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NOAA Ship *Okeanos Explorer*
Mapping Systems Readiness Report
2010

Figure 1. NOAA Ship *Okeanos Explorer*

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Purpose

The purpose of this document is to describe NOAA Ship *Okeanos Explorer* mapping system and the performance evaluation undertaken in 2009 and 2010. The intent of this report is to provide a comprehensive listing of all system components, configuration, calibrations and system performance evaluations.

Background

NOAA Ship Okeanos Explorer, R 337 (WTDH) is NOAA's only ship dedicated exclusively for ocean exploration. Okeanos Explorer is one of the five former U.S. Navy T-AGOS ships acquired and converted by NOAA for use as a scientific research ships. Originally built for anti-submarine warfare, former USNS Capable was commissioned as NOAA Ship Okeanos Explorer on August 13, 2008. Prior to commissioning, the vessel underwent extensive refurbishment from 2005 – 2008 by Todd Pacific Shipyards Corporation, including adding mission space for the ROV hanger, bow and stern thrusters, fairings for mapping sensors, and bridge upgradation. The ship has been outfitted with a deep-water multibeam echo sounder (MBES), a singlebeam echo sounder (SBES), and a subbottom profiler (SBP), along with host of ancillary equipment. Detailed layouts of the all of the new, modified and relocated equipment can be accessed at http://www.moc.noaa.gov/oe/index.htm. Videos of the conversion can be accessed at http://oceanexplorer.noaa.gov/okeanos/welcome.html.

Vessel Specifications

Table 1. Vessel specifications available online at http://www.moc.noaa.gov/oe/Specs/General%20Specifications.pdf (last accessed April 2010).

Vessel Specifications			
Hull Number	337	Cruising speed	10 knots
Call letters	WTDH	Mapping speed	8 knots
Builder	VT Halter Marine, Inc., Moss Point, MS	Berthing	46
Launched	Oct 28, 1988	Commissioned officers	6
Delivered to NOAA	Sept 10, 2004	Licensed engineers	3
Commissioned	Aug 14, 2008	Crew	18
Length (LOA)	68.3 m (224 feet)	Scientists	19
Breadth	13.1 m (43 feet)	Ambar RHIB	
Draft	5.18 m (17 feet)	Full Load displacement	2312 long tons
Range	9600 nm	Light ship displacement	1616 long tons
Endurance	40 days		
Main propulsion	2800 hp General electric DC drive motors	Power	4 Caterpillar D398 12 cylinder 800 HP diesel generators produce 240,000 watts at 600

			vac.

Hardware

Table 2. Mapping hardware inventory.

Equipment	Install Date	Quantity	Manufacturer	Equipment name	Firmware version	Serial No.
30 kHz Multibeam Echo Sounder	3/2008	1	Kongsberg	EM 302	SIS v.3.5	1 (HWS 10 is 271)
Inertial Measurement Unit	5/2008	1	Applanix	POS/MV	320 V.?	2572
Pressure Sensor & Deck Unit	7/2008	2 each	Sea-Bird	SBE 9/11 Plus	N/A	09P47490-0906 11P45414-0752
Temperature & Conductivity Sensors	7/2008	2 each	Sea-Bird	SBE 3Plus & 4C	N/A	03P5023 03P5026 4C43455 4C43456
Pump	7/2008	2	Sea-Bird	SBE 5T	N/A	05T4974 05T4975
Thermosalinograph (TSG)	4/2007	2	Sea-Bird	SBE 45	N/A	45414-0194
External Temperature Sensor	9/2007	2	Sea-Bird	SBE 38	N/A	3852209-0317
Carousel Rosette	7/2008	1	Sea-Bird	SBE 32	N/A	3247490-0674
~~Fluorometer~~	~~4/2007~~	~~1~~	~~Turner Designs~~	~~10-AU Field Fluorometer~~	~~N/A~~	~~6918 RTD~~
Single beam echo sounder (12 kHz)	3/2008	1	Kongsberg	EA 600	V. 2.3.0	(GPT: 385)
Sub bottom profiler	4/2008	1	Knudsen	Chirp 3260	V. 1.61	K2K-07-0910
Met station	11/2007	1	RMRCO	RM Young, Zeno	V. 1.965	BP05149 0302.116004
Dynamic Positioning System	9/2007	1	Kongsberg	?	N/A	N/A
~~Pinger~~	~~10/2008~~	~~1~~	~~Benthos~~	~~BFP-312~~	~~N/A~~	~~42855~~
Satellite Navigation System (C-NAV)	7/2007	1	C&C Technologies	2050G	N/A	5164

Additional deck equipment used during mapping operations includes:

- J-Frame (3,500 lbs. safe working load) used for vertical CTD casts and a towing capacity of 3,000 lbs. up to 45 degrees from vertical.
- CTD Winch (3,500 lbs safe working load using a 0.375 inch electromechanical cable) with 8,000 m of cable for CTD.
- A-Frame (20,000 lbs. safe working load,) used for deployment of ROV

Figure 2. J frame located on starboard side (left). CTD Winch (right).

Figure 3. View of A-Frame looking aft.

Multibeam Echo Sounder (MBES)

Okeanos Explorer is equipped with Kongsberg Maritime EM 302 multibeam sonar system. The sonar system was hull mounted by Todd Shipyard in Seattle during 2006/2007, and was completed in March 2008. The installation was accepted after field tests in September, 2008. The EM 302 receiver and transmit array are arranged in a transducer fairing installed between frame 15 and 42 (Figure 3). The top side electronics (trans-receiver unit – PU unit) for the EM 302 are located in an enclosed closet in the Ship's library, and the EM 302 control and acquisition software SIS (Seafloor Information System) station is located in main mission space in the Control Room on the 01 deck. A remote on/off switch is also located next to the SIS acquisition station. The SIS computer is located in the rack room (Figure 3).

The nominal frequency of EM 302 is 30 kHz. The system can be operated in two modes – CW or FM mode. The distinctive advantage of FM mode is that larger swath coverage can be realized as compared to traditional deep water multibeam systems. The sonar also utilizes multi-ping technology (dual swath) where two pings are simultaneously sent into water thereby increasing the data density.

Figure 4. (Clockwise from left) EM 302 TRU unit, Transducer fairing, Elements of EM 302 being installed inside the fairing, TRU remote on / off switch.

During the 2009-2010 winter in port, the EM302 TRU closet was refitted with a new air ventilation system and insulation. Thermometers were installed in the closet to monitor

temperature control. During the 2010 shakedown cruise (EX1001), temperatures in the TRU closet were observed to remain below 85 degrees Fahrenheit at all times.

Figure 5. Temperature gauges installed 2009/2010 winter inport.

Single Beam Echo Sound (SBES)

SBES system consists of 12 kHz transducer (Kongsberg 12-16/60) with 2 KW transmit power that can collect data in up to 7000 m of water. The tranreceiver unit is connected to EA-RDS that provides the user interface to control the system settings. The tranreceiver unit is located in the closet in the ship's library. Top side electronics including the controlling computer are located in dry lab. The singlebeam sonar has been tested to a depth of 4500 m. 2009 acceptance report of EA 600 is included [5].

Figure 6. EA 600 RDS controller.

Figure 7. EA600 TRU interior (left) and EA600 TRU outer casing (right).

Sub Bottom Profiler (SBP)

Okeanos Explorer is outfitted with 3.5 kHz Knudsen chirp 3260 sub-bottom profiler. The system was accepted by ship in Nov 2008 after some initial checks [1] on the system using simulator mode. However, the system was not configured to receive navigation and heave input at that time. During March 2009 sea trials the system was configured to collect some data. The data has been sent to Knudsen for evaluation.

During the 2009 evaluation, a strong interference was observed between SBP and EM302 / EA 600. Consequently, the SBP profiler was outfitted to accept an external trigger from EM 302. During the 2010 shakedown cruise, the subbottom was run in tandem with the multibeam. No interference was observed in up to 1400 meters of water. Further deep water testing may be required.

Positioning and Orientation equipment

Applanix TSS Positioning and Orientation system for Marine Vehicles (POS/MV) estimates position, heading, attitude and heave of the vessel. The system includes POS computer system (PCS), an Inertial measurement unit (IMU) and two GPS antennas. The IMU is located in the fan room in front of Ship's library (between frames 35-40).

During the 2009-2010 winter in port, a protective case was secured around the IMU.

Figure 8. Clockwise from top left: IMU and granite block, IMU, IMU under protective housing.

Figure 9 shows the arrangement of miscellaneous antennas onboard, including the CNAV GPS antenna, and the POS M/V port and starboard antennas.

Figure 9. POS/MV antennas mounted on the Flying Bridge (below). Also shown is the CNAV antenna.

Sound Speed Measurements

Vertical Profiling:

Okeanos Explorer has two Sea-Bird electronics, Inc. (SBE) 9/11Plus CTDs, each with dual "3plus Temperature" and "4C Conductivity" sensors. "3plus Temperature" sensors are certified by Seabird to demonstrate temperature measurement drift of less than 0.001 °C and time measurement accuracy within 0.065 ± 0.010 seconds. "4 C Conductivity" sensors are ideally suited for obtaining horizontal data with towed systems or vertical data with lowered systems.

