NOAA *Okeanos Explorer* Program

MAPPING DATA REPORT

CRUISE EX1005

Exploration Mapping: Guam to Hawaii

August 23 to September 5, 2010

Guam to Honolulu, HI

Report Contributors:

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1. Introduction

The *Okeanos Explorer* Program

Commissioned in August 2008, the NOAA Ship *Okeanos Explorer* is the nation's only federal vessel dedicated to ocean exploration. With 95% of the world's oceans left unexplored, the ship's combination of scientific and technological tools uniquely positions it to systematically explore new areas of our largely unknown ocean. These exploration cruises are explicitly designed to generate hypotheses and lead to further investigations by the wider scientific community.

Using a high-resolution multibeam sonar with water column capabilities, a deep water remotely operated vehicle, and telepresence technology, *Okeanos Explorer* provides NOAA the ability to foster scientific discoveries by identifying new targets in real time, diving on those targets shortly after initial detection, and then sending this information back to shore for immediate near-real-time collaboration with scientists and experts at Exploration Command Centers around the world. The subsequent transparent and rapid dissemination of information-rich products to the scientific community ensures that discoveries are immediately available to experts in relevant disciplines for research and analysis

Through the *Okeanos Explorer* Program, NOAA's Office of Ocean Exploration and Research (OER) provides the nation with unparalleled capacity to discover and investigate new oceanic regions and phenomena, conduct the basic research required to document discoveries, and seamlessly disseminate data and information-rich products to a multitude of users. The program strives to develop technological solutions and innovative applications to critical problems in undersea exploration and to provide resources for developing, testing, and transitioning solutions to meet these needs.

Okeanos Explorer Management – a unique partnership within NOAA

The *Okeanos Explorer* Program combines the capabilities of the NOAA Ship *Okeanos Explorer* with shore-based high speed networks and infrastructure for systematic telepresence-enabled exploration of the world ocean. The ship is operated, managed and maintained by NOAA's Office of Marine and Aviation Operations, which includes commissioned officers of the NOAA Corps and civilian wage mariners. OER owns and is responsible for operating and managing the cutting-edge ocean exploration systems on the vessel (ROV, mapping and telepresence) and ashore including Exploration Command Centers and terrestrial high speed networks. The ship and shore-based infrastructure combine to be the only federal program dedicated to systematic telepresence-enabled exploration of the planet's largely unknown ocean.

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2. Report Purpose

The purpose of this report is to briefly describe the mapping data collection and processing methods, and to report the results of the cruise. For a detailed description of the *Okeanos Explorer* mapping capabilities, see appendix D and the ship's readiness report, which can be obtained by contacting the ships operations officer (ops.explorer@noaa.gov).

3. Cruise Objectives

The main objective of cruise EX1005 was to 24 conduct hour mapping exploration operations while in transit from Guam to Honolulu. The planned transit route followed the great circle route and was offset by approximately five miles to the south from the multibeam data collected during the Honolulu to Guam transit (EX1003). This offset was chosen to build upon previous EM302 data collected by the *Okeanos Explorer* during EX1005. There was no overlap between the two lines in the deep sea, only near Guam and Oahu. Many interesting features were detected and are described in more detail in Appendix D of this report.

A survey of opportunity was conducted by the National Marine Fisheries Service (NMFS). A Continuous Plankton Recorder was towed, contributing plankton data to what is likely the longest transect of this data type ever collected. The results of this survey are not discussed in this report. Further details can be found in the EX1005 cruise instructions, or by contacting Michael Ford at NMFS (michael.ford@noaa.gov).

The cruise also presented an opportunity to test the capabilities of the EM302 over the Mariana Trench. This data is discussed in Appendix C of this report.

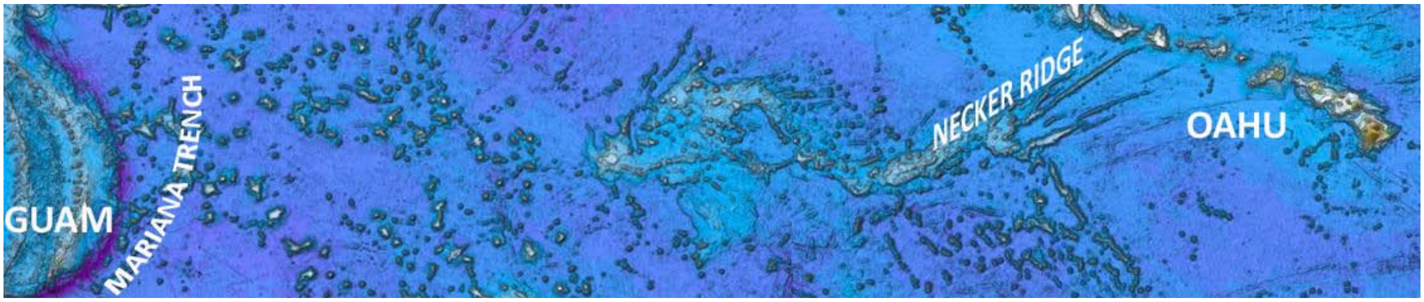


Figure 1. Graphic showing transit from Guam to Hawaii. Satellite derived bathymetry from Sandwell and Smith. Image credit: NOAA.

The goals of the mapping department included collecting continuous high quality bathymetry during the entire transit, as well as assessing the following data quality issues observed following the upgrade to the new TX36 LC boards in the EM302:

- Side lobe detection observed as severe rail road tracks in waters 2000 m-4000 m
- Apparent reduced swath coverage as compared to 2009 field season
- Apparent reduced weather threshold tolerance

Operational plans were designed to run a series of BISTs at least once a day to monitor TX board and RX noise levels seen in various weather conditions and at various vessel headings and speeds. These results would then be correlated to data quality issues above.

4. Participating Personnel

CDR Robert Kamphaus	Commanding Officer	NOAA Corps
LTJG Megan Nadeau	Expedition Coordinator/ Mapping Watchstander	NOAA Corps
LT Nicola VerPlanck	Field Operations Officer	NOAA Corps
Colleen Peters	Mapping Team Lead/ Senior Survey Technician	NOAA OMAO
Lillian Stuart	Mapping Watchstander	NOAA OMAO
Shannon Hoy	Mapping Watchstander	NOAA OER / UCAR Intern
Jack Payette	Mapping Watchstander	NOAA OER / UCAR Intern
Brian Shiro	Mapping Watchstander	NOAA Pacific Tsunami Warning Center
LTJG Ben LaCour	Mapping Watchstander	NOAA Corps

5. Cruise Statistics

Dates	August 23 – September 5, 2010
Weather delays days	0.5
Total non-mapping days	0
Total survey mapping days	14.5
Total transit mapping days	14.5
Line kilometers of survey	6186 km
Average ship speed during multibeam collection	9.59 kts
Number of multibeam files	65

Number of XBT casts	59
Number of CTD casts	0
Beginning draft	Fwd: 15’ ½”, Aft: 14’ 9”

6. Mapping Sonar Setup

The NOAA Ship *Okeanos Explorer* (EX) is equipped with a 30 kHz Kongsberg EM 302 multibeam sonar. During this cruise EM 302 bottom bathymetric and backscatter data were collected. The ship used a POS MV, ver. 4, to record and correct the multibeam data for any vessel motion. A C-Nav GPS system provided DGPS correctors with positional accuracy expected to be better than 2.0 m.

All corrections (motion, sound speed profile, sound speed at sonar head, draft, sensor offsets) were applied during real time data acquisition. Expendable bathythermograph (XBT) casts (Deep Blue, max depth 760 m) were taken every six hours and/or as necessary to correct for sound speed. The XBT cast data were converted to SIS compliant format using NOAA Velocipy. See Appendix A for a complete list of software used for data processing.

In April 2010, a sonar technician from Kongsberg replaced all 24 of the PCB transmit boards (TX36) in the EM302 TRU with a newer version (TX36 LC).

The TX36 slot #16 in the TRU has been consistently critically damaging transmit boards since the 2009 field season. As part of ongoing testing to determine the problem with TX36 slot #16, Kongsberg suggested swapping out the TX RIO board #8 and running a series of internal tests. The mapping department performed this test during EX1004 Leg 4 On August 19, after crossing into the US EEZ (Guam), the EM302 was powered on and test was conducted, per guidance from Kongsberg engineers. See Appendix D of the EX1004 Leg 4 Mapping Cruise Report for complete test steps. At the time of writing the EX1005 mapping report, Kongsberg analysis of test results was still pending, therefore no update is available for this mapping report.

7. Data Acquisition Summary

Table 1 lists the transducer and attitude sensor offsets determined during the February 2010 sea acceptance test (EX1001). The pitch attitude offset of -0.8 was increased from the previous value of -0.7 while a Kongsberg technician was onboard in April (EX1002 Leg 3). Apart from this change, the PU Parameters were setup to be identical to the 2009 survey season. For complete processing unit setup utilized for the cruise, please refer to Appendix F.

Table 1. 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	-0.8	0.0

Multibeam data was continuously collected during the entire transit from Guam to Honolulu. Interruptions in data continuity are due to built in system tests (BIST) periodically run on the multibeam system for approximately 10 to 40 minutes, or loss of bottom tracking due to weather conditions. All data is either within the US Exclusive Economic Zone (EEZ) or the high seas. All data will be archived at NGDC (www.ngdc.noaa.gov) with individual metadata records. All raw and processed data products are in the ? WGS84 coordinate system.

A note on time zone changes: all multibeam and associated data are time stamped with UTC time. The daily cruise log included in this report uses local ship's time, and gives details of when ship's time was shifted for gradual time zone adjustment throughout the cruise.

Due to time constraints, lines parallel to previous transit data from the 2009 field season (from Necker Ridge area to Oahu) were not practicable. The ship used a course for best speed to arrive in Hawaii as soon as possible.

