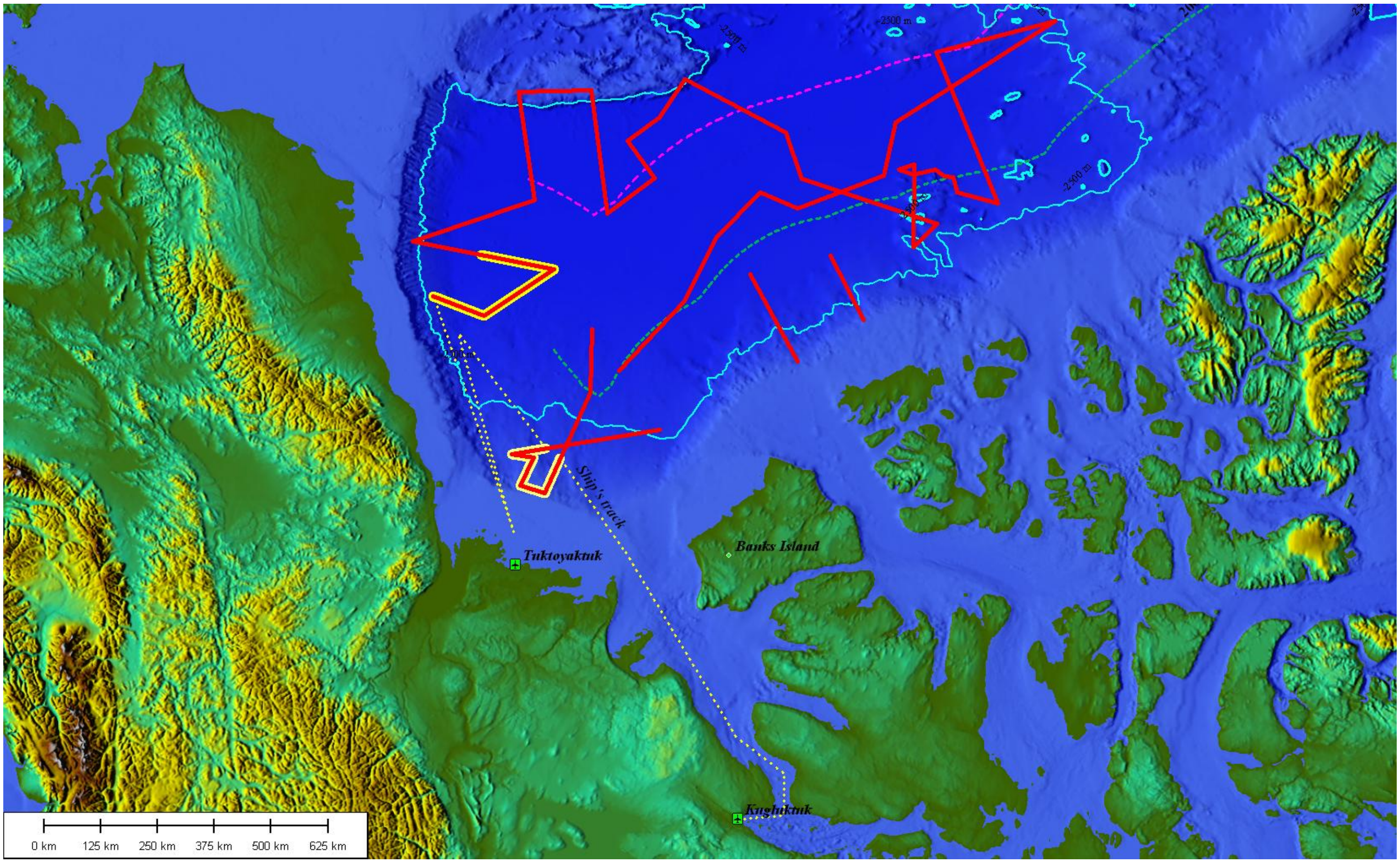
UNCLOS – CCGS Louis S. St Laurent 2010
Highlights: Two ship operations CCGS Louis S St. Laurent and Coast Guard icebreaker Healy has commenced, bathymetry/seismic program underway, 2000 line kilometers of bathymetry collected to date.

Weekly Summary: Aug 9 to 15
Aug 9 Monday – sounding and seismic ops, minor problems with Knudsen sounder, operating 3.5 kHz and 12 kHz Knudsen sounders
Aug 10 Tuesday – stopped seismic after breakfast, calibration of air guns, remove all gear, heading for Healy, continued sounding ops with 12 kHz Knudsen sounder, deployed XCTDs, General Dynamics ruggedized laptop which is used for the Expendable probes has a boot file error, unusable, replaced with laptop used for Iridium phone email system, staff was exchanged with the Healy, SVP plus probe is now operational, the time/date was set up wrong in unit which was conflicting with the other the parameters
Aug 11 Wednesday – sounding ops, enroute to start of line when one of the engineers badly cut his hand, returning to Tuktoyaktuk for a medavac, helicopter a shore late in the evening
Aug 12 Thursday – sounding ops, returning to start of line, deployed seismic gear shortly before dinner, seismic ops started
Aug 13 Friday – sounding and seismic ops, deployed the XBT in the AM, started into the ice with Healy escort, about 4/10s ice, problems with streamer in afternoon, repaired, redeployed, XCTD and XBT deployed, prepared SVP plus probe for winch ops
Aug 14 Saturday – sounding and seismic ops, problems with seismic equipment early morning, redeployed other streamer and continued operations, 2 XBTs deployed
Aug 15 Sunday – sounding and seismic ops, moving south out of the ice approximately 13:00 local, 2 XBTs deployed

Plans: Continue seismic / bathymetry survey operations 24/7 with the Healy, expect to be at end of line Monday morning turning north, survey plan is being modified to account for lost time.

Sketch: Red lines are the proposed survey lines; yellow highlighted lines are completed to date.



Tuktoyaktuk
Ship's track
Banks Island
Kugluktuk
-2500 m
0 km
125 km
250 km
375 km
500 km
625 km

UNCLOS – CCGS Louis S. St Laurent 2010

Highlights: Two ship operations CCGS Louis S St. Laurent and Coast Guard icebreaker Healy continues, bathymetry/seismic program underway, To date 4736 line kilometers of bathymetry has been collected along with 24 XCTD, 14 XBT, 2 deep-water SVP cast and 23 spot soundings. Helicopter logged 4.4 hours of flight time. The helicopter spot-sounding ops were hampered most of the week because of weather conditions. Saturday evening the surveying was suspended and presently the Louis S St Laurent is heading for Tuktoyaluk for Medavac of a crewmember. Sounding operations continue enroute.

Weekly Summary: Aug 23 to 29

Aug 23 Monday - sounding and seismic ops, breakdowns with seismic air compressor, recovered seismic gear at noon, Louis is escorting Healy sounding ops continues, attempted helicopter spot sounding but problems with the larger Airmar 12 kHz transducer, switched to smaller 12 kHz transducer, noticeable volume difference in pinging, CDU Novatel software froze, restarted and reset port, Monday night the propeller shaft bearings failed, ship down for repairs, Healy continued on

Aug 24 Tuesday – stopped overnight and most of the day for ship repairs, resumed sounding ops approximately 10PM heading north

Aug 25 Wednesday – sounding ops, modified survey lines heading for east/west line to rendezvous with Healy at start point, helicopter flight with 11 spot soundings

Aug 26 Thursday – deployed seismic gear approximately 4 AM, ships now into heavier ice, helicopter flight with 12 spot soundings, standby for weather for second helicopter flight

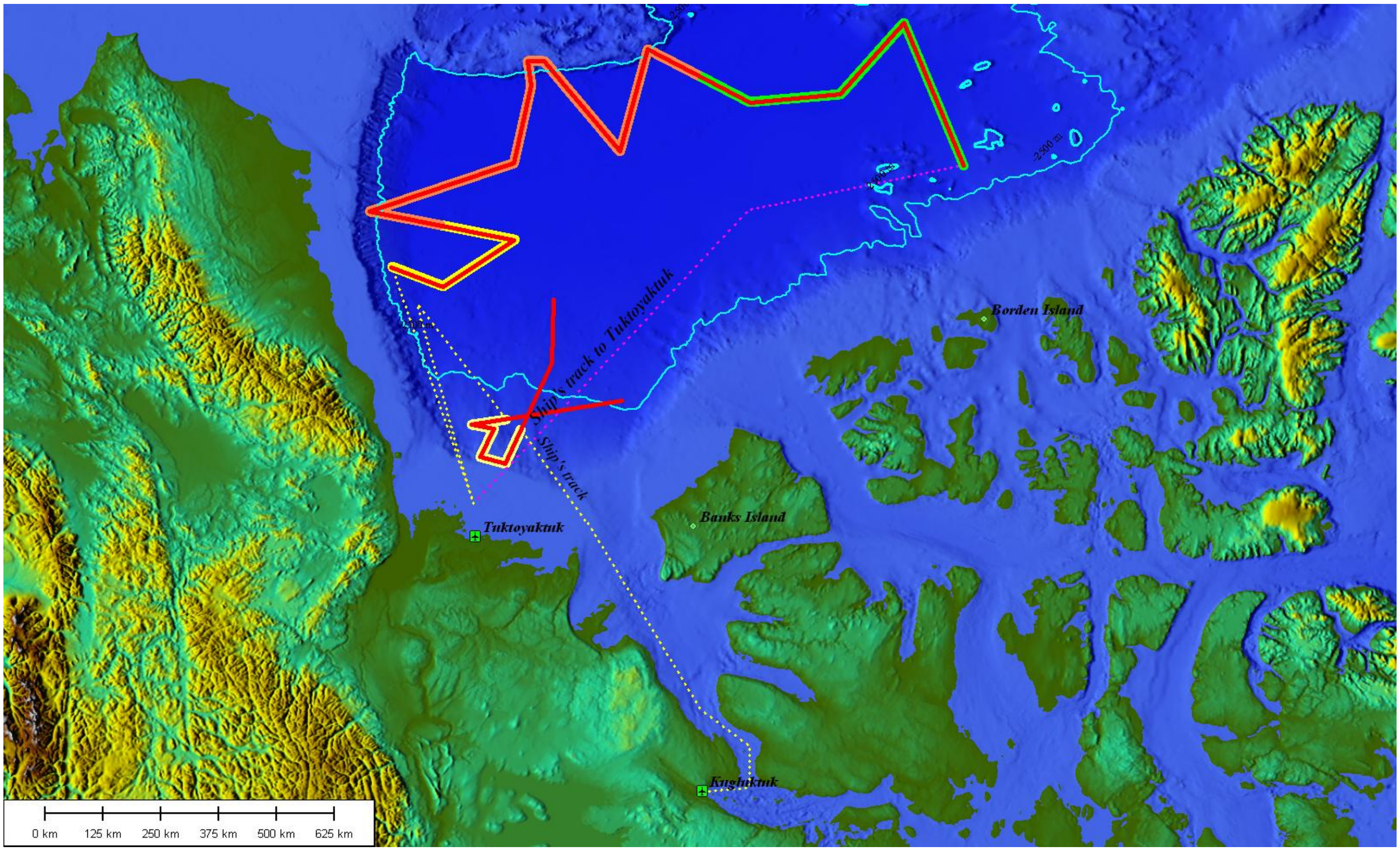
Aug 27 Friday – sounding and seismic ops, several problems with seismic streamer, recovered and deployed numerous times during the day, left on deck for repairs, SVP cast to 3600 metres, Louis escorting Healy continuing line to the east into 2500 metre contour, standby for weather for helicopter spot sounding ops

Aug 28 Saturday – sounding ops, Louis escorting Healy, turned towards Tuktoyaktuk approximately 18:00 for a medavac of a crew member, standby for weather for helicopter spot sounding ops

Aug 29 Sunday – sounding ops in heavy ice, both ships enroute to Tuktoyaktuk, standby for weather for helicopter spot sounding ops

Plans: Expect to be in Tuktoyaktuk mid week for Medavac, continue seismic / bathymetry survey operations in the Beaufort Sea/southern Canada Basin area, Healy is scheduled to depart from the program Sept 2/3 depending on location.

Map: Red lines are the proposed survey lines; highlighted lines are completed to date, purple dotted line indicates course to Tuktoyaktuk.



UNCLOS – CCGS Louis S. St Laurent 2010

Highlights: Two ship operations CCGS Louis S St. Laurent and Coast Guard icebreaker Healy was suspended for the majority of the week. Most of the week was committed to traveling to Tuktoyaluk (and return to work area) for a Medavac. Sounding operations did continue while enroute. To date; 7500 line kilometers of bathymetry has been collected along with 32 XCTD, 14 XBT, 2 deep-water SVP cast and 61 spot soundings. Helicopter logged 11.5 hours of flight time. The helicopter spot-sounding ops again were hampered by weather conditions. Saturday was the last day for helicopter spot soundings operations.

Weekly Summary: Aug 23 to 29

Aug 30 Monday – sounding ops, fog and lighter ice, enroute Tuktoyaluk, standby for weather for helicopter spot sounding ops

Aug 31 Tuesday – sounding ops, arrive Tuktoyaluk around 10PM, helicopter to shore for Medavac, turned north approximately 11 pm after engine work

Sept 1 Wednesday – sounding ops, heading north to start of east to west line, travelling between Banks Island and ice edge, noticed differences of 100 metres between actual and charted depths on chart 7600

Sept 2 Thursday – sounding ops, deployed seismic gear at 18:00 local running west with Healy escort

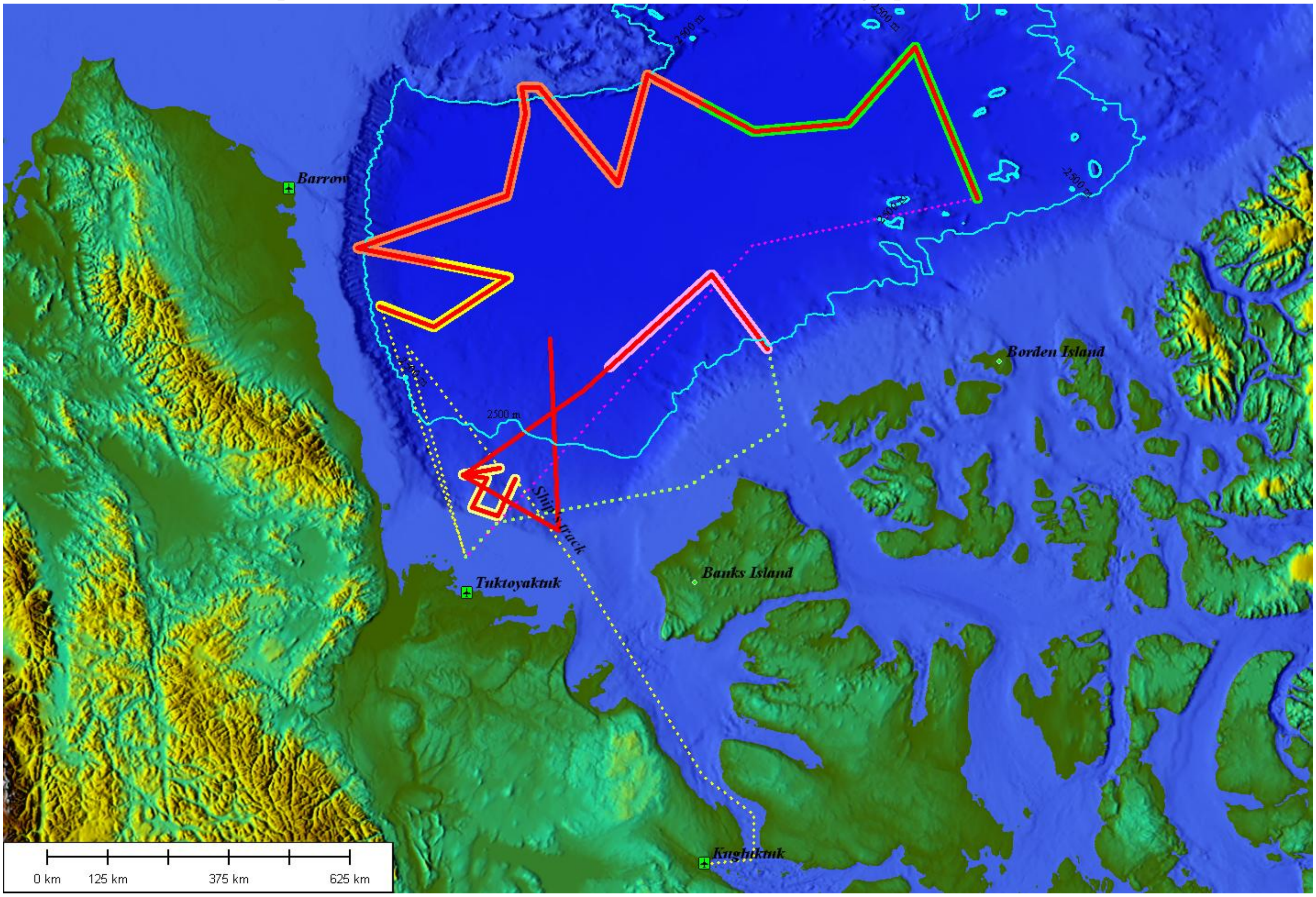
Sept 3 Friday – sounding and seismic ops, Healy escort, 2 helicopter flights 25 spots soundings collected

Sept 4 Saturday - sounding and seismic ops, Healy departed for Barrow after lunch, helicopter spot soundings flight, 13 spot soundings collected, end of helicopter spot sounding operations, not a requirement in southern areas, stopped to do seismic air gun calibration after dinner, started logging segy files on Knudsen sounder

Sept 5 Sunday - sounding and seismic ops, Knudsen sounder/computer froze in AM, still logging depths but no keb/segy files created, rebooted Knudsen computer in science lab on 3rd level to solve problem

Plans: continue seismic / bathymetry survey operations in the Beaufort Sea/southern Canada Basin area until required to meet crew change flight scheduled for Sept 15 for Kugluktuk.

Map: Red lines are the proposed survey lines; highlighted lines are sounding/seismic lines completed to date, a dotted line indicates only sounding operations.



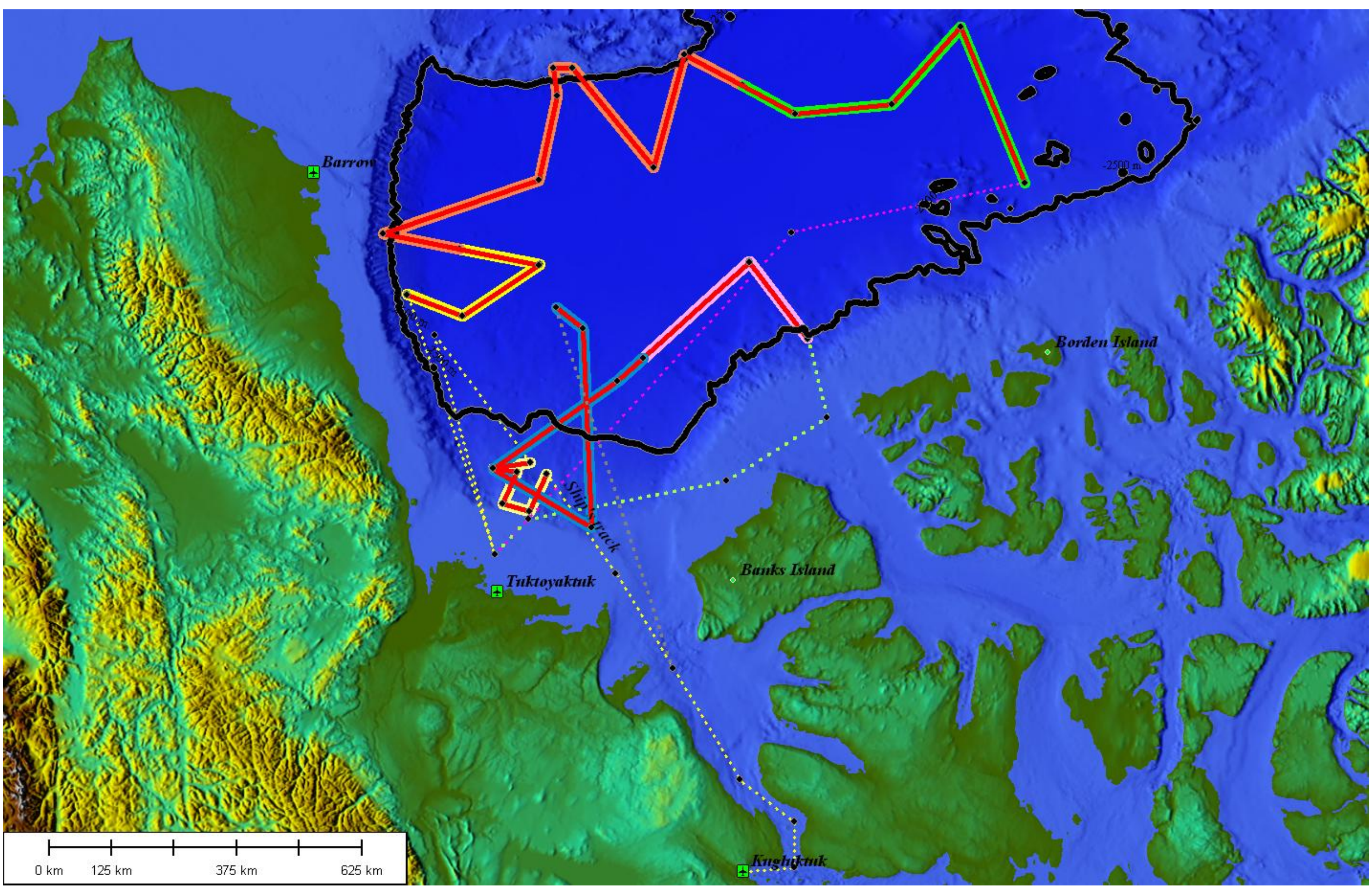
UNCLOS – CCGS Louis S. St Laurent 2010

Highlights: Seismic program is finished. To date; 9145 line kilometers of bathymetry has been collected along with 34 XCTD, 13 XBT, 3 deep-water SVP cast and 61 spot soundings. Seismic operations ended Saturday, continue sounding ops until Kugluktuk.

Weekly Summary: Sept 6 to Sept 12
Sept 6 Monday - sounding and seismic ops
Sept 7 Tuesday - sounding and seismic ops, problems picking up bottom with the sea conditions and ship orientation, lost several hours, CHS computer also lost connection several times to Knudsen sounder during the day
Sept 8 Wednesday - sounding and seismic ops
Sept 9 Thursday - sounding and seismic ops, stopped logging seg-y files, crashes computer and slows down/corrupts the logging of keb files
Sept 10 Friday - sounding and seismic ops
Sept 11 Saturday - sounding and seismic ops, last day of seismic operations, gear onboard at noon, deep water SVP cast, continue sounding ops, heading for Paulaltuk for mammal observers to disembark
Sept 12 Sunday – sounding ops, enroute to Paulatuk

Plans: continue bathymetry operations until Kugluktuk. Board crew change flight to St John's on Wednesday Sept 15th and return to Burlington Sept 16th.

Map: Red lines are the survey lines; highlighted lines are sounding/seismic lines completed to date, a dotted line indicates only sounding operations.



Appendix B: Bridge Instructions

<u>Bridge Instructions, August 6 (JD 218), 2010</u>

1) Proceed to Rendezvous point with USCGC Healy
   72º 57.0'N 137º 34.3'W
Distance from Kugluktuk: 560 nMi
(Note: may modify depending on communication with Healy)

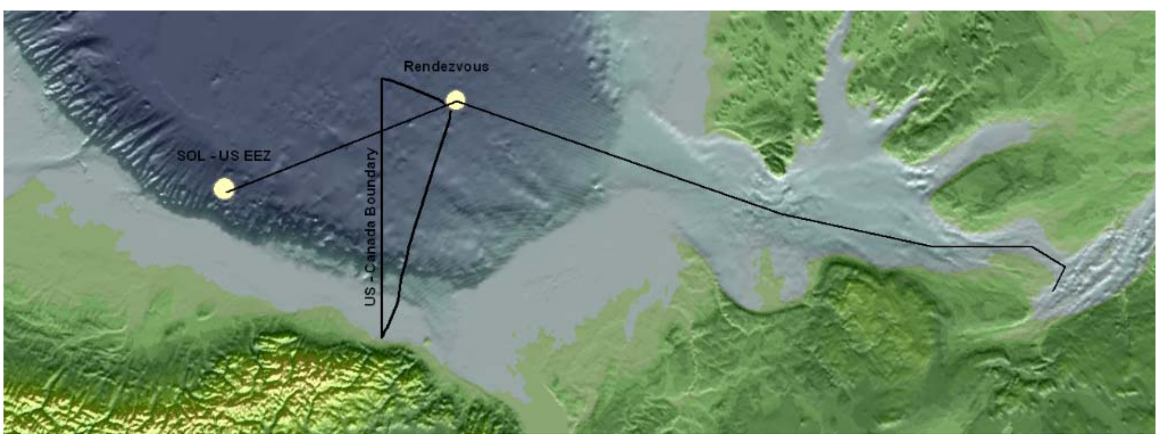
2) En Route or upon arrival at rendezvous point, LSSL to conduct deployment and towing tests of 3.5 kHz system and conduct seismic calibration experiment. estimated time 6 hours

3) commence survey operations as time permits (waypoints to be provided)

4) Cease survey operations approximately 1300hr August 9 (JD 221)

5) Transfer personnel

6) Approx. 1700hr, August 9 (JD 221), pull seismic gear and proceed to US EEZ
   to arrive at 71º 39.174' -148º 11.28' SOL (US EEZ)
   for 10:00 hr, August 10 (Day 222)
Deploy seismic equipment and commence survey operations



Bridge Instructions, August 10, 2010

1) Proceed to start of line in US EEZ (Waypoint 10 below) (ETA 1030h, Aug. 11 (assuming 12 knots)).

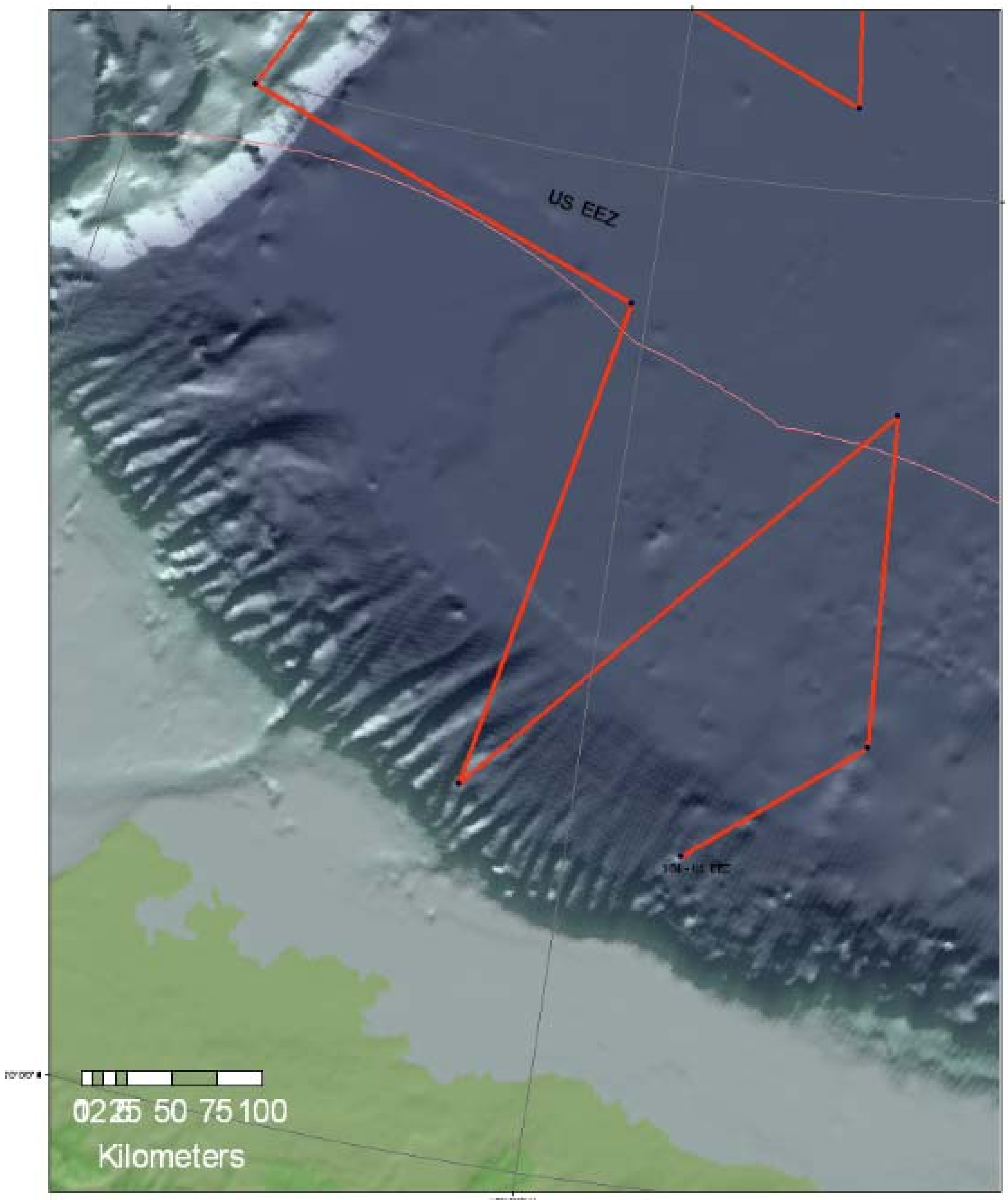
2) Once on station, gear assembly has to be completed and prepared for deployment...that may take several hours.

3) If US approvals are given, then commence seismics along track provided below. If no approvals provided, then we wait .

WP	Latitude		Longitude	
10	71	39.174	-148	11.333
11	72	16.296	-145	24.594
12	73	54.91278	-145	18.0849
13	71	50.24202	-151	49.41438
14	74	19.08114	-150	17.79852
15	74	57.8721	-158	0.73548

Note that the Healy is to join us at WayPoint 11 to assist with ice breaking. She will be the lead vessel during seismic operations off the LSSL.