This unit is capable of collecting temperature, conductivity, and pressure in real time and depth, salinity and sound velocity are calculated in real time via SBE Seasave acquisition software. One complete package is used to collect data and the other is kept as a spare. The ship must hold station to conduct a CTD cast. The CTD is lowered through the water column at 60m/min.

Lockheed Martin Sippican expendable bathy thermograph (XBT) casts are conducted on the aft deck with a portable launcher. XSV (Expendable Sound Velocity) probes are also used to measure sound velocity directly. The data is collected in real time with the WinMK21 acquisition software. The major difference between the CTD and XBT is that an XBT/XSV cast can be completed while the ship is underway. The mapping department stocks "Deep Blue" XBT probes, which can be launched at ship speeds of up to 20 knots, and collect data to a maximum depth of 760 m. A small amount of"T-5" XBT probes are available onboard, to be used for comparisons casts when CTD operations are not available."T-5" probes can be launched at ship speeds of up to 6 knots and collect data to a maximum depth of 1830 m.

Figure 10. XBT launch from the aft deck (left). Deck unit for XBT (right)

Data from the CTD and XBT are viewed and processed using the Velcipy computer. The sound speed computed by TSG is fed into SCS. Sound speed profiles obtained from CTD/XBT casts can be converted to EM 302 compliant data format using Velocipy version X.

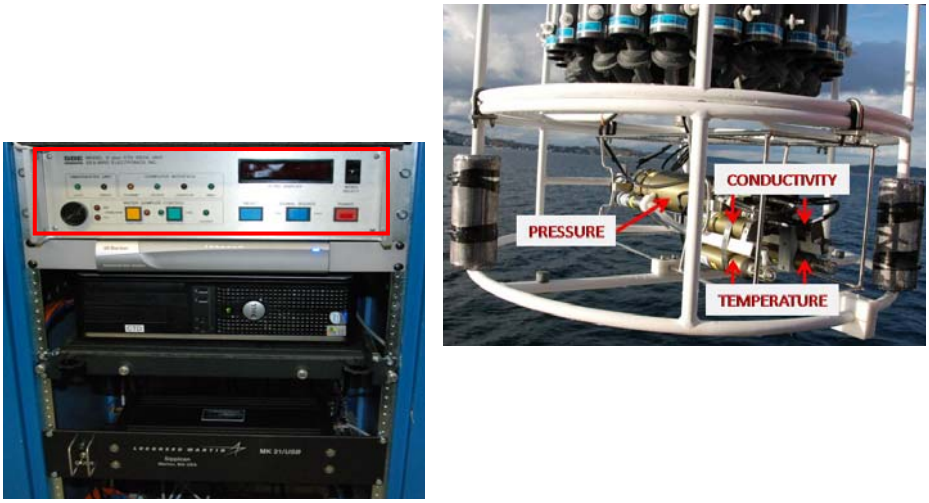


Figure 11. (Left) Deck Unit (SBE 11) for acquisition of real time sound speed profile from SBE 9 plus CTD (Right) Horizontally mounted CTD with dual Temperature and Conductivity sensors and SBE 32 Carousel for 24-bottle water sampling.

The primary Sea-Bird CTD sensor for the 2010 field season is SBE-9Plus CTD SN 107068. See calibration report SBE9p_0906_052208.pdf [6] for manufacturer calibration information and testing report. During the shakedown cruise simultaneous comparison of CTDs, XBT and surface sound speed comparison showed a close agreement between CTD and XBT sound velocity profiles.

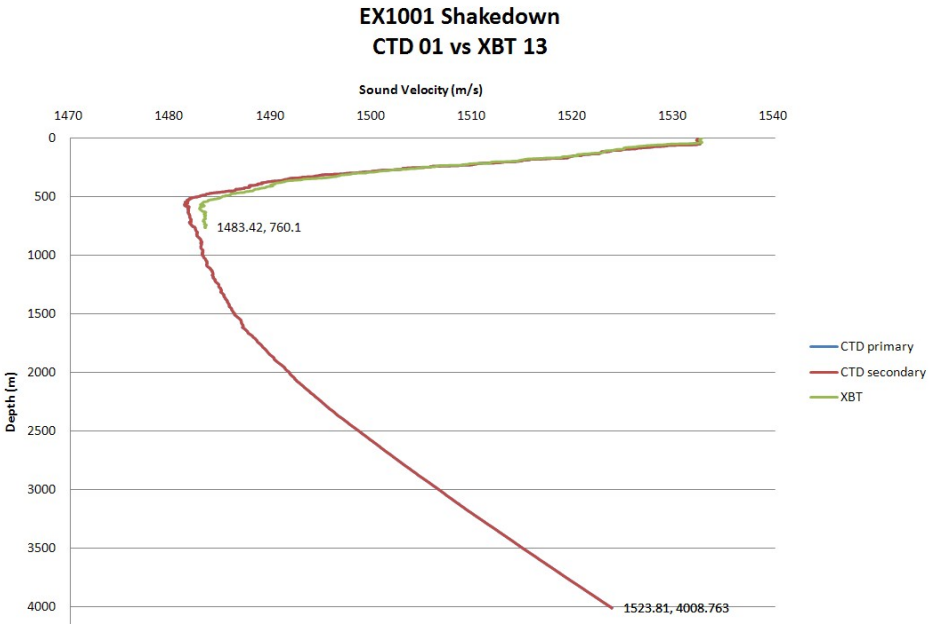


Figure 12. Comparison of simultaneous casts taken by CTD and XBT on 2/14/10. Two measurements agree with in 1 m/s at all measured depths.

Sea Surface Sound Speed Measurement:

The scientific seawater system utilizes a SBE 45 Thermosalinograph (TSG), to collect continuous sea surface data. Located in the Wet Lab, the TSG collects temperature and conductivity readings, and is capable of deriving salinity and sound velocity data in real time. The pump is located in the bow thruster room. It sucks water from eleven feet below the water line into the Bow Thruster Room, where a SBE 38 Remote Temperature Sensor acquires sea surface temperature. Afterwards, the water continues aft to the wet lab where it passes through the SBE 45 and is expelled on the port side below and a little forward of the wet lab.

This setup is susceptible to air bubble intake during rough weather. An improved setup has been proposed and is expected to be installed during the 2010-2011 winter in port.

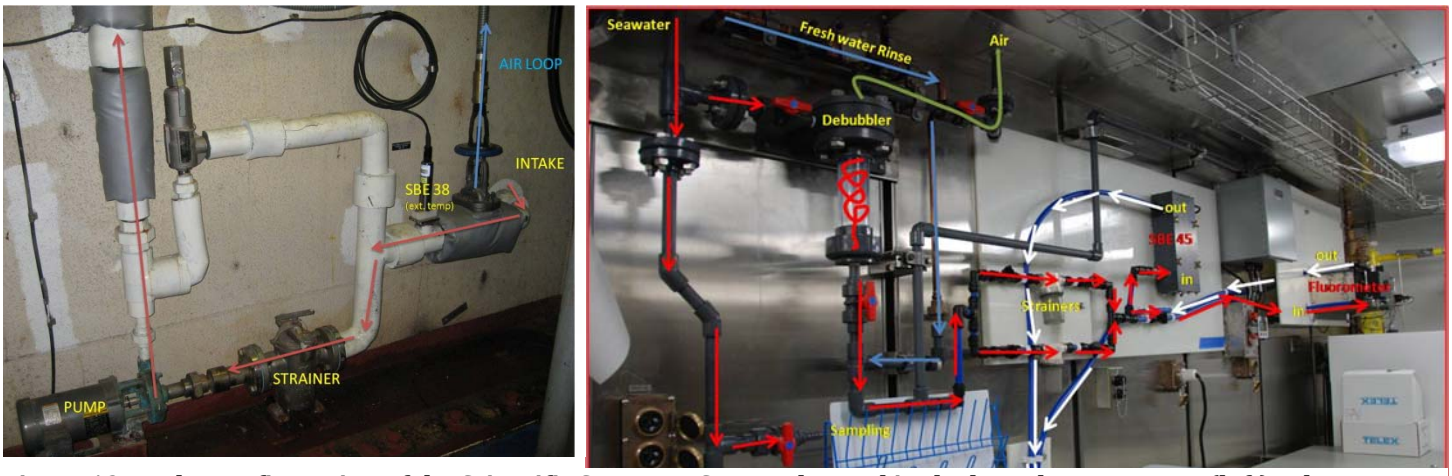


Figure 13.Intake configuration of the Scientific Seawater System, located in the bow thruster room (left). Flow diagram of Scientific Seawater System components in the wet lab, including TSG.

SBE 32 Carousel (Water Sampler)

SBE 9/11 plus CTD is connected to the SBE 32 Carousel. The SBE 32 is rigged with 24-2.5L water sampling bottles. The bottles can be fired to close at any depth during a cast through the Seasave acquisition software on CTD computer in the dry lab or control room.

Fluorometer

At present this system is not being used for mapping and has been returned to the manufacturer for repair.

Bridge DP system

Okeanos Explorer has been equipped with Kongsberg Dynamic position (DP) that has been integrated with the navigation system to help Okeanos Explorer maintain her position within a few meters during ROV operations using bow and stern thrusters. The DP system is also capable of running predefined track lines with minimal supervision.