8. Multibeam Data Quality Assessment and Data Processing

Acquisition Observations:

- In 5,000+ m depth on very soft and flat seafloor, as observed via the acquisition screen, it was observed that Auto Angular Coverage Mode with 15 degrees port and starboard max angles was the best setting to maintain tracking of the seafloor while experiencing 6-8 ft seas.
- In shallower depths, manual angular coverage mode may result in a decrease of valid beams.
- Harder substrates continue to provide the best swath width at depths greater than 5000 m.
- Along Direction angle of +2-6 degrees helps reduce railroad tracks, provided that the bottom is not too soft or too deep to maintain tracking.
- SIS did not generate grids in the same manner on both sides of the date line. Prior to crossing the grids were normal. After crossing, the grids had many unusual holes in them, making it harder to determine what were holidays and artifacts and what were rendering issues while acquiring the data.
- With the penetration filter off, railroad tracks were minimal, and generally only in 4000+ meters depth on very soft and flat seafloor.
- Acquisition was significantly more labor intensive than during the INDEX-SATAL 2010 expedition of the last few months. It may be due to ship's speed (10-10.5 kts on average) and/or weather conditions (heading into seas the whole time and significant pitching/bubble sweep down) throughout the transit, considerably more than experienced in the Honolulu to Guam transit earlier this year (EX1003).
- In 3000+ meters depth on very soft and flat seafloor, if the bottom is not detected well and leaves holes, it can be corrected by manually selecting the next ping mode (i.e. if in Auto ping mode it is in Deep, if you manually put it into Very Deep, it will regain the bottom, even though it is not the 'correct' mode for that depth.)

Every BIST test failed subtests 1# and #3, due to the damaged status of TX36 PCB #16. There were no other notable changes or results in the BISTs throughout the cruise.

On August 24, the ship crossed the Mariana Trench, which presented an opportunity to test the maximum depths to which the EM302 can obtain quality multibeam data. The results were that after examining and cleaning the raw data collected while transiting over the Mariana Trench, the deepest accurate depth recorded at nadir was 7964 m and 8089 m at the outer beams. A full report of the data collected over the Marianna Trench is included in Appendix C.

The ship crossed over Necker Ridge while transiting to Oahu. A data analysis was conducted regarding the surface difference between EX1005 data and EX0909 Legs 1 and 2 data. The full report is included as Appendix E.

Field Data Processing and Archiving

For quality control purposes, all raw multibeam data was imported, cleaned and gridded (50 meter cell size) in CARIS 6.1 at sea in near real time. Field sheets within CARIS were organized up by UTM zone, manually setting the field sheet boundaries to be the UTM zone boundaries. This eliminated any display distortion due to projection. A new project was started east of the date line because CARIS would not convert/project the western hemisphere coordinates correctly. Gridded data were exported to ASCII xyz text files. These xyz's were then used to generate Fledermaus v.6 *.sd objects via IVS AvgGrid and IVS DMagic. Each *.sd object was then exported to a georeferenced image (embedded geotiff).

Shoreside Data Processing and Data Archiving

All field cleaning and processing were reviewed shoreside after the cruise was completed. Each bathymetry file was then exported to ASCII xyz text file, which contained every accepted sounding. These text files were then gridded (50 m cell size) in Fledermaus DMagic, and an .sd object was generated. The .sd object was then exported to geotiff.

All raw and processed multibeam data will be archived with NGDC with individual metadata records. All processed data products are in Latitude/Longitude coordinates, WGS84 datum. All raw and processed multibeam data products will be accessible via www.ngdc.noaa.gov.

Archived multibeam products include:

1) Level 00
   a) Raw multibeam bathymetry files. (*.all)
2) Level 01
   a) ASCII xyz text file of each multibeam bathymetry line file, cleaned, not gridded. (*.txt)
3) Level 02
   a) ASCII xyz text file of all multibeam bathymetry gridded at 50 m cell size. (*.xyz)
   b) Fledermaus v. 6 .sd object of 50 me bathymetry grid. (*.sd)
   c) Georeferenced (geotiff) image of 50 m bathymetry grid(*.tif)

9. Cruise Calendar

For a more detailed account of daily events, see *Daily Cruise Log (section 10).*

August 2010						
Mon	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
23 0800 Depart Guam Change of Command Ceremony, CDR Kamphaus relieves CDR Pica *Continuous Plankton Recorder (CPR) Deployed*	24 Continued transit to HI *CPR Recover/Deploy*	25 Continued transit to HI *CPR Recover/Deploy*	26 Continued transit to HI	27 Continued transit to HI *CPR Recover/Deploy*	28 Continued transit to HI	29 Continued transit to HI *CPR Recover/Deploy*

30 x 2 **DAY REPEATED FOR DATE LINE CROSSING WEST TO EAST** Continued transit to HI *CPR Recover/Deploy* (30th #1)	31 Continued transit to HI *CPR Recover/Deploy*	1 Continued transit to HI	2 Continued transit to HI *CPR Recover/Deploy*	3 Continued transit to HI *CPR Recover/Deploy*	4 Continued transit to HI	5 Continued transit to HI *CPR Recovered* 2200 Arrival Pearl Harbor

10. Daily Cruise Log

ALL DATES AND TIMES IN SHIP LOCAL TIME

August 23, 2010

The ship departed Apra Harbor, Guam, at 0800. The ship's crew conducted emergency drills during the morning. At 1245, the Change of Command Ceremony was held on the bow. CDR Kamphaus relieved CDR Pica. CDR Pica departed the ship shortly after, and the EX began transiting for Honolulu at 1400. A BIST was run prior to starting to data collection. The BIST failed tests #1 and #3 for PCB board #16, which is consistent with system performance since June. At 1835 the UPS alarm went off. There were some undetermined data artifacts that we couldn't get rid of by tweaking the SIS settings. A while later, it was discovered that the EA600 was pinging when it was not supposed to be since settings in the operating software were set to 'passive' and 'maximum ping'. There was interference between the two systems, causing the artifacts. The singlebeam was then secured and data quality returned.

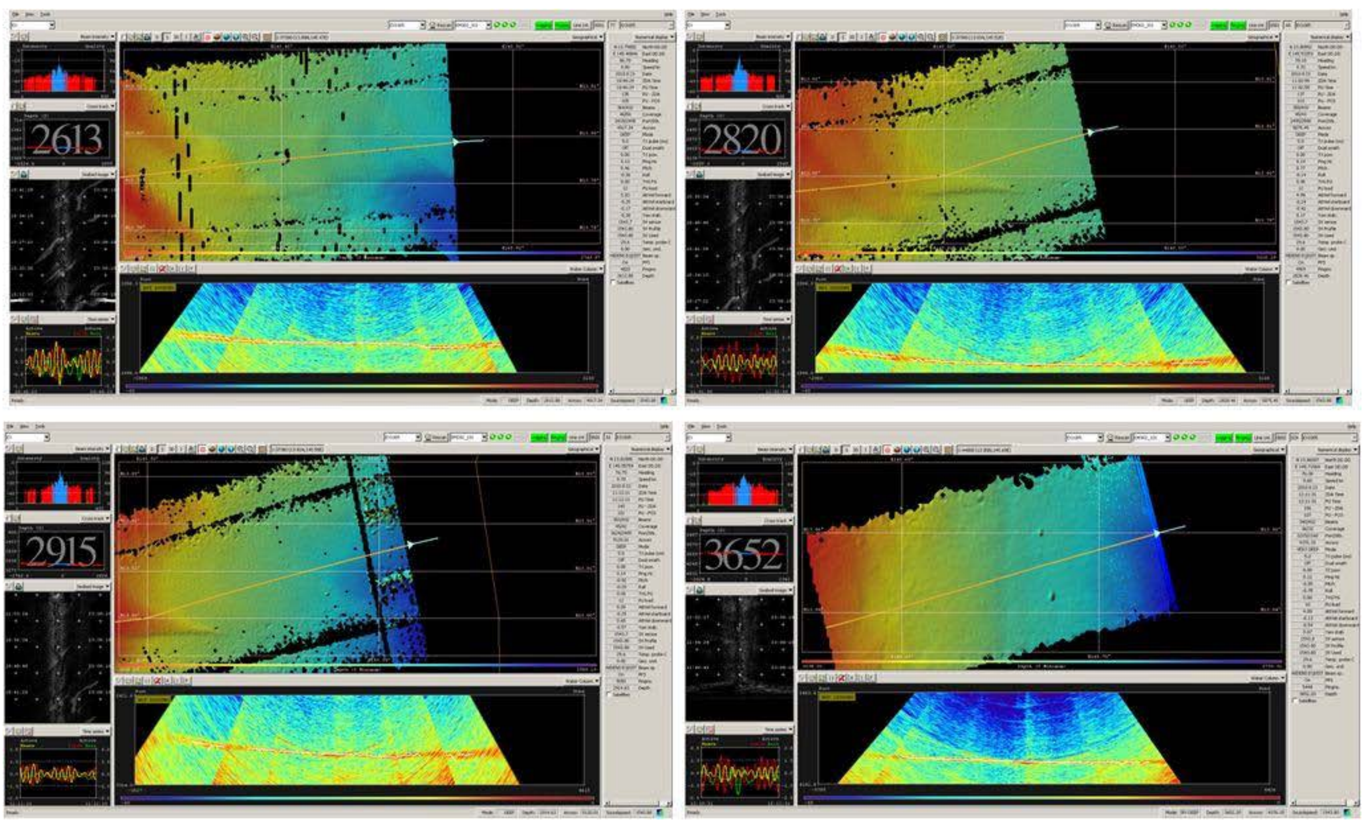


Figure 2. Screen capture of Kongsberg SIS Software showing four screen grabs in chronological order (top left, top right, bottom left, bottom right) of the single beam interference started, worse, investigated and secured [20100823_110259]. Image credit: NOAA.

August 24, 2010 - *Continued transit to Hawaii with continuous multibeam data collection.*

In preparation for the Mariana Trench, once the EX reached the 7000 m contour, the max depth was changed to 8000 m (limit of SIS), and the sector coverage maximum angle to 20 degrees for port/starboard. The system was changed from Auto Ping Mode to Extra Deep Mode. 0626 started

Singlebeam in Multi-pulse Ping Mode, which is recommended by the manual for very deep waters. The ship slowed down to 8 knots (from 10.4 knots) and the multibeam data began to improve. 0630 XBT cast conducted when the EX approached the trench, and the SVP was applied to both the multibeam and the singlebeam sonars. 0635 the ship slowed to 7 knots. As the EX approached the trench, the EM302 began to lose track of the bottom at depths greater than 8000m, starting near nadir. The multibeam and singlebeam were approximately 50 meters different in depth, which is about as close as the two systems have been observed in similar water depths in the past. 0650 the ship resumed cruising speed (10kts) to cross the trench. At that time the multibeam was secured and a BIST conducted. The maximum depth recorded by the singlebeam was 9514m.