***NOTE: THROUGH MUTUAL AGREEMENT WITH THE HEALY WE ARE TO RUN AZIMUTHAL TRACKS, NOT GREAT CIRCLE AS PREVIOUS**


US EEZ
50 75 100
Kilometers

Bridge Instructions, August 16, 2010

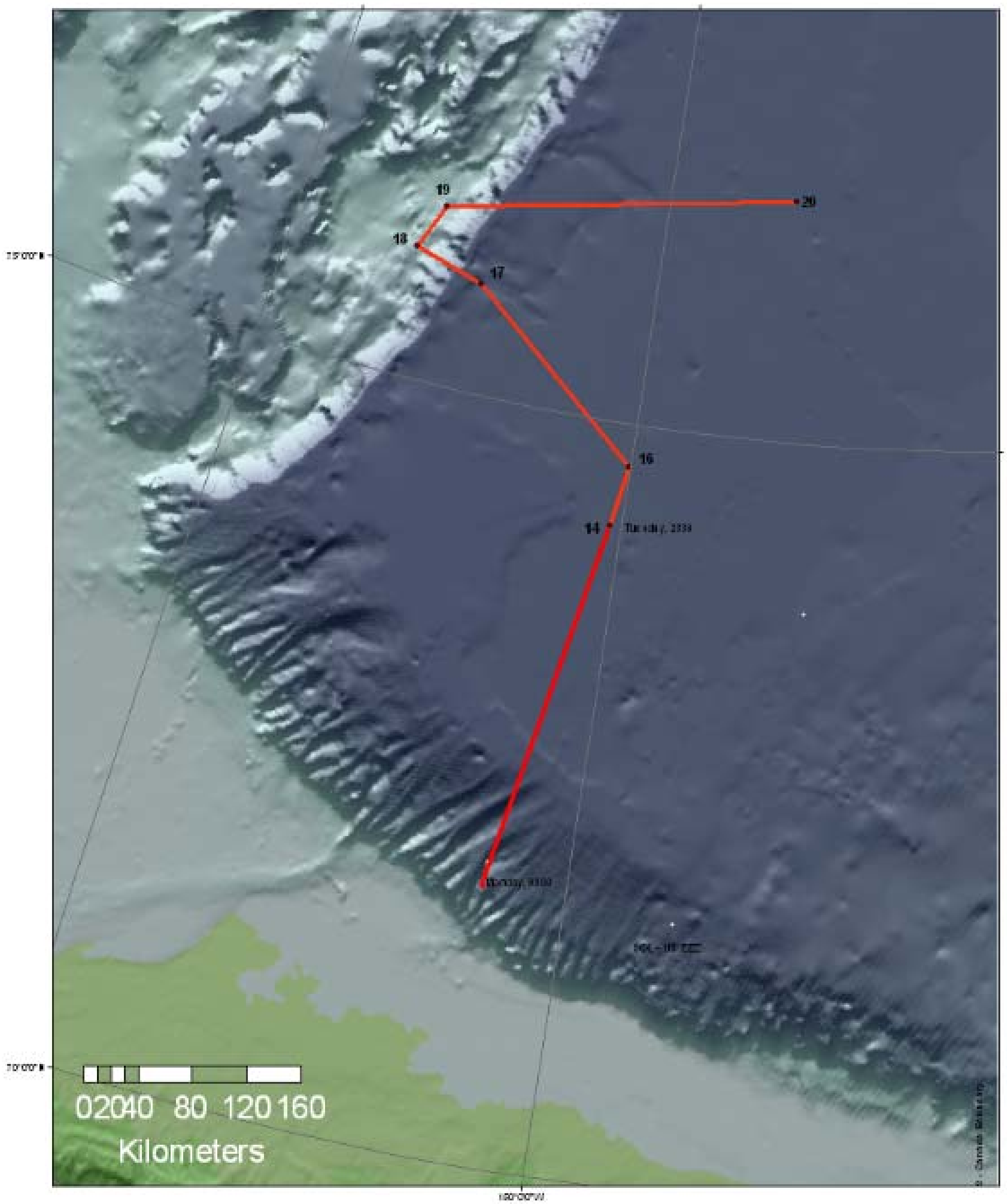
1) Continuation of seismic operations. At Waypoint 14 (74º 19.08N, 150º 17.79'W) proceed to Waypoint 16 provided in the table below. Ignore previously provided Waypoint 15. Continue survey pattern sequentially from 16 through to 20.

WP	Latitude	Longitude
16	**74° 43.2317'**	**-150° 03.1283'**
17	**75° 42.8441'**	**-154° 41.5019'**
18	**75° 51.2512'**	**-156° 37.1032'**
19	**76° 09.5383'**	**-156° 05.2307'**
20	**76° 35.2378'**	**-146° 30.1164'**

Total Track length is 307 nMi

Note: After Waypoint 14, we will be out of the US EEZ and requirements of Marine Mammal Observations revert back to Canadian guidelines. The US Marine Mammal Observers are free to transfer back to the Healy at that point in time.

THROUGH MUTUAL AGREEMENT WITH THE HEALY WE ARE TO RUN AZIMUTHAL TRACKS, NOT GREAT CIRCLE AS PREVIOUS


19
20
18
17
16
14
0 20 40 80 120 160
Kilometers

Bridge Instructions, August 19, 2010

1) At WayPoint 20, we will bring in the seismic gear and transit to Waypoint 21. We can break ice for the Healy during that transit, if preferred.

2) Deploy seismic equipment at Waypoint 21 and proceed seismic operations from WP21 to WP22 and WP23

WP	Latitude	Longitude
20	**76° 35.24'**	**-146° 30.12'**
21	**78° 06.00'**	**-153º 10.00'**
22	**79° 12.00'**	**-143° 10.00'**
23	**78° 53.00'**	**-138° 30.00'**

Total Track length is 321 nMi (including transit from wp20 to wp21)

THROUGH MUTUAL AGREEMENT WITH THE HEALY WE ARE TO RUN AZIMUTHAL TRACKS, NOT GREAT CIRCLE AS PREVIOUS

Bridge Instructions, August 21, 2010

1) At WayPoint 22, we will bring in the seismic gear and transit to Waypoint 24, ignoring former Waypoint 23. LSSL can break ice for the Healy during transit.

2) waypoint 24 to 25 is meant to pass over the seamount from the SouthWest, where multibeam data infill is required

3) Deploy seismics - preferably in an open water area near WP 25 and survey up to WP 26

4) Recover seismics and transit/multibeam to WPs 27 and 28

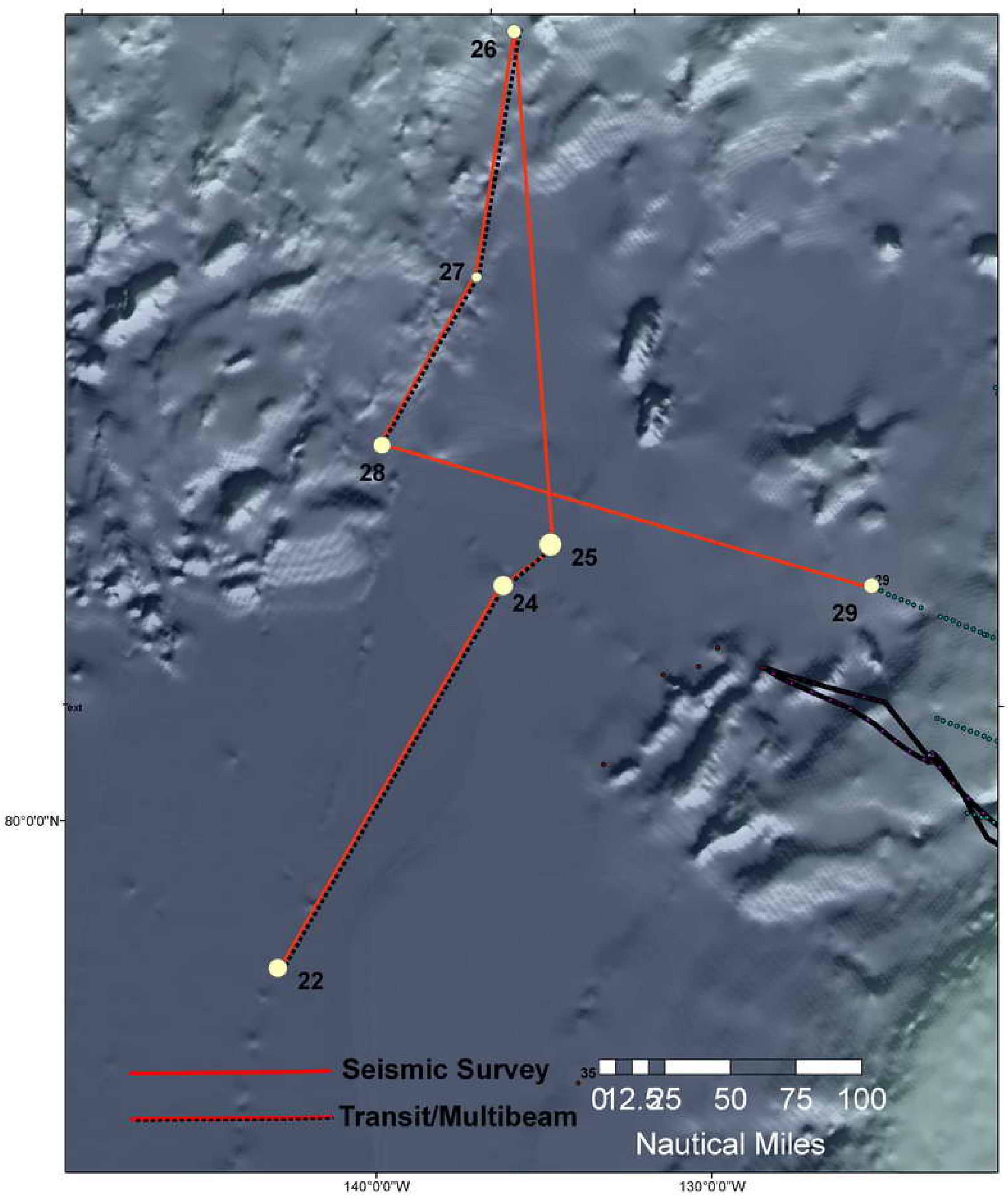
5) Deploy seismics at WP 28 - preferably in open water - and survey to WP 29

6) Recover gear at WP 29

WP	Latitude	Longitude	Line/Distance nMi	Operation
22	79º 12.00'	-143º 10.00'	22-24 / 170 nMi	Transit
24	81º 33.50'	-134º 06.00'	24-25 / 25 nMi	Transit
25	81º 46.34'	-131º 42.60'	25-26 / 200 nMi	Deploy/Survey
26	85º 00.40'	-128º 08.60'	26-27 / 95 nMi	Recover/Transit
27	83º 32.61'	-133º 23.44'	27-28 / 75 nMi	transit
28	82º 31.80'	-139º 10.70'	28-29 / 195 nMi	Deploy/Survey
29	80º 58.71'	-119º 14.18'		Recover

Multibeam data will be collected on transit lines. Seismics will be collected along Survey lines.

Heavy ice is expected during this survey, particularly on the northern most section of the line between WP 25 and WP 26, and on the eastern end of the line between WP 28 and 28. If unable to conduct seismic operations, then we will revert to bathymetric/multibeam operations.


26
27
28
25
24
29
22
Seismic Survey
Transit/Multibeam
0 12.5 25 50 75 100
Nautical Miles
80°0'0"N
140°0'0"W
130°0'0"W

Bridge Instructions, August 23, 2010

1) Pull in seismic gear immediately after lunch (aug 23) and transit to WP 23. LSSL can break ice for the Healy during transit.

2) Dogleg to WP 24 and WP 25 - is meant to pass over the newly discovered seamount from the SouthWest, where multibeam data infill is required

3) Deploy seismics - WP 25 and survey up to WP 26

4) Recover seismics and transit/multibeam to WPs 27 and 28

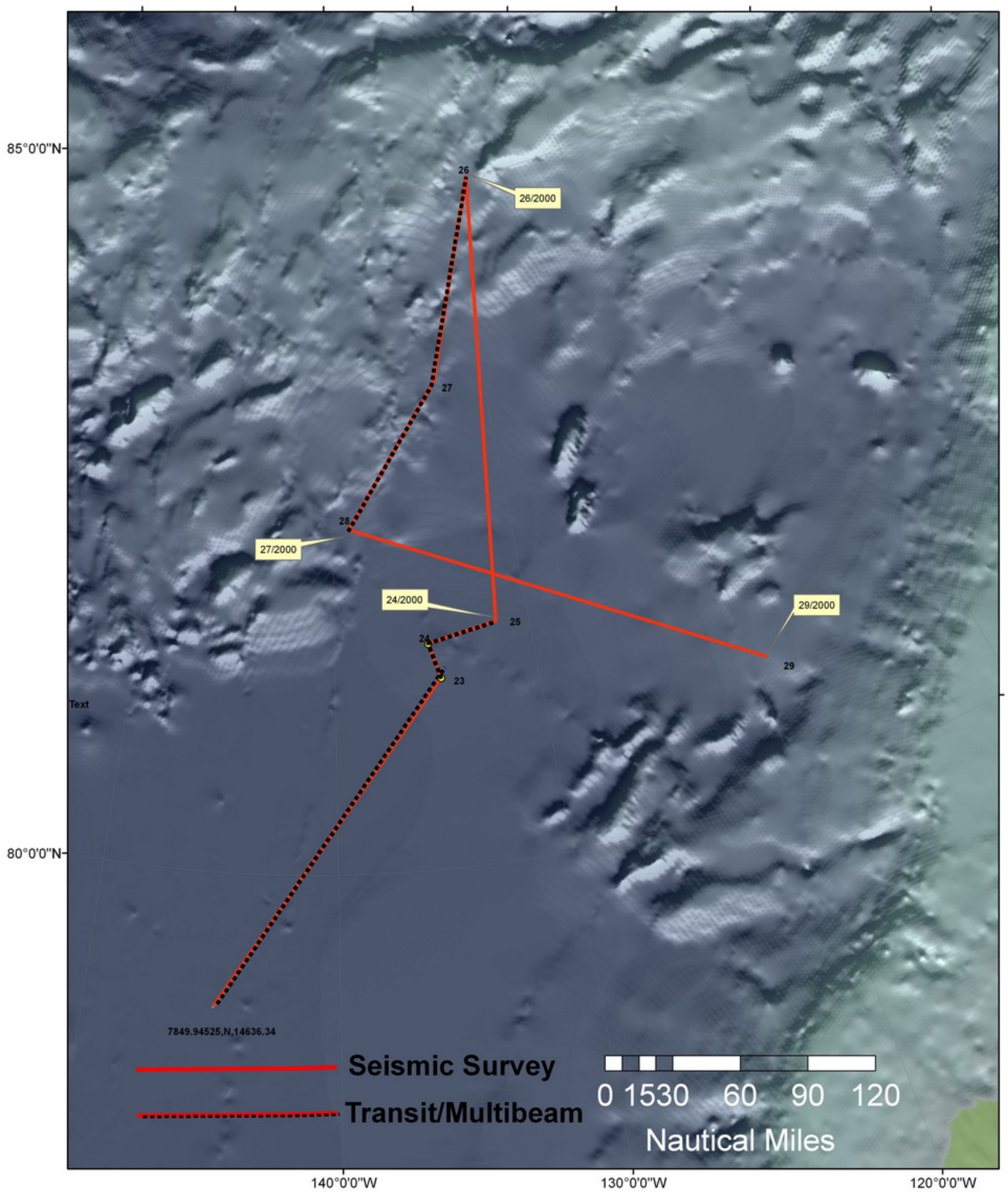
5) Deploy seismics at WP 28 - preferably in open water - and survey to WP 29

6) Recover gear at WP 29

WP	Latitude	Longitude	Line/Distance nMi	Operation
22	79° 12.00'	-143° 10.00'	22-23 / 178 nMi	Transit
23	81° 24.03'	-134° 46.07	23-24/16 nMi	Transit/mb
24	81° 39.61'	-135° 14.75	24-25 / 32 nMi	Transit/mb
25	81° 46.34'	-131° 42.60'	25-26 / 200 nMi	Deploy/Survey
26	85° 00.40'	-128° 08.60'	26-27 / 95 nMi	Recover/Transit
27	83° 32.61'	-133° 23.44'	27-28 / 75 nMi	transit
28	82° 31.80'	-139° 10.70'	28-29 / 195 nMi	Deploy/Survey
29	80° 58.71'	-119° 14.18'		Recover

Multibeam data will be collected on transit lines. Seismics will be collected along Survey lines.

Heavy ice is expected during this survey, particularly on the northern most section of the line between WP 25 and WP 26, and on the eastern end of the line between WP 28 and 29. If unable to conduct seismic operations, then we will revert to bathymetric/multibeam operations.



85°0'0"N
80°0'0"N
140°0'0"W
130°0'0"W
120°0'0"W
26
26/2000
27
28
27/2000
24/2000
25
24
23
29/2000
29
Text
7849.94525,N,14636.34
Seismic Survey
Transit/Multibeam
0 1530 60 90 120
Nautical Miles

Bridge Instructions, August 25, 2010

1) Steam directly to WP 28

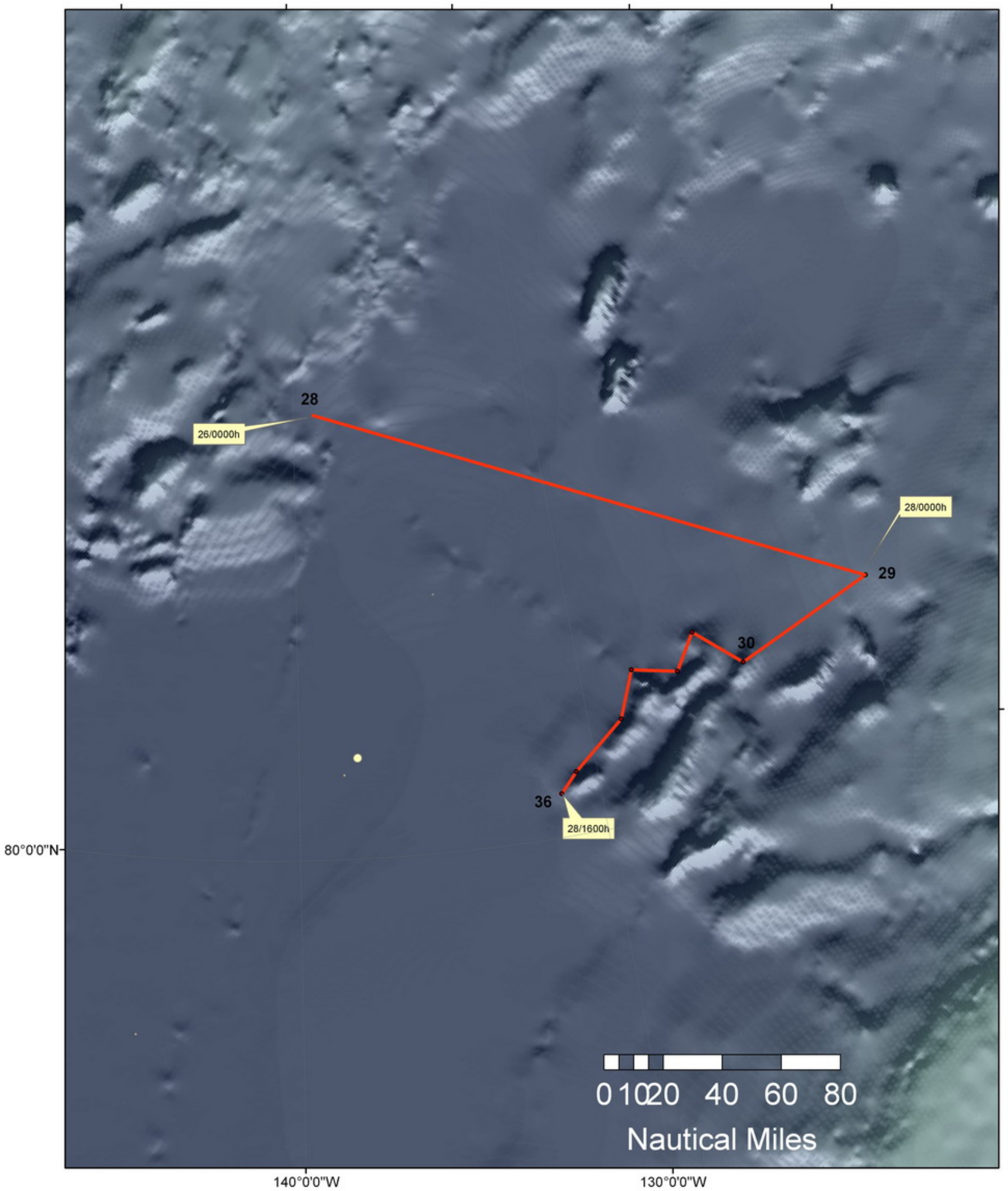
2) Deploy seismics at WP 28 and survey to WP 29

3) Recover gear at WP 29

4) Multibeam survey (Louis leading Healy) through from WP 29 through to 36
We're trying to follow a morphologic feature from wp 30 to 36 - Healy will have to offer instructions based on its multibeam signature.

WP	Latitude	Longitude	Line/Distance nMi	Operation
28	82º 31.80'	-139º 10.70'		Deploy/Survey
29	80º 58.71'	-119º 14.18'	194 nMi	Recover
30	80º 44.3005'	124º 18.639'	51 nMi	Multibeam
31	80º 58.5395'	125º 45.6791'		Multibeam
32	80º 47.0839'	126º 35.9663'		Multibeam
33	80º 51.1334'	128º 09.8565'	99 nMi	Multibeam
34	80º 35.644'	128º 52.1972'		Multibeam
35	80º 21.0932'	130º 42.347'		Multibeam
36	80º 14.6493'	-131º 18.1384'		Multibeam

Heavy ice is expected on the eastern end of the line between WP 28 and 29. If unable to conduct seismic operations, then we will revert to bathymetric/multibeam operations.


28
26/0000h
28/0000h
29
30
36
28/1600h
80°0'0"N
0 10 20 40 60 80
Nautical Miles
140°0'0"W
130°0'0"W

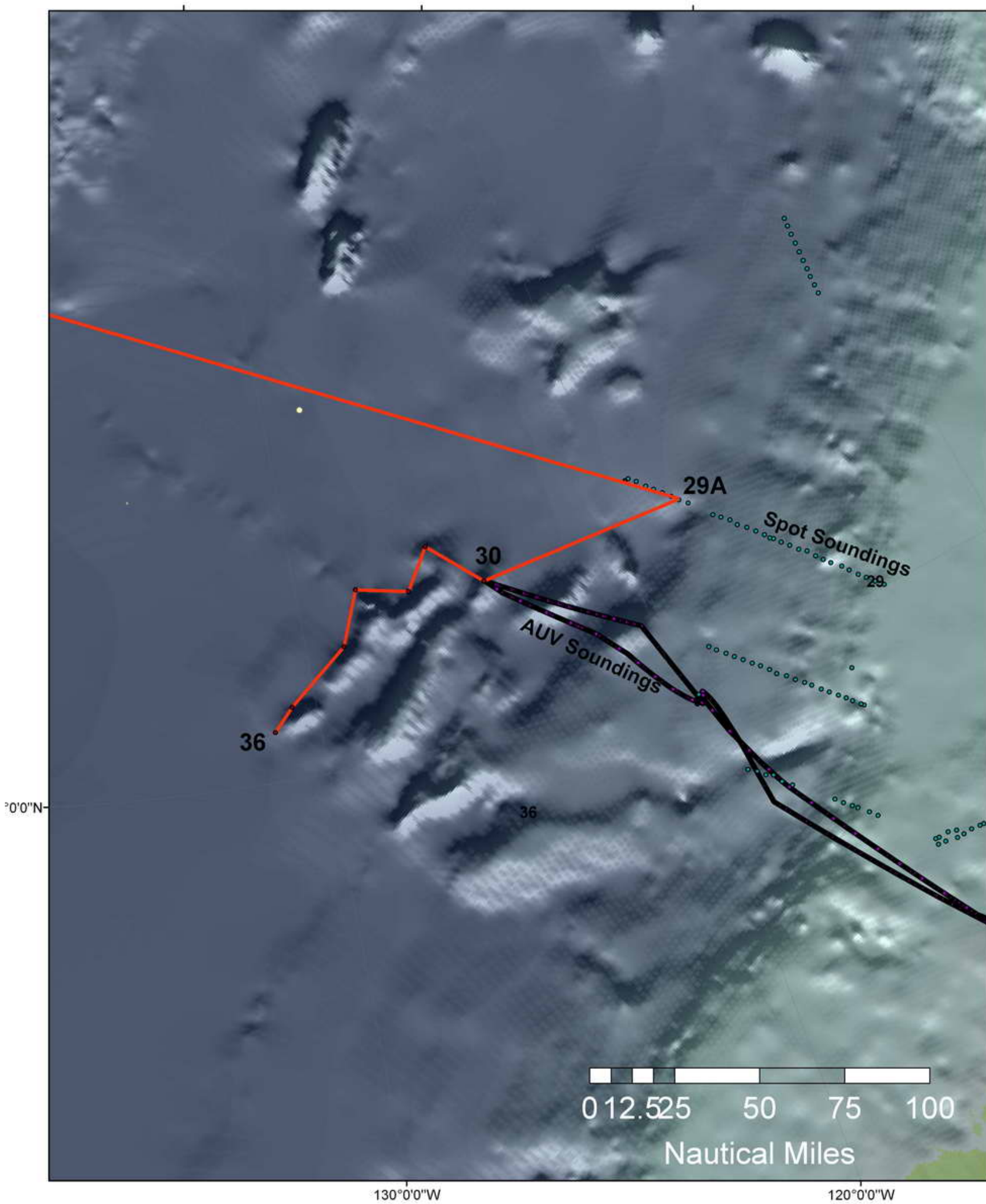
Bridge Instructions, August 27, 2010

1) Continue seismics as long as feasible along line between WP 28 and 29. At some point it will be necessary to recover seismic gear and switch to multibeam mode.

2) Continue in multibeam mode (LSSL leading Healy) through Waypoint 29 and continue to Waypoint 29A. (29A is 114 nMi from present position; 0930PST, August 27)

3) Multibeam survey (Louis leading Healy) through from WP 29, 29A through to 36 Between WP30 to 36, we are trying to follow a morphologic feature (ridge). Healy will have to offer instructions based on its multibeam signature.

WP	Latitude	Longitude	Line/Distance nMi	Operation
28	82º 31.80'	-139º 10.70'		Deploy/Survey
29	80º 58.71'	-119º 14.18'		Recover
29A	80º 47.75'	-117º 55.64'		Multibeam (EOL)
30	80º 44.3005'	-124º 18.639'	51 nMi	Multibeam
31	80º 58.5395'	-125º 45.679'		Multibeam
32	80º 47.0839'	-126º 35.966'		Multibeam
33	80º 51.1334'	-128º 09.856'	99 nMi	Multibeam
34	80º 35.644'	-128º 52.197'		Multibeam
35	80º 21.0932'	-130º 42.347'		Multibeam
36	80º 14.6493'	-131º 18.138'		Multibeam


29A
Spot Soundings
29
30
AUV Soundings
36
36
°0'0"N
0 12.5 25 50 75 100
Nautical Miles
130°0'0"W
120°0'0"W

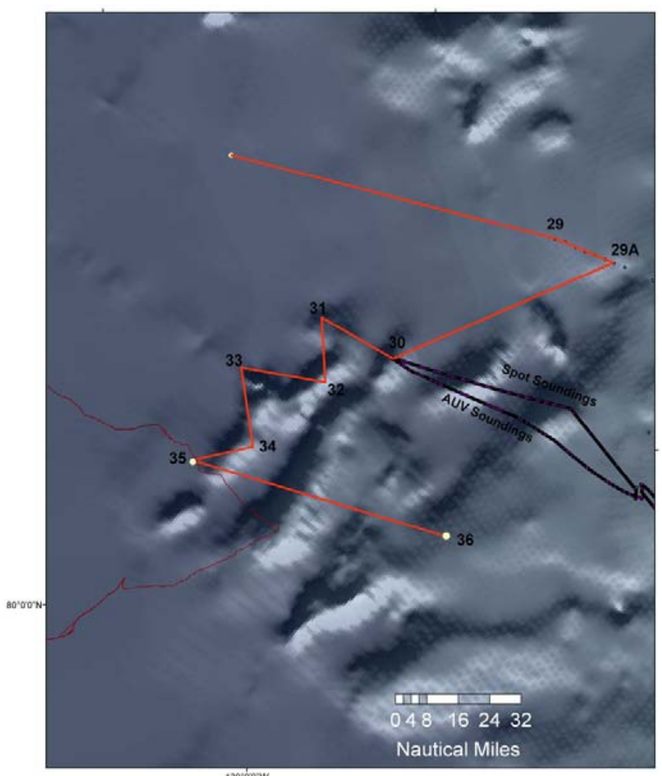
Bridge Instructions, August 27(2), 2010

1) Healy Multibeam and chirp operations from present position to Waypoint 35.

2) If ice conditions permit, deploy seismics at WP 35 and acquire data to WP35. If no seismics, then continue with multibeam and chirp.

WP	Latitude	Longitude	Operation	Distance
29	80º 58.96'	-119º 07.65'	Multibeam	
29A	80º 47.75'	-117º 55.64'	Multibeam	
30	80º 43.64'	-124º 13.99'	Multibeam	
31	80º 58.54'	-125º 45.68'	Multibeam	
32	80º 42.44'	-126º 06.34'	Multibeam	
33	80º 51.13'	-128º 09.86'	Multibeam	
34	80º 30.80'	-128º 18.62'	Multibeam	
35	80º 30.66'	-129º 54.78'	Multibeam	265 nMi
36	79º 56.36'	-124º 10.47'	Seismic/Multibeam	67 nMi

Possible 2 ship rafting and ceremony here at WP 36



Bridge Instructions, Sept 5, 2010

1) Slight course alteration at waypoint 40 to Waypoint 41
on track, deploy Ocean Bottom Seismometer (OBS)

2) Pick up seismics and transit from WP41 to Waypoint 42
3) Deploy seismics and survey to Waypoint 43

2) Survey westward to Waypoint 38 then southward to Waypoint 39. Healy will have to break off at some point after waypoint 39, but we should be in this finger of lighter ice by then.