During the 2009 performance evaluation, the bridge DP system was found to be performing satisfactorily, in particular capable of maintaining position and following predetermined track lines. The bridge DP system requires the track lines be input in a specific format, specifically as a series of way points. Lines created by the survey department in MapInfo and Hypack are converted via MATLAB routine to be compliant with the bridge DP system. The DP system at present is not connected to ship's net work and therefore way point files need to be manually fed to the DP system through local USB port. An alternative work around is to manually input the way points into DP system via key pad.

An example of a DP system compliant way point file is provided in Appendix B.

Figure 14. Bridge DP system installed on Okeanos Explorer showing different controls and the USB drive for feeding the way point table.

Static Vessel offsets

The sensors (IMU and GPS antennas), the sonar system, and permanent benchmarks were measured with respect to the vessel's reference point (a granite block). The ship was surveyed by Westlake Consultants, Inc. The resultant preliminary report "Report of Sonar Systems and GPS Antennae as-builting on the NOAA Okeanos Explorer" March 18, 2008 [2] summarizes Westlake Consultant's survey methodology, defines the coordinate system and details the offsets measurements. All measurements described within the report are referred to the granite block and follow coordinate system all values STBD (Y), FWD (X) and down of the granite block (Z) as positive. Positive pitch is described as bow up and positive roll is described as STBD up.

Center of Roll and Pitch

The position of center of gravity changes with ship loading conditions. The position of the center of the gravity was available from the records of the ship's inclining experiment done in 2008 [3]. For lever arm offsets determination, the center of gravity was assumed to be a reasonable approximation of the center of rotation. The position of the ship's center of gravity based on light conditions detailed in the Stability Test report [3], was measured to be 31.501 m aft of the forward perpendicular (frame 0), 0.0 m starboard of the center line, and 5.514 m above the keel base line. These values were transformed into the POS/MV reference frame with reference to the granite block (RP).

Table 3. Granite block (RP) to center of gravity (rotation) offsets

RP to center of gravity (rotation) (m)		
X	Y	Z
-7.896	2.487	0.825

Mapping sensor Specific offsets

The GPS antenna to reference point lever arm was accounted for in the POS/MV controller. The sonar specific offsets such as roll mounts and sonar locations were entered into Kongsberg seafloor information system (SIS) acquisition software. These figures are referenced to the granite block (RP).

Table 4. EM 302 specific offsets as entered in SIS.

	Sonar coordinates (m)			Angular offsets (Degrees) after patch test		
	X	Y	Z	Roll	Pitch	Heading
EM 302 Transmit array	6.147	1.822	6.796	0.0	0.0	359.98
EM 302 Receiver array	2.497	2.481	6.790	0.0	0.0	0.03
EM 302 Water line	----	----	1.838	----	----	----
EA 600						
Knudsen SBP	3.967	3.500	6.746	----	----	----

IMU and Antenna Offsets

The offsets between the reference point and the GPS antenna were referenced to the primary antenna. The port antenna is primary.

Table 5. POS MV settings for offsets to primary GPS, aux GPS (C-NAV) and IMU.

POS /MV Coordinates			
	X	Y	Z
Primary GPS (Port Ant.)	8.265	1.335	-15.403
Ref to IMU	0.734	0.008	-0.022
Ref to Aux 1 GPS (C-NAV)	8.353	5.927	-15.396

Static draft measurement

The static draft is measured by the bridge before the start of each cruise. The bow draft is directly read off draft marks on the hull and the stern draft is measured and then calculated from a specific frame on the fantail. These draft measurement are then compared to and verified with the results from the ship's stability calculations.

The nominal draft measurements before start of May 05 cruise (EX0903) were 4.81 m bow and 4.49 m stern.

Draft measurements taken during cruise EX1001 were as follows:

Beginning draft 02/09/10	Fwd: 15'01" (4.6 m) Aft: 14'05.5" (4.4 m)
Ending draft 02/17/10	Fwd: 14'3" (4.3 m) Aft: 15'3" (4.6 m)

Dynamic Draft

Dynamic draft measurements not been calculated for *Okeanos Explorer*.

System Calibrations and Performance Evaluations

GAMS calibration was conducted during the EX1001 Mapping Shakedown Cruise (Feb 2010). GAMS calibration records can be found in the POS MV controller.

Measured distance between the antennas [3, Westlake report], is 2.3001. POS MV manual (section 4) describes that the distance between the antennas calculated in GAMS calibration should be within 5 mm to actual distance. The GAMS calibration resulted in a distance between the antennas to be 2.297 m therefore the difference between actual antennas separation and GAMS solution antennas separation is 4 mm (< 5mm). Therefore the GAMS calibration seems to be done correctly.

GAMS did not appear to require calibration during the 2010 shakedown cruise, with the GAMS status consistently "online" or "ready online". However, a GAMS calibration was run as a precautionary measure, resulting in no change of GAMS status.

EM 302 Patch Test

During the EX1001 Shakedown cruise (Feb 6 – 19, 2010), a series of three patch tests were performed off of Hawaii. The results of each patch test were analyzed in both SIS Calibration Mode and CARIS HIPS 6.1 Calibration Tool. See Appendices D, E, and F for screen grabs of all CARIS calibrations.

The first patch test was run just offshore of Pearl Harbor near Honolulu, Hawaii. The patch test was run with the same software set up as last year (SIS 3.6.1, TRU: BSV 2.2.2 081216, PSV 1.4.5 090421)) and with last year's offsets applied. The results shows the offsets had not changed from last year.

Table 6. Angular offsets for Transmit (TX) and Receive (TX) transducer and attitude sensor

	Roll	Pitch	Heading
TX Transducer	0.0	0.0	359.98
RX Transducer	0.0	0.0	0.03
Attitude	0	-0.7	0.0

After the first patch test was run, the system was upgraded with new TRU software (BSV 2.2.3 090702, PSV 1.4.8 091110) for the EM302 and the new version of SIS (v 3.6.4). The same shallow water patch test lines were then rerun. The results showed the same calculated offsets as last year.

The shallow water patch test lines were approximately 8 km long. Line spacing for the shallow water patch test was 2.5 km. Additional test lines were acquired as part of the patch test to be used as a reference surface for seafloor backscatter data collection and quality assessment, and for overall multibeam data quality assessment.

After the second shallow patch test was completed, the ship transited to Kealakekua Bay, an area off of Kona on the Big Island of Hawaii, to conduct a deep water patch test.
The deep water patch test lines were approximately 21.5 km (east-west) and 12.5 km (north-south) long. Line spacing for the deep water patch test was 2.5 km.

Timing and Pitch Offset

The navigation time error and pitch biases were determined by running a single line in opposite directions at two speeds over a sloped area.

All three patch tests determined a zero timing offset.

All three patch tests determined the pitch offset to be -0.07.

Roll Offset

The roll bias was determined by running a single line at the same speed over a flat area in opposite directions.

All three patch tests determined a zero roll offset.

Heading Offset

The heading bias was determined by running a pair of lines offset from each other by approximately 2.5 km. The lines were run in the same direction and at the same speed. In both the shallow water and deep water patch tests, the lines ensonified steep slopes in the outer beams of the swath.

All three patch tests determined a zero heading offset.

Data Processing

Detailed documentation is available in the form of standard operating procedures (SOPs) for all data processing performed by the mapping team onboard the Okeanos Explorer. The purpose of this data processing section is to describe the current status of a few data processing pipelines.

Bottom Bathymetric Data Processing
CARIS v. 6.1 is used to edit the bathymetric data from the EM302 multibeam and EA600 singlebeam. At present, an uncertainty model for the EM302 is not available and therefore manual editing of bathymetric data is necessary. Cleaned data is exported to ASCII text files and then imported to IVS Fledermaus v. 7 for further processing, visualization, quality control, and product generation.

Bottom Backscatter Data Processing
FMGeocoder Version 7.1.0a, Build 481 Professional, 32 bit Edition is currently used for processing EM302 bottom backscatter data. This version of FMGeocoder is installed when upgrading to the Fledermaus Version 7.1.0a, Build 481 from March 3, 2010.

Water Column Data Processing
The IVS 3D MidWater tool "FM MidWater" version 7.0.0b, Build 191 Beta, 32 bit edition, and FledermausMW version 7.0.0b Build 191 Professional, 32 bit edition, are used to process EM302 water column backscatter data and view the resulting Fledermaus SD objects. These programs are available as beta versions only and are not included in the standard distribution of Fledermaus software. However, these programs are the best method available to the mapping department for water column data processing. A new version of FM Midwater is expected to be released in the first quarter of 2010.

At this time, it is possible to produce the following SD objects using FM MidWater: beam fan, beam line, volume, and track line, The utility of each of these SD object types is currently being investigated. Attempting to export a point SD object results in a C++ RunTime error and flash exit of FM Midwater.

Subbottom Data Processing
Sonar Wiz v. 4004.0034 is available for processing the SEG-Y files, and possibly the KEB and KEA files, generated by the Knudsen 3260 subbottom profiler. Complete testing of this data processing pipeline is in progress.