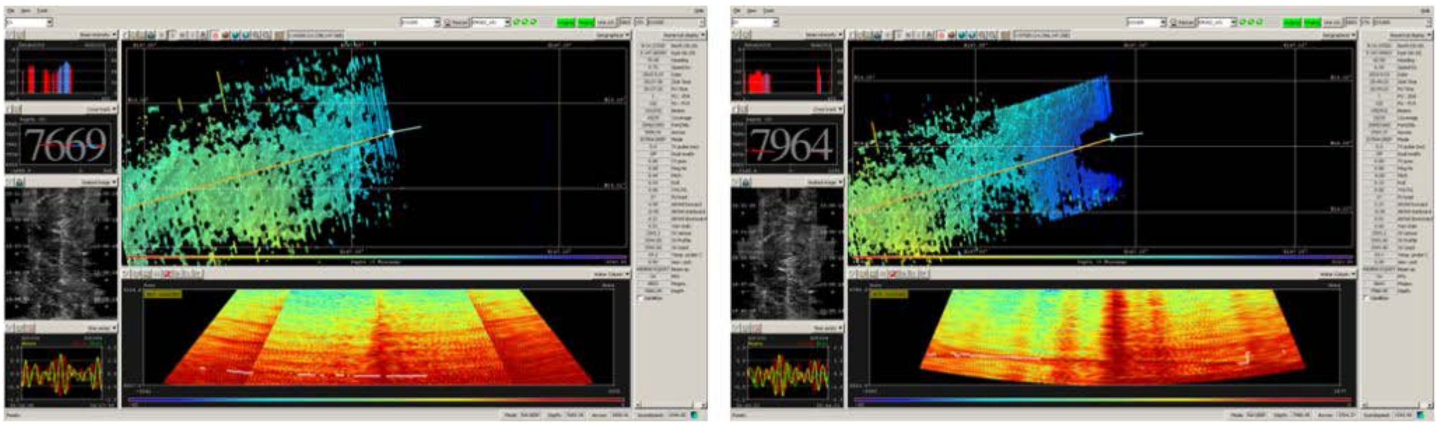


Figure 3. Screen capture of Kongsberg SIS Software showing the data quality approaching the trench at full speed was poor (left). When the ship slowed down the data quality at the maximum depth of the system improved (right) [20100823_204422]. Image credit: NOAA.

0830 the ship reduced speed to 5 kts for CPR recovery. As the singlebeam sonar indicated a depth of 8100m, the multibeam pinging was resumed. The EM302 locked onto the bottom at 7900m with sector coverage set at 15/15 p/s max angles, along direction set to 0, and ping mode manually set in Extra Deep Mode. Began to see artifacts in multibeam data so the singlebeam was secured once the EM302 was sufficiently tracking bottom. The data was looking good, so the max angles were widened to 20/20 p/s, continuing at 5.5 kts for the CPR deployment.

0918 changed min depth to 3000 m. Once the CPR was deployed and the ship reached the 7000m contour, full speed (10.5 kt) was resumed.

Data quality continues to keep watch standers very involved in the acquisition. Changing along direction helps reduce the outer beam noise as well as rail road tracks that appeared at 5600 m. BIST failed tests 1 and 3, board 16 failed (expected).

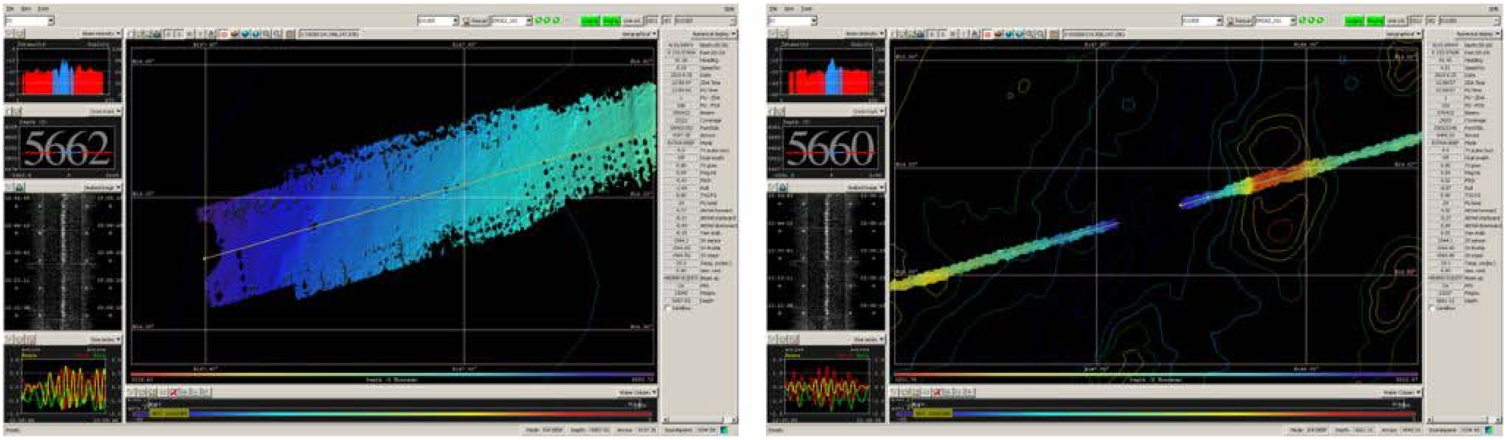


Figure 4. Screen capture of Kongsberg SIS Software showing data quality going upslope was good with a speed of 5.5 kts (Left). An overview of the EM302 data over the Mariana Trench (Right) [20100823_230007]. Image credit: NOAA.

August 25, 2011 - *Continued transit to Hawaii with continuous multibeam data collection.*

The bottom is lost frequently due to swells. With soft bottom, there is noise in the outer beams. Changing along direction helps reduce the noise to some extent. Once EX reaches a feature, with a harder substrate and shallower depth, the data quality and coverage improves significantly. 1200 the ship reduced speed to 5 kts for CPR recovery; swath coverage and data quality improved exponentially with slower speed. 1212 CPR on deck, ship maintaining slow speed. 1230 CPR deployed. 1233 Ship increasing speed to 10.5 kts.

1730 Ship slowed down to 4.5kts for CPR recovery. Coverage 7000 m swath width in 5300 m water depth (it increased from 5500 m). 1749 Finished with CPR deployment resumed cruising speed (9.8 kts). Coverage 6230 m swath width in 4794 m water depth.

In 5500+ meters with a soft bottom, the EM302 has trouble tracking bottom while transiting at full speed (10+ knots). When the bottom is not being tracked well or bottom is lost and not quickly picked up again, changing the along direction to 0 degrees seems to help. Once the multibeam has steadied out, the along direction can be changed to accommodate railroad tracks when present. BIST failed tests 1 and 3, board 16 failed (expected).

August 26, 2010 - *Continued transit to Hawaii with continuous multibeam data collection.*

0200 Ship time change 0200 became 0300

It is suspected that the lost data at and around nadir more than usual maybe due to weather as the sea state increases. Changing the range gate to small and narrowing the min/max depth range also seems to help track the bottom. Coverage began to decrease on the port side, so along direction and sector angles were reduced to try and regain proper coverage. While in Auto Ping Mode, it was observed that Very Deep was being used in 5800 m when Extra Deep should have been selected. The Ping Mode was then changed in manual to Extra Deep. The ship was pitching +/- 2.5 degrees and experiencing bubble sweep-down.

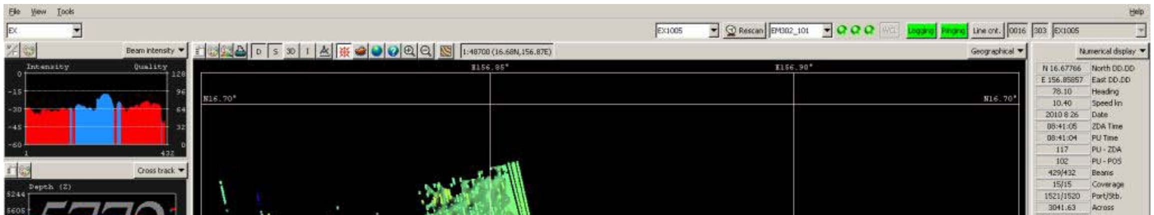


Figure 5. Screen capture of Kongsberg SIS Software showing that when constantly losing bottom in large swells (6-8 feet) changing the sector angles to 15 degrees port and starboard helps focus the energy straight down at these depths with flat soft bottom seems to be the most effective way to resume detecting the seafloor [20100826_084105]. Image credit: NOAA.

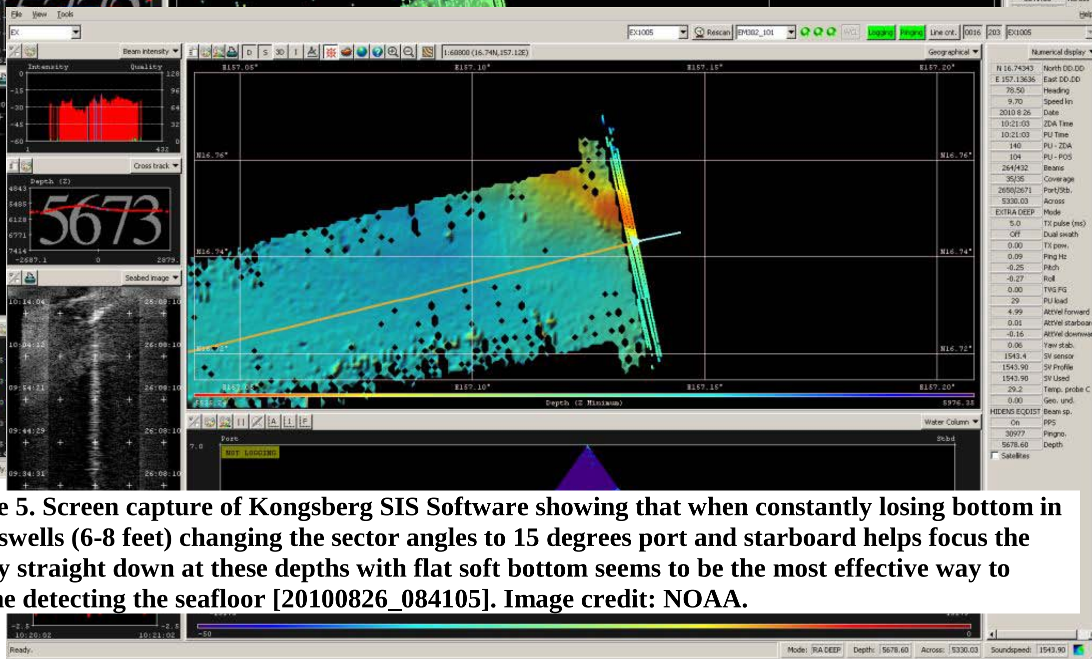


Figure 6. Screen capture of Kongsberg SIS Software showing wider coverage is observed when transiting over a harder bottom, as depicted by the seabed image on the left side of the acquisition screen [20100826_102104]. Image credit: NOAA.