WP	Latitude	Longitude	Line/Distance nMi	Operation
40	73° 41.1137'	-136° 24.1702'		Seismic
41				Deploy OBS
42	70° 59.7718'	-137° 36.1483'	103	Seismic
43	71° 29.6984'	-131° 29.5989'	344	
44	73° 50.8777'	-140° 20.659'		

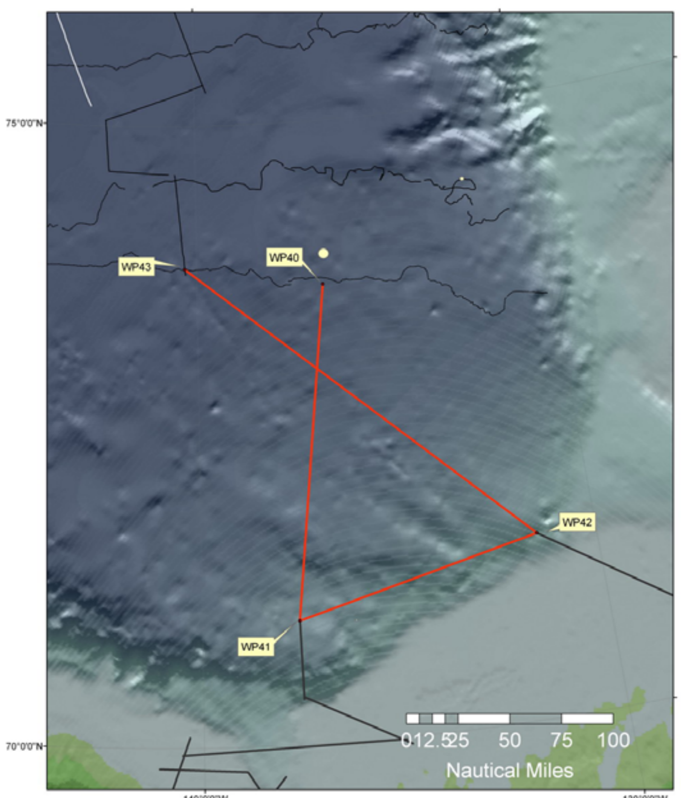
Bridge Instructions, Sept 5, 2010

1) Slight course alteration at WP40 to WP41

2) Recover seismics at WP41 and transit to WP42

3) Deploy seismics at WP42 and survey to WP43

WP	Latitude	Longitude	Line/Distance nMi	Operation
40	73° 41.11'	-136° 24.17'		Seismic
41	70° 59.77'	-137° 36.15'	162	Seismic
42	71° 29.70'	-131° 29.60'	121	Transit
43	73° 50.88'	-140° 20.66'	213	Seismic



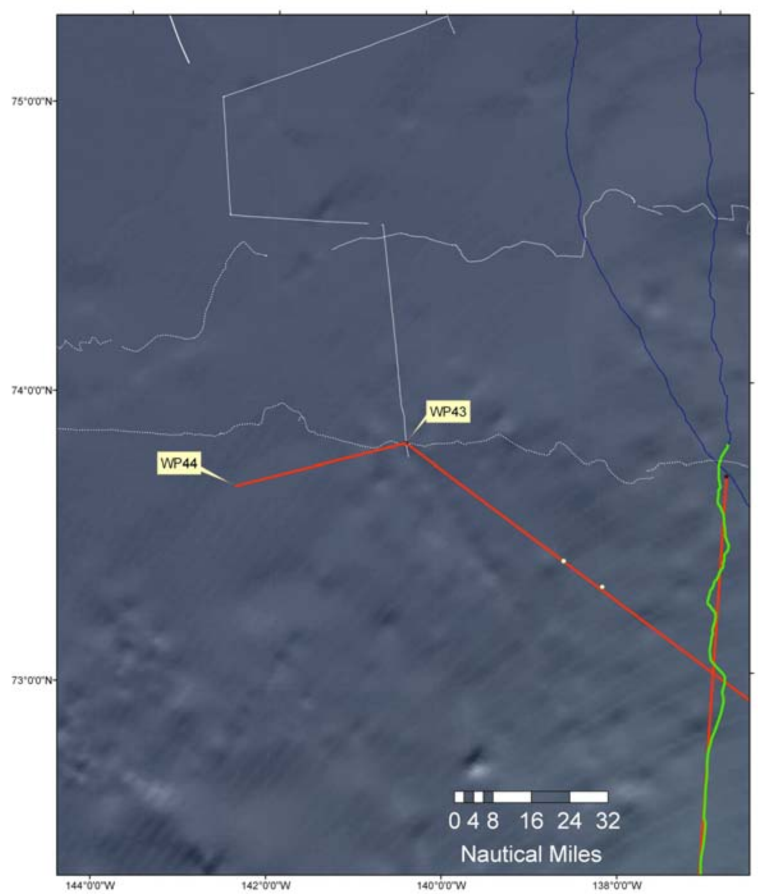
Bridge Instructions, Sept 10, 2010

1) After making WP 43 (ETA 0300h, Sept. 11), turn to port to WP44

2) Recover seismics seismics at WP44

3) Conduct Sound Velocity Profile (SVP)

WP	Latitude	Longitude	Line/Distance nMi	Operation
43	73º 50.88'	-140º 20.66'		Seismic
44	73º 42.20'	-142º 28.86'	37	Seismic
	SVP			



Appendix C

Gundalf, G Gun Modeling Results

GUNDALF array modelling suite - 1150 in3, 6 m depth Array report

Gundalf revision AIR6.1c, Date 2010-01-07, Epoch 2010-01-07

Sun Sep 05 23:15:03 Atlantic Daylight Time 2010 (David Mosher)

Report pre-amble

Author: Mosher

Author Organisation: NRCan

Contents

Signature filtering policy

For marine environmental noise reports, Gundalf performs no signature filtering other than that inherent in modelling at a sample interval small enough to simulate an airgun array signature at frequencies up to 100kHz.

For all other kinds of reports, Gundalf performs filtering in this order:-

- If a pre-conditioning filter is chosen, for example, an instrument response, it is applied at the modelling sample interval.
- If the output sample interval is larger than the modelling sample interval, Gundalf applies appropriate anti-alias filtering. (This can be turned off in the event that anti-alias filtering is included in the pre-conditioning filter, in which case Gundalf will issue a warning.)
- Finally, Gundalf applies the chosen set of post-filters, Q, Wiener and band-pass filtering as specified, at the output sample interval.

In reports, when filters are applied, they are applied to the notional sources first so that signatures, directivity plots and spectra are all filtered consistently.

Finally note that modelled signatures always begin at time zero for reasons of causality.

Anti-alias and pre-condition filtering

In this case, no pre-conditioning filter has been applied.

In this case, no anti-alias filtering was necessary.

Post filtering

Details of the post-filtering used in this report follow. Post filters are applied at the output sample interval after any pre-conditioning and anti-alias filters have been applied.

Q filtering

No Q filtering performed.

Wiener filtering

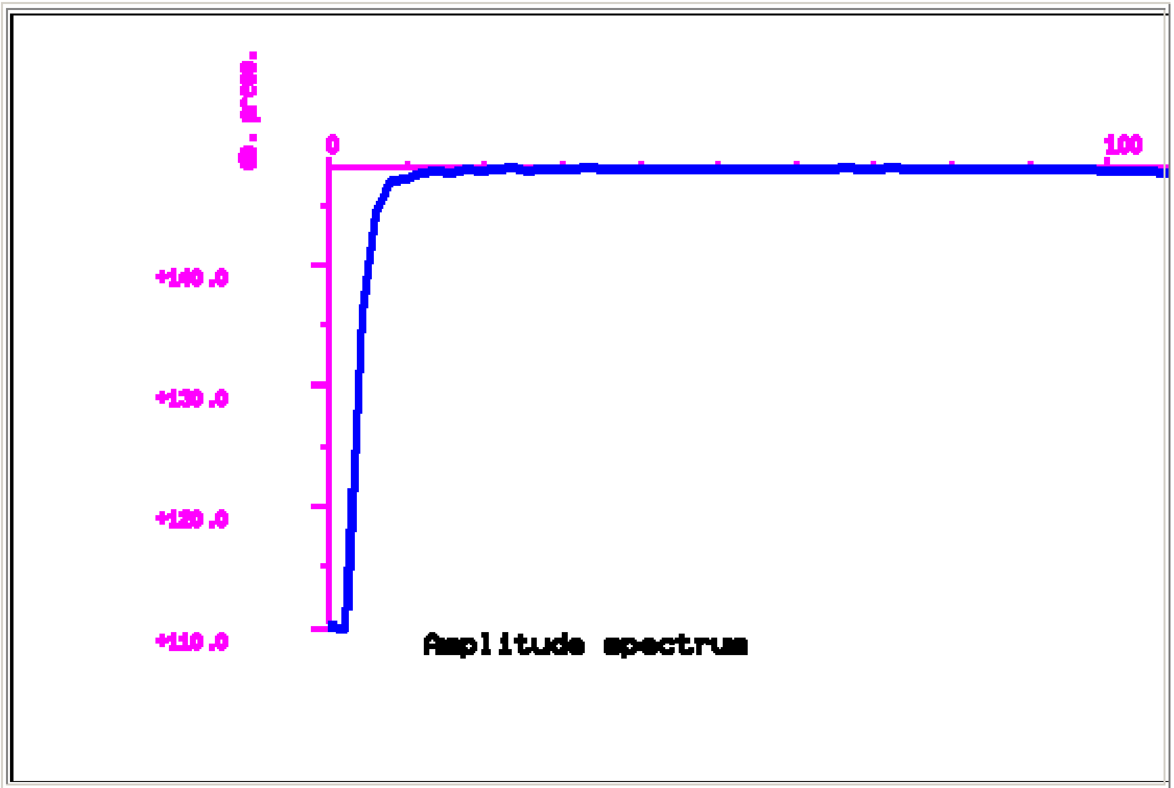
No Wiener filtering performed.

Band-pass filtering

Signatures were band-passed filtered using the following parameters:-

Internally generated as 6.0/18.0 - 128.0/72.0

The amplitude spectrum of the band-pass filter used is shown below.



Some notes on the modelling algorithm

The Gundalf airgun modelling engine is the end-product of 15 years of state of the art research. It takes full account of all air-gun interactions including interactions between sub-arrays. No assumptions of linear superposition are made. This means that if you move sub-arrays closer together, the far-field signature will change. The effect is noticeable even when sub-arrays are separated by as much as 10m.

The engine is capable of modelling airgun clusters right down to the 'super-foam' region where the bubbles themselves collide and distort. It has been calibrated against both single and clustered guns for a number of different gun types under laboratory conditions and accurately predicts peak to peak and primary to bubble parameters across a very wide range of operating conditions.

In many cases, the predicted signatures are good enough to be used directly in signature deconvolution procedures.

Array summary

The following table lists the statistics for the array quoted in various commonly used units for convenience. Note that the rms value is computed over the entire modelled signature.

Array parameter	Array value
Number of guns	3
Total volume (cu.in).	1150.0 (18.8 litres)
Peak to peak in bar-m.	11.4 (1.14 MPa, 241 db re 1 microPascal. at 1m.)
Zero to peak in bar-m.	6.42 (0.642 MPa, 236 db re 1 microPascal. at 1m.)
RMS pressure in bar-m.	0.85 (0.085 MPa, 219 db re 1 microPascal. at 1m.)
Primary to bubble (peak to peak)	8.01
Bubble period to first peak (s.)	0.247
Maximum spectral ripple (dB): 10.0 - 50.0 Hz.	8.39
Maximum spectral value (dB): 10.0 - 50.0 Hz.	197
Average spectral value (dB): 10.0 - 50.0 Hz.	194
Total acoustic energy (Joules)	20505.2
Total acoustic efficiency (%)	8.3

Array geometry and gun contribution

The following table lists all the guns modelled in the array along with their characteristics. The last column is completed only if the array has actually been modelled during the interactive session and contains the approximate contribution of that gun as a percentage of the peak to peak amplitude of the whole array. Please note the following:-

- The peak to peak varies only as the cube root of the volume for the same gun type so that even small guns contribute significantly. This is particularly relevant to drop-out analysis.
- The peak to peak can also be depressed due to clustering effects as reported by Strandenes and Vaage (1992), "Signatures from clustered airguns", First Break, 10(8).

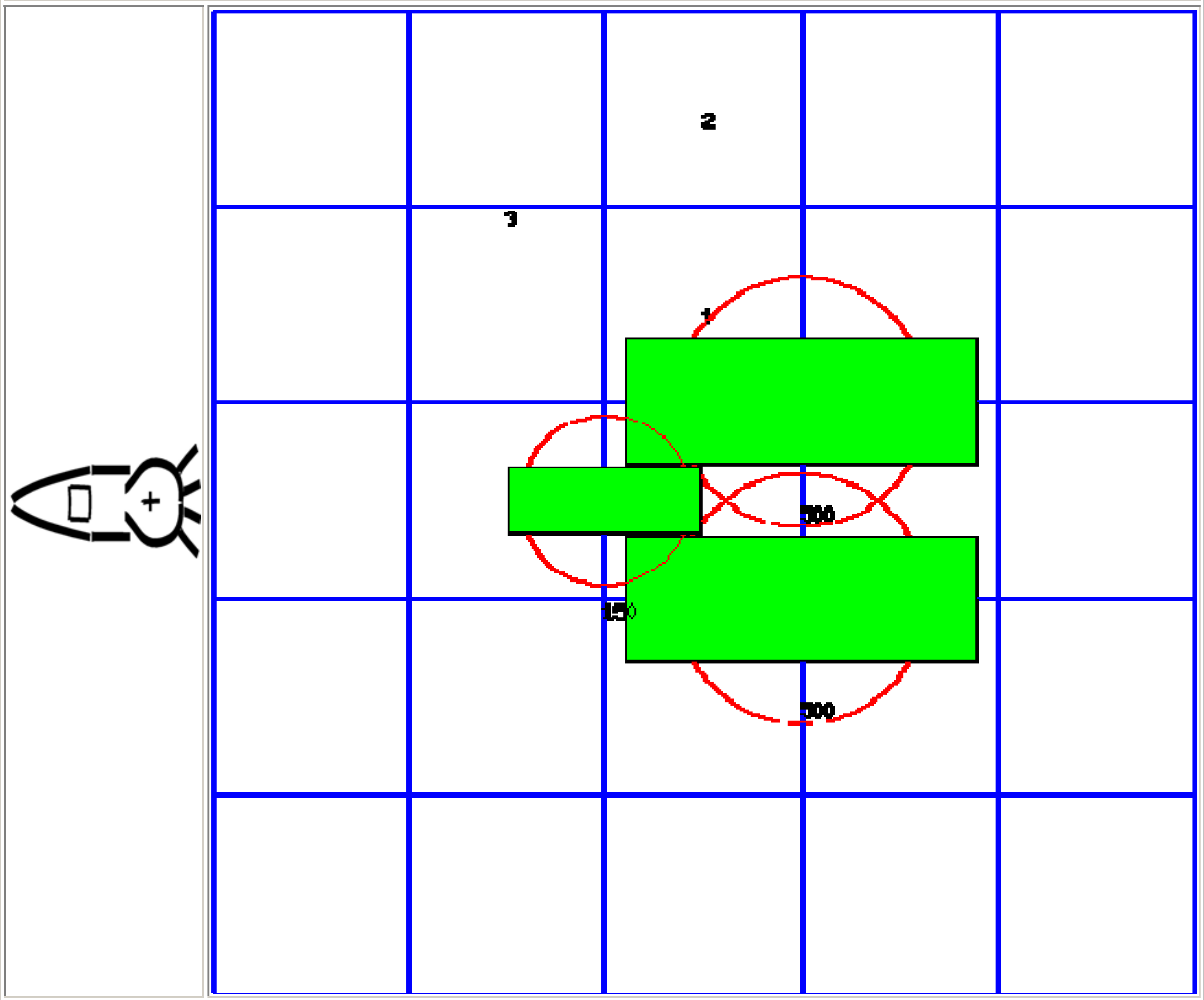
Gun	Pressure (psi)	Volume (cuin)	Type	x (m.)	y (m.)	z (m.)	delay (s.)	sub-array	p-p contrib (pct.)
1	1900.0	500.0	G-GUN	1.000	0.500	6.000	0.000	1	35.4
2	1900.0	500.0	G-	1.000	-	6.000	0.000	1	35.5

			GUN		0.500				
3	1900.0	150.0	G-GUN	0.000	0.000	6.000	0.000	1	29.1

The array is shown graphically below.

Hydrophone position: Infinite vertical far-field

<----- Direction of travel ----- --, (1m. grid, plan view)



The red circles denote the maximum radius reached by the bubble. Please note that pressure-field interactions take place over a much larger distance than this, (typically 10 times larger). However when bubbles touch or overlap, super-foam interaction can be expected. In this zone, significant peak AND bubble suppression will normally be observed.

Note also that a green rectangle represents a single gun and an orange rectangle indicates that the gun is currently dropped out. Where present, a yellow rectangle represents a vertical cluster (V.C.) of guns. Please see the geometry table above for more details. The small number to the

above left of each gun is its reference number in this table. For clusters of guns, these reference numbers mirror the symmetry of the cluster.

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Array centres and timing

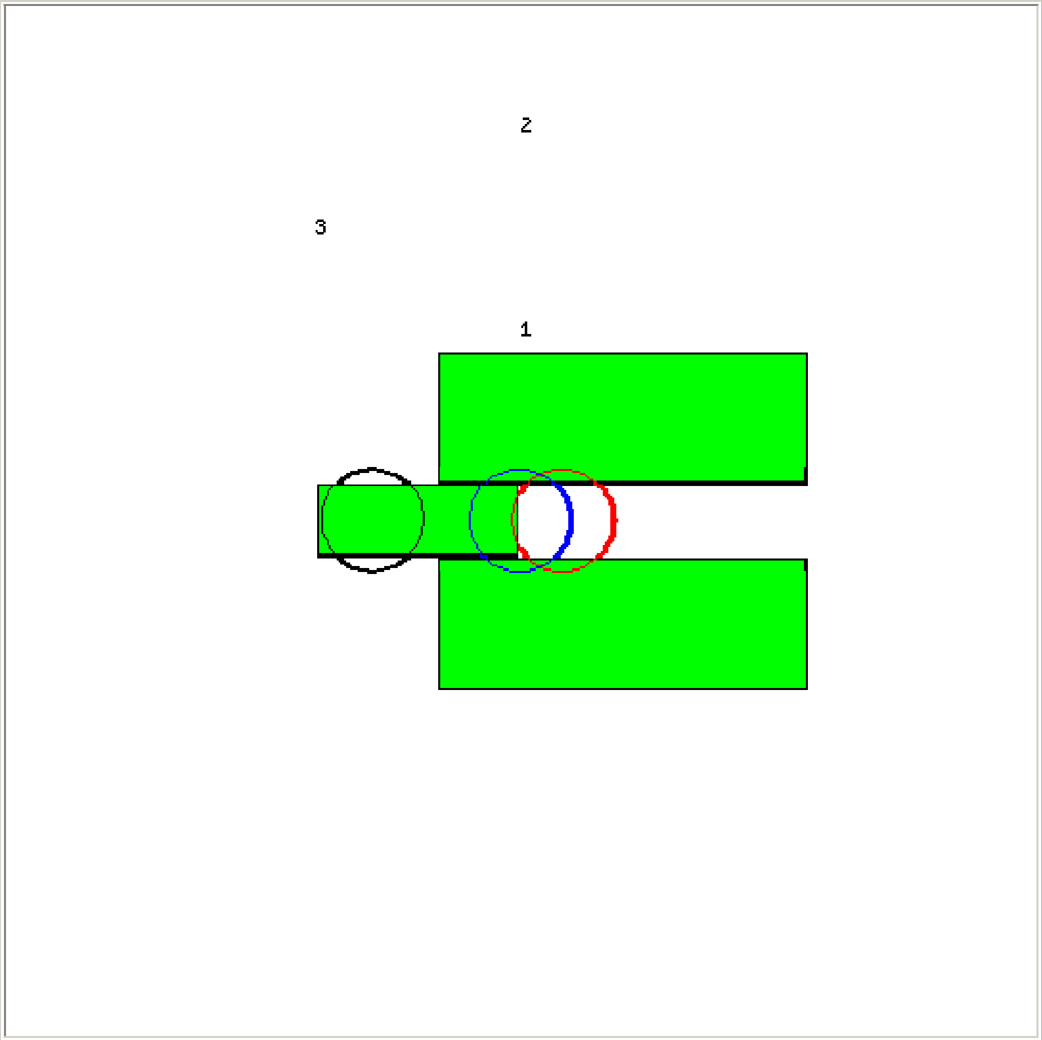
The following diagram shows the array geometric centre, the centre of pressure and the centre of energy defined as follows:-

- The array geometric centre is defined to be the centre of the rectangle formed by the largest and smallest x and y values of the active guns (dropped out guns are ignored). This is shown as a blue circle.
- The centre of pressure is defined to be the array centre when each active gun position is weighted by its contribution to the overall peak to peak pressure value. This is shown as a red circle.
- The centre of energy is computed by weighting the coordinates by the self-energy of the active gun at that position. In an interacting array this may be a long way from the centre of pressure as some guns may absorb energy giving a negative self-energy. This is shown as a black circle.

Depending on how first breaks are calculated, these can be used for first break analysis.

Dropped out guns are shown as orange rectangles whilst live guns are shown as green rectangles.

Array centres



The geometric centre is at (0.5, 0, 6)

The centre of pressure is at (0.709,-0.00025, 6)

The centre of energy is at (-0.224,-0.00475, 6)

Note that Gundalf by default uses the deepest gun to define time zero for the vertical far-field and it uses the nearest gun to the observation point to define time zero if an observation point is specified. This means that if one gun is accidentally run deep, this will cause the bulk of the signature to appear to be delayed. It is still a research question how an airgun array should be timed. There are several candidates as defined above but it is not currently clear which if any is appropriate in complex scenarios such as Ocean Bottom Deployment.

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Array directivity

The following tables show the inline and crossline directivity of the array in both (angle-frequency) and (angle-amplitude) form and optionally, the azimuthal directivity (theta-phi) form.

Note that the effects of cable ghosting if present are not shown in Gundalf directivity displays although source ghosting is included. This matches common practice in such displays.

For inline directivity displays, the x-axis is the inline angle from the vertical with the word fore indicating the end nearest the boat. For crossline directivity displays, the x-axis is the crossline angle from the vertical with the word port indicating the port side.

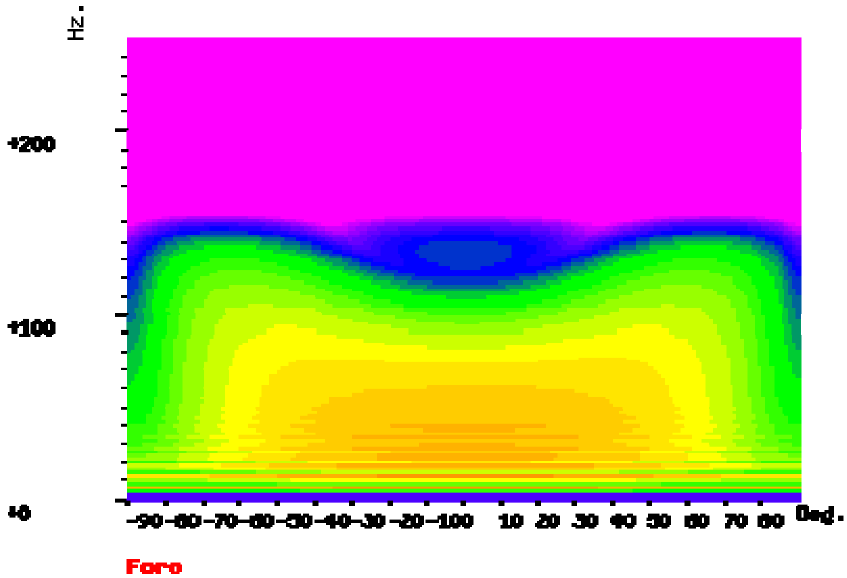
Note that *inline* is used nominally to mean any angle within 45 degrees of the boat direction (which corresponds to a bearing of zero degrees). Similarly, *crossline* is used nominally to mean any angle within 45 degrees of the perpendicular to the boat direction which is measured as a bearing of 90 degrees, (i.e. starboard). The nominal inline and crossline angles can be set by the user in the report options. The values used are indicated in the diagram titles below as bearings.

Where shown, the azimuthal plots show contours at four chosen frequencies as a function of phi (angle from the x-axis, opposite to the boat direction) and theta (the angle from the vertical). A bearing of zero degrees corresponds to a value of phi of 180 degrees.

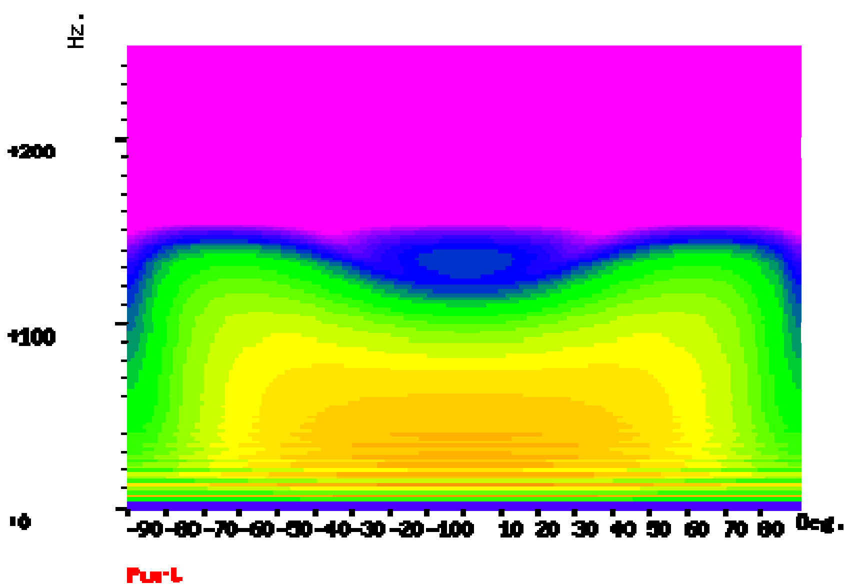
Angle-frequency form

The following tables show the inline and crossline directivity of the array in (dip angle-frequency) form. Both plots are scaled as dB. relative to 1 microPa. per Hz. at 1m.

Inline directivity, bearing = 0 degrees

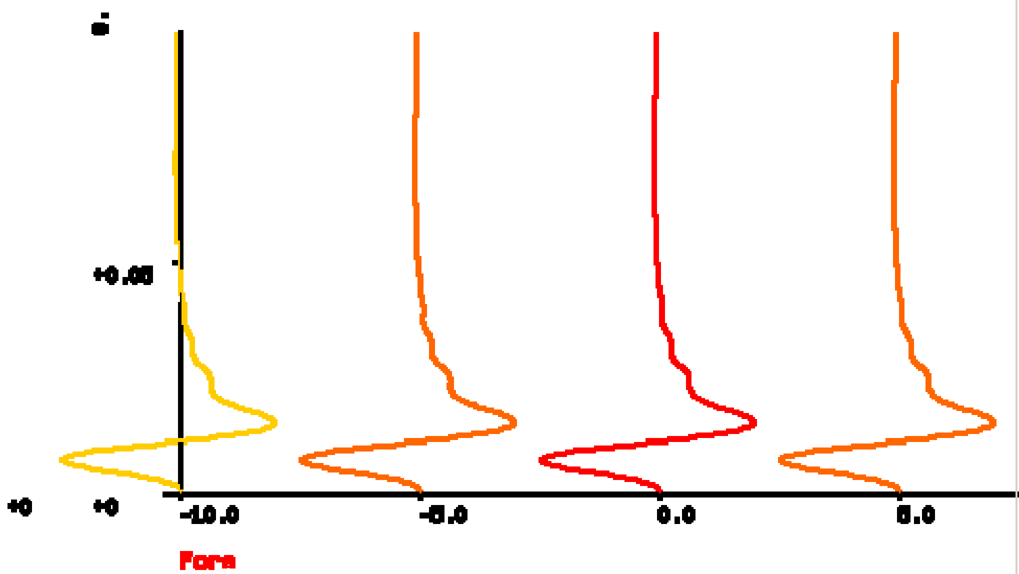


Crossline directivity, bearing = 90 degrees

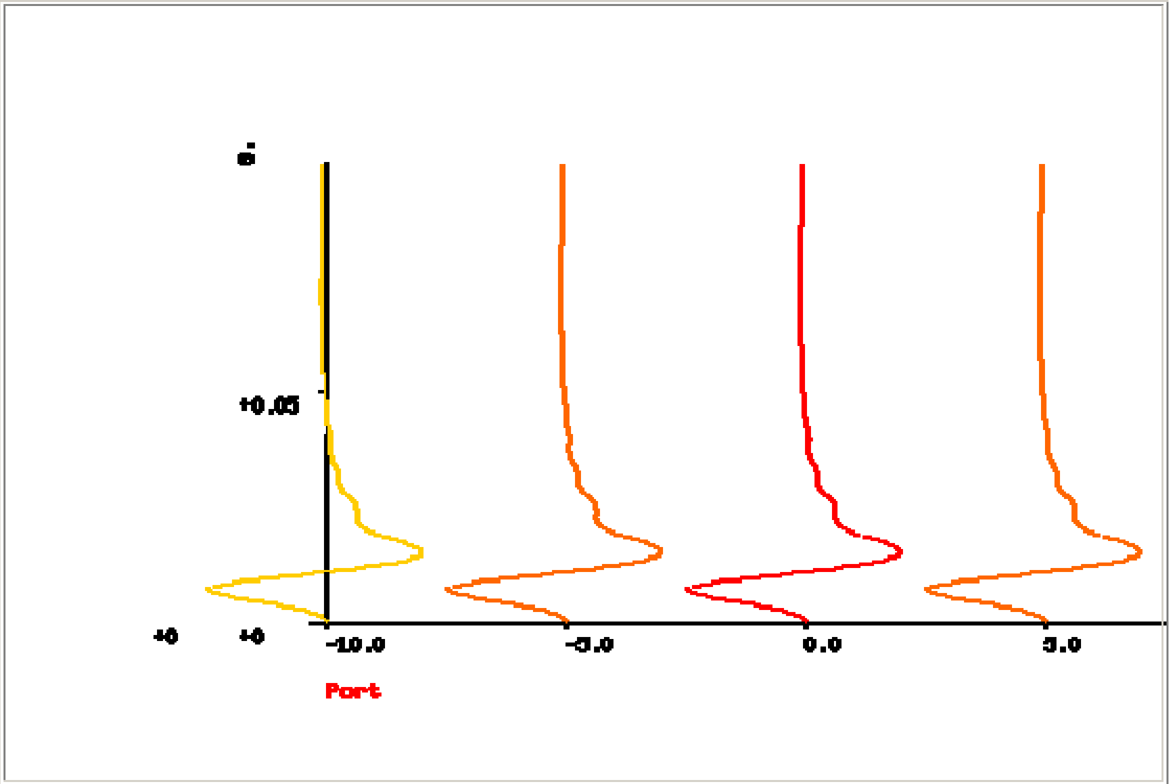


Angle-amplitude form

The following tables show the inline and crossline directivity of the array in (dip angle, amplitude) form. The computed signature (or under option the amplitude spectrum) for each angle is shown in colour varying form with red signatures shown in the centre, shading to blue at the furthest angles computed. The vertical scale indicates the type of plot, time or frequency. Both types of plot are individually scaled and plotted with the same units as the corresponding plots in the Signature Characteristics section.