Sound Speed Cast Processing
Kongsberg SIS, the multibeam acquisition software, requires that sound speed profiles are extended to 12,000 m, regardless of expected water depth. Previously, the procedure has been to use NOAA's in-house software Velociwin to perform this extension on sound velocity profiles originating from the XBT and CTD sensors. However, it was determined during the EX1001 Shakedown cruise that Velociwin is not reliable in its extension of casts, and therefore could be introducing error in the multibeam data. NOAA is in the process of porting Velociwin functionality into Velocipy, an updated Python-based version of the software. However, the current version of Velocipy does not reliably extend casts. As Velocipy is further developed, the mapping team will continue to evaluate its reliability in extending profiles to 12000 m. The current procedure is to process casts in Velocipy, and to extend the resulting *.asvp file in SIS.

Figure 15 shows a comparison of the same XBT extended in SIS and Velocipy compared to a CTD cast that was taken at the same time as the XBT. The SVP for the CTD was then

processed and manually extended to 12,000 meters in Velocipy (blue). The XBT cast was processed and manually extended to 12,000 meters in Velocipy (red). The XBT cast was processed again and not extended in Velocipy, instead extended in SIS (green).

Figure 16 is a comparison of all of the extending methods available in Velocipy as well as SIS. Select manually an additional point (Manual), Use most probably slope algorithm (Slope Algorithm), Use historical data as reference 1 Deg, Annual (Historical 1) or 5 Deg, Annual (Historical 5), and Do NOT extend cast (SIS). When "Do NOT extend cast" was selected in Velocipy, it was instead extended in SIS for comparison.

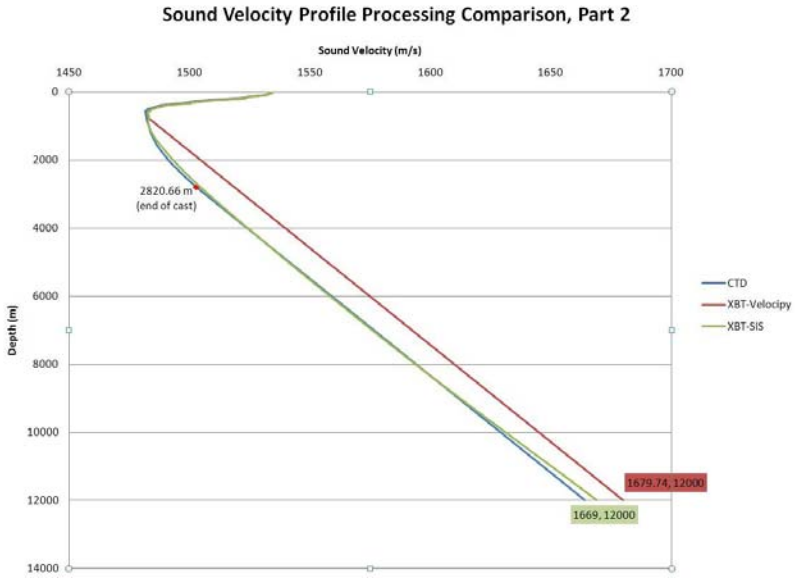


Figure 15. Results of XBT extension of in SIS and Velocipy as compared to comparison CTD.

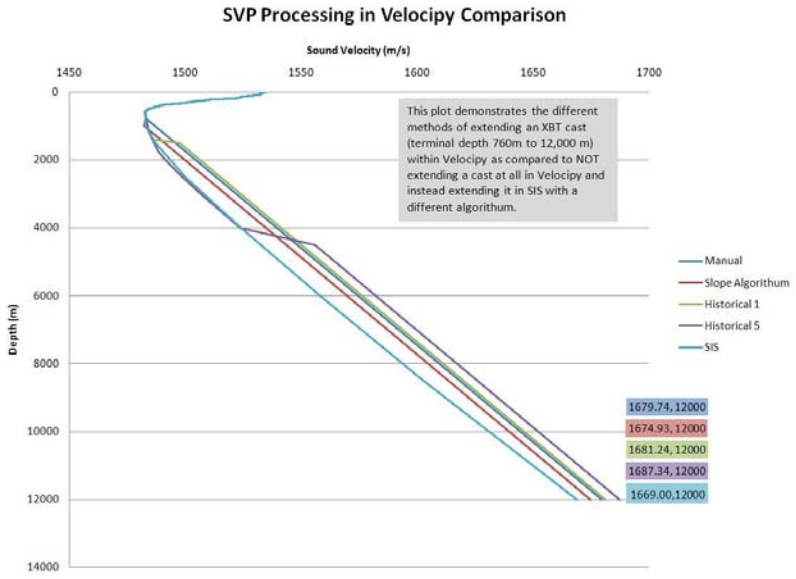


Figure 16. Results of each Velocipy extension option on the same XBT cast.

Additional Mapping Processing Software

Additional relevant software onboard including ArcMap, MapInfo, Hypack, and Global Mapper are available onboard. For a complete list of software available, see Table 7.

Hips Vessel File

The Kongsberg SIS system accounts for all the static offsets and biases during real time acquisition. The motion data from POS MV is directly fed into SIS during data acquisition to account for ship motion (i.e. heave, roll, pitch, yaw). Also the real time sound speed at the sonar head is fed into SIS and the recently acquired sound speed profile is used in real time to correct soundings for sound speed corrections during data acquisition. Unless there are problems observed in the data, there is no requirement to apply these corrections during post processing in CARIS HIPS. Therefore the vessel configuration file (VCF) for *Okeanos Explore*r contains zeros offsets and the motion data is also not applied during post processing. However, for the computation of uncertainty in CARIS HIPS, actual offsets are required along with standard deviations for miscellaneous sensors used. The HIPS VCF is provided as Appendix C.

Mapping Software

Table 7. Mapping software in use 2010 during 2010 field season.

Software	Version	Computer	License	Expiration Date	Agreements	Hot fix	Contract Duration
Caris HIPS	6.1	MBPROC1, MBPROC2	CW9605164; CW9605165	12/31/2009 Yearly update via website	Service pack 2: Upgrade Protection & Technical support	None--1-8 downloaded but not applied	5 years for both dongles (2014)
C-NAV	3.0.45	N/A	License Code : 5E15CC-7F53D1-0E2044-25B4D1-79538F-01C828 Serial No : 5164 LBM No : 1416	5/10/2012	3 years	N/A	3 years
DP Line Conversion Utility (Matlab)	1	N/A	N/A	N/A	N/A	N/A	N/A
ESRI ArcMap	9.3	MBPROC2	Customer Number: 291779	9/25/2010	Software Updates	N/A	1 year
Fledermaus (IVS 3D)	7	MBPROC2	Dongle ID: 1187753821			N/A	
Fledermaus (IVS 3D)	6.7.0	MBPROC3	Dongle ID: 1181442213		1 yr of support w/ dongle	N/A	1 year (09/2010)
Global Mapper	11.01	EXSCSCL2	RegName: mamalik@cisunix.unh.edu RegCode: 3309497171	1/13/2011	Support	N/A	1 year
Hydro_MI	8.3	MBPROC1 & 2	N/A	N/A	N/A	N/A	N/A
Hypack	9.0.0.22 (hypack admin) - 9.0.5.3 (survey)	Hypack	USB #003681	N/A	N/A	N/A	N/A
KAP Converter	5.7.2	N/A	N/A	N/A	N/A	N/A	N/A
Knudsen SBP, Sounder Suite Echo Control Server and Client	Software: V 2.07 Firmware: V.2.04	Knudsen SBP	Part # D429-04216	N/A	N/A	N/A	N/A
MapInfo	10	MBPROC1 & 2	(SN#) MINWEU0950038973 & MINWEU0950038974	2012	Upgrade protection & Technical support	Release Build 35	3 years
NOAA Chart Reprojector	2.0.6	N/A	N/A	N/A	N/A	N/A	N/A
POS Controller	320 MV V4 SN# 2572 Firmware: 4.0.2.0	Hypack	998777	N/A	N/A	N/A	N/A
Pydro	9.4	MBPROC2	Python22	1/1/2010	N/A	N/A	N/A
SCS	4.3.4	SCS-A	N/A	N/A	N/A	N/A	N/A
Seasave	7.18	CTD	N/A	N/A	N/A	seabird.com	N/A
SIS EM 302	3.6.4	Multibeam	N/A	N/A	N/A	N/A	N/A

Snagit	9.1.2	MBPROC1 & SURVEY2	CAWCM-QG4PF-MGYCA-34SNM-P4695 & D494F-5AKSZ-CQ8FV-CHA4U-S4F36	N/A	N/A	N/A	N/A
SonarWiz	4004.0034	MBPROC2	Dongle # Mfg 290 CTI 456	5/14/2012	EMA 05/14/12	N/A	3 Years
TRU EM 302	BSV 2.2.3 090702, PSV 1.4.8 091110	N/A	N/A	N/A	N/A	N/A	N/A
Velociwin	8.92 Plus	MBPROC1	N/A	N/A	N/A	N/A	N/A

Appendices

Appendix A: Arrangement and location of deck hard ware and transducer fairing after the completion of Okeanos Explorer conversion. NOAA ship Okeanos Explorer general arrangement plans and profiles, 2005. NOAA drawing number OE -601-001, 2005.