August 27, 2010 - *Continued transit to Hawaii with continuous multibeam data collection.*

0000 Soft bottom. Hard to track bottom due to increased pitching. Adjusting along direction in both directions has had no effect. Been getting one or two full swaths every ten minutes or so. Mostly poor quality data or none at all. 0510 the wind is 21 kts from 080 deg, swell 5-7ft from 090 deg heavier pitching causing worse data. Bottom continually drops out with ship speed of 9.5 knots, rolling 8-10 deg, pitch 6-7 deg and sea state 4-5. As the weather deteriorates so does the data. 1232 Ship reduced speed to 5 kts for CPR recovery. Data is better with angular coverage mode in auto. Sector angles increased from 15 to 30 degrees port/starboard since the data quality has been improving due to a slower speed. 1305 CPR on deck and maintaining 5.5 kts. 1308 Ship increasing speed to 9.5 knots. 1344 CPR deployed, ship increased speed to 9.5 knots. Back to bottom dropping out constantly; changed max angle to 15/15 p/s. BIST failed tests 1 and 3, board 16 failed (expected).

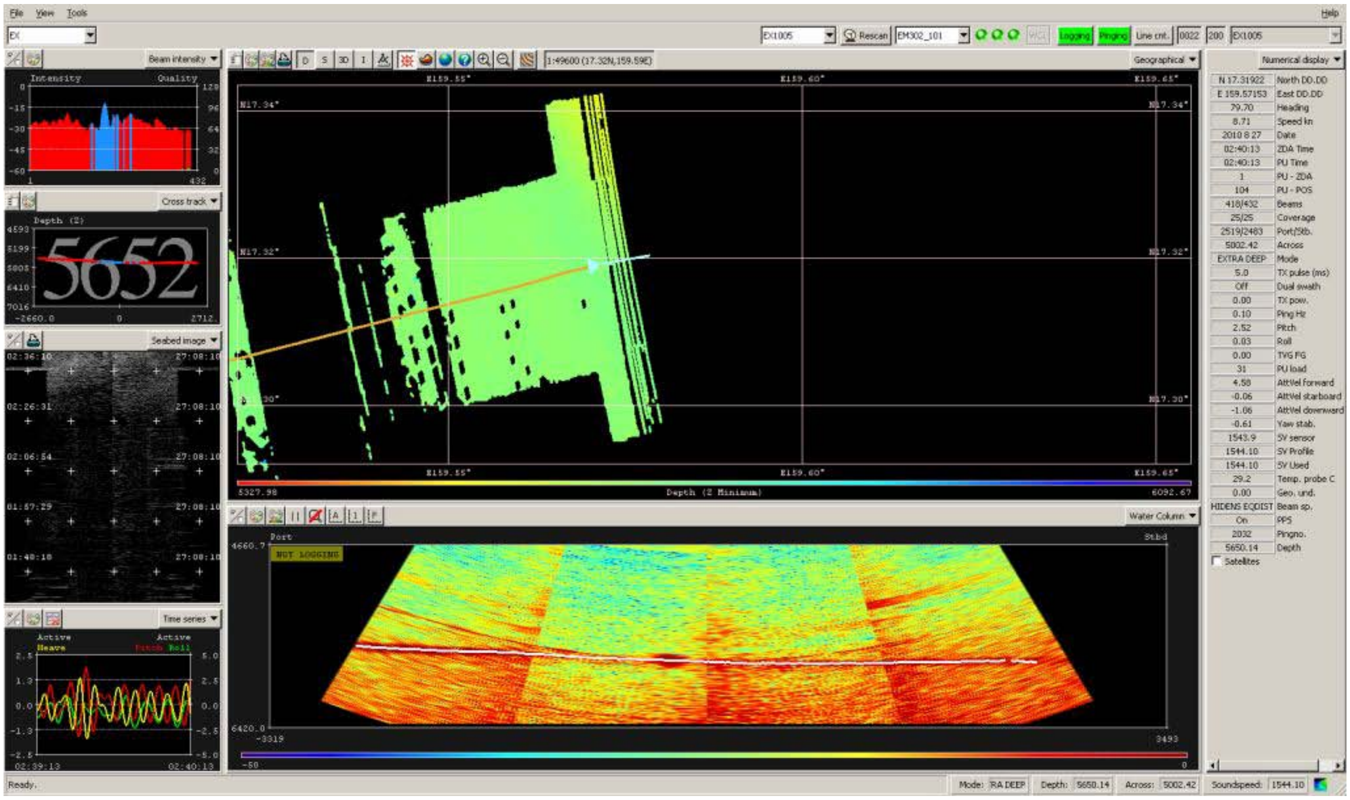


Figure 7. Screen capture of Kongsberg SIS Software showing that when the ship slowed down to recover/deploy the CPR, the multibeam data quality improved. At the slower speed of 5 knots, the sector angles were increased to the limit of Extra Deep Ping Mode (35/35 port and starboard) and was able to retain bottom contact throughout the operation until full speed was resumed [20100827_24014]. Image credit: NOAA.

1645 course change to 083 deg and adding ballast to fwd tanks over the previous 2-3 hours seems to have improved data quality. The ship is now pointed more dead into seas. The multibeam started to experience penetrations of the seafloor, so Along Direction was changed to 6 degrees. A large swell caused the sonar to lose track of the bottom and it took a while to get it back. Changing the sector angles to 15/15 port/starboard with an along direction of 0 degrees seems to have helped. Once the data was steady, the sector angles were changed to 20/20, but the outer beams were full of noise, so it was reduced again to 15/15. Changing Along Direction from +2 to -2 degrees helped stabilize the data coverage and reduce outer beam noise.

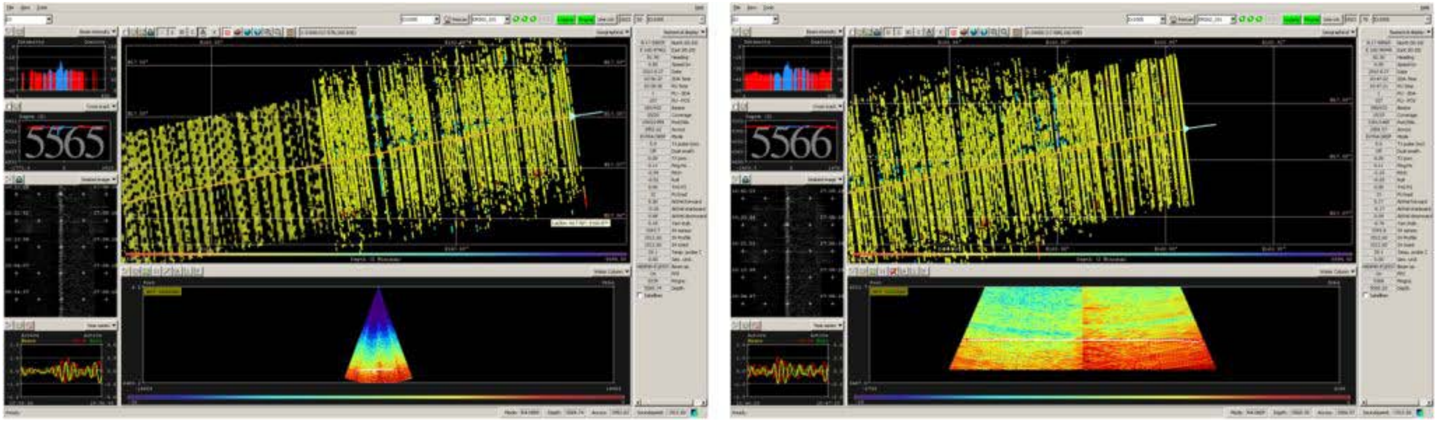
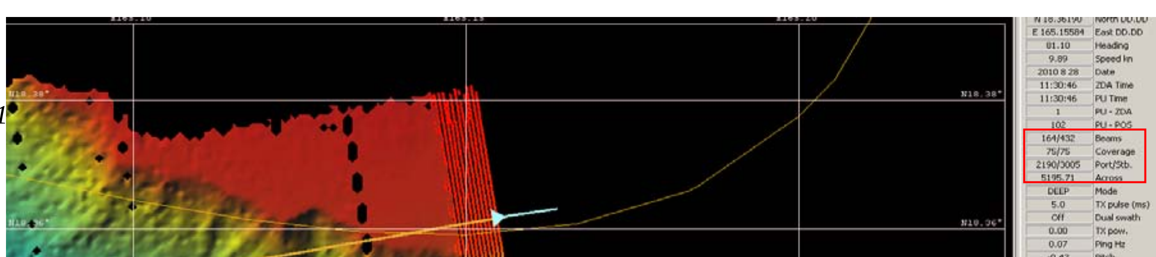


Figure 8. Screen capture of Kongsberg SIS Software showing sector coverage at 15 degrees port and starboard provides reasonable quality data. When switched to 20 degrees port and starboard, more coverage is obtained, but at a lesser quality (left). When switched back to 15 degrees port and starboard, the data quality improves. Much of the outer beams from the 20/20 settings get edited out during processing, so it seems better to leave the system at a lower angle of coverage to obtain the best quality data (right) [20100827_104722]. Image credit: NOAA.

August 28, 2010 - *Continued transit to Hawaii with continuous multibeam data collection.*

Sector angles were changed several times throughout the watches to try and maximize the coverage while retaining data quality. When the bottom was harder, the angles were increased. 0500 swells started to subside, which resulted in losing the bottom less frequently. 0820 Weather overall has improved with sea state 2-3. Data quality has improved since yesterday, the bottom type is harder and the bathymetry is not completely flat. These conditions have resulted in less data loss until the substrate gets softer, in which case the multibeam begins to lose the bottom again. As the data improves, the sector angles are increased. 1300 the bottom is harder and is able to maintain auto angular coverage mode with angles of 75/75 port/starboard (limited to 35 in extra deep mode). 2107 the Along Direction was changed to 0deg as the EX transited over a seamount. With a hard bottom in 4196 m, ping mode in Auto Very Deep, and Angular Coverage Mode in Auto, the coverage was 45/32. When it was changed to manual 75/75, sector coverage was 52/52. The number of valid beams was significantly different between the two modes, as represented in Figure 9.