Inline directivity, bearing = 0 degrees


Crossline directivity, bearing = 90 degrees



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Signature characteristics

The following tables show the signature parameters, the signature and the amplitude spectrum of the modelled signature.

The amplitude spectrum is shown in units of dB. relative to 1 microPa. per Hz. at 1m.

The position of the bubble by default is determined internally but can be overridden by interacting with the modelled signature using the right hand mouse button to determine the start of the bubble.

Signature ghost information

The source ghost has been included. The source ghost was input directly with the value -0.7.

The cable ghost has been switched off.

Output signature parameters

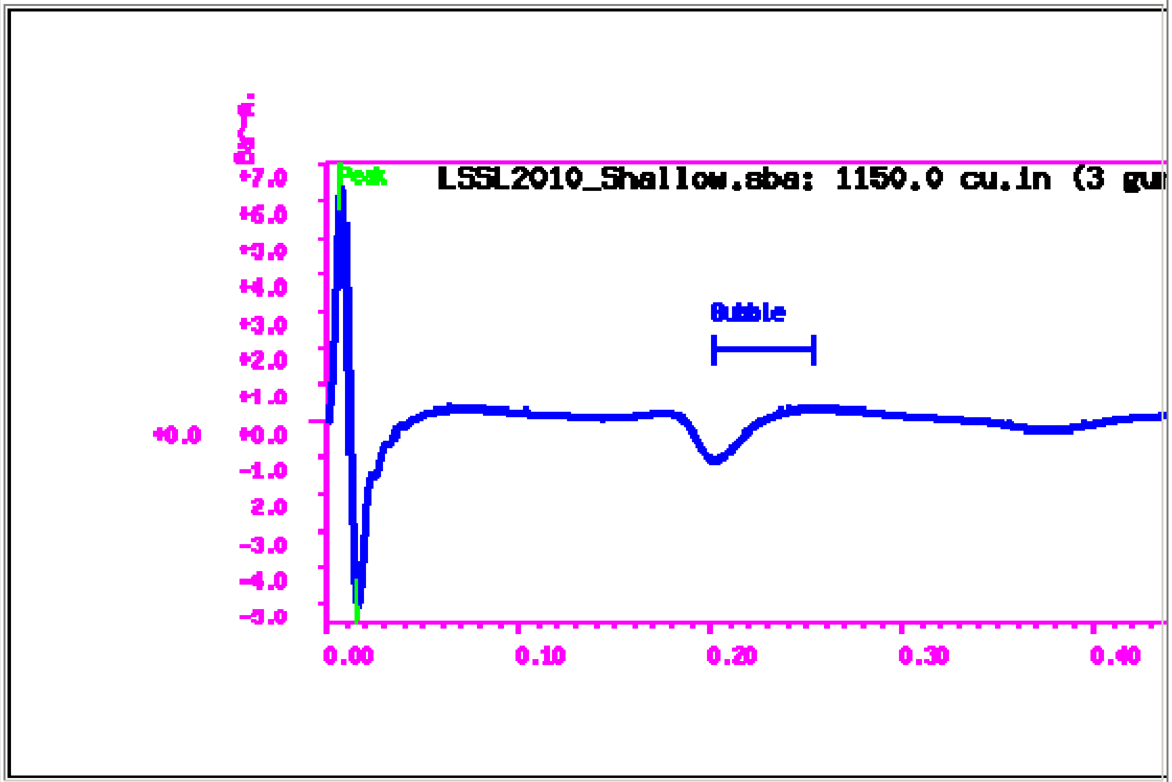
Signature filtering details	Number of samples in signature	Sample interval (s.)	Hydrophone position

6.0/18.0 - 128.0/72.0	2000	0.00025	Infinite vertical far-field

Signature and statistics

In this case, the bubble position was determined internally. The start of the search window for the bubble was: 0.04 (s.)

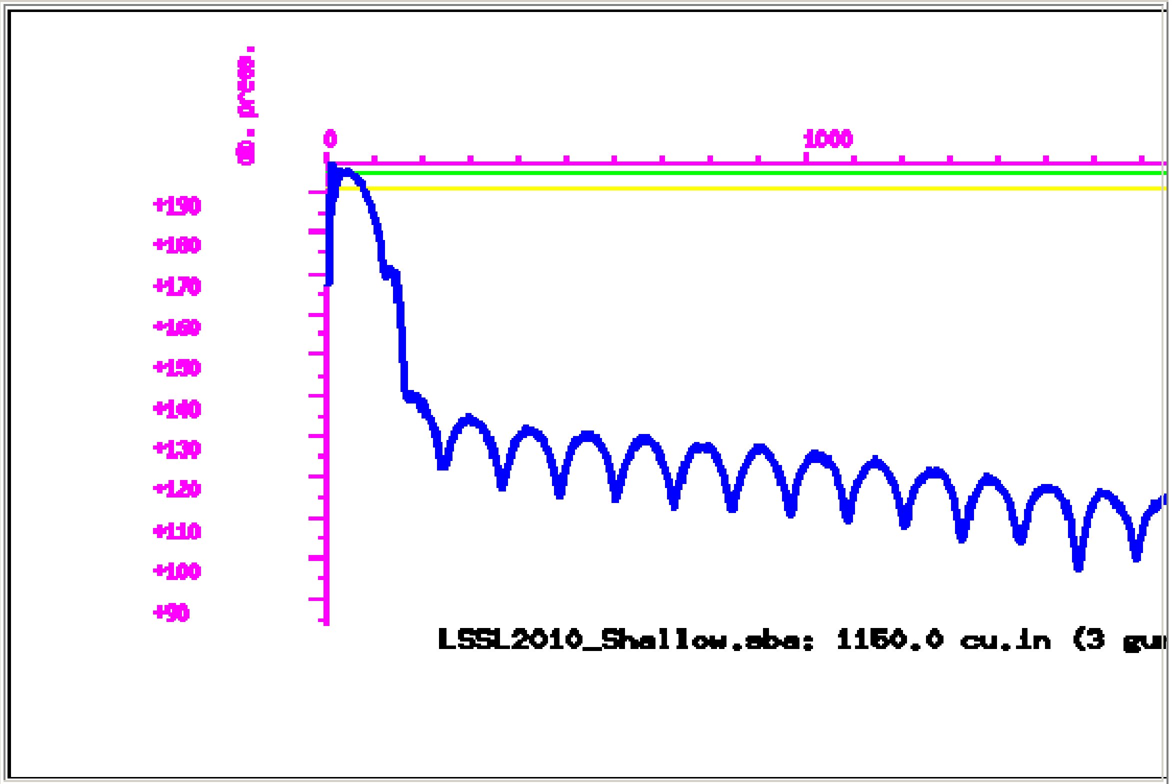
Peak to peak in bar-m.	Zero to peak in bar-m.	Primary to bubble (peak to peak)	Bubble period to first peak (s.)
11.4	6.42	8.01	0.24675



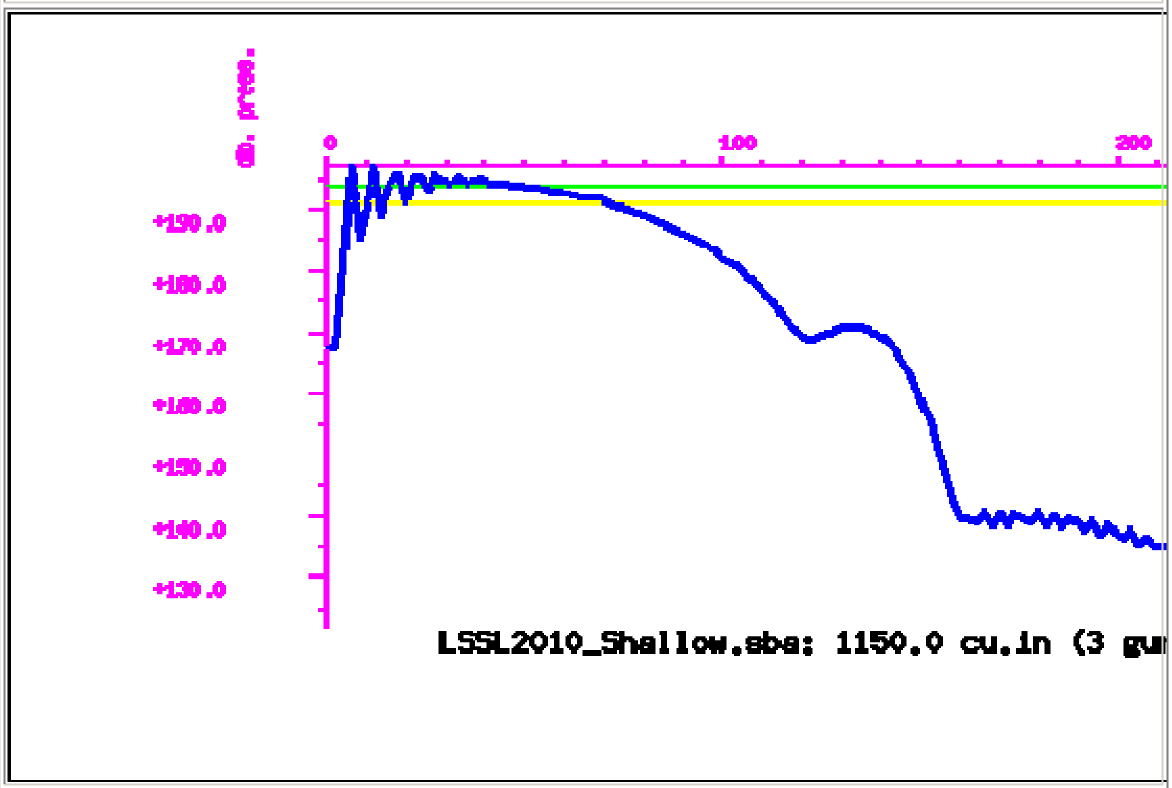
Band-pass filter: 6.0/18.0 - 128.0/72.0

Filtered amplitude spectrum

Amplitude spectrum. Amplitude Units are dB. relative to 1 mPa / Hz. at 1m.



Close up of amplitude spectrum



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Acoustic energy characteristics

The following table lists the individual gun contributions to the acoustic energy field in joules. A negative value means the gun is actually absorbing energy. This is very common in interacting arrays. It does not however mean that the gun is damaging the array performance. Rather it is acting as a catalyst to allow the other guns to perform more efficiently. The total acoustic energy gives the true performance of the array as a whole. See Laws, Parkes and Hatton (1988) Energy-interaction: The long-range interaction of seismic sources, Geophysical Prospecting (36), p333-348 and 38(1) 1990 p.104 for more details. Note that internal energy is not included in the data below. The true acoustic efficiency of airgun arrays is typically < 5% of the total initial energy.

Overall acoustic energy contribution

Total acoustic energy output (j.)	Acoustic energy output due to energy-interaction (j.)	Total potential energy available in array(j.)	Percentage of total potential energy appearing as acoustic energy
20505.2	6476.0	247102.5	8.3%

Individual acoustic energy contributions

Volume (cuin)	x (m.)	y (m.)	z (m.)	Acoustic energy contribution (j.)
500.0	1.00	0.50	6.00	-2397.6
500.0	1.00	-0.50	6.00	-2203.0
150.0	0.00	0.00	6.00	25105.8
The red entries denote guns which are catalysing the array by absorbing energy.				

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Amplitude drop-out characteristics

The following table lists those 1 and 2 gun combinations which would cause the drop-out percentage limit for amplitudes to be breached. If the drop-out limit is set to 0.0 or if the far-field signature parameters have not been calculated, this analysis is not done. (Note that this calculation is by its very nature, approximate as it is calculated from the notional sources. In order to do drop-out calculation correctly, each combination of 1, 2 and potentially more guns must be physically dropped out and the array recalculated because the overall interaction balance changes. Gundalf can do this under option for various gun drop-outs but the calculation can be very expensive. The simple amplitude drop-out calculation described in this section is a first approximation.)

The maximum allowable percentage drop in peak to peak amplitude was set to 10.0

Single gun percentage amplitude drop breaches

Drop-out detail	Approximate percent amplitude loss
GUN 1; G-GUN: Vol 500.00	35.4
GUN 2; G-GUN: Vol 500.00	35.5
GUN 3; G-GUN: Vol 150.00	29.1

Double gun percentage amplitude drop breaches

Drop-out detail	Approximate percent amplitude loss
GUN 1; G-GUN: Vol 500.00 and GUN 2; G-GUN: Vol 500.00	70.9
GUN 1; G-GUN: Vol 500.00 and GUN 3; G-GUN: Vol 150.00	64.5
GUN 2; G-GUN: Vol 500.00 and GUN 3; G-GUN: Vol 150.00	64.6

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Spectral drop-out characteristics

Information only available in Gundalf Optimiser

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Physical parameters

The following table summarises the physical parameters used in modelling.

Sea temperature (C)	Velocity of sound in water (m./s.)	Expected dominant frequency in signature (Hz)	Observed wave height (m)
-1	1444	20.0	0.0

Note that the gun controller variation was set to 0.0 (s.)

GUNDALF array modelling suite – 1150 in^3, 12 m depth Array report

Gundalf revision AIR6.1c, Date 2010-01-07, Epoch 2010-01-07

Sun Sep 05 23:17:10 Atlantic Daylight Time 2010 (David Mosher)

Report pre-amble

Author: Mosher

Author Organisation: NRCan

Contents

Signature filtering policy

For marine environmental noise reports, Gundalf performs no signature filtering other than that inherent in modelling at a sample interval small enough to simulate an airgun array signature at frequencies up to 100kHz.

For all other kinds of reports, Gundalf performs filtering in this order:-

- If a pre-conditioning filter is chosen, for example, an instrument response, it is applied at the modelling sample interval.
- If the output sample interval is larger than the modelling sample interval, Gundalf applies appropriate anti-alias filtering. (This can be turned off in the event that anti-alias filtering is included in the pre-conditioning filter, in which case Gundalf will issue a warning.)
- Finally, Gundalf applies the chosen set of post-filters, Q, Wiener and band-pass filtering as specified, at the output sample interval.

In reports, when filters are applied, they are applied to the notional sources first so that signatures, directivity plots and spectra are all filtered consistently.

Finally note that modelled signatures always begin at time zero for reasons of causality.

Anti-alias and pre-condition filtering

In this case, no pre-conditioning filter has been applied.

In this case, no anti-alias filtering was necessary.

Post filtering

Details of the post-filtering used in this report follow. Post filters are applied at the output sample interval after any pre-conditioning and anti-alias filters have been applied.

Q filtering

No Q filtering performed.

Wiener filtering

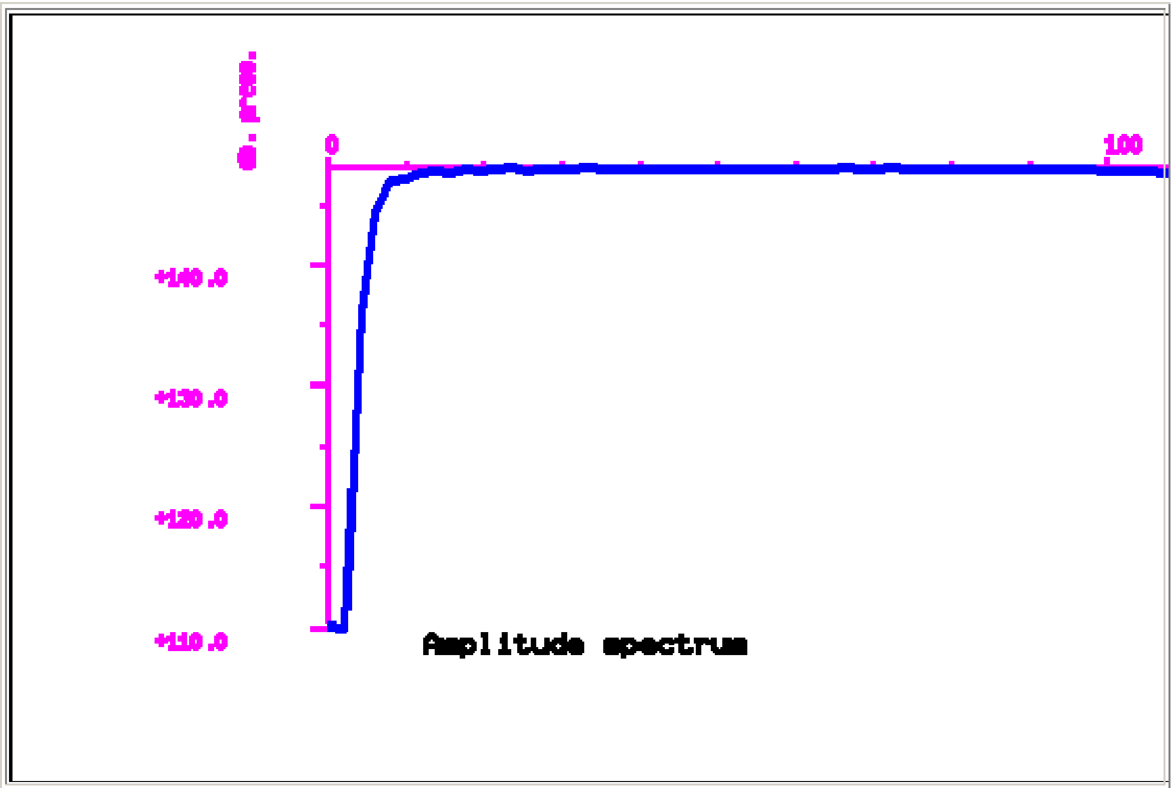
No Wiener filtering performed.

Band-pass filtering

Signatures were band-passed filtered using the following parameters:-

Internally generated as 6.0/18.0 - 128.0/72.0

The amplitude spectrum of the band-pass filter used is shown below.



Some notes on the modelling algorithm

The Gundalf airgun modelling engine is the end-product of 15 years of state of the art research. It takes full account of all air-gun interactions including interactions between sub-arrays. No assumptions of linear superposition are made. This means that if you move sub-arrays closer together, the far-field signature will change. The effect is noticeable even when sub-arrays are separated by as much as 10m.

The engine is capable of modelling airgun clusters right down to the 'super-foam' region where the bubbles themselves collide and distort. It has been calibrated against both single and clustered guns for a number of different gun types under laboratory conditions and accurately predicts peak to peak and primary to bubble parameters across a very wide range of operating conditions.

In many cases, the predicted signatures are good enough to be used directly in signature deconvolution procedures.

Array summary

The following table lists the statistics for the array quoted in various commonly used units for convenience. Note that the rms value is computed over the entire modelled signature.

Array parameter	Array value
Number of guns	3
Total volume (cu.in).	1150.0 (18.8 litres)
Peak to peak in bar-m.	12.9 (1.29 MPa, 242 db re 1 microPascal. at 1m.)
Zero to peak in bar-m.	6.33 (0.633 MPa, 236 db re 1 microPascal. at 1m.)
RMS pressure in bar-m.	1.08 (0.108 MPa, 221 db re 1 microPascal. at 1m.)
Primary to bubble (peak to peak)	4.62
Bubble period to first peak (s.)	0.052
Maximum spectral ripple (dB): 10.0 - 50.0 Hz.	12.2
Maximum spectral value (dB): 10.0 - 50.0 Hz.	202
Average spectral value (dB): 10.0 - 50.0 Hz.	196
Total acoustic energy (Joules)	29209.8
Total acoustic efficiency (%)	11.8

Array geometry and gun contribution

The following table lists all the guns modelled in the array along with their characteristics. The last column is completed only if the array has actually been modelled during the interactive session and contains the approximate contribution of that gun as a percentage of the peak to peak amplitude of the whole array. Please note the following:-

- The peak to peak varies only as the cube root of the volume for the same gun type so that even small guns contribute significantly. This is particularly relevant to drop-out analysis.
- The peak to peak can also be depressed due to clustering effects as reported by Strandenes and Vaage (1992), "Signatures from clustered airguns", First Break, 10(8).

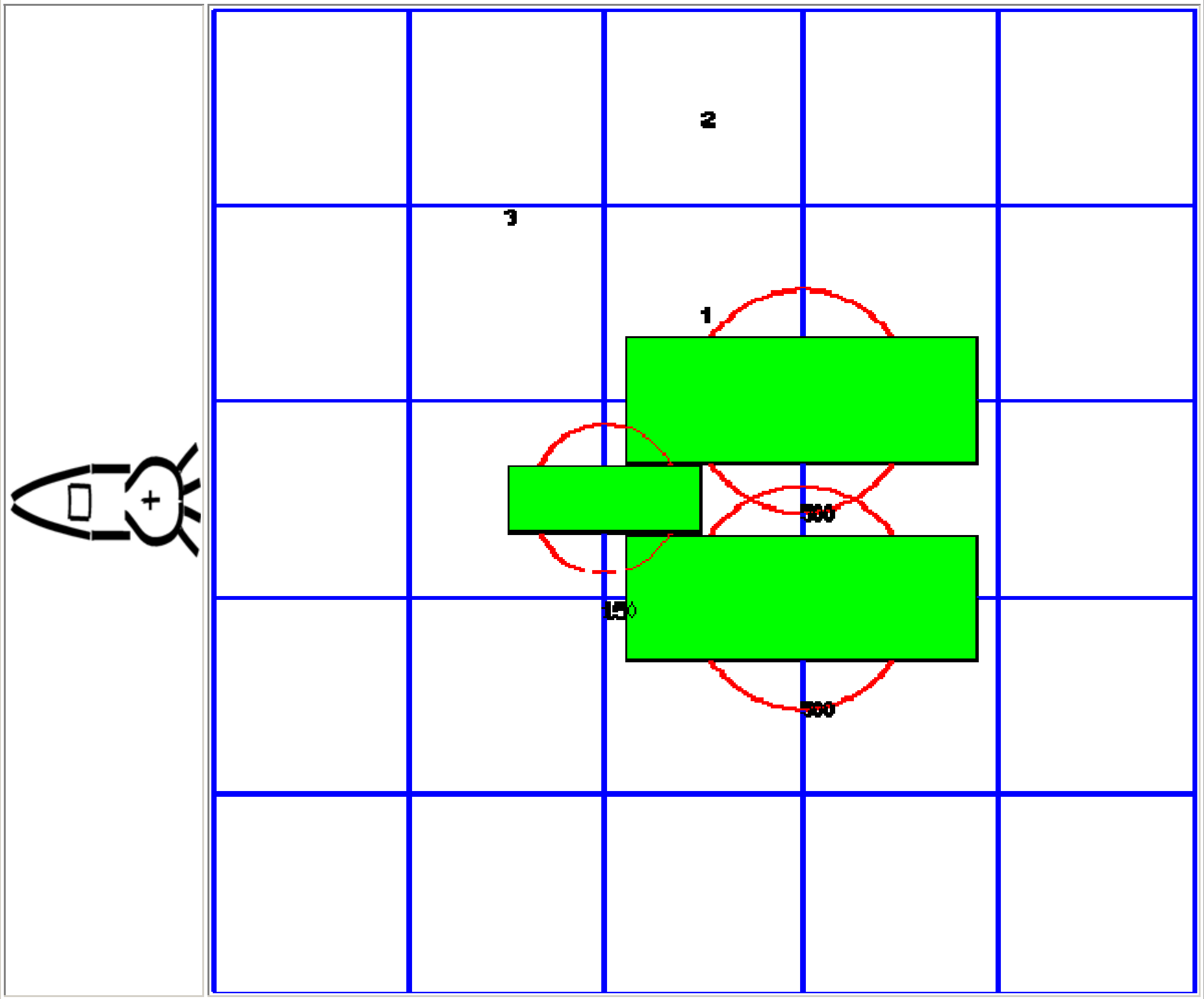
Gun	Pressure (psi)	Volume (cuin)	Type	x (m.)	y (m.)	z (m.)	delay (s.)	sub-array	p-p contrib (pct.)
1	1900.0	500.0	G-GUN	1.000	0.500	12.000	0.000	1	37.1
2	1900.0	500.0	G-	1.000	-	12.000	0.000	1	37.1

			GUN		0.500				
3	1900.0	150.0	G-GUN	0.000	0.000	12.000	0.000	1	25.8

The array is shown graphically below.

Hydrophone position: Infinite vertical far-field

<----- Direction of travel ----- --, (1m. grid, plan view)



The red circles denote the maximum radius reached by the bubble. Please note that pressure-field interactions take place over a much larger distance than this, (typically 10 times larger). However when bubbles touch or overlap, super-foam interaction can be expected. In this zone, significant peak AND bubble suppression will normally be observed.

Note also that a green rectangle represents a single gun and an orange rectangle indicates that the gun is currently dropped out. Where present, a yellow rectangle represents a vertical cluster (V.C.) of guns. Please see the geometry table above for more details. The small number to the

above left of each gun is its reference number in this table. For clusters of guns, these reference numbers mirror the symmetry of the cluster.

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Array centres and timing

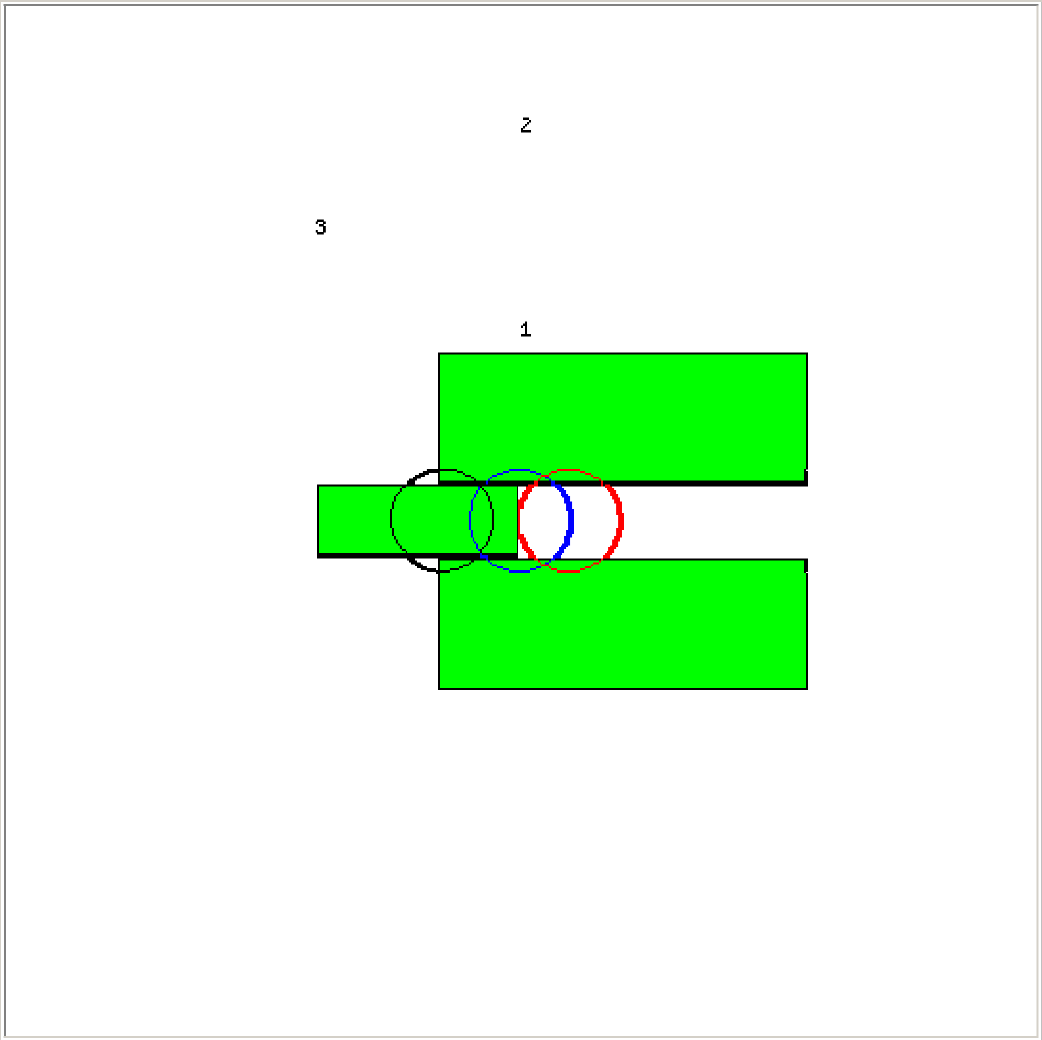
The following diagram shows the array geometric centre, the centre of pressure and the centre of energy defined as follows:-

- The array geometric centre is defined to be the centre of the rectangle formed by the largest and smallest x and y values of the active guns (dropped out guns are ignored). This is shown as a blue circle.
- The centre of pressure is defined to be the array centre when each active gun position is weighted by its contribution to the overall peak to peak pressure value. This is shown as a red circle.
- The centre of energy is computed by weighting the coordinates by the self-energy of the active gun at that position. In an interacting array this may be a long way from the centre of pressure as some guns may absorb energy giving a negative self-energy. This is shown as a black circle.

Depending on how first breaks are calculated, these can be used for first break analysis.

Dropped out guns are shown as orange rectangles whilst live guns are shown as green rectangles.

Array centres



The geometric centre is at (0.5, 0, 12)

The centre of pressure is at (0.742,-0.000197, 12)

The centre of energy is at (0.121,-0.00362, 12)

Note that Gundalf by default uses the deepest gun to define time zero for the vertical far-field and it uses the nearest gun to the observation point to define time zero if an observation point is specified. This means that if one gun is accidentally run deep, this will cause the bulk of the signature to appear to be delayed. It is still a research question how an airgun array should be timed. There are several candidates as defined above but it is not currently clear which if any is appropriate in complex scenarios such as Ocean Bottom Deployment.

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Array directivity

The following tables show the inline and crossline directivity of the array in both (angle-frequency) and (angle-amplitude) form and optionally, the azimuthal directivity (theta-phi) form.