Appendix B: Format of bridge DP system compliant way point table

Appendix C: CARIS HIPS vessel configuration file

Appendix D: 2010 Results of Shallow Water Patch Test Calibration before TRU / SIS software updates (Feb 2010)

Appendix E: Results of Shallow Water Patch Test Calibration after TRU / SIS software updates (Feb 2010)

Appendix F. Results of Deep Water Patch Test Calibration after TRU / SIS software updates (Feb 2010)

References

[1] Knudsen chirp 3260 acceptance test report, 2008. D101-04819-Rev 1.

[2] Westlake Consultant report of Sonar Systems and GPS Antennae as-builting on the NOAA Okeanos Explorer. March 18, 2008.

[3] Ship inclining experiment report, 2008.

[4] Sea Acceptance Test (SAT) report from Kongsberg EM 302

[5] Sea Acceptance Test (SAT) report from Kongsberg EA 600

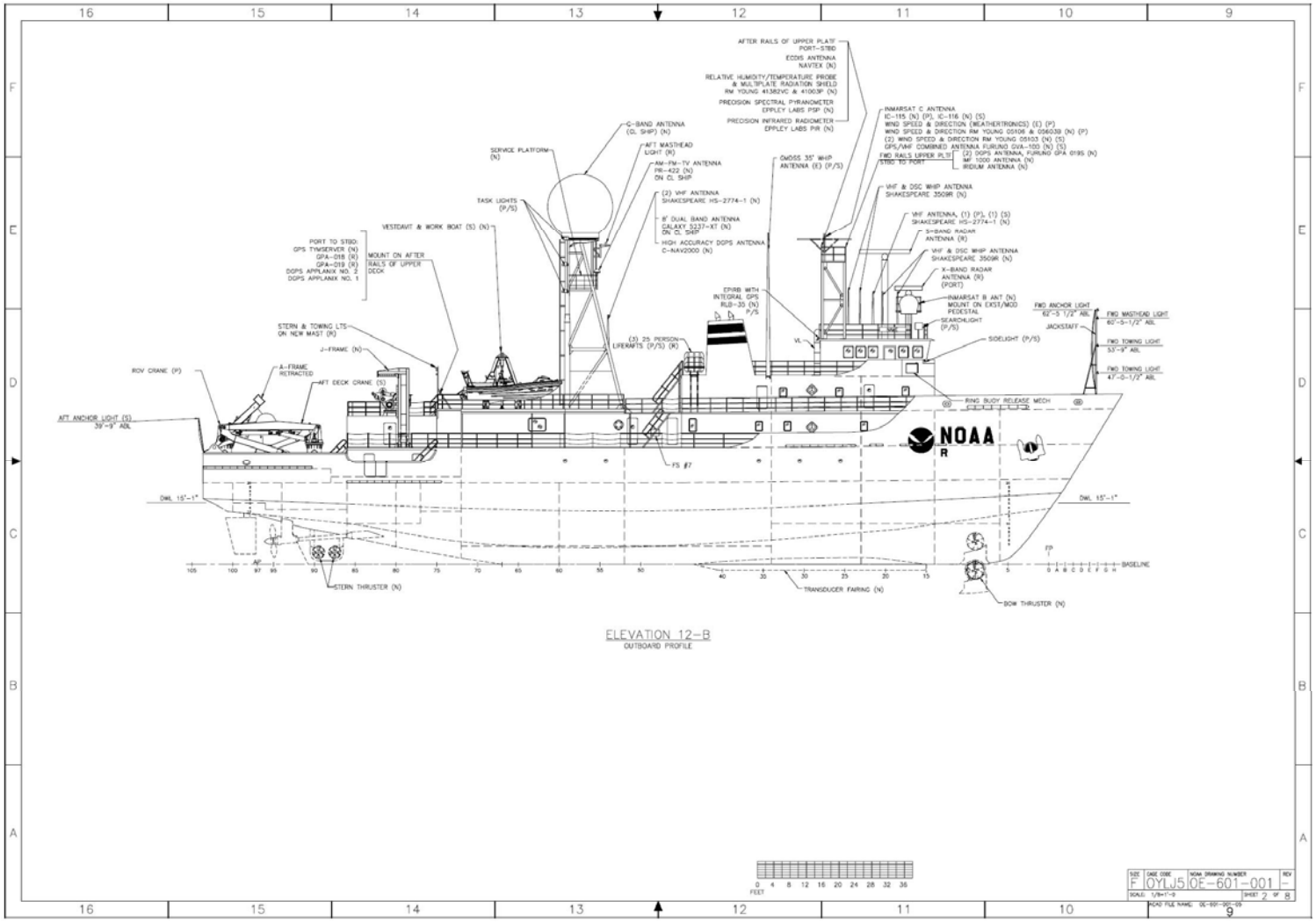
[6] Sea-Bird calibration report SBE9p_0906_052208.pdf

Report Items in Development

- *Updated vessel / equipment offsets and wiring (simple) drawings.*
  - *Being developed in AutoCAD by PS Lobecker.*
- *Final sound velocity extension procedure.*
  - *New NOAA SVP processing software Velocipy is in development. Further testing required.*
- *SPB noise level testing.*
  - *Initial noise level tests indicate sound levels during SBP operation are not dangerous to human hearing. Further testing with different sonar settings and sound meter settings is planned to confirm this.*
- *Results of patch test after EM302 transmit boards replaced with LC version.*
  - *During cruise EX1001 Leg III, Kongsberg tech will be onboard to swap out transmit boards. Patch test will be run using new boards.*
- *Sample data package folder structure.*

- *This will provide details of the standard file structure of a cruise data package.*

Appendix A: Arrangement and location of deck hard ware and transducer fairing after the completion of Okeanos Explorer conversion (Source: AMSEC LLC Naval Architect and Marine Engineers, Bremerton, Oakland, San Diego drawings 2005).



Appendix B: Example of DP system compliant way point table

CreateDate (UTC),Sunday, September 28, 2008 20:20:20
Version,4
TrackName,
NoOfWp,7
Datum,WGS84
WPFormat,WPId,WPHemisNS,WPLatDeg,WPLatMin,WPHemisEW,WPLonDeg,WPLo
nMin,WPLegType,WPHead,WPSpeed,WPTurnRad
WP,1,N,43,3.5609,W,126,40.3078,0,180,1.5433,200
WP,2,N,42,46.1603,W,126,49.2321,0,180,1.5433,200
WP,3,N,42,21.5328,W,127,15.5262,0,180,1.5433,200
WP,4,N,42,0.65965,W,127,14.6833,0,180,1.5433,200
WP,5,N,41,42.5906,W,127,22.0253,0,180,1.5433,200
WP,6,N,42,2.684,W,127,31.3482,0,180,1.5433,200
WP,7,N,42,16.7337,W,127,20.7283,0,180,1.5433,200
END