August 29th

0000 Stuart and Hoy on watch
0035 XBT #24 processed and applied to line #28

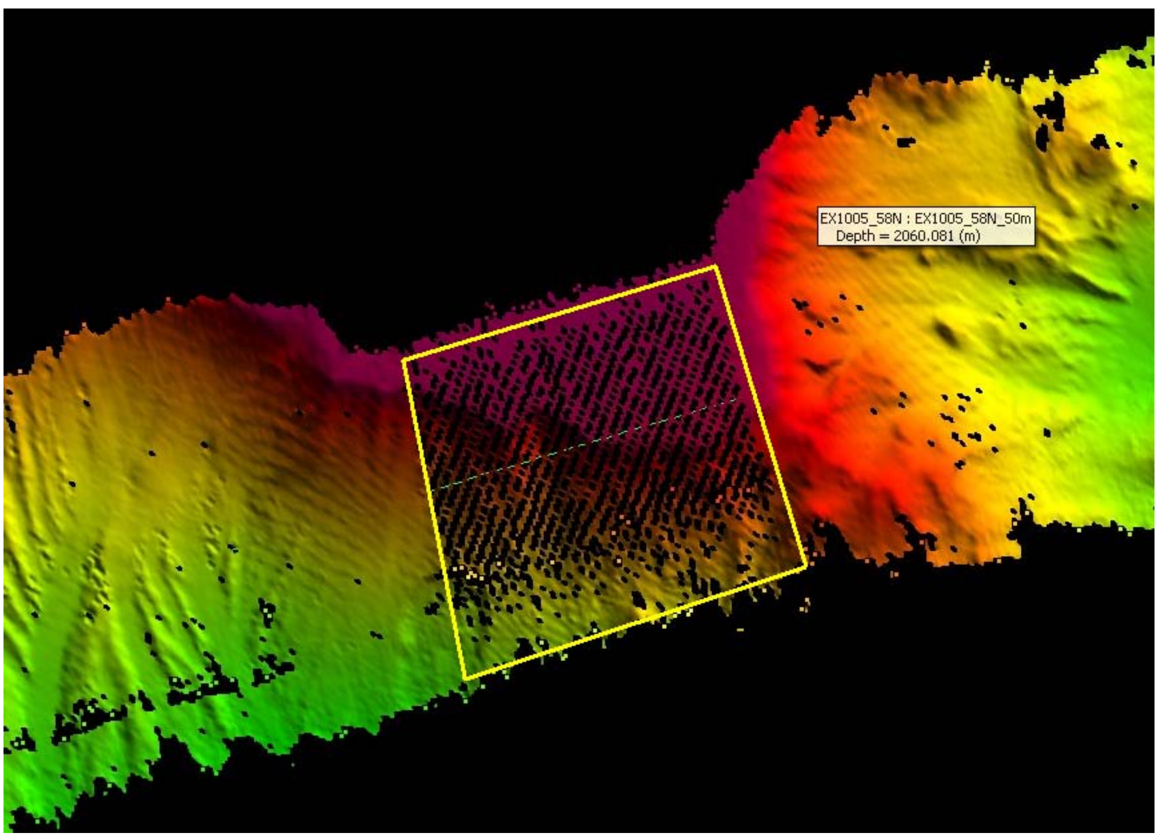


Figure 9. Screen capture of Kongsberg SIS Software showing that when the multibeam is in Manual Angular Coverage Mode, there is a decrease in the valid beams. This mode is most used in flat deep bottom in order to restrict the coverage to focus more of the energy straight down (top). When switched to Auto Angular Coverage Mode, the swath width increases as well as the number of valid beams (middle). Screen capture of CARIS showing that if the "beams" value in numerical display is not monitored, then the situation goes unnoticed until the data is processed (bottom) [20100828_113353]. Image credit: NOAA.

August 29, 2010 - *Continued transit to Hawaii with continuous multibeam data collection.*

More railroad tracks over flat 5000+ m bottom. 0915 Currently on line #29. Bridge called and they are switching to manual helm for training (ship will be conducting course changes and the data might be slightly affected). 1005 Ship slowing down for CPR recovery ~8 kts. 1015 Ship increasing speed for CPR cartridge swap out, then slowing down to 8 kts again. 1032 CPR deployed, ship increasing to full speed again 10 kts. 1127 CNAV drop out, ETs suspect it will be a while before satellites regain position information. BIST failed tests 1 and 3, board 16 failed (expected).

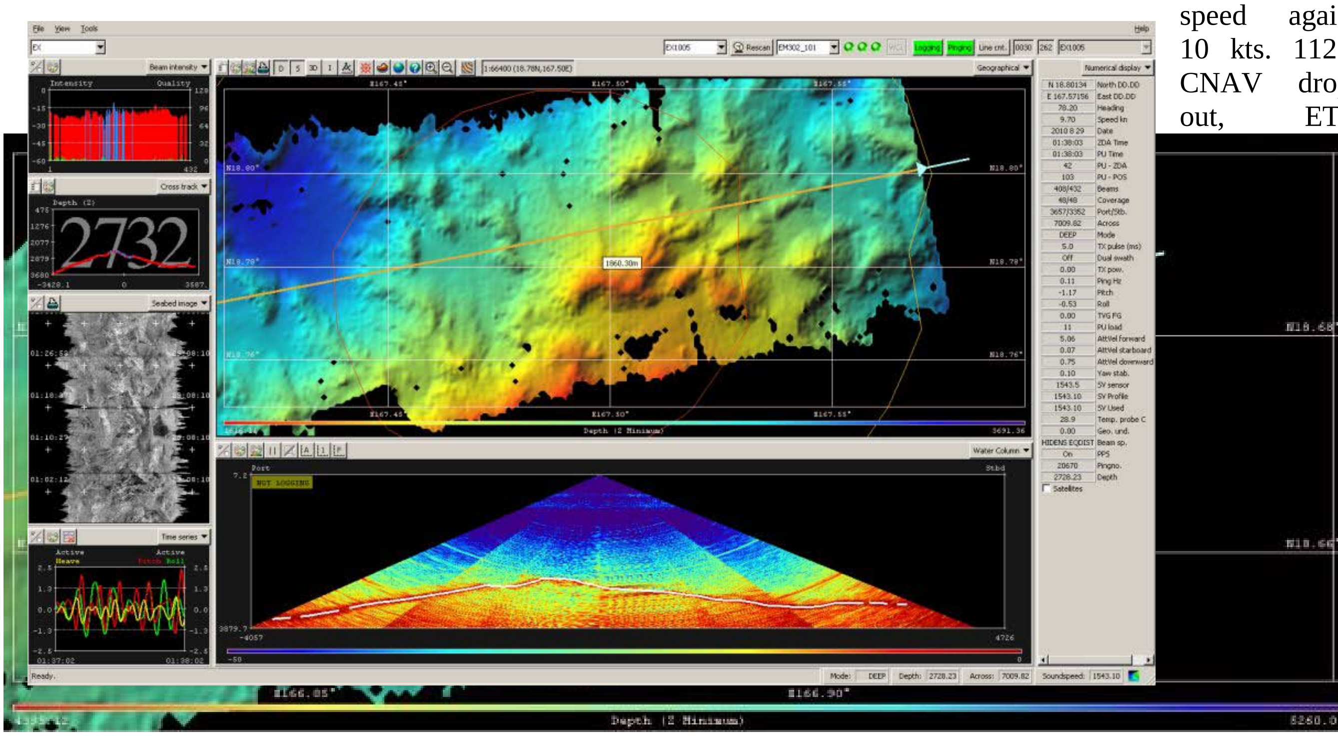


Figure 10. Screen capture of Kongsberg SIS Software showing a crater that is not identified in the Sandwell and Smith data (see Appendix D, 'Features of Interest' for more discussion) [20100828_215037]. Image credit: NOAA.

Figure 11. Screen capture of Kongsberg SIS Software showing that harder bottom produces better coverage and data quality [20100829_13803]. Image credit: NOAA.

August 30, 2010 - *Continued transit to Hawaii with continuous multibeam data collection.*

0120 SIS lost bottom at nadir for no apparent reason, depth is around 5538 m. Adjusting along direction between 0 & 5. 5 deg seems to be working so far. The ship has started to roll more but it is still a good ride. Data has been good. Ship changed course by a few degrees mid line (#32). 0820 Bottom coverage is spectacular, along direction is 3 deg, min/max depth 3000/6000 m, ping mode is Auto Very Deep and depth is ~3800 m.
With a hard bottom and features, the data is excellent; ship speed is 9.5 kts, heading 083 deg and along direction set to 2deg. 1035 Slight change in heading for helmsman practice. 1346 Position went Red on POSMV due to CNAV loss of satellite connections. 1722 Slow down for CPR recovery (7.4 kts). 1800 back to full speed. 1857 experiencing penetrations at nadir. Changed Along Direction to 4deg. BIST failed tests 1 and 3, board 16 failed (expected).

August 31, 2010 - *Continued transit to Hawaii with continuous multibeam data collection.*

0015 PPS red for a few seconds, back to green.

August 30, 2010 (repeat day for date line crossing) - *Continued transit to Hawaii with continuous multibeam data collection.*

0400 TIME CHANGE 0400 becomes 0500. Tuesday, August 31 becomes Monday, August 30 for crossing the International Date Line.

0510 Changed along direction to 3, bottom is soft. OK coverage except for the outer beams. 0800 ship speed is 10.5 kts, heading 083 deg, min/max depths are 2000/6000 m. Angular Coverage Mode in auto, max angle 75/75, coverage is 44/40. Along direction is 3 deg. Ping Mode is in Auto – chose Very Deep. Depth ~3761m. 1004 Ship is training helmsmen on maneuvering – slight course change on line 38 halfway through. 1245 conducted Emergency Drills during which the multibeam is unmanned. 1310 Drills complete. BIST failed tests 1 and 3, board 16 failed (expected).