Note that the effects of cable ghosting if present are not shown in Gundalf directivity displays although source ghosting is included. This matches common practice in such displays.

For inline directivity displays, the x-axis is the inline angle from the vertical with the word fore indicating the end nearest the boat. For crossline directivity displays, the x-axis is the crossline angle from the vertical with the word port indicating the port side.

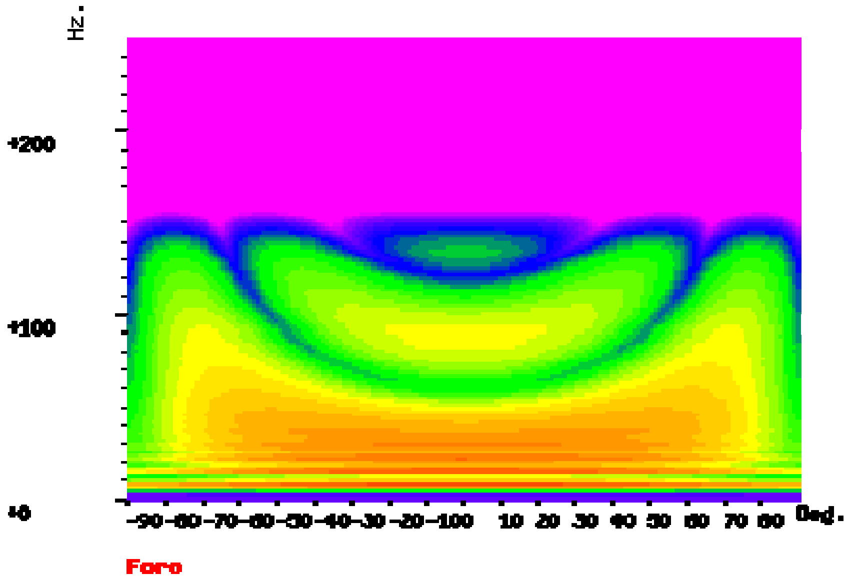
Note that *inline* is used nominally to mean any angle within 45 degrees of the boat direction (which corresponds to a bearing of zero degrees). Similarly, *crossline* is used nominally to mean any angle within 45 degrees of the perpendicular to the boat direction which is measured as a bearing of 90 degrees, (i.e. starboard). The nominal inline and crossline angles can be set by the user in the report options. The values used are indicated in the diagram titles below as bearings.

Where shown, the azimuthal plots show contours at four chosen frequencies as a function of phi (angle from the x-axis, opposite to the boat direction) and theta (the angle from the vertical). A bearing of zero degrees corresponds to a value of phi of 180 degrees.

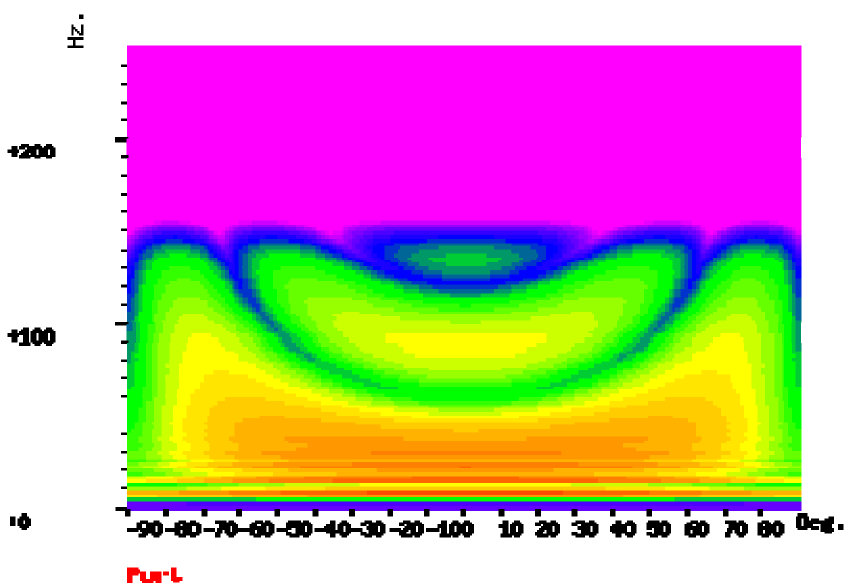
Angle-frequency form

The following tables show the inline and crossline directivity of the array in (dip angle-frequency) form. Both plots are scaled as dB. relative to 1 microPa. per Hz. at 1m.

Inline directivity, bearing = 0 degrees

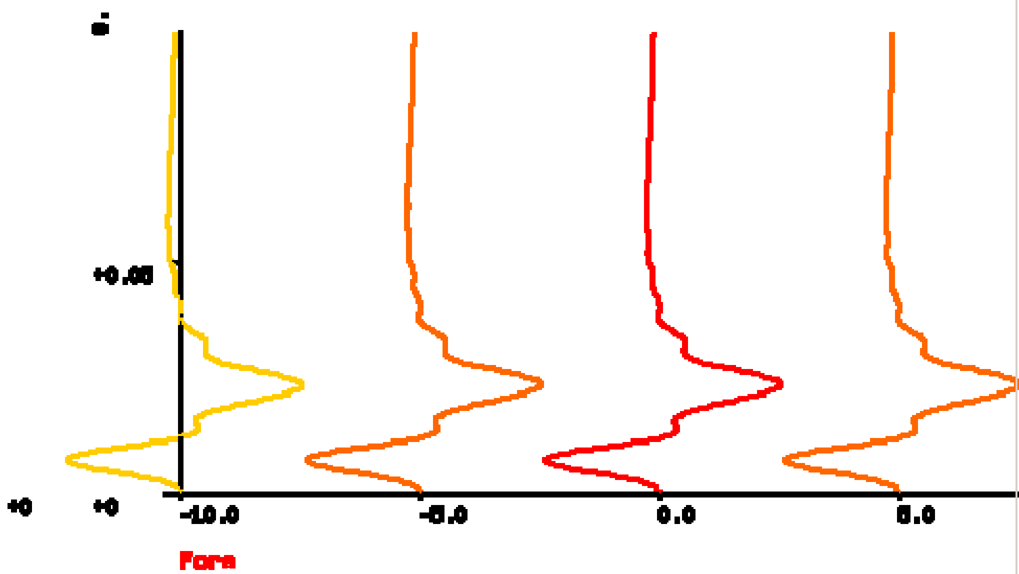


Crossline directivity, bearing = 90 degrees

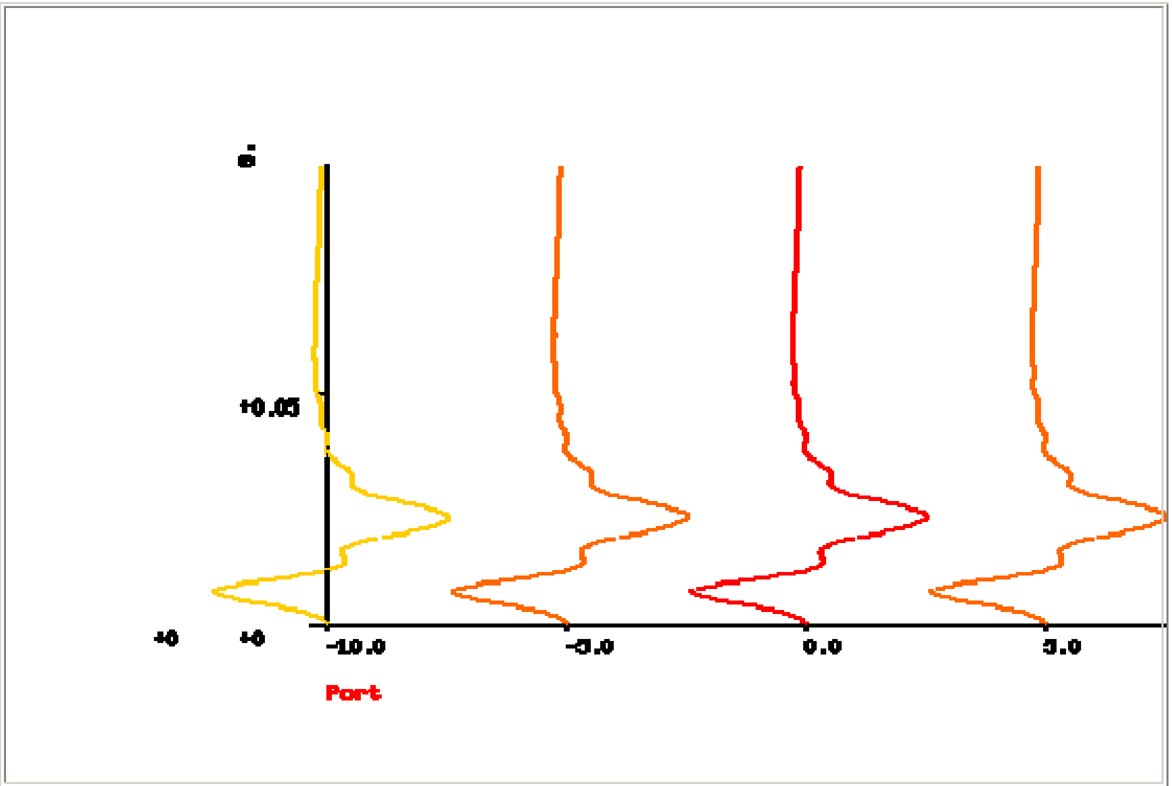


Angle-amplitude form

The following tables show the inline and crossline directivity of the array in (dip angle, amplitude) form. The computed signature (or under option the amplitude spectrum) for each angle is shown in colour varying form with red signatures shown in the centre, shading to blue at the furthest angles computed. The vertical scale indicates the type of plot, time or frequency. Both types of plot are individually scaled and plotted with the same units as the corresponding plots in the Signature Characteristics section.

Inline directivity, bearing = 0 degrees


Crossline directivity, bearing = 90 degrees



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Signature characteristics

The following tables show the signature parameters, the signature and the amplitude spectrum of the modelled signature.

The amplitude spectrum is shown in units of dB. relative to 1 microPa. per Hz. at 1m.

The position of the bubble by default is determined internally but can be overridden by interacting with the modelled signature using the right hand mouse button to determine the start of the bubble.

Signature ghost information

The source ghost has been included. The source ghost was input directly with the value -0.7.

The cable ghost has been switched off.

Output signature parameters

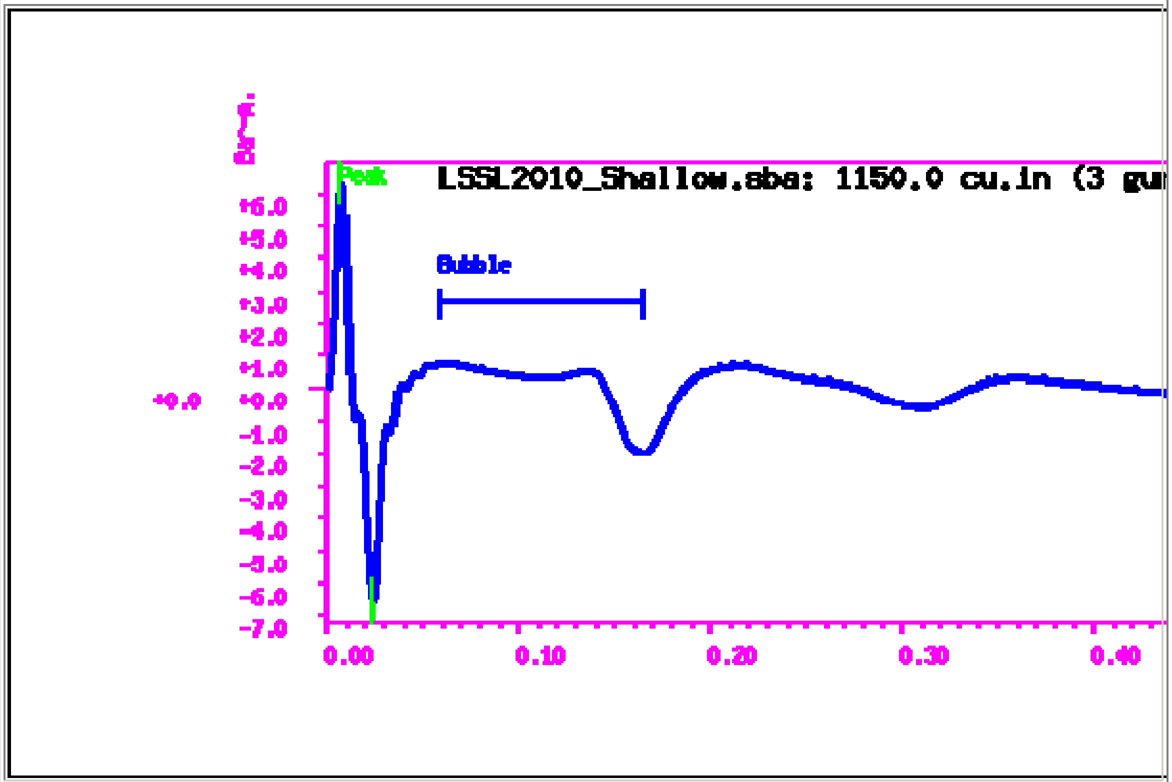
Signature filtering details	Number of samples in signature	Sample interval (s.)	Hydrophone position

6.0/18.0 - 128.0/72.0	2000	0.00025	Infinite vertical far-field

Signature and statistics

In this case, the bubble position was determined internally. The start of the search window for the bubble was: 0.04 (s.)

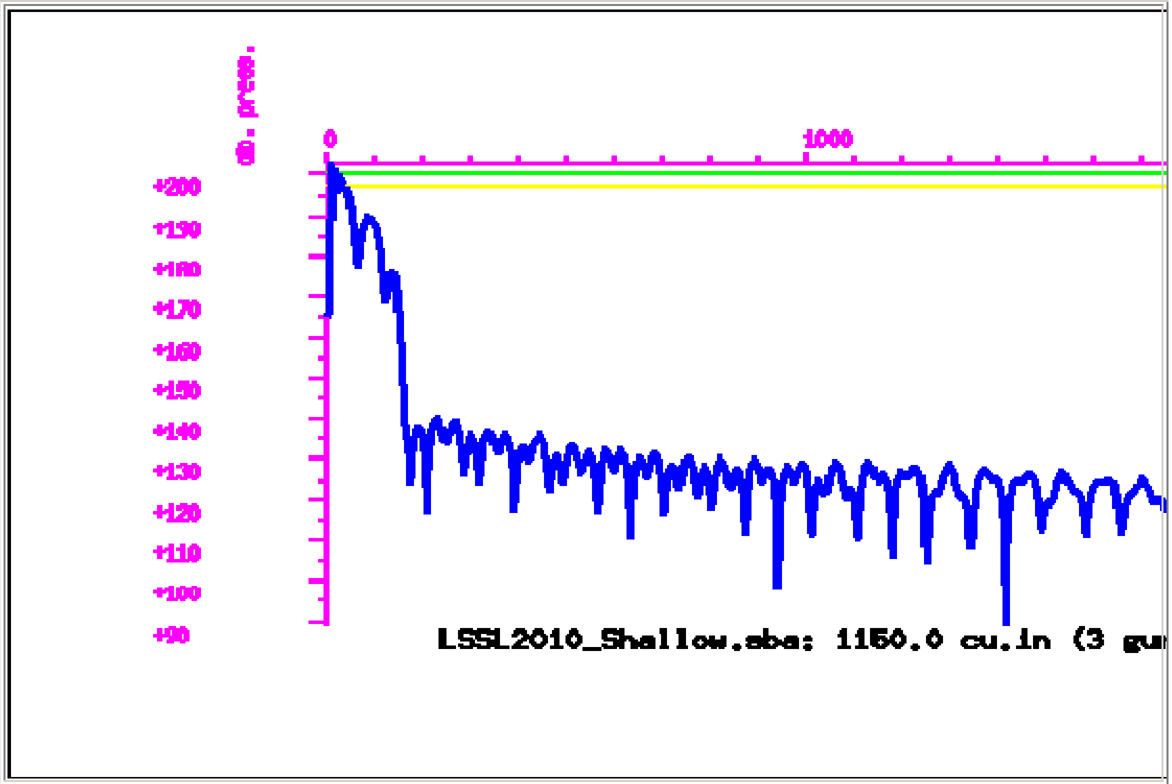
Peak to peak in bar-m.	Zero to peak in bar-m.	Primary to bubble (peak to peak)	Bubble period to first peak (s.)
12.9	6.33	4.62	0.052



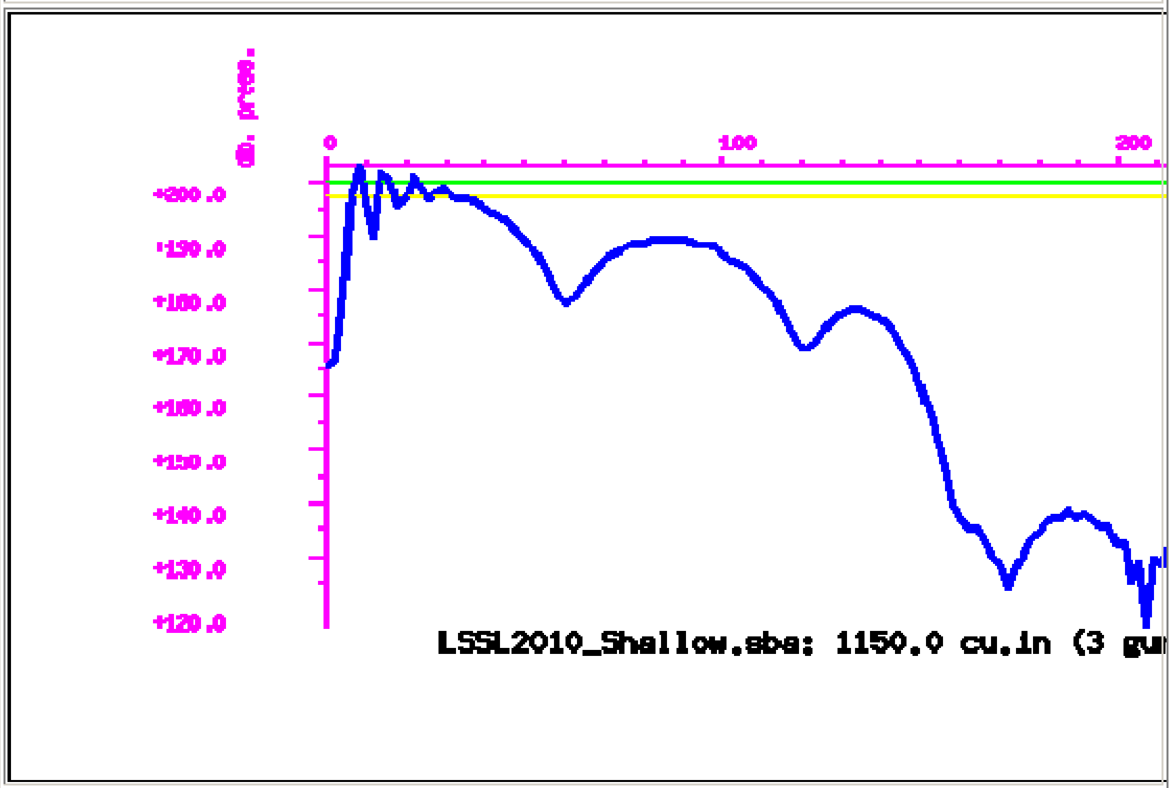
Band-pass filter: 6.0/18.0 - 128.0/72.0

Filtered amplitude spectrum

Amplitude spectrum. Amplitude Units are dB. relative to 1 mPa / Hz. at 1m.



Close up of amplitude spectrum



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Acoustic energy characteristics

The following table lists the individual gun contributions to the acoustic energy field in joules. A negative value means the gun is actually absorbing energy. This is very common in interacting arrays. It does not however mean that the gun is damaging the array performance. Rather it is acting as a catalyst to allow the other guns to perform more efficiently. The total acoustic energy gives the true performance of the array as a whole. See Laws, Parkes and Hatton (1988) Energy-interaction: The long-range interaction of seismic sources, Geophysical Prospecting (36), p333-348 and 38(1) 1990 p.104 for more details. Note that internal energy is not included in the data below. The true acoustic efficiency of airgun arrays is typically < 5% of the total initial energy.

Overall acoustic energy contribution

Total acoustic energy output (j.)	Acoustic energy output due to energy-interaction (j.)	Total potential energy available in array(j.)	Percentage of total potential energy appearing as acoustic energy
29209.8	10150.2	247102.5	11.8%

Individual acoustic energy contributions

Volume (cuin)	x (m.)	y (m.)	z (m.)	Acoustic energy contribution (j.)
500.0	1.00	0.50	12.00	1660.1
500.0	1.00	-0.50	12.00	1871.5
150.0	0.00	0.00	12.00	25678.1

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Amplitude drop-out characteristics

The following table lists those 1 and 2 gun combinations which would cause the drop-out percentage limit for amplitudes to be breached. If the drop-out limit is set to 0.0 or if the far-field signature parameters have not been calculated, this analysis is not done. (Note that this calculation is by its very nature, approximate as it is calculated from the notional sources. In order to do drop-out calculation correctly, each combination of 1, 2 and potentially more guns must be physically dropped out and the array recalculated because the overall interaction balance changes. Gundalf can do this under option for various gun drop-outs but the calculation can be very expensive. The simple amplitude drop-out calculation described in this section is a first approximation.)

The maximum allowable percentage drop in peak to peak amplitude was set to 10.0

Single gun percentage amplitude drop breaches

Drop-out detail	Approximate percent amplitude loss

GUN 1; G-GUN: Vol 500.00	37.1
GUN 2; G-GUN: Vol 500.00	37.1
GUN 3; G-GUN: Vol 150.00	25.8

Double gun percentage amplitude drop breaches

Drop-out detail	Approximate percent amplitude loss
GUN 1; G-GUN: Vol 500.00 and GUN 2; G-GUN: Vol 500.00	74.2
GUN 1; G-GUN: Vol 500.00 and GUN 3; G-GUN: Vol 150.00	62.9
GUN 2; G-GUN: Vol 500.00 and GUN 3; G-GUN: Vol 150.00	62.9

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Spectral drop-out characteristics

Information only available in Gundalf Optimiser

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Physical parameters

The following table summarises the physical parameters used in modelling.

Sea temperature (C)	Velocity of sound in water (m./s.)	Expected dominant frequency in signature (Hz)	Observed wave height (m)
-1	1444	20.0	0.0

Note that the gun controller variation was set to 0.0 (s.)

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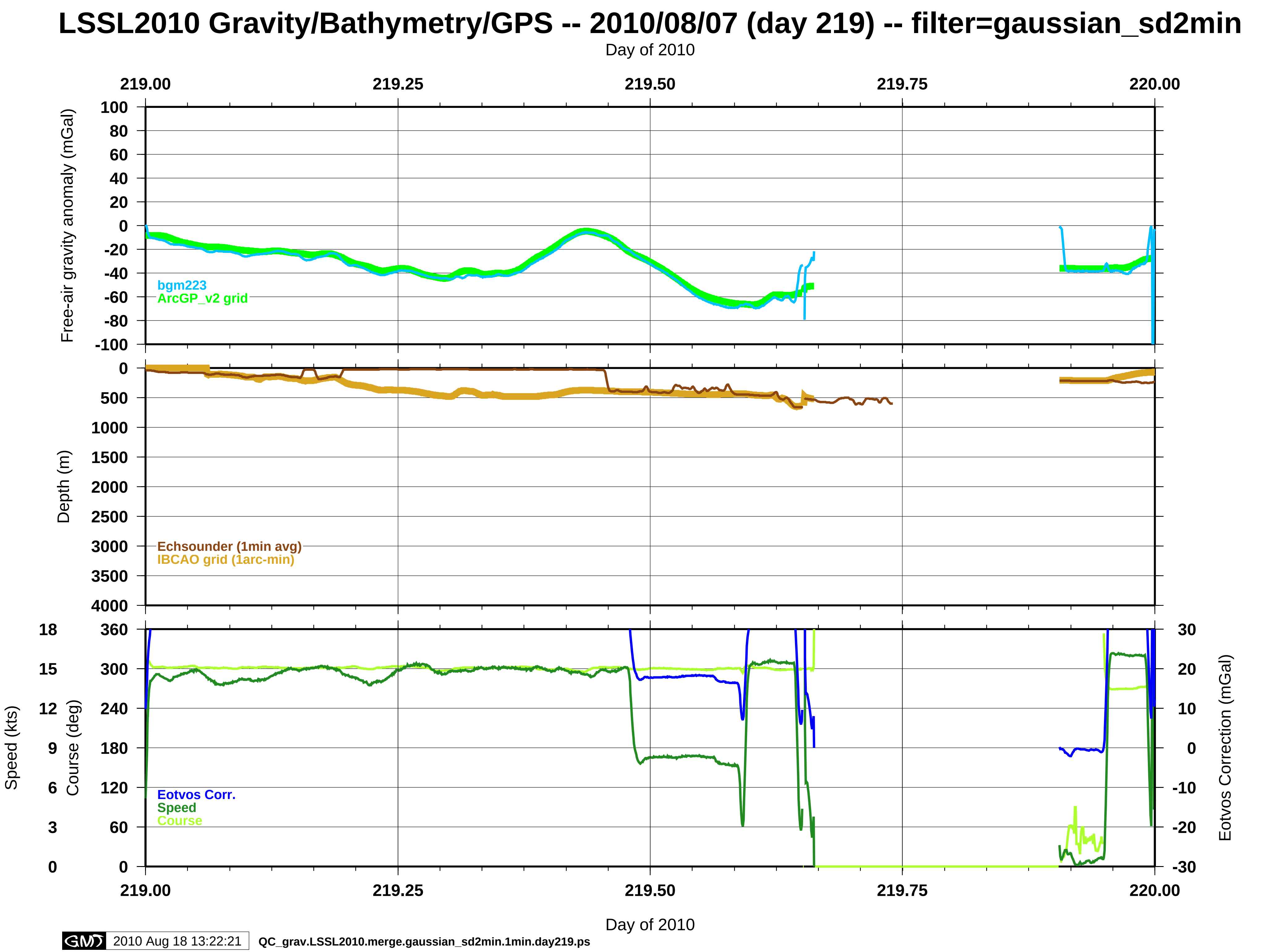
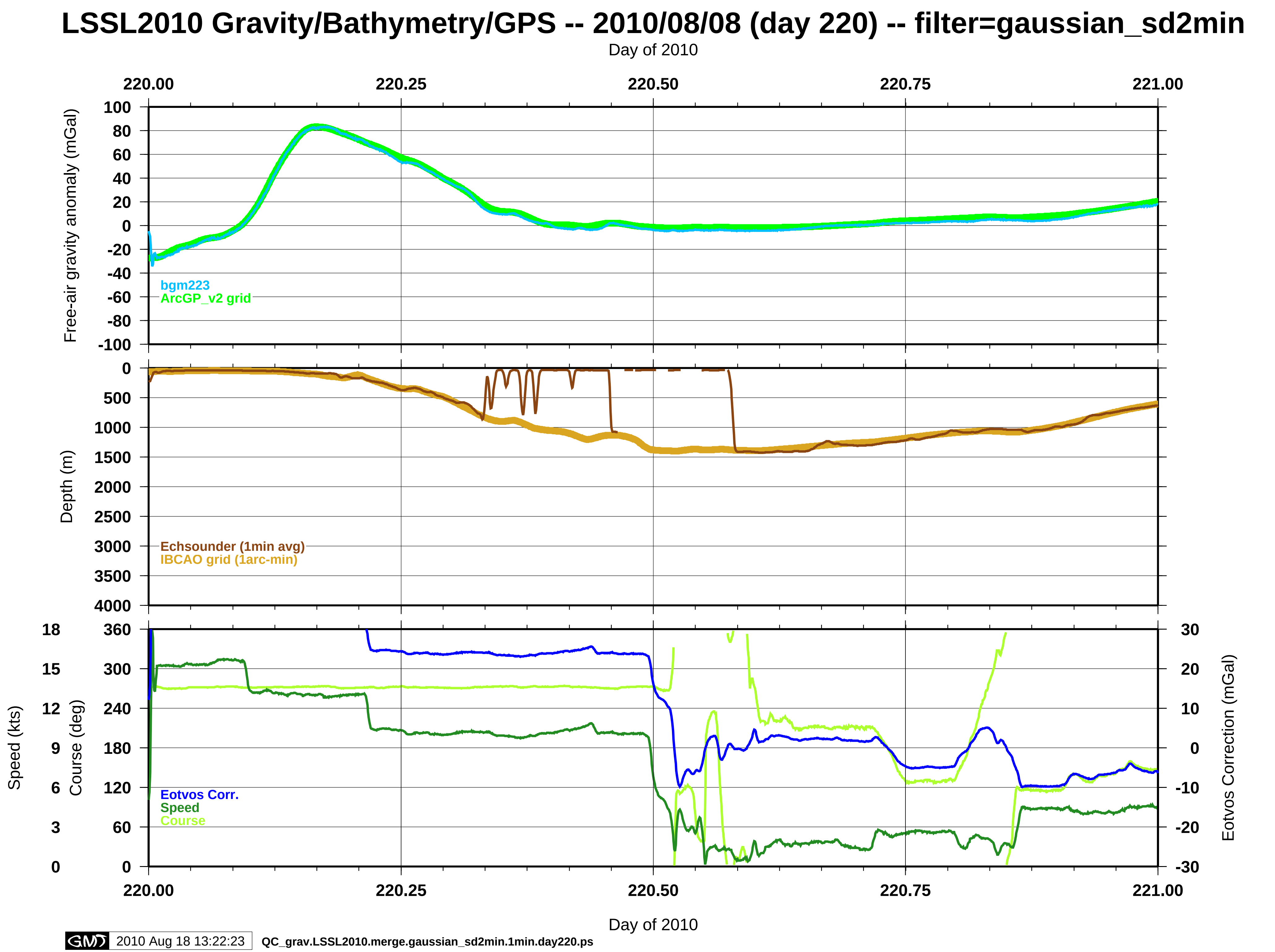
Gundalf calibration details

All modelling software requires calibration against convincing experimental data. Gundalf provides accurate modelling of airguns across a wide range of gun types, gun parameters and operating environments, however, we do not expect you to take this simply on trust. It is therefore our policy to keep users of Gundalf aware of its latest calibration status and up to date information is available under Help -> Calibration.