Appendix C: CARIS HIPS Vessel Configuration File (VCF) for NOAA Okeanos Explorer April, 2009.

```
<?xml version="1.0"?>
<HIPSVesselConfig Version="2.0">
 <VesselShape>
  <PlanCoordinates>
   <Entry X="-5.500000" Y="-10.000000"/>
   <Entry X="7.500000" Y="-10.000000"/>
   <Entry X="7.500000" Y="40.000000"/>
   <Entry X="1.000000" Y="58.000000"/>
   <Entry X="-5.500000" Y="40.000000"/>
   <Entry X="-5.500000" Y="-10.000000"/>
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  <ProfileCoordinates>
   <Entry Y="-10.000000" Z="4.000000"/>
   <Entry Y="-10.000000" Z="-6.000000"/>
   <Entry Y="40.000000" Z="-6.000000"/>
   <Entry Y="58.000000" Z="4.000000"/>
   <Entry Y="-10.000000" Z="4.000000"/>
  </ProfileCoordinates>
  <RP Length="10.000000" Width="7.500000"
Height="6.000000"/>
 </VesselShape>
 <DepthSensor>
  <TimeStamp value="2009-115 00:00:00">
   <Latency value="0.000000"/>
   <SensorClass value="Swath"/>
   <TransducerEntries>
    <Transducer Number="1" StartBeam="1"
Model="em300">
     <Offsets X="0.000000" Y="0.000000"
Z="0.000000" Latency="0.000000"/>
     <MountAngle Pitch="0.000000"
Roll="0.000000" Azimuth="0.000000"/>
    </Transducer>
   </TransducerEntries>
  </TimeStamp>
 </DepthSensor>
 <GyroSensor>
  <TimeStamp value="2008-252 00:00:00">
   <Latency value="0.000000"/>
   <ApplyFlag value="No"/>
  </TimeStamp>
 </GyroSensor>
 <HeaveSensor>
  <TimeStamp value="2008-252 00:00:00">
   <Latency value="0.000000"/>
   <ApplyFlag value="No"/>
   <Offsets X="0.000000" Y="0.000000"
Z="0.000000" Heave="0.000000"/>
  </TimeStamp>
 </HeaveSensor>
 <NavSensor>
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   <Latency value="0.000000"/>
   <Ellipse value="WG84"/>
   <Offsets X="0.000000" Y="0.000000"
Z="0.000000"/>
  </TimeStamp>
 </NavSensor>
 <PitchSensor>
  <TimeStamp value="2008-252 00:00:00">