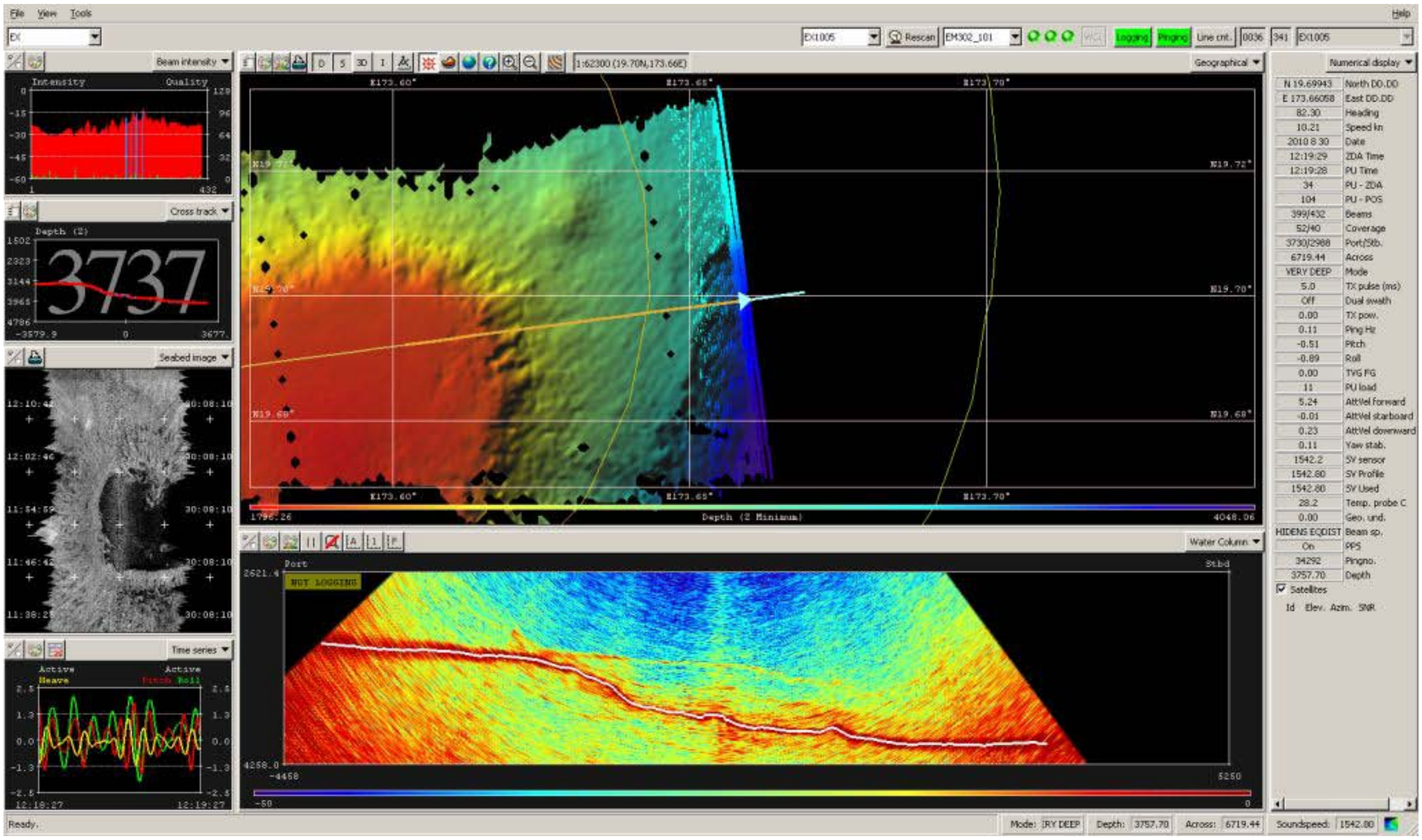


Figure 12. Screen capture of Kongsberg SIS Software showing high quality data going over a feature. The seabed image shows that the flat top of the feature has a softer substrate than the sloping sides [20100830_121929]. Image credit: NOAA.

August 31th - *Continued transit to Hawaii with continuous multibeam data collection*

C-Nav showing errors again. ET reset C-Nav – problem solved, no more errors. 1241 PU-POS red light blinking in SIS, HYPACK MV-POS OK. 1250 Crossed the International Date Line.
Nadir drop outs continue, penetrations @ nadir, once in a while changed min/max depths to 2000/5500m. 1400 ship reduced speed to 8 kts for CPR recovery. 1409 CPR on deck, maintaining 8 kts. 1420 CPR in the water, ship increasing speed to 10kts. 1605 stop logging and pinging for BIST #12 SIS grids not staying loaded, also not loading previous lines in survey. When changing grid display the grid disappears and starts all over. Restart SIS. 1615 SIS did not start correctly. Logging and pinging buttons remained grayed out. Restarted SIS again and it is now working fine. BIST failed tests 1 and 3, board 16 failed (expected). Coverage on the starboard side started to decrease. Settings were changed, but it was eventually determined that the loss of coverage was likely due to softer sediment in the outer beams on the starboard side. SIS showing holes in the gridded data, so line #44 was stopped to evaluate the data quality in CARIS. Although the gridding shows holes, they are not depicted in the data once processed in CARIS. Also during this process, it was determined that CARIS cannot project a line that crosses the 180th parallel. Lines completely on one side or the other work normally, but this particular line #43 cannot be processed with normal methods and will be further examined on shore.

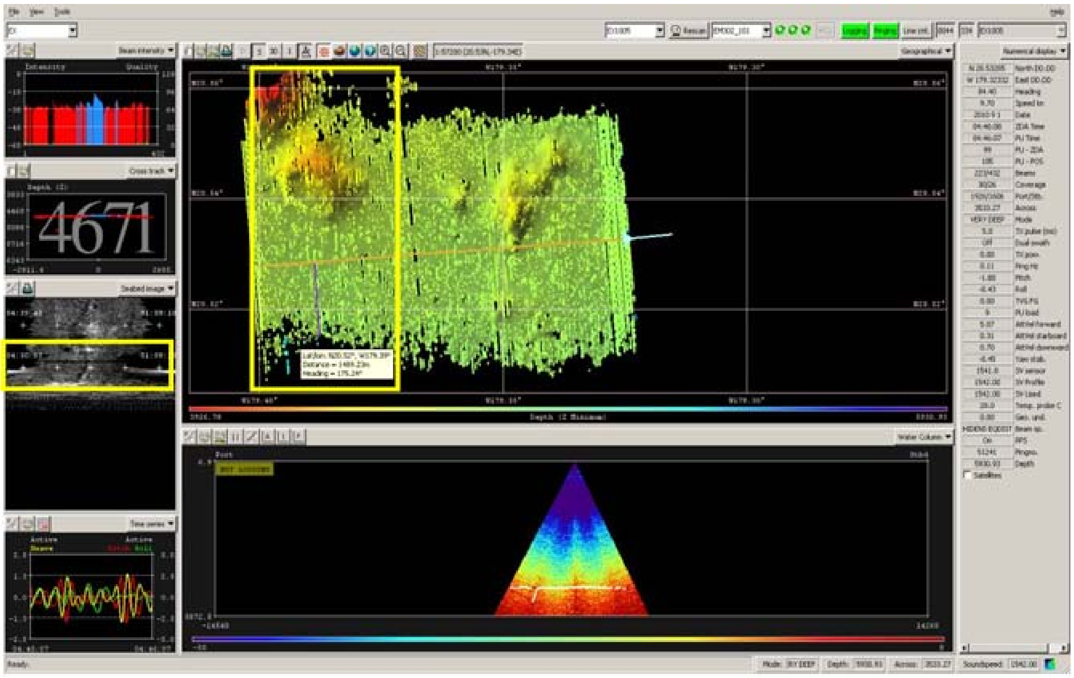


Figure 13. Screen capture of Kongsberg SIS Software showing the starboard side is experiencing less coverage. Changing settings did not help. When the ship reached a harder substrate (according to seabed image) the coverage increased [20100901_44608]. Image credit: NOAA.

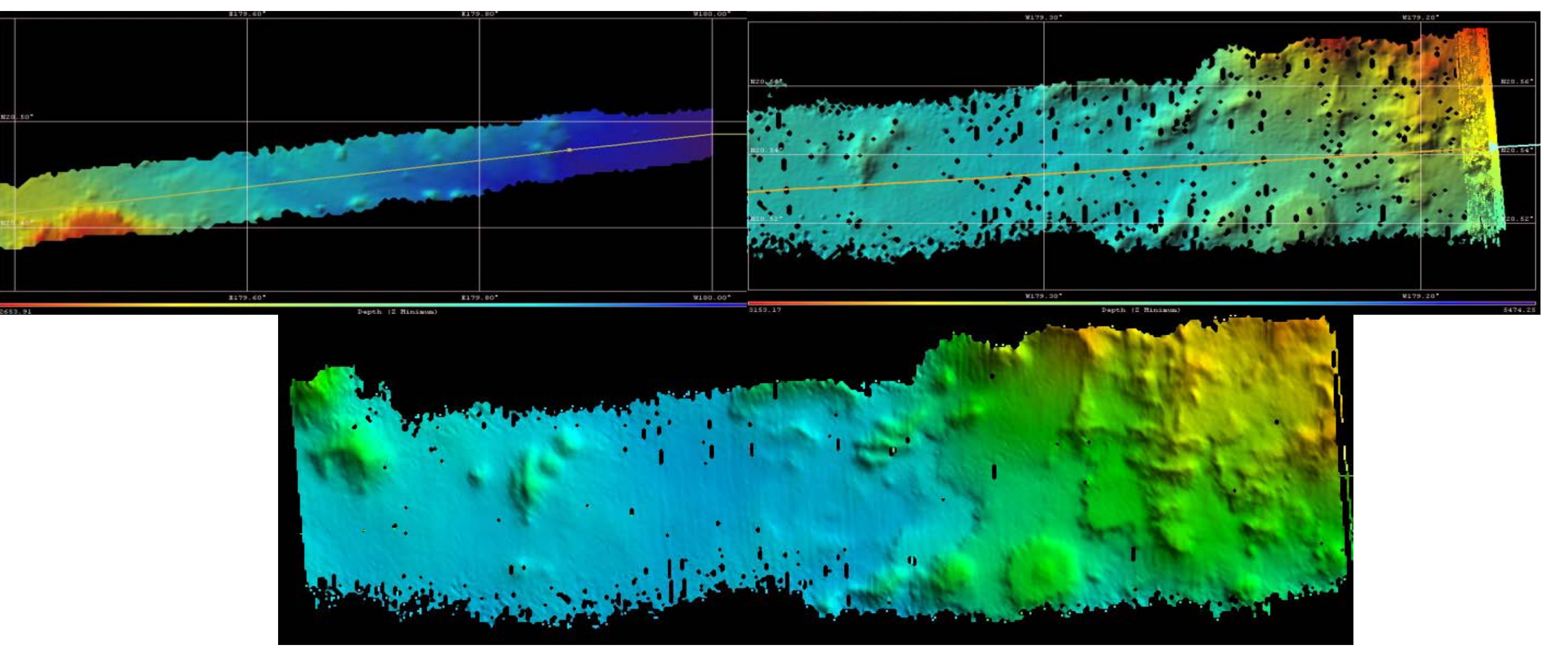


Figure 14. Screen capture of Kongsberg SIS Software showing the way the data is displayed prior to (left) and after (right) crossing the date line. Screen capture of CARIS shows how Line 44 (bottom) looks after being processed. When viewing the grids in SIS, it will only show one side of the date line or the other. The difference in SIS rendering makes it difficult to detect artifacts and/or holidays [20100901_053458]. Image credit: NOAA.