Appendix D

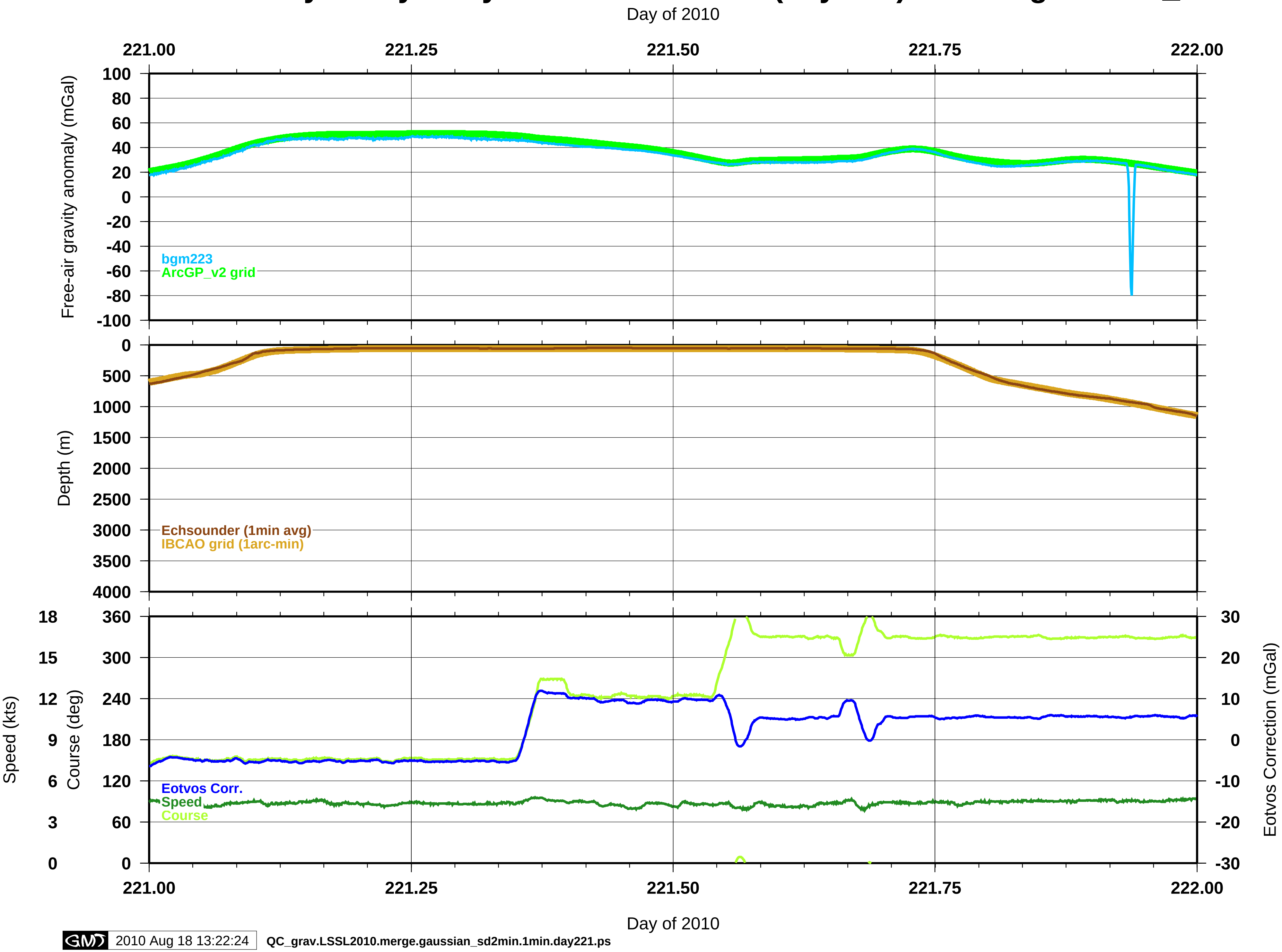
Daily Gravity Plots


LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/07 (day 219) -- filter=gaussian_sd2min
Day of 2010
219.00
219.25
219.50
219.75
220.00
Free-air gravity anomaly (mGal)
bgm223
ArcGP_v2 grid
Depth (m)
Echsounder (1min avg)
IBCAO grid (1arc-min)
Speed (kts)
Course (deg)
Eotvos Correction (mGal)
Eotvos Corr.
Speed
Course
Day of 2010
2010 Aug 18 13:22:21
QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day219.ps

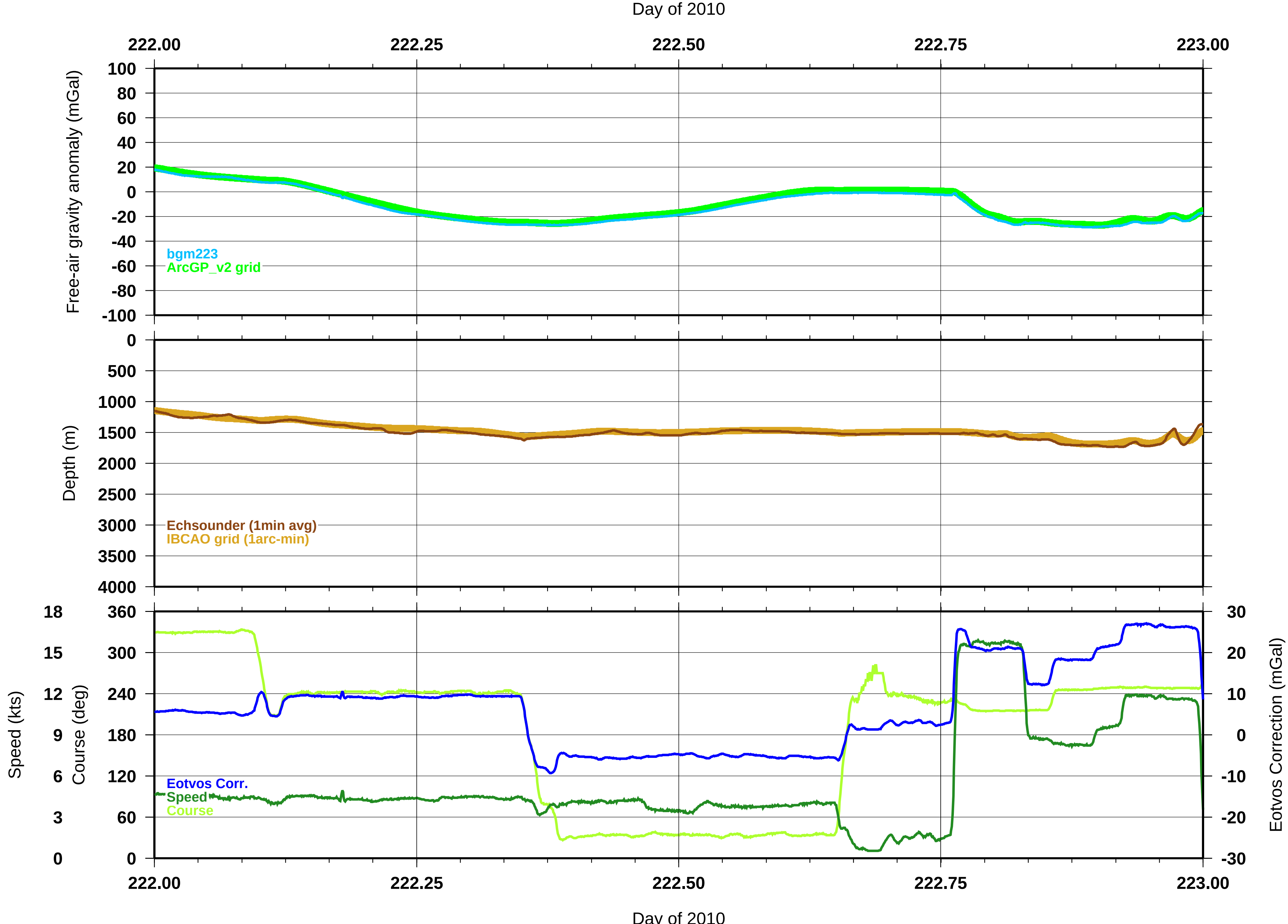


LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/08 (day 220) -- filter=gaussian_sd2min
Day of 2010
220.00
220.25
220.50
220.75
221.00
Free-air gravity anomaly (mGal)
bgm223
ArcGP_v2 grid
Depth (m)
Echsounder (1min avg)
IBCAO grid (1arc-min)
Speed (kts)
Course (deg)
Eotvos Correction (mGal)
Eotvos Corr.
Speed
Course
Day of 2010
2010 Aug 18 13:22:23
QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day220.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/09 (day 221) -- filter=gaussian_sd2min

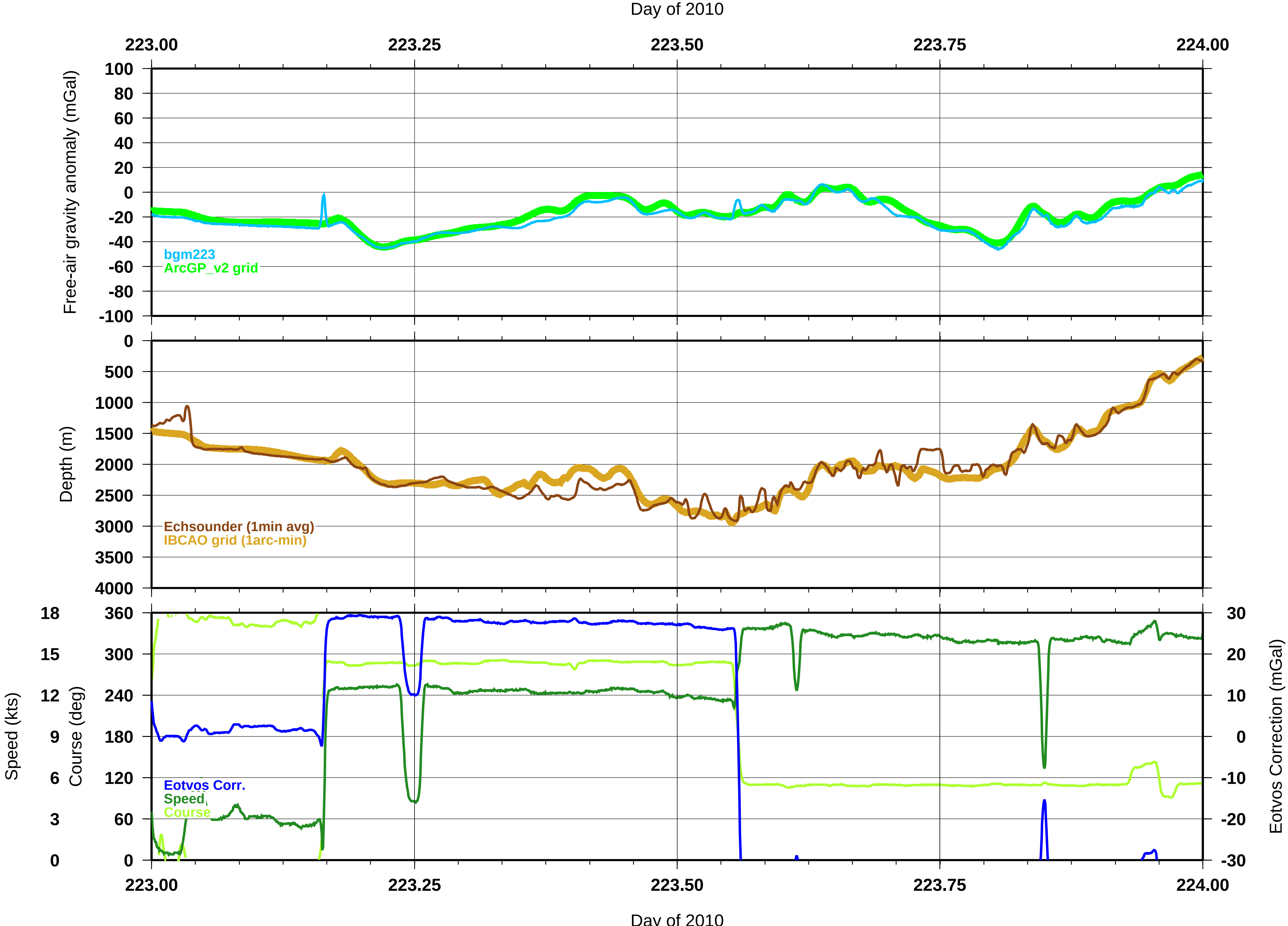


LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/10 (day 222) -- filter=gaussian_sd2min



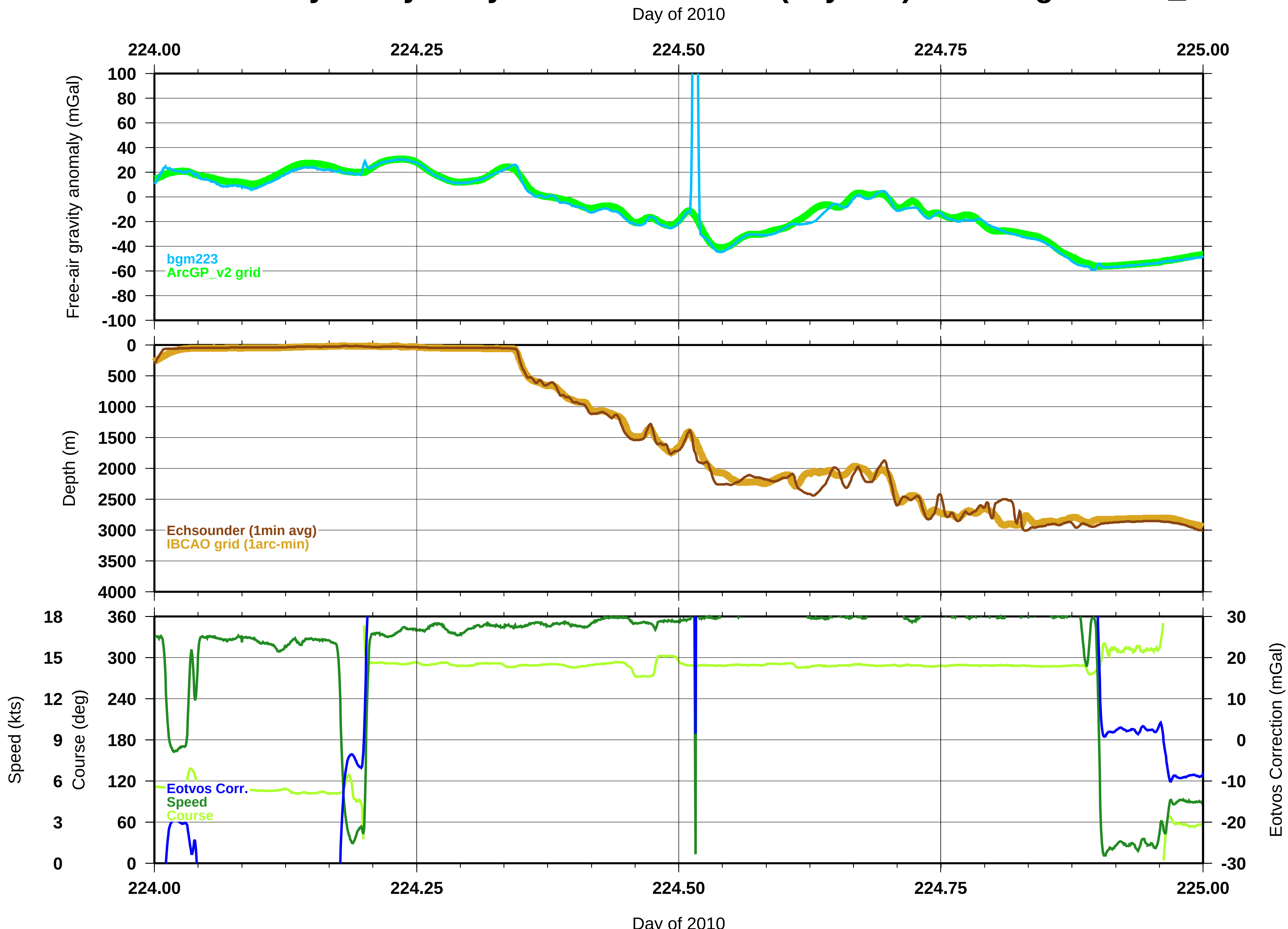
2010 Aug 18 13:22:25 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day222.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/11 (day 223) -- filter=gaussian_sd2min



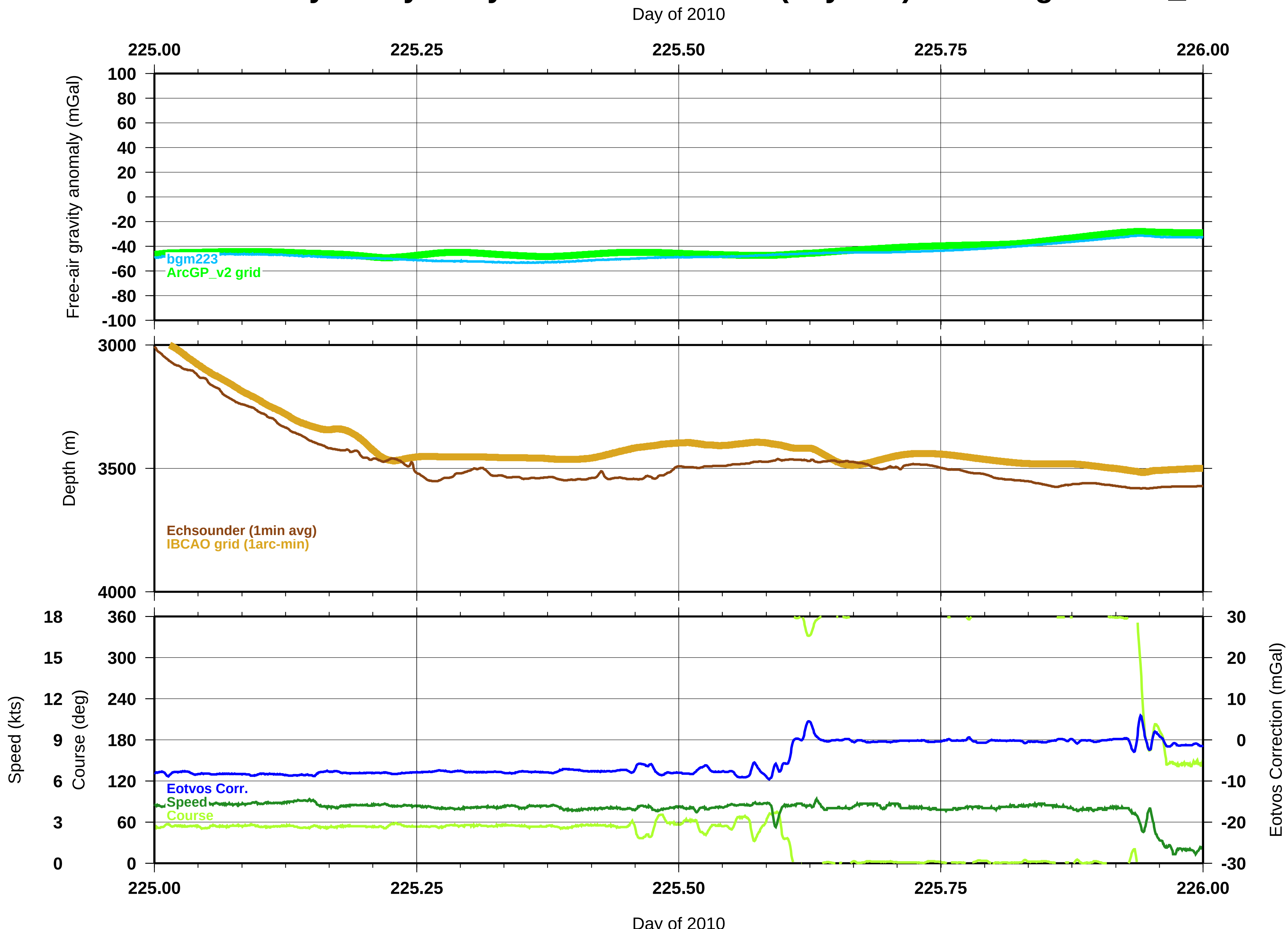
2010 Aug 18 13:22:26 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day223.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/12 (day 224) -- filter=gaussian_sd2min



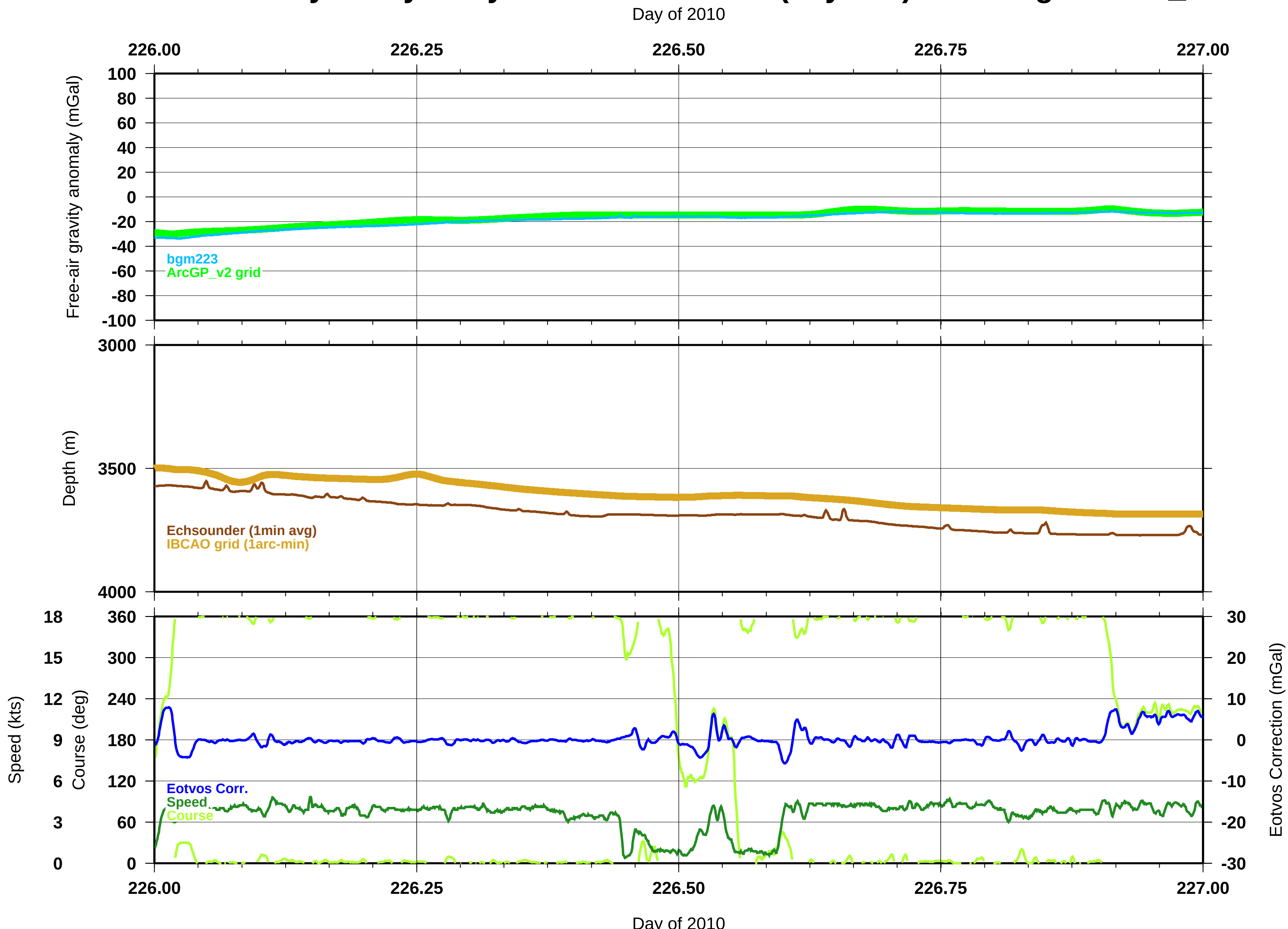
2010 Aug 18 13:22:28 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day224.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/13 (day 225) -- filter=gaussian_sd2min



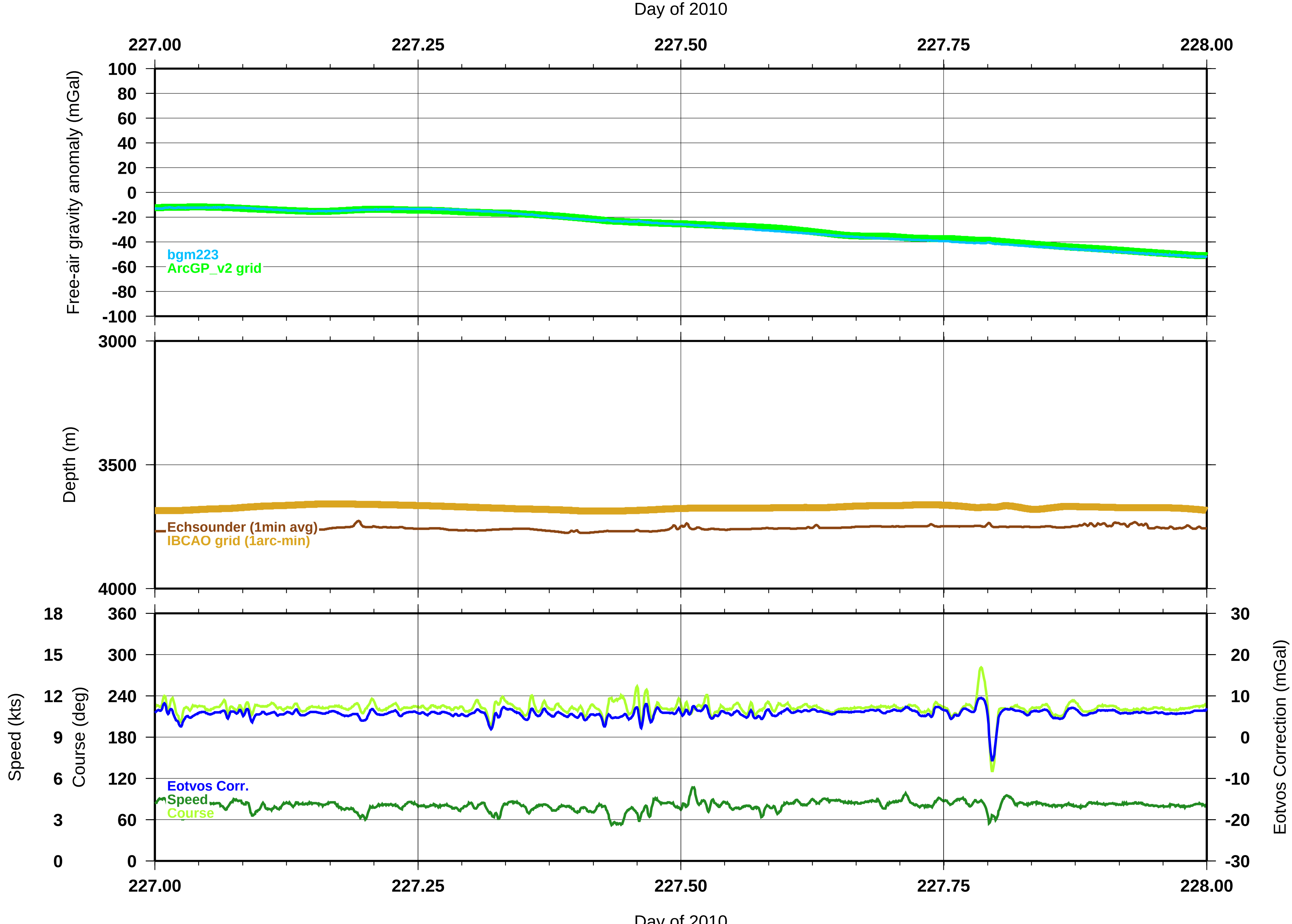
2010 Aug 20 11:38:53 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day225.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/14 (day 226) -- filter=gaussian_sd2min



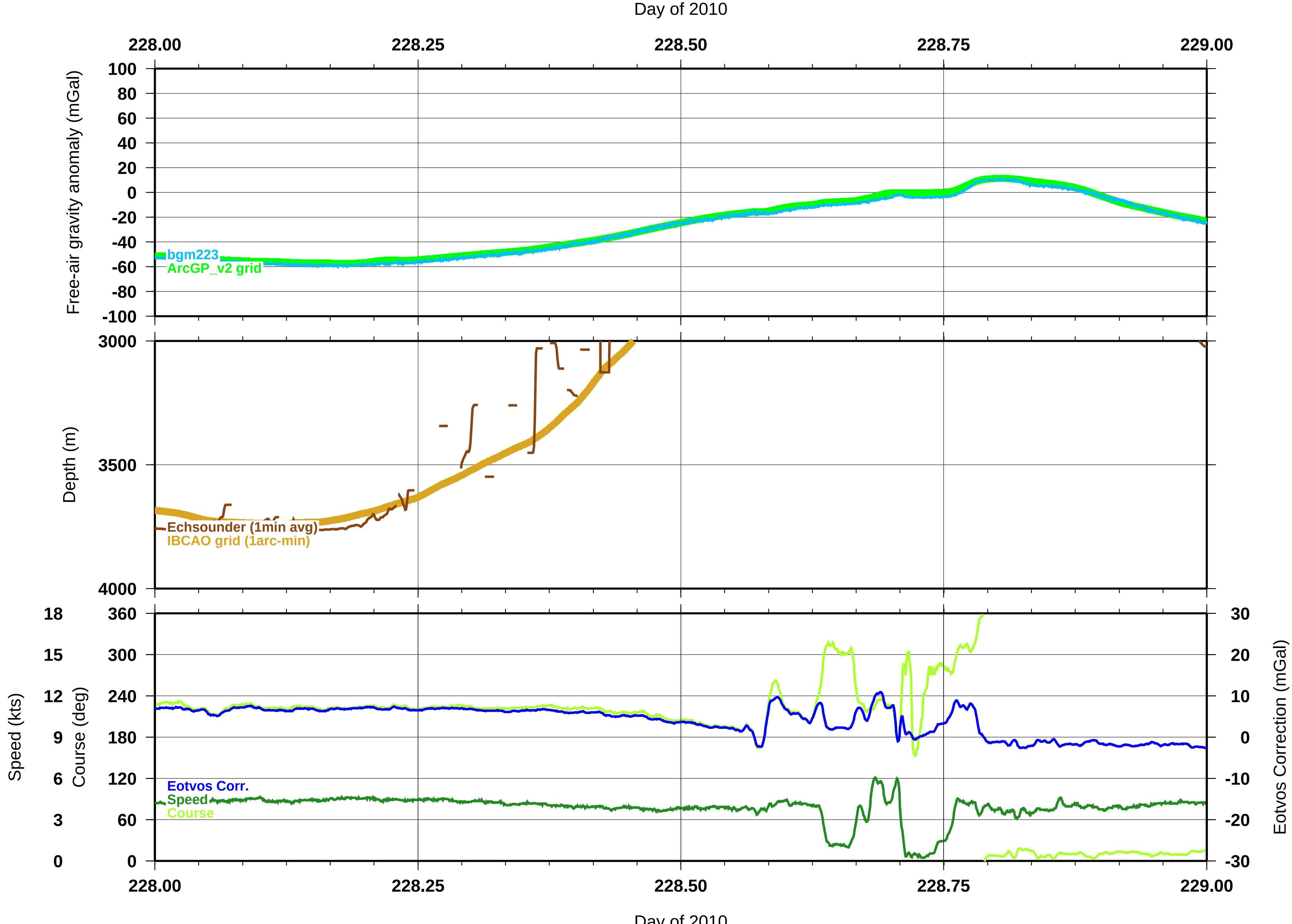
2010 Aug 20 11:38:54 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day226.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/15 (day 227) -- filter=gaussian_sd2min