   <Latency value="0.000000"/>
   <ApplyFlag value="No"/>
   <Offsets Pitch="0.000000"/>
  </TimeStamp>
 </PitchSensor>
 <RollSensor>
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   <Latency value="0.000000"/>
   <ApplyFlag value="No"/>
   <Offsets Roll="0.000000"/>
   <Comment value="(null)"/>
   <Manufacturer value="(null)"/>
   <Model value="(null)"/>
   <SerialNumber value="(null)"/>
  </TimeStamp>
 </RollSensor>
 <TPEConfiguration>
  <TimeStamp value="2008-252 00:00:00">
   <Comment value=""/>
   <Latency value="0.000000"/>
   <Offsets>
    <MRUtoTransducer X="1.800000"
Y="6.100000" Z="6.900000" X2="0.000000"
Y2="0.000000" Z2="0.000000"/>
    <NavigationToTransducer X="6.100000"
Y="1.800000" Z="6.100000" X2="0.000000"
Y2="0.000000" Z2="0.000000"/>
    <Transducer Roll="0.000000"
Roll2="0.000000"/>
    <Navigation Latency="0.000000"/>
   </Offsets>
   <StandardDeviation>
    <Motion Gyro="0.000000"
HeavePercAmplitude="5.000000"
Heave="0.050000" Roll="0.020000"
Pitch="0.020000"
PitchStablized="0.000000"/>
    <Position Navigation="0.500000"/>
    <Timing Transducer="0.010000"
Navigation="0.010000" Gyro="0.010000"
Heave="0.010000" Pitch="0.010000"
Roll="0.010000"/>
    <SoundVelocity Measured="0.000000"
Surface="0.000000"/>
    <Tide Measured="0.000000"
Zoning="0.000000"/>
    <Offsets X="0.010000" Y="0.010000"
Z="0.010000"/>
    <MRUAlignment Gyro="0.010000"
Pitch="0.010000" Roll="0.010000"/>
    <Vessel Speed="0.250000"
Loading="0.100000" Draft="0.100000"
DeltaDraft="0.100000">
     <StDevComment value="(null)"/>
    </Vessel>
   </StandardDeviation>
  </TimeStamp>
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</HIPSVesselConfig>
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Appendix D: 2010 Results of First Shallow Water Patch Test Calibration before TRU / SIS software updates

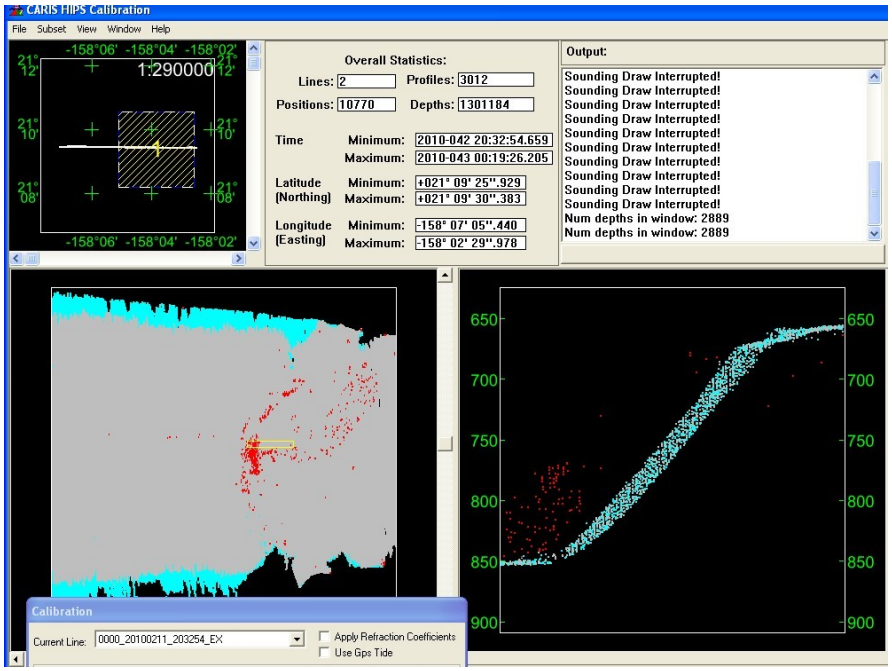