September 1st - *Continued transit to Hawaii with continuous multibeam data collection*

Bottom is flat with occasional features. Seas are picking up, ship is pitching and rolling so the EM302 keeps losing bottom. Once the ship passes over a feature with harder bottom, tracking is easier. Narrowing the sector angles and minimizing the depth min and max range as well as directing the beams along track in the forward (+) direction seems to help track bottom with reasonable quality data in 5,000+ meters with soft substrate. 15 degrees p/s works the best. When widened, the data in the few extra meters of coverage are of poor quality. BIST failed tests 1 and 3, board 16 failed (expected). 2200 becomes 2300 for time zone change.

September 2nd - *Continued transit to Hawaii with continuous multibeam data collection*

0800 Bottom holding well. Soft substrate with flat and featureless bathymetry. Depth ~5143m. max angle 15/15. Angular Coverage Mode in Auto. Ping Mode in Extra Deep. Min/max depth is 4000/6000m. Along Direction is 6deg on line #50. In SIS display as well as processed lines, stbd side of the multibeam data has holes and the overall data quality is not as good as the port side. Looking back, this started occurring when the depth was around 5000m and consistently flat. 1041 Ship reducing speed to 8kts for CPR recovery. 1051 CPR on deck. 1105 Ship increasing speed back to 10kts. Max angle at 15/15 p/s provides best coverage– no outer beam noise or very minimal. BIST failed tests 1 and 3, board 16 failed. 1820 change max sector angles to 75/75. In 3700m depth. SIS settings were not changed to reflect changes in bottom type, resulting in data loss in outer beams. Bottom harder, shallower, coverage increased immediately, 2000m to 6300m. No AutoCAD.dxf of contours on this side of the dateline is available to see features ahead of the ship. 1825 helmsman practicing. Along Direction to 0 deg. Observed that coverage decreased from 6200m to 5500m after a few minutes, also observed that bottom appears to be softer (as well as deeper) which likely contributes to loss of coverage.

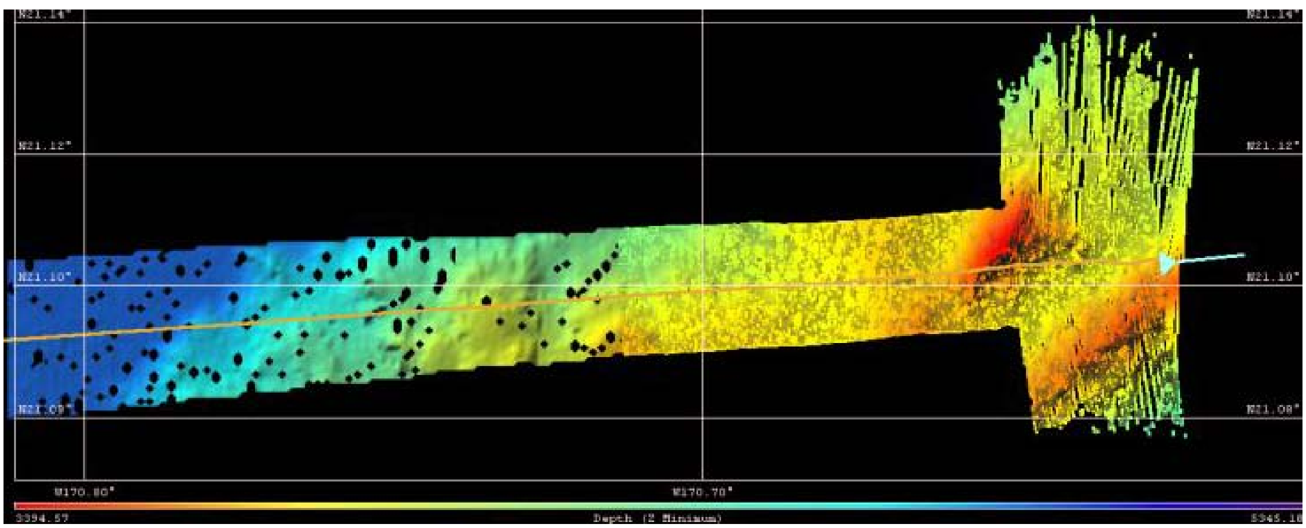


Figure 15. Screen capture of Kongsberg SIS Software showing line 52 in SIS. SIS settings were not changed to keep up with changing bottom conditions, causing a loss of data [20100903_52714]. Image credit: NOAA.

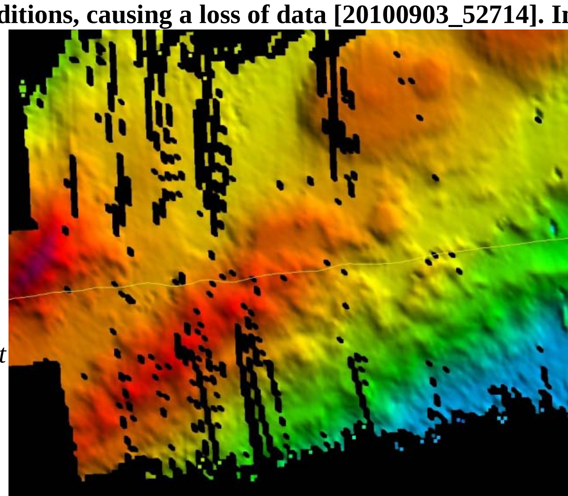


Figure 16. Screen capture of line 52 in CARIS. The loss of data is more noticeable after the line is processed. Image credit: NOAA.

September 3- *Continued transit to Hawaii with continuous multibeam data collection*

0104 Approaching Necker Ridge. Changed Along Direction to 0 and max angle to 75/75 p/s
As substrate is becoming soft, outer beam noise is heavy, changed max angle to 25/25. Max angles continue to be reduced to provide less noisy data. Noticing some nadir penetration. Changed Along Direction to 3 degrees. Changed beam spacing to Equiangular- no difference, changed back to High Density Equidistant. Nadir penetration or data missing at nadir quite frequently, changed Along Direction to 4 degrees. Constant nadir loss of data. Continues to be soft substrate and soft bottom. Changed min depth to 4000m, not quite as much nadir loss/penetration. Depth ~4600m. Changed Ping Mode to Extra Deep. When Ping Mode was in auto, MB chose VERY DEEP in typical extra deep depths– Bottom is holding much better. No more nadir drop outs. BIST failed tests 1 and 3, board 16 failed (expected).

It wasn't discovered until this point that the XBT data backup was not working properly. All of the *.asvp files are present, but we are missing TD_0002.EDF/.RDF, TD_00003.EDF/.RDF and TD_00004.EDF/.RDF. The actual files that were applied to the multibeam are present, but the original temperature profiles are not. The ETs made a great effort to locate and/or recover these files but were not successful. BIST failed tests 1 and 3, board 16 failed (expected).

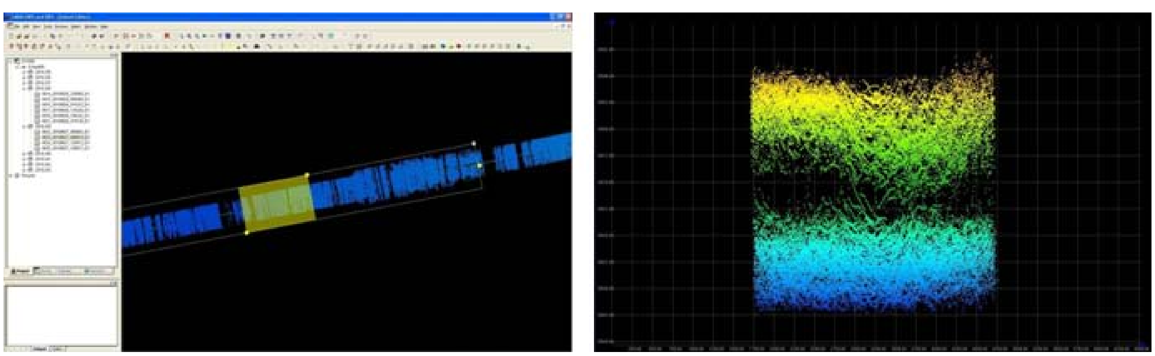


Figure 17. Screen capture of CARIS software showing that during fine cleaning of line 23 a discrepancy of height of the seafloor was found by the data processor. After looking at the log, it was determined that this change in height occurred when the sound velocity profile was applied in SIS acquisition. Additionally, one of the watchstanders recalls there being an incorrect entry for salinity in the XBT software. The details were not recorded in the cruise log, so this cannot be verified. Image credit: NOAA.

September 4, 2010 (different date format used here – synch up with other entries) - *Continued transit to Hawaii with continuous multibeam data collection*

0200 Time change 0200 became 0300. 0538 losing bottom more often due to increased seas. Ship is pitching and rolling. 0852 AttVel in SIS– forward, starboard, downward – all flashed red for a second. 0956 In numerical display – Attvel forward, starboard and downward all flashed red for a couple seconds again. 1630 bottom dropped out just as coming up on seamount. Angles reduced to 40/40 and depth range briefly changed to 4500-5500 (accidentally excluding actual bottom depth). Range changed to 2000/5500 and regained bottom. Near top of feature lost bottom again so changed Along Direction to -1 and immediately got it back. 1707 Off seamount, started losing bottom so set ping mode Extra Deep, angles to 20/20. Regained bottom. 1857 Changed Ping Mode to Auto – went into deep (lost bottom) so changed Ping Mode to Very Deep. Coverage 3000m. Broken every other ping. Changed Ping Mode to Extra Deep. Depth is 4638m. Seabed looks light enough for very deep mode, but won't lock onto the bottom well. Coverage 3600m – better lock on bottom. 1925 Ship pitching more, losing bottom every few minutes. 2350 tried Auto/VERY Deep- less coverage, bad tracking Back to Manual/Extra Deep. BIST failed tests 1 and 3, board 16 failed (expected).