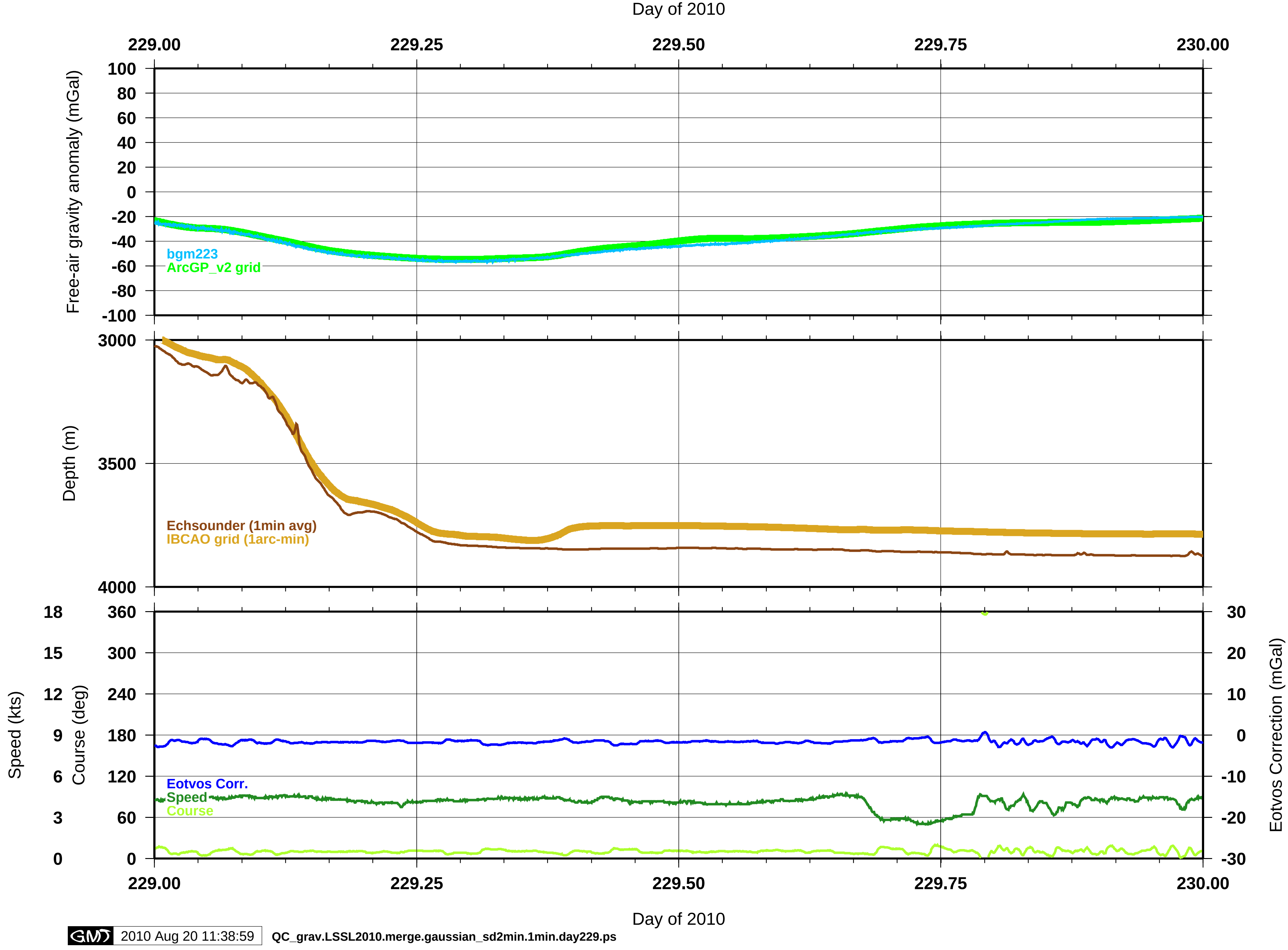
2010 Aug 20 11:38:56 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day227.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/16 (day 228) -- filter=gaussian_sd2min

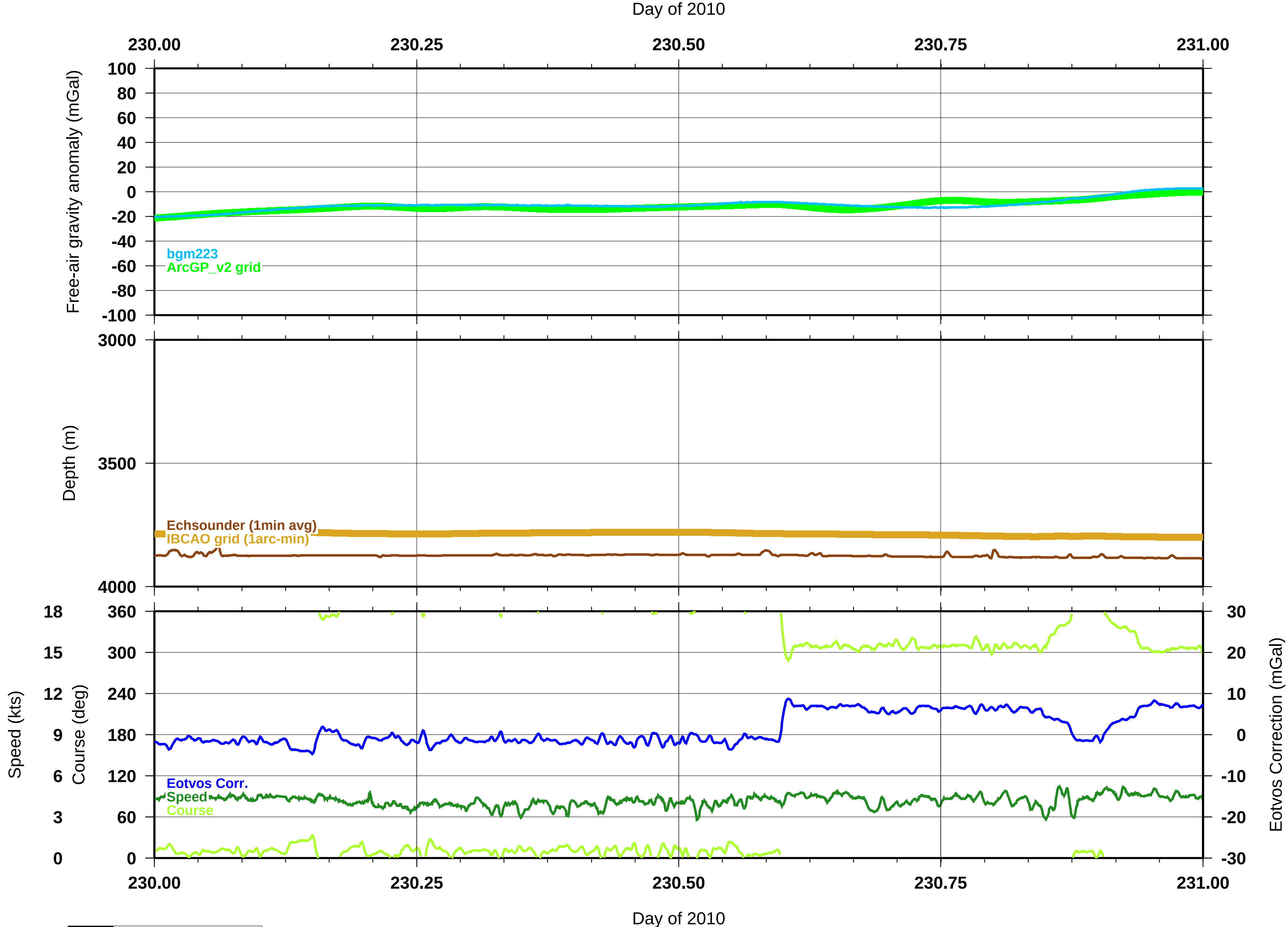


GMT 2010 Aug 20 11:38:57 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day228.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/17 (day 229) -- filter=gaussian_sd2min

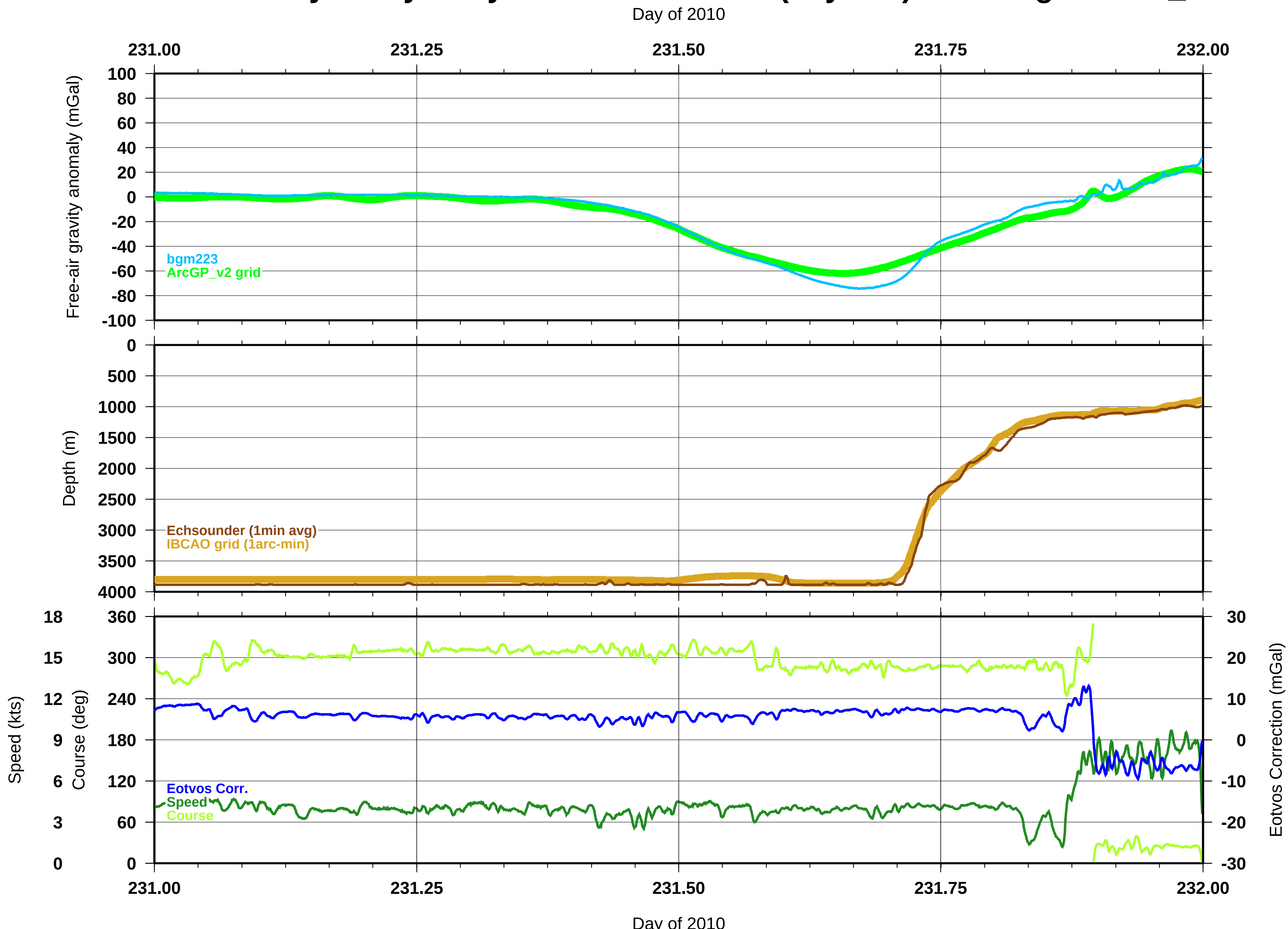


LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/18 (day 230) -- filter=gaussian_sd2min

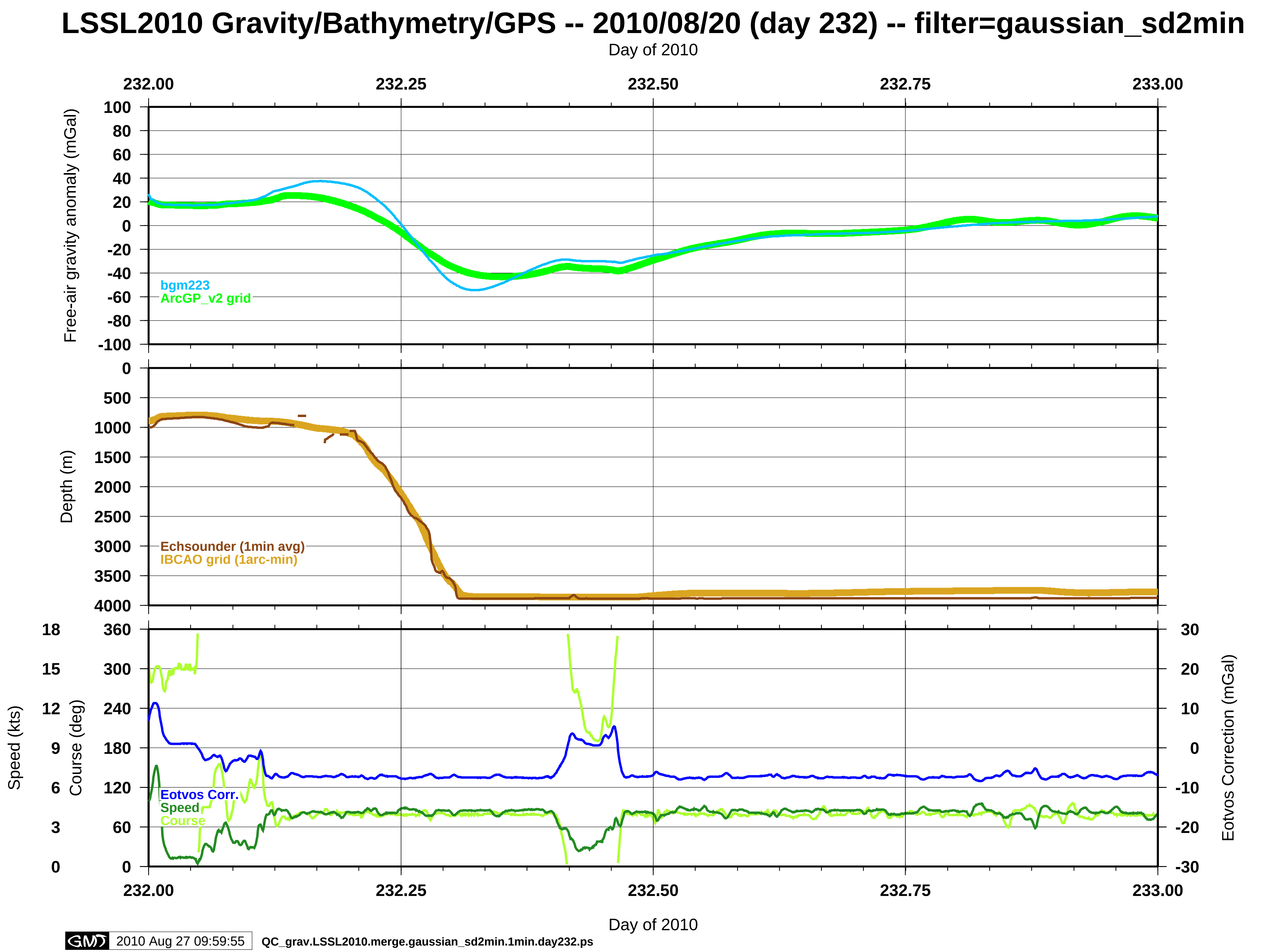


2010 Aug 20 11:39:00 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day230.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/19 (day 231) -- filter=gaussian_sd2min

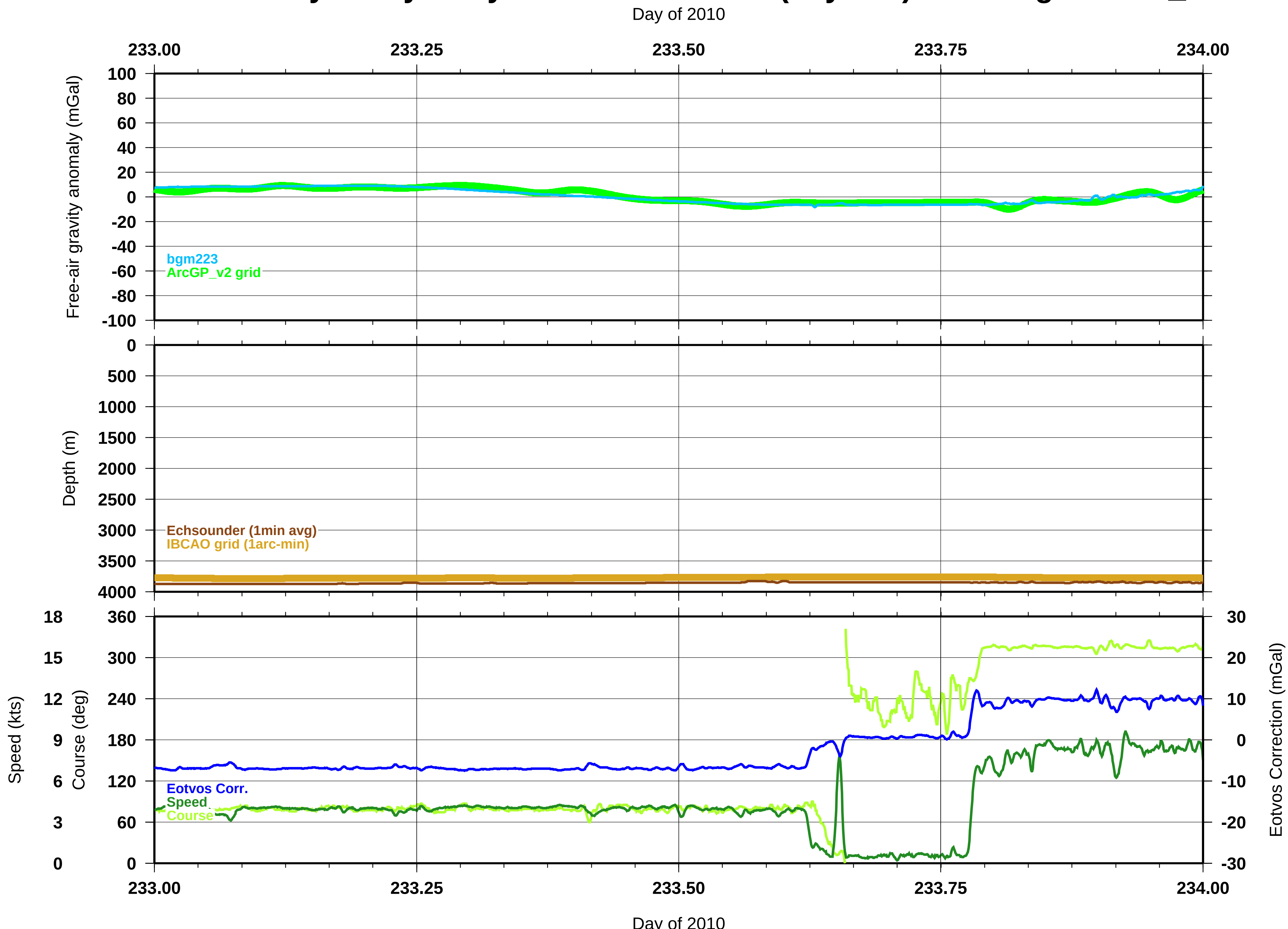


2010 Aug 20 11:39:02 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day231.ps



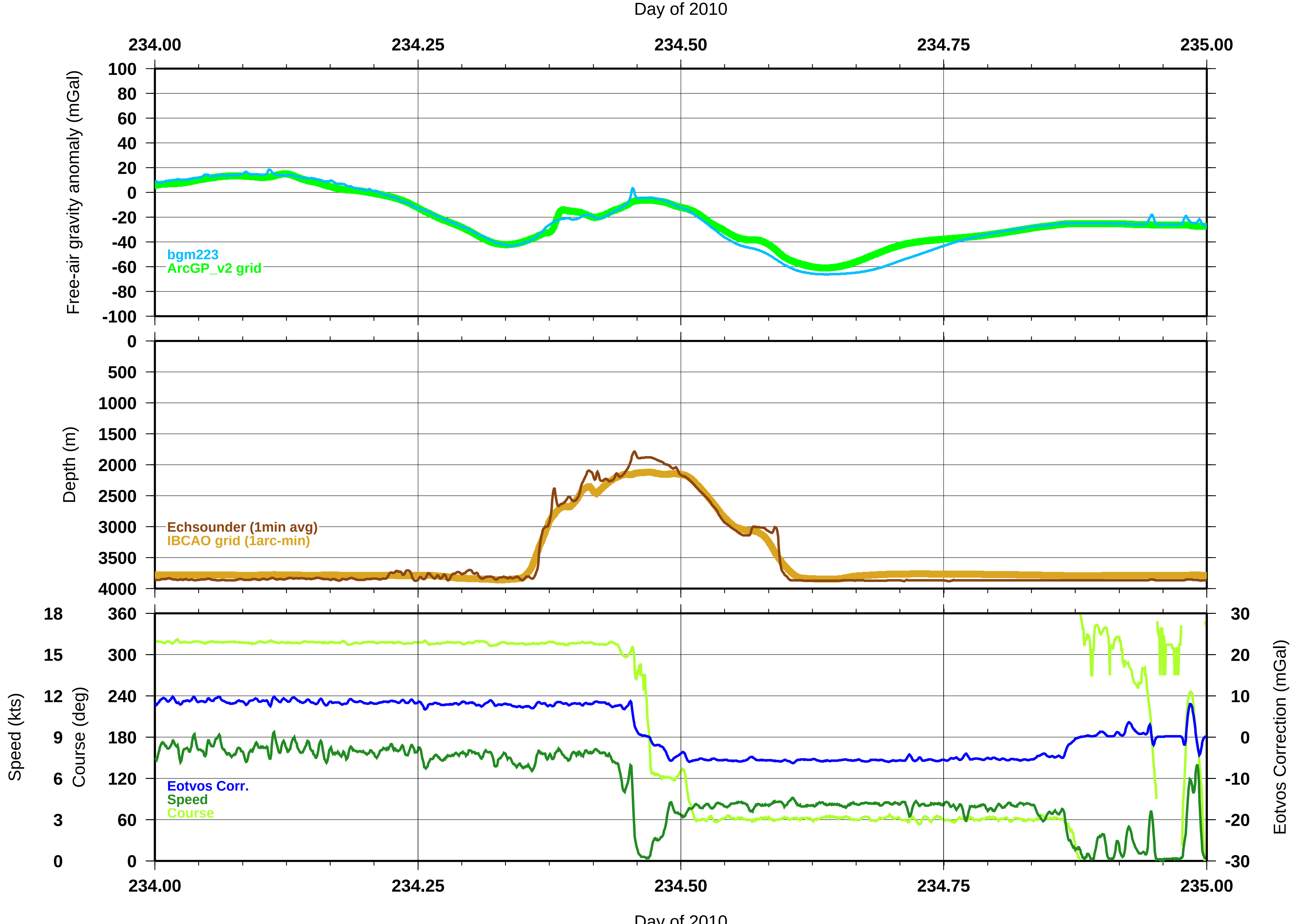
LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/20 (day 232) -- filter=gaussian_sd2min
Day of 2010
232.00
232.25
232.50
232.75
233.00
Free-air gravity anomaly (mGal)
bgm223
ArcGP_v2 grid
Depth (m)
Echsounder (1min avg)
IBCAO grid (1arc-min)
Speed (kts)
Course (deg)
Eotvos Correction (mGal)
Eotvos Corr.
Speed
Course
Day of 2010
2010 Aug 27 09:59:55
QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day232.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/21 (day 233) -- filter=gaussian_sd2min



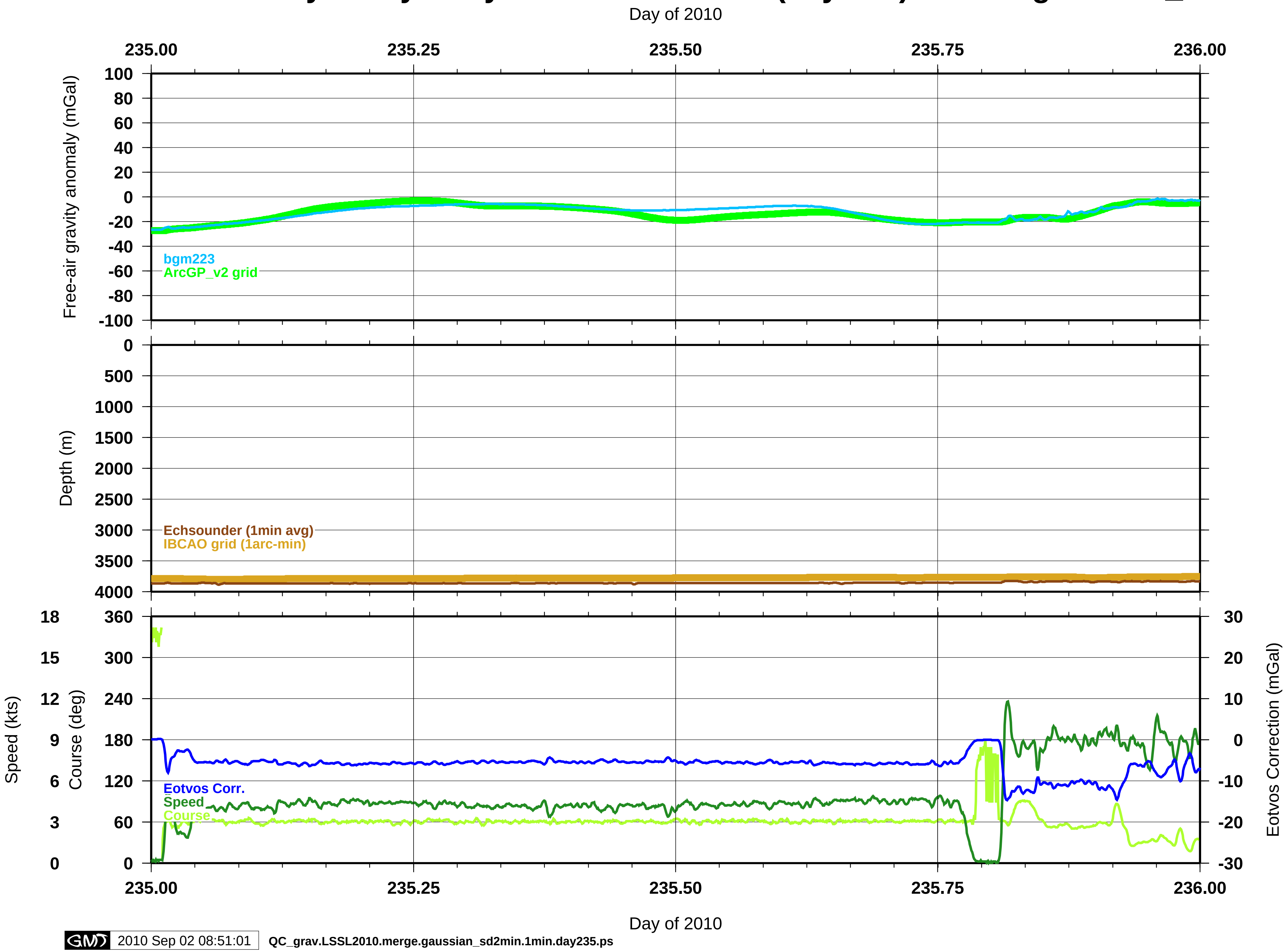
2010 Aug 27 09:59:57 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day233.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/22 (day 234) -- filter=gaussian_sd2min