Figure 17. Timing calibration of lines 0000 and 0003 shown in CARIS HIPS and SIPS v.6.1. Zero timing offset.

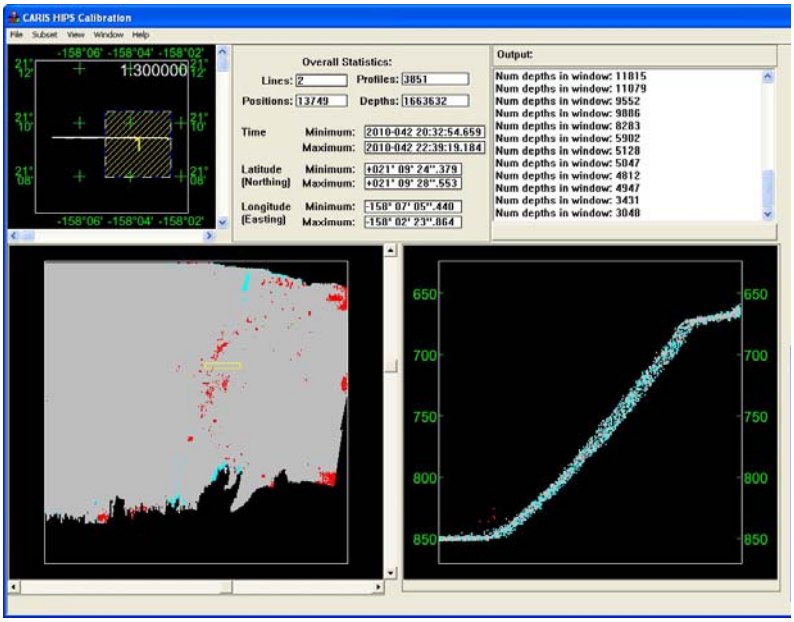

Figure 18. Pitch calibration of lines 0000 and 0002 shown in CARIS and SIPS 6.1. Applied pitch offset: -.07.

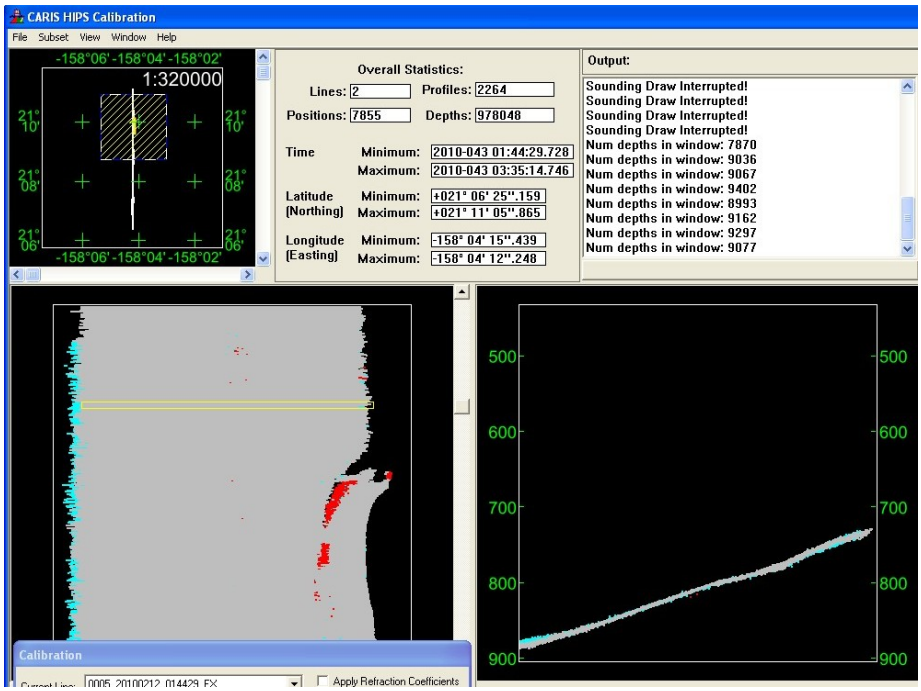

Figure 19. Roll calibration of lines 0005 and 0006 shown in CARIS HIPS and SIPS 6.1. Zero roll offset.

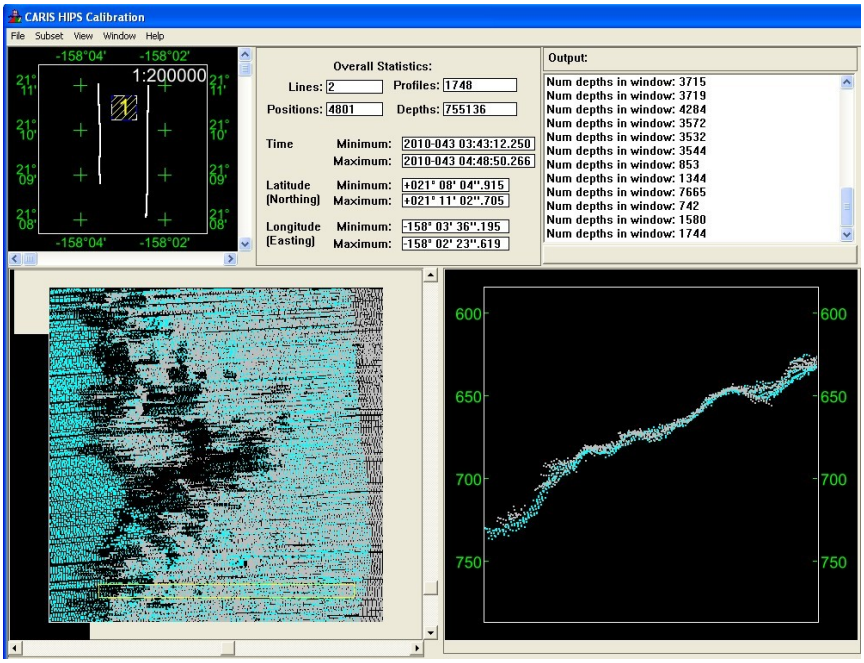

Figure 20. Heading calibration of lines 0007and 0008 shown in CARIS. Zero heading offset.

Appendix E. Results of Second Shallow Water Patch Test Calibration after TRU / SIS software updates

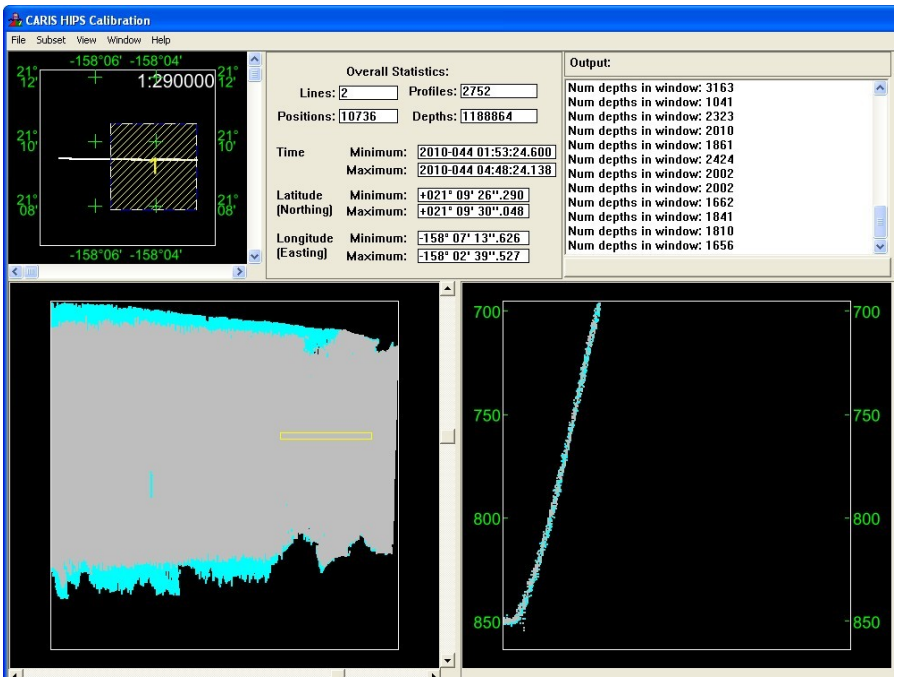

Figure 21. Timing calibration of lines 0001 and 0003 shown in CARIS HIPS and SIPS 6.1. Zero timing offset.

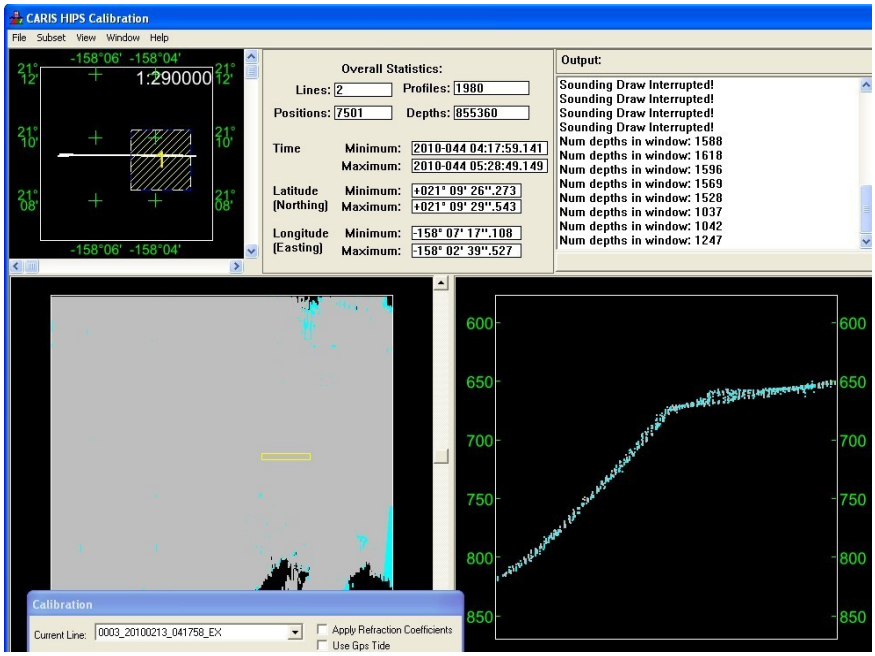

Figure 22. Pitch calibration of lines 0003 and 0004 shown in CARIS HIPS and SIPS 6.1. Pitch offset -.07.

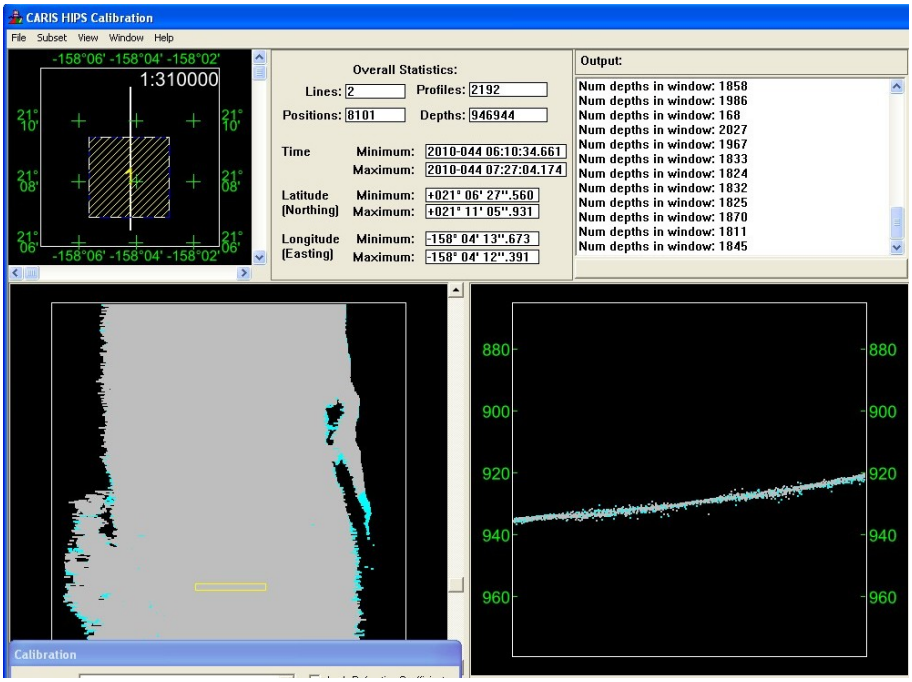

Figure 23. Roll calibration of lines 0006 and 0008 shown in CARIS HIPS and SIPS 6.1. Zero roll offset.

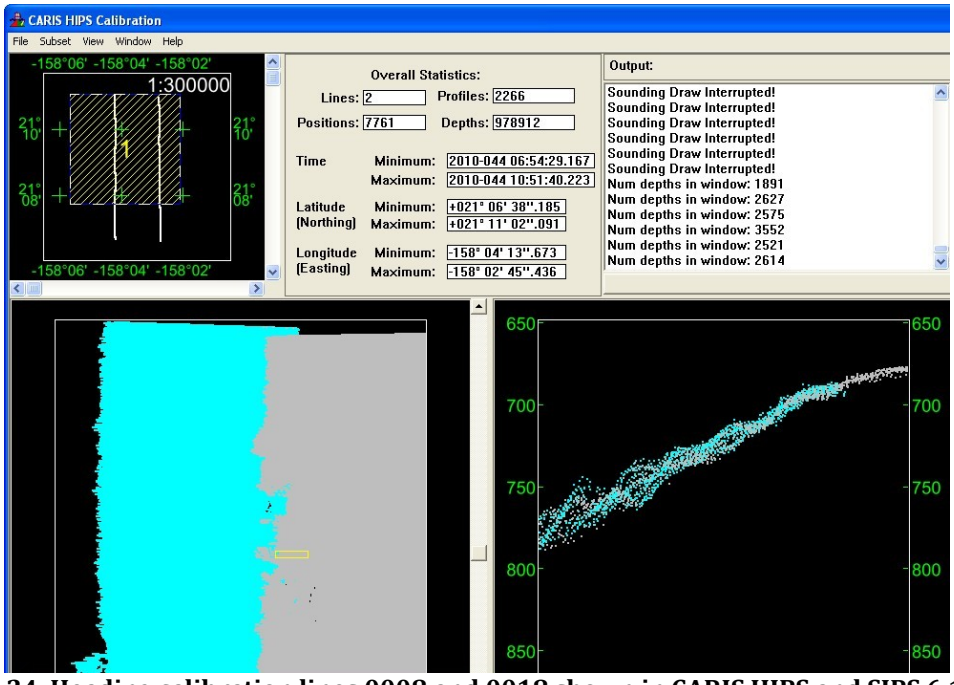

Figure 24. Heading calibration lines 0008 and 0018 shown in CARIS HIPS and SIPS 6.1. Zero heading offset.

Appendix F. Results of Deep Water Patch Test Calibration after TRU / SIS software updates

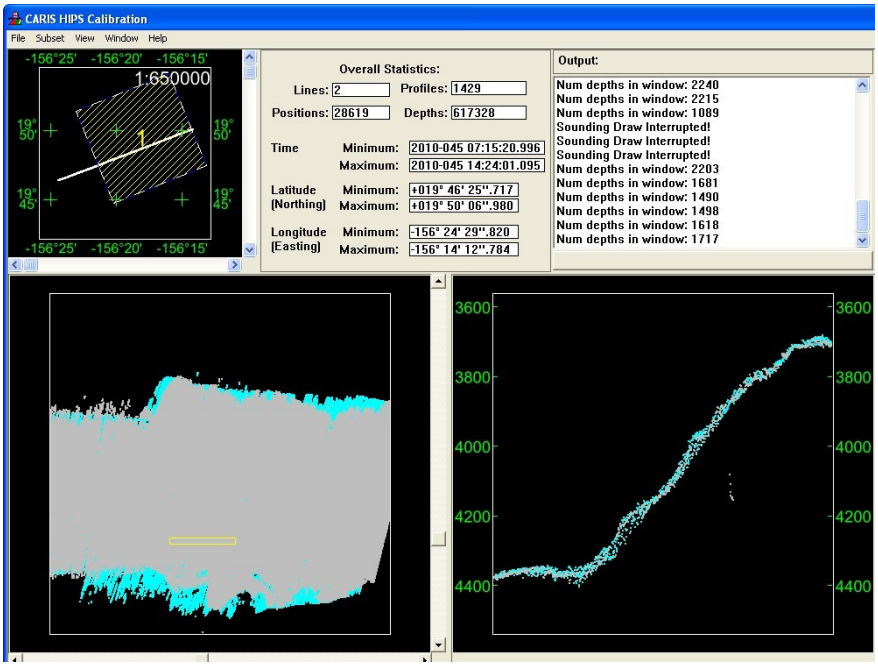

Figure 25. Timing calibration lines 0001 and 0005 shown in CARIS 6.1. Zero timing offset.

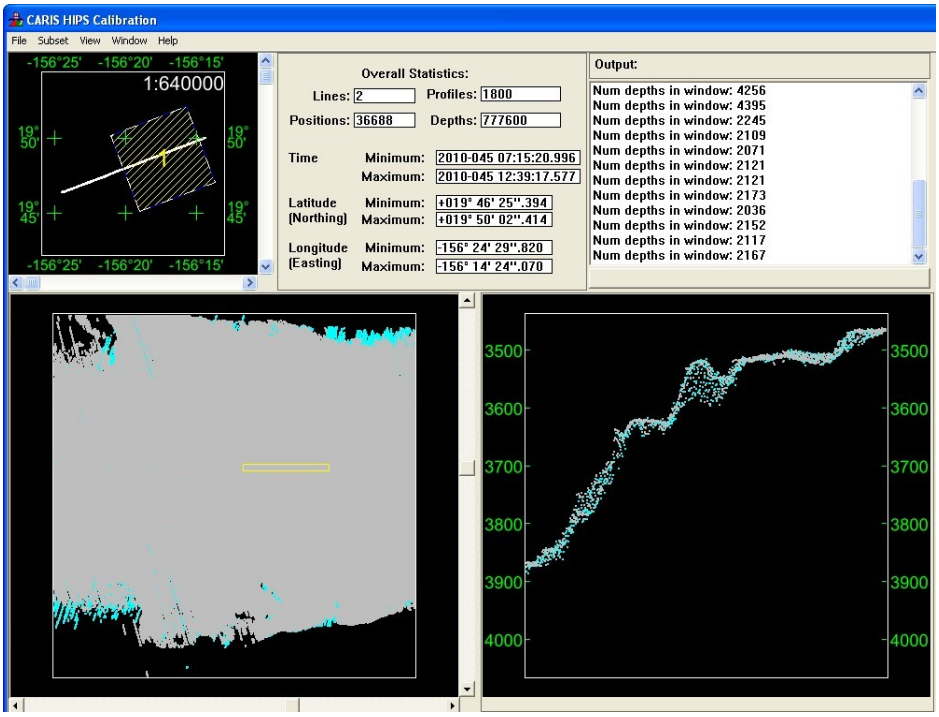

Figure 26. Pitch calibration lines 0001 and 0003 shown in CARIS 6.1. Pitch offset -0.7.

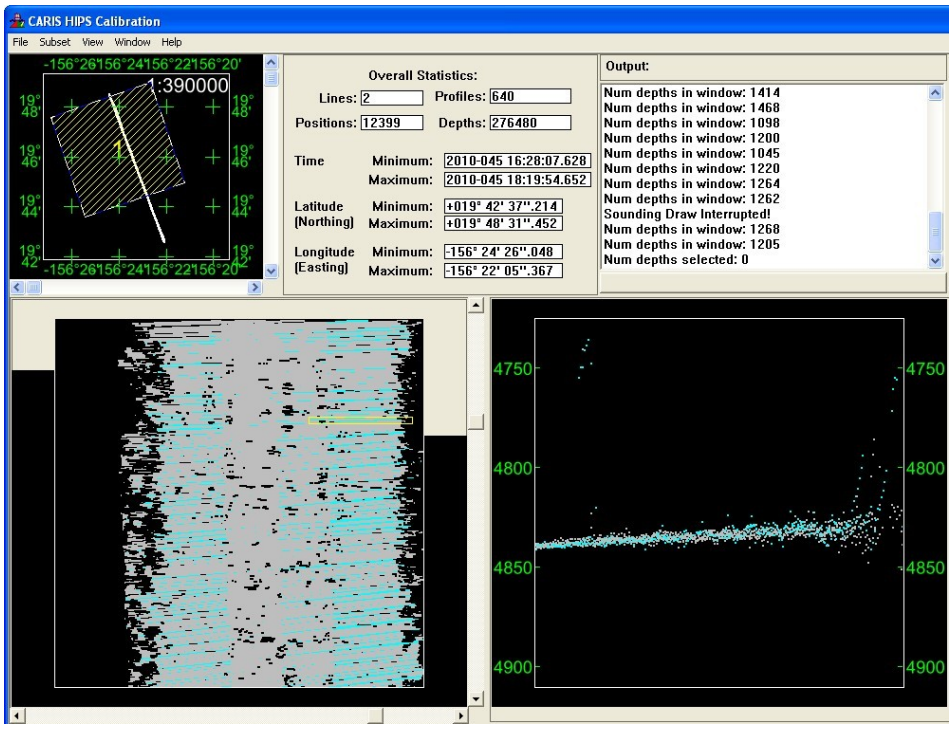

Figure 27. Roll lines 0009 and 0011 shown in CARIS 6.1. Zero roll offset.

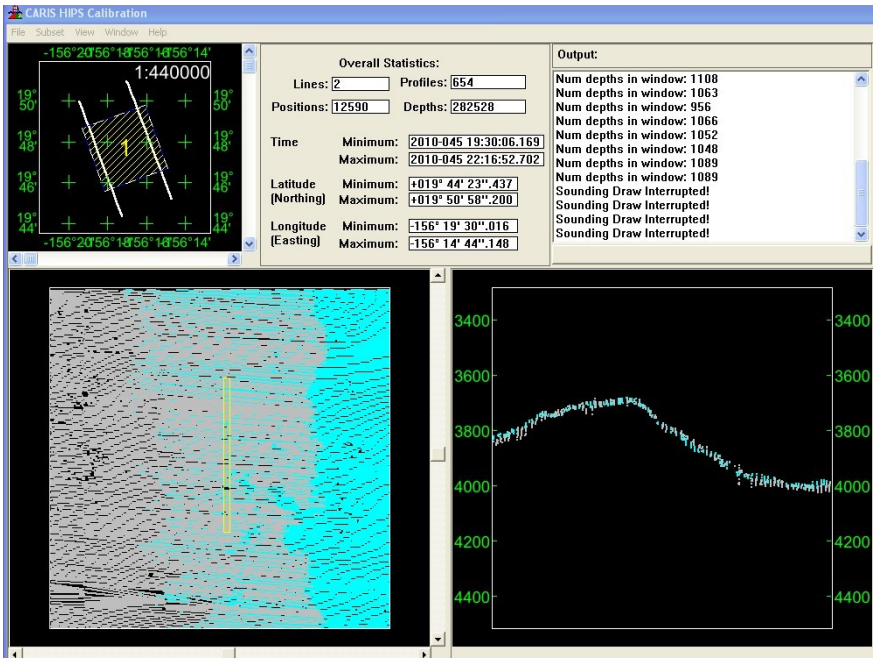

Figure 28. Heading lines 0013 and 0015 shown in CARIS 6.1. Zero heading offset.