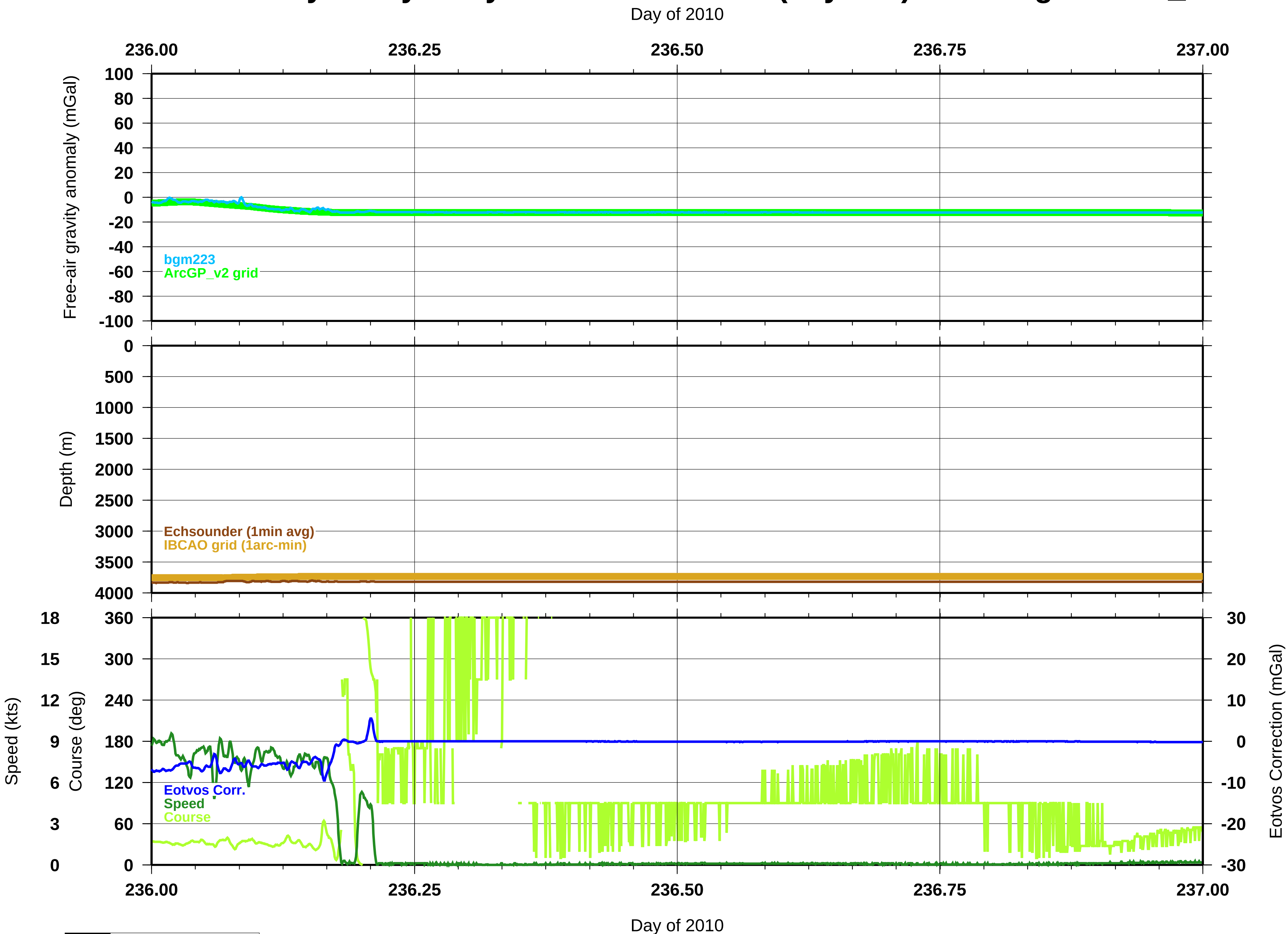


GMT 2010 Aug 27 09:59:59 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day234.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/23 (day 235) -- filter=gaussian_sd2min

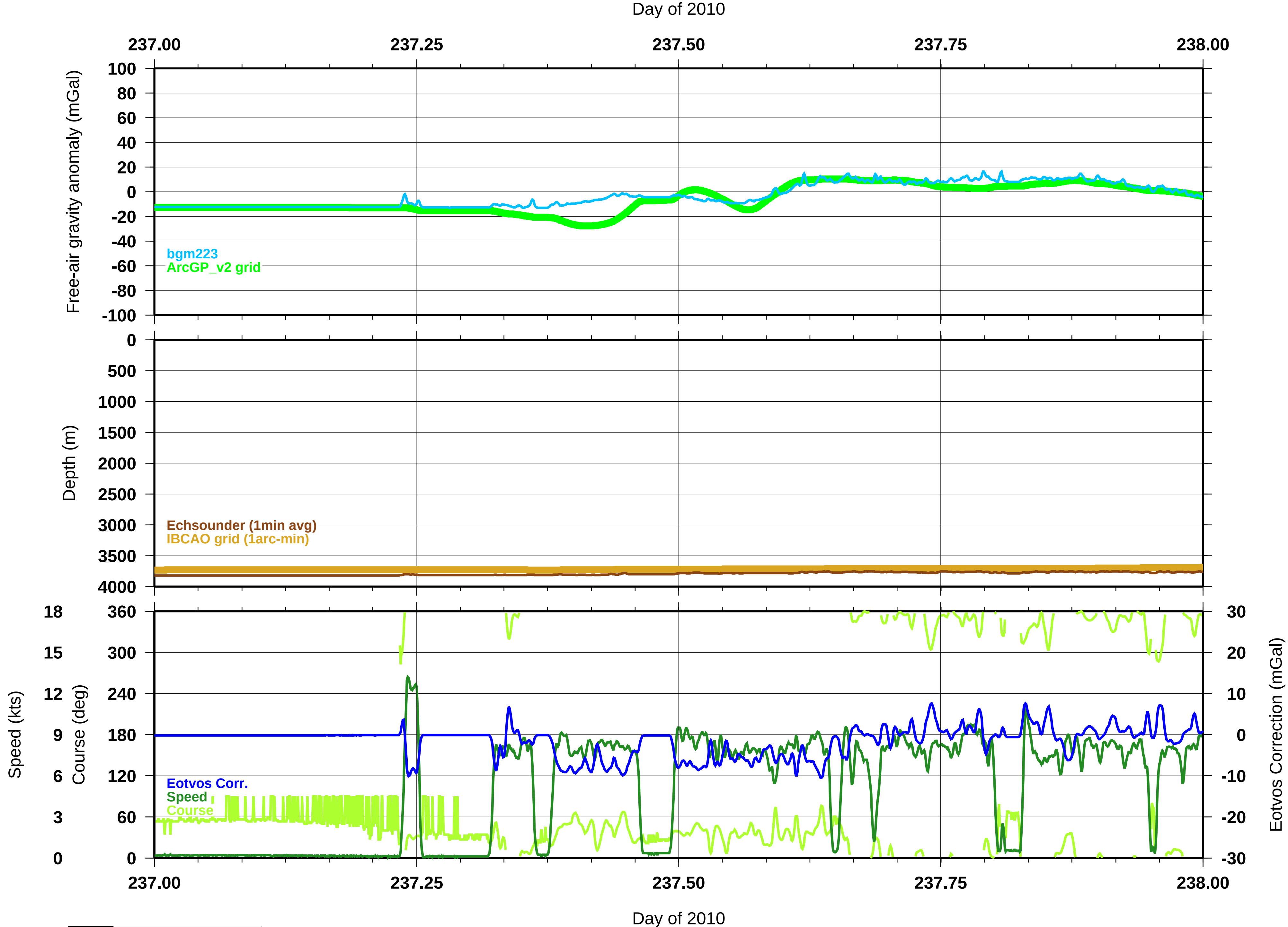


LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/24 (day 236) -- filter=gaussian_sd2min



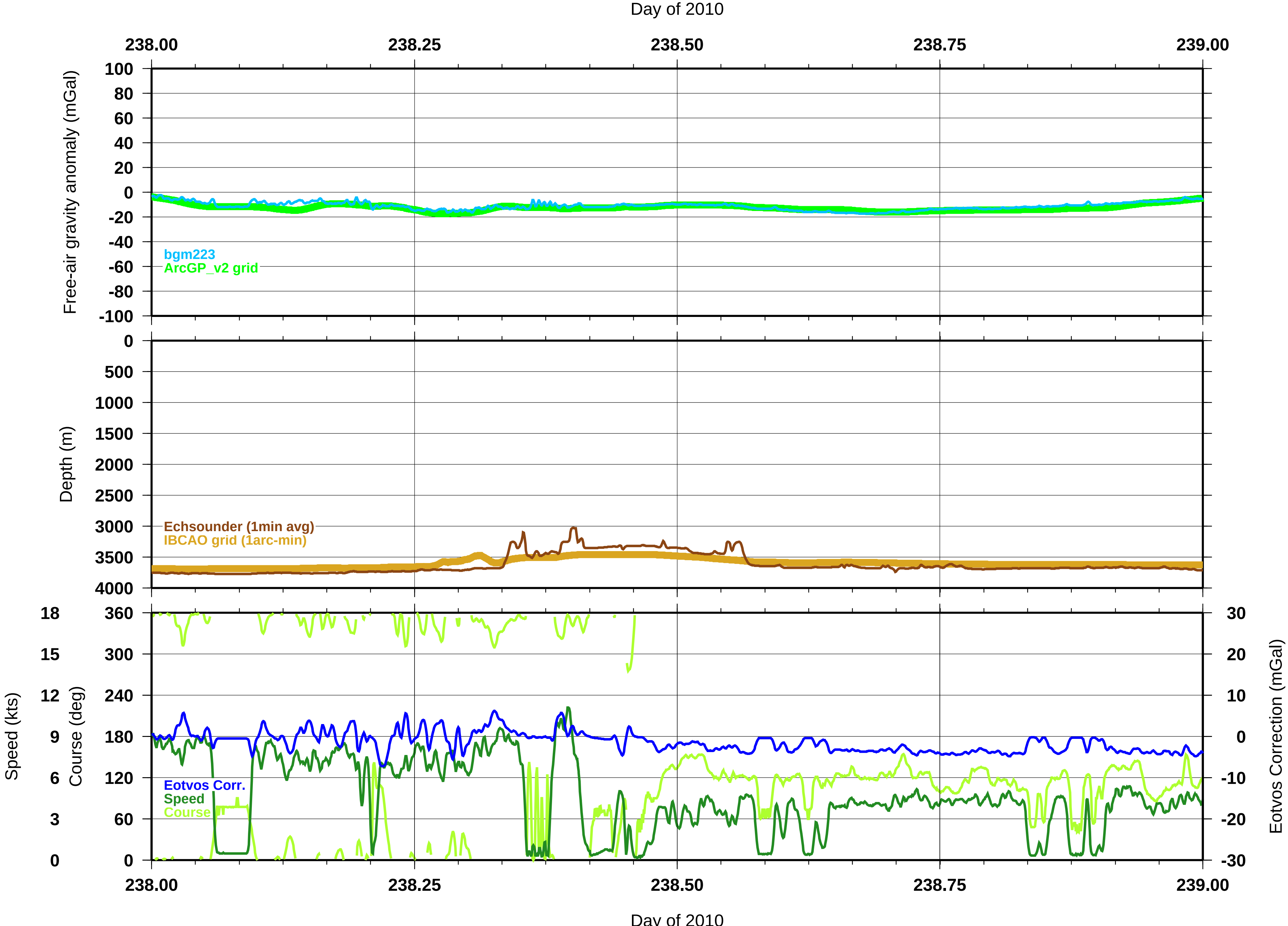
2010 Sep 02 08:51:04 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day236.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/25 (day 237) -- filter=gaussian_sd2min



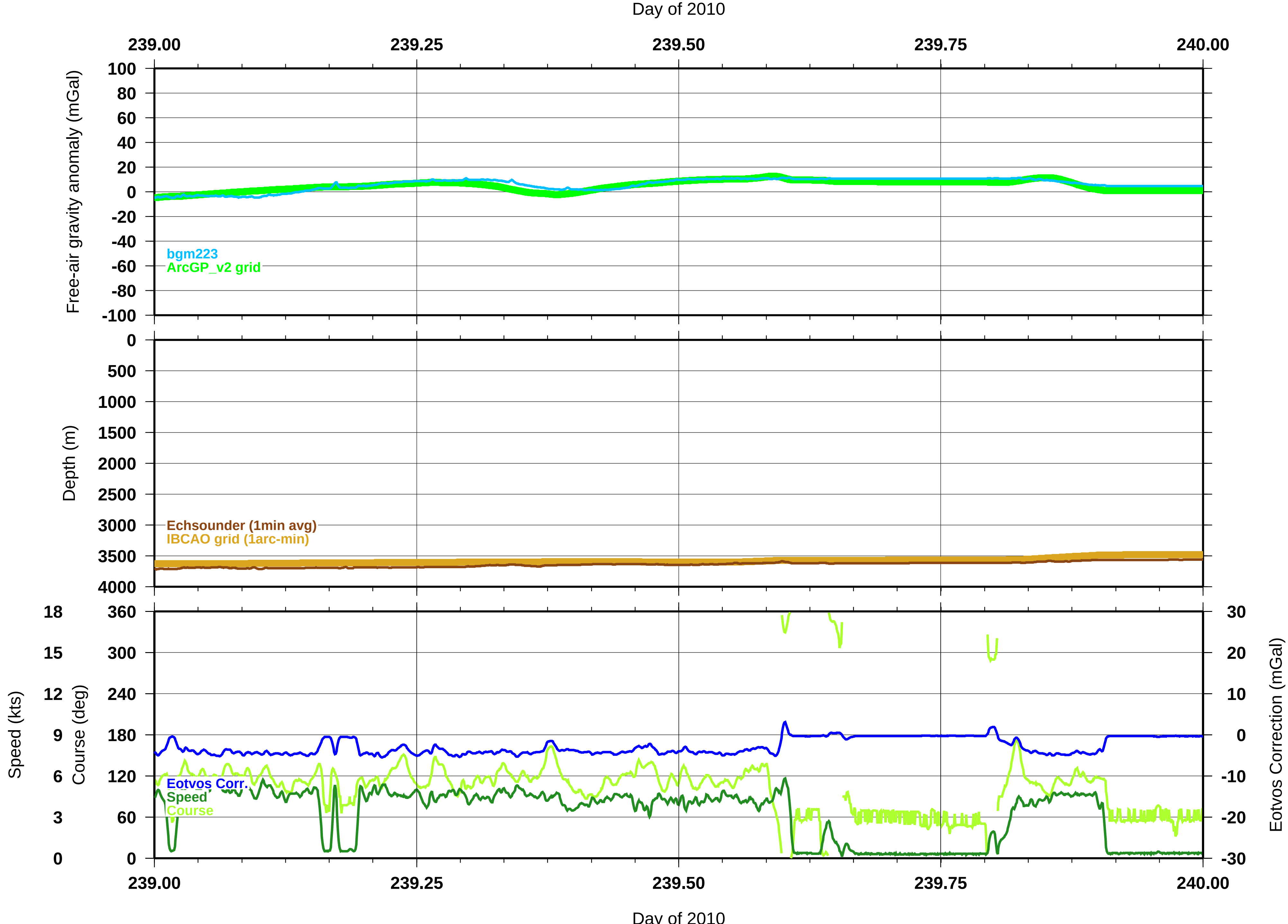
2010 Sep 02 08:51:06 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day237.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/26 (day 238) -- filter=gaussian_sd2min



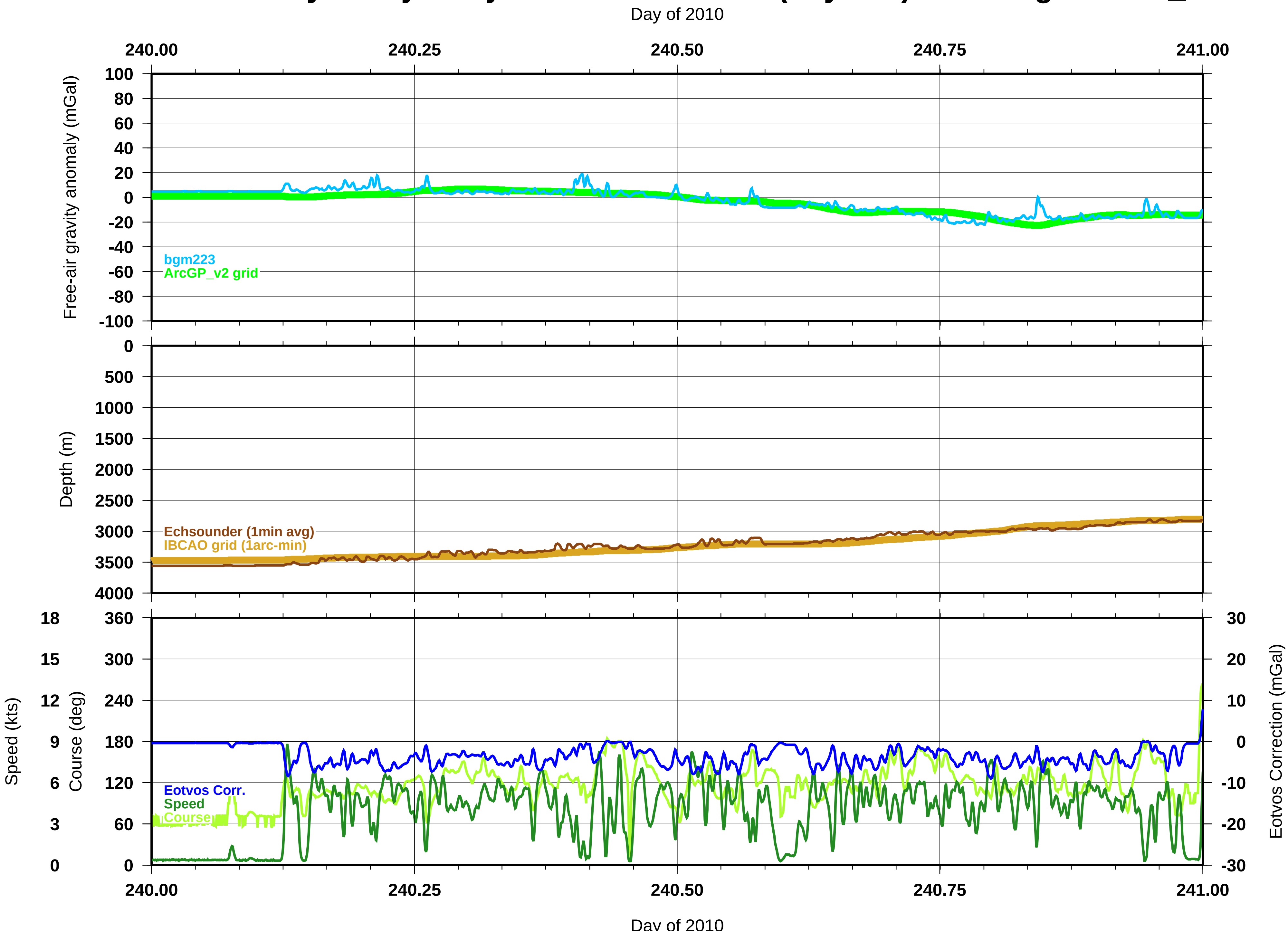
2010 Sep 02 08:51:09 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day238.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/27 (day 239) -- filter=gaussian_sd2min



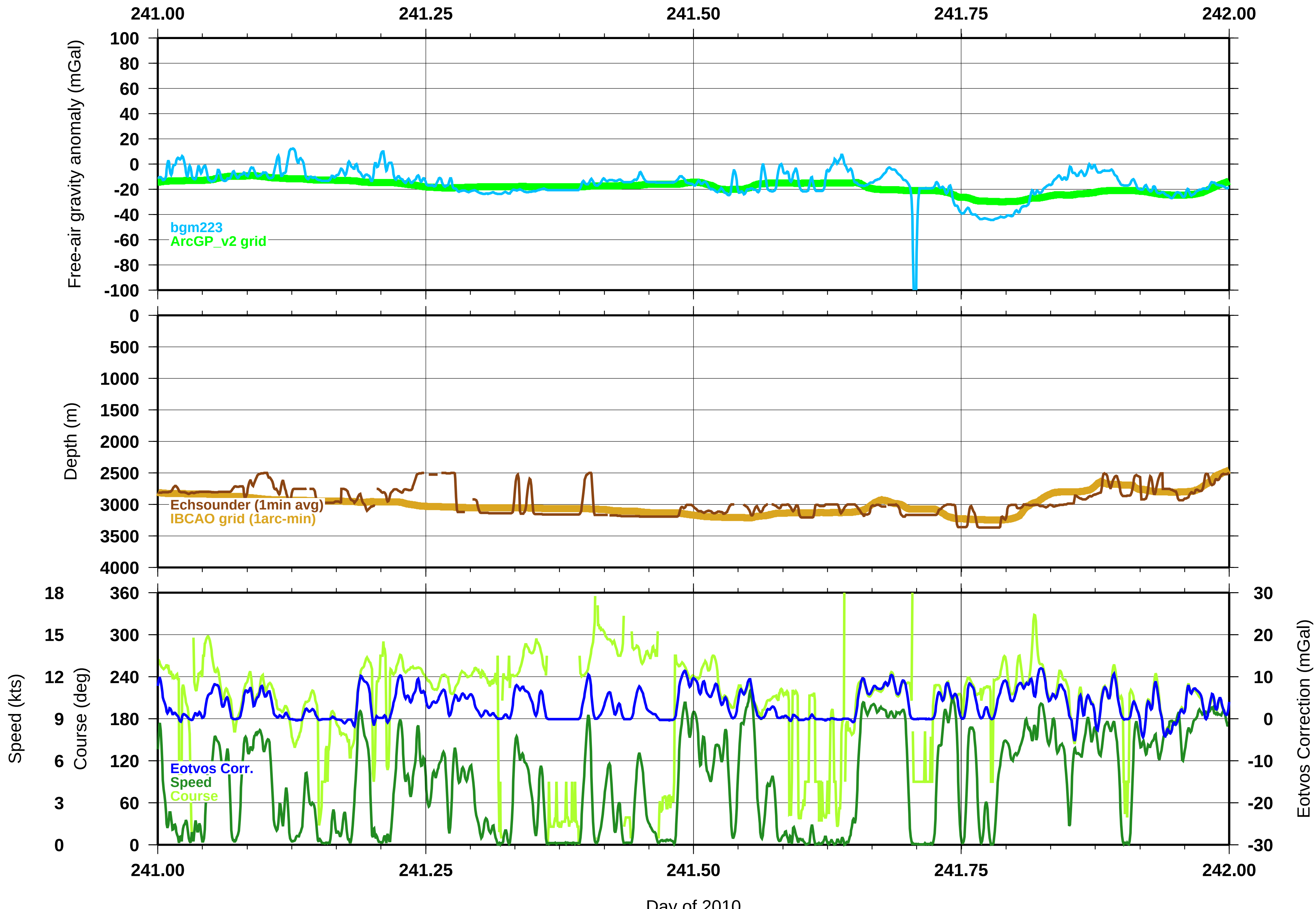
2010 Sep 02 08:51:12 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day239.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/28 (day 240) -- filter=gaussian_sd2min



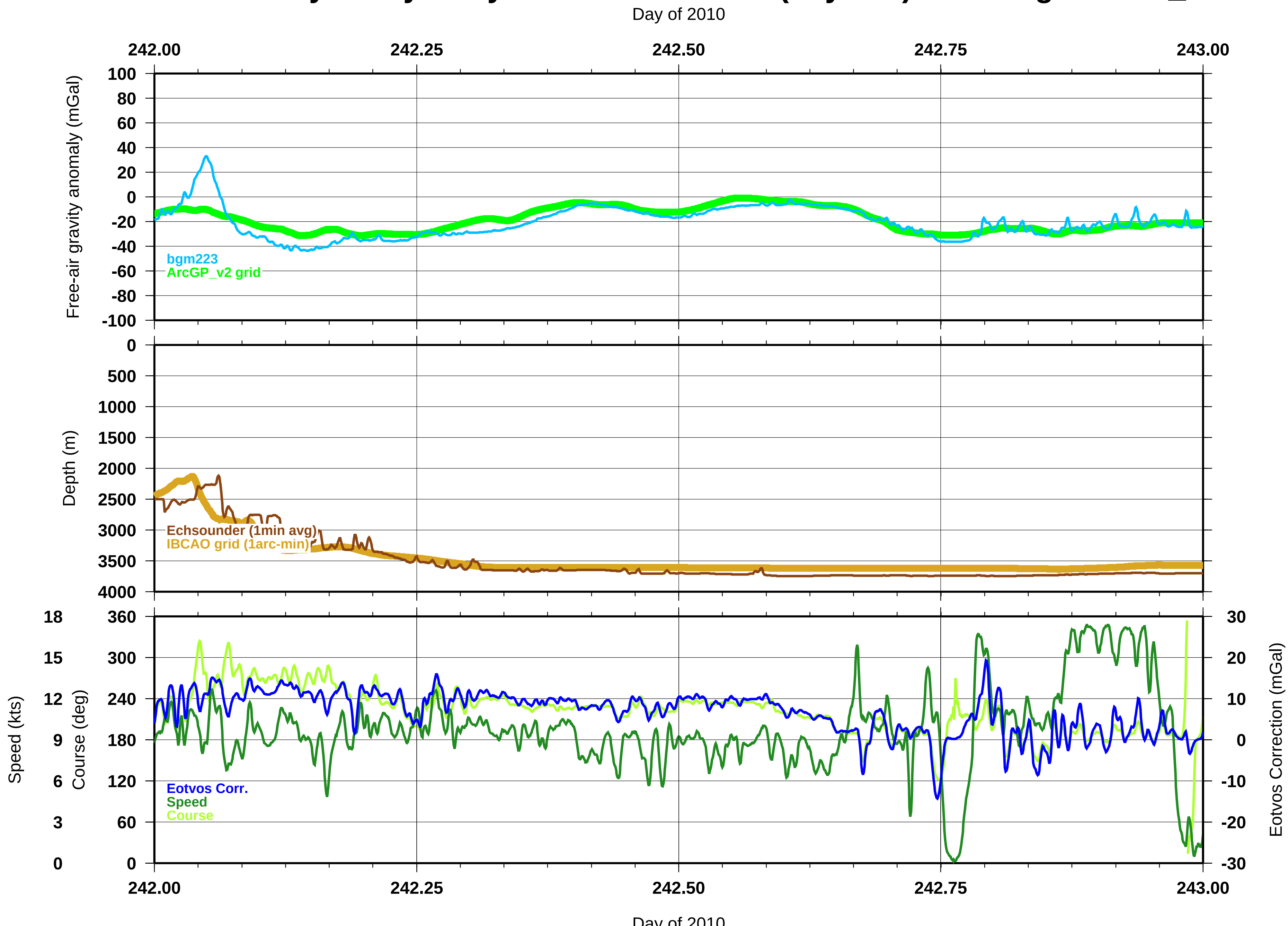
2010 Sep 02 08:52:45 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day240.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/29 (day 241) -- filter=gaussian_sd2min

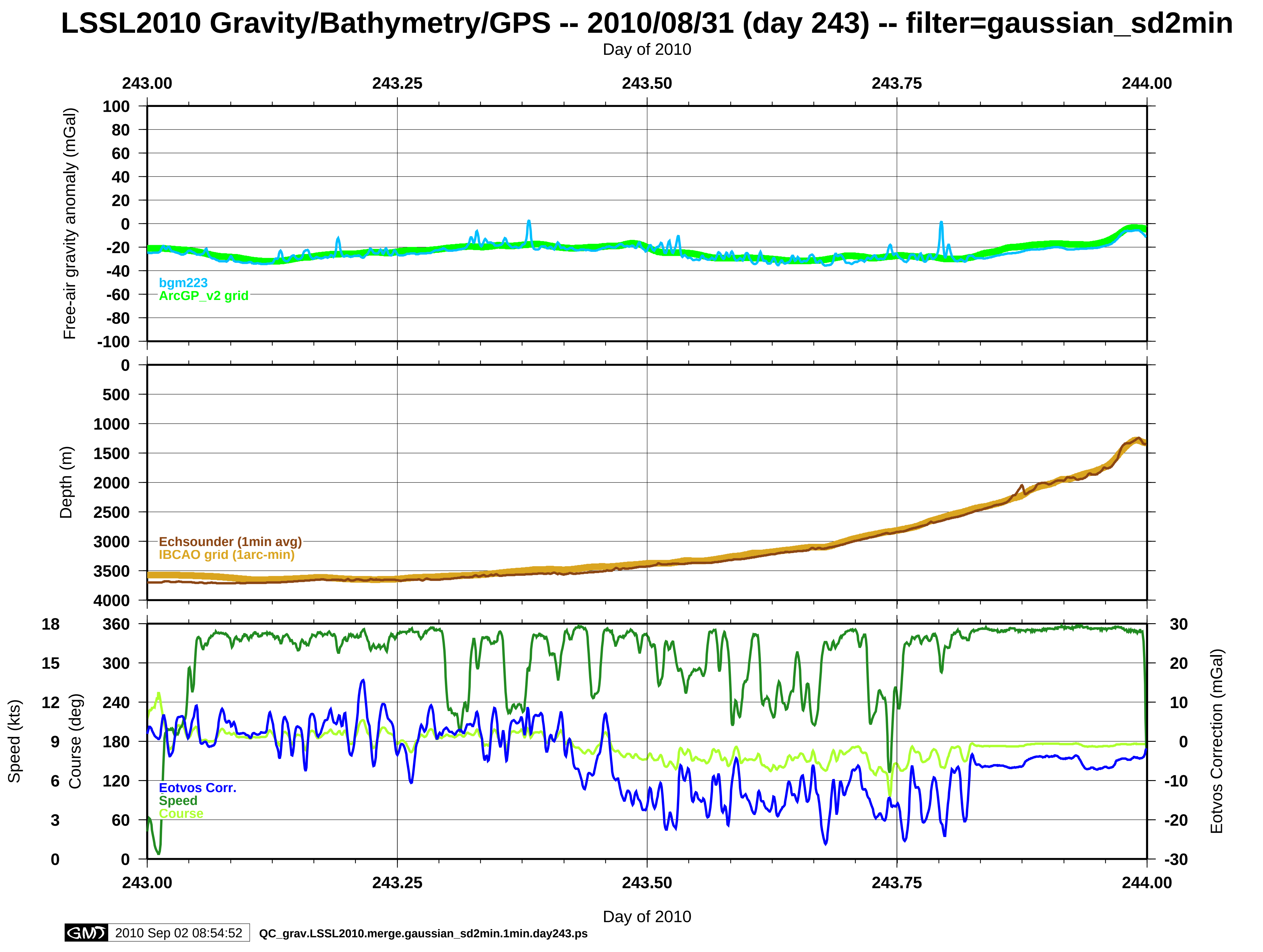


2010 Sep 02 08:52:47 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day241.ps

LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/30 (day 242) -- filter=gaussian_sd2min



2010 Sep 02 08:52:50 QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day242.ps


LSSL2010 Gravity/Bathymetry/GPS -- 2010/08/31 (day 243) -- filter=gaussian_sd2min
Day of 2010
243.00
243.25
243.50
243.75
244.00
Free-air gravity anomaly (mGal)
100
80
60
40
20
0
-20
-40
-60
-80
-100
bgm223
ArcGP_v2 grid
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
Echsounder (1min avg)
IBCAO grid (1arc-min)
Speed (kts)
Course (deg)
Eotvos Correction (mGal)
18
15
12
9
6
3
0
360
300
240
180
120
60
0
30
20
10
0
-10
-20
-30
Eotvos Corr.
Speed
Course
Day of 2010
GMT
2010 Sep 02 08:54:52
QC_grav.LSSL2010.merge.gaussian_sd2min.1min.day243.ps