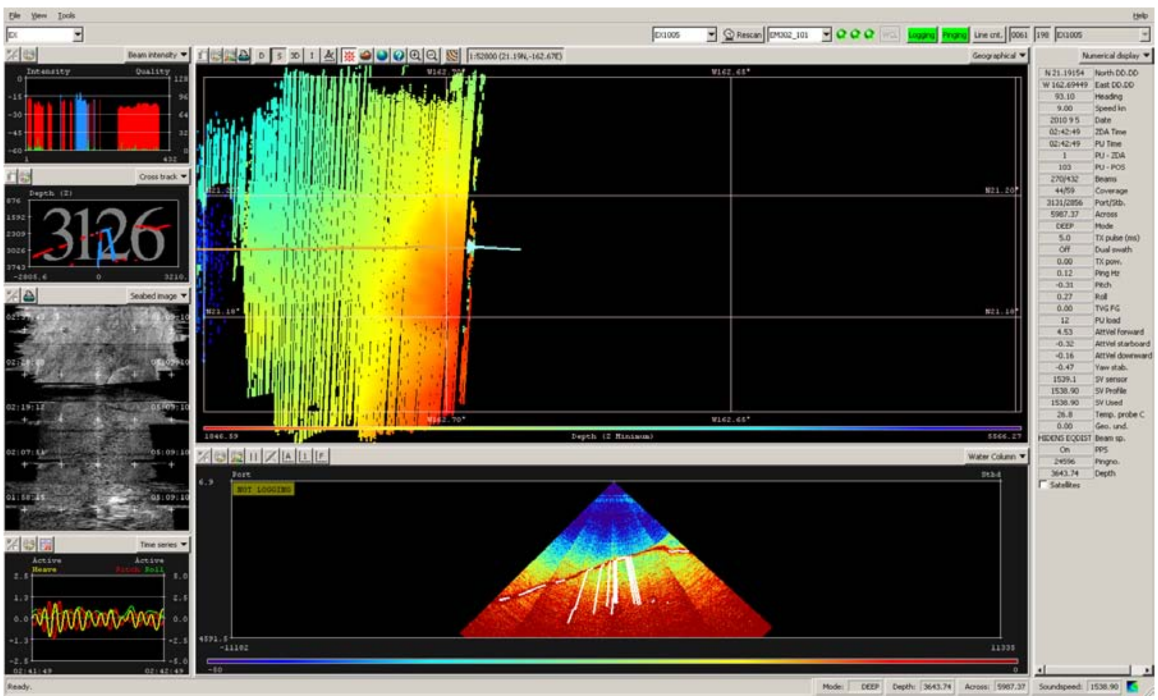


Figure 18. Screen capture of Kongsberg SIS Software showing that the bottom mysteriously dropped out as the EX approached a feature with relatively hard and shallow bottom, where the multibeam is typically consistent [20100905_024249]. Image credit: NOAA.

September 5, 2010 - *Continued transit to Hawaii with continuous multibeam data collection*

0135 Ship changed course right into the swell, so we are experiencing some heavy pitching. SIS is losing bottom often and having a hard time recovering. 0708 Pitching has subsided greatly but SIS is still losing bottom often. Depth is around 4550m. The reason could be the soft bottom. 0800 Max angle is 20/20 p/s. Auto Coverage Mode in auto min/max 3500/5000m. Along direction is 2 deg. Ping mode in AUTO, Multibeam selected Very Deep, Depth ~4600m. On line 63 Ship speed 9kts, Hdg 090deg. 0826 Nadir loss and nadir penetration occurring, changed Ping Mode to Extra Deep, Depth ~ 4625m, Nadir issues are gone, bottom is holding. 1058 PU-POS flashing Red in SIS, bottom dropping out, POS in HYPACK OK. 1110 POS light Red in Hypack, went away after a second, flashing red occasionally then going back to green again SIS OK. 1254 Bottom dropping out constantly; changed max angle 50/50 p/s changed Along

Direction to 3 deg, changed min depth to 2000m for small feature. 1358 changed Ping Mode to Auto, Multibeam selected Very Deep, Depth ~ 4414m, bottom holding better. 1420 Ship reducing speed to 8 kts for CPR recovery. 1430 CPR on deck, ship increasing speed to full speed ~ 10kts. 1525 Data looking great; ship riding better. 1735 experiencing artifacts on both sides, holes where RRT would be. Change Along Direction to 3. Hard bottom at nadir, soft on sides, but flat. 3000m. 1743 change Along Direction to 0. Can't get rid of holes. 1747 10deg turn. In auto Ping Mode/Deep. Change Ping Mode to manual/very deep. Flat bottom, no holes. 1905 tried auto, brought back RRT. Back to very deep. 1915 manual deep mode-some holes, but not tracks. 2000 stop log/ping to pull into port. No 1830 XBT. Final BIST, failed tests 1 and 3, board 16 failed (expected). Shut down TRU. Copy files, defragment drives, shut down computer.

11. Appendices

Appendix A: Field Products

Cruise Overview

The *Okeanos Explorer's* EM 302 multibeam system mapped more than 8000 linear km of the seafloor during the EX1003 and EX1005 transits in summer 2010. The two cruise legs approximately followed a great circle path between Guam and Oahu with a central beam separation about 12 km. This allowed for mapping of adjacent but non-overlapping regions on the seafloor.

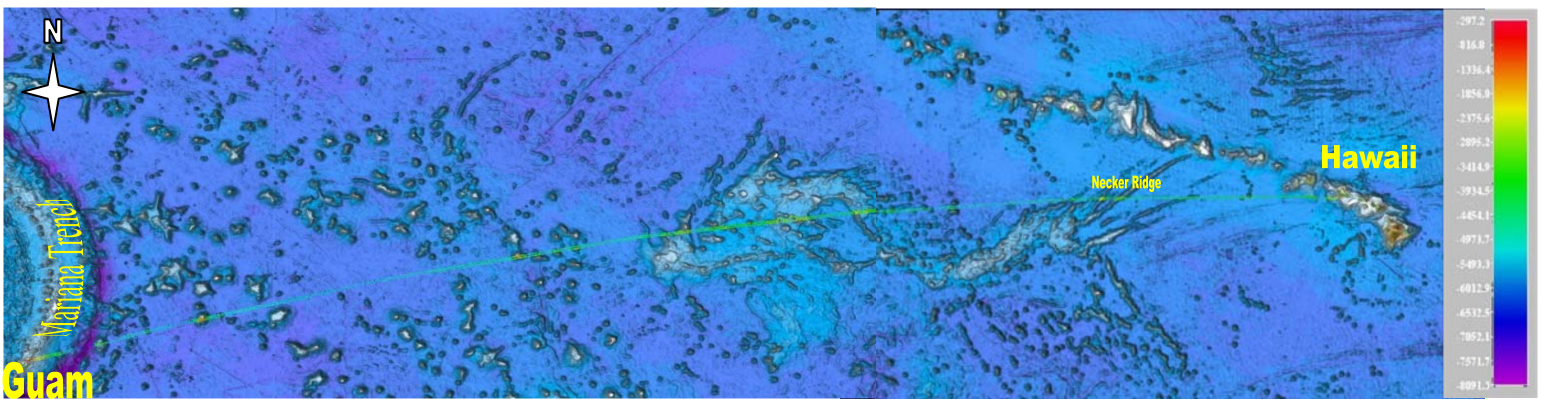


Figure 21: *Graphic showing transit from Guam to Hawaii. Bathymetry from Sandwell and Smith overlaid with EM302 data from EX1003 and EX1005.*

Mariana Trench EM302 Data, Part 2
Multibeam data collected by the *Okeanos Explorer* on August 24, 2010
By Shannon Hoy

Overview
On August 24, 2010, during the transit from Guam to Hawaii (EX1005), the *Okeanos Explorer* once again crossed the Mariana Trench. On the previous crossing of the Mariana Trench during the EX1003 cruise it was observed that the EM302 (multibeam) could acquire data up to a depth of 8000m, which is the maximum depth that Kongsberg's data acquisition, SIS is hard-coded to accept. This is a 1000m extension of the predicted range of the EM302. The objectives of EX1005 while transiting over the trench were: 1) Be able to obtain data up to the 8000m mark and 2) Improve the data quality leading up to and exiting the trench. Throughout EX1005, the system was able to achieve a higher quality of data up to 8000m on both entering and exiting, especially exiting, the Mariana Trench. Weather conditions did not have a significant effect on the acquisition or quality of data, as the seas were mild with wind speed ranging from 11-16kts and an average swell height of 2-4ft.

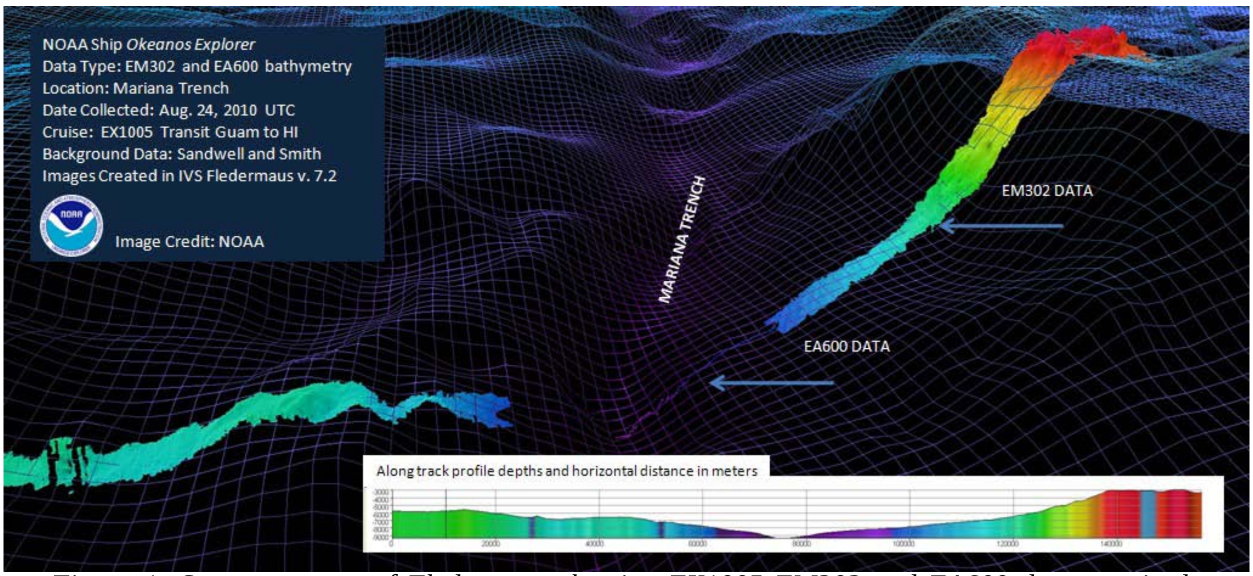


Figure 1: Screen capture of Fledermaus showing EX1005 EM302 and EA600 data acquired over the Mariana Trench under lain with wireframe of Sandwell and Smith data.

Going Over the Trench
Throughout the time period of 0600-0655 (Guam local time), the *Okeanos Explorer* acquired data while entering the Mariana Trench. During this time Seafloor Information System (SIS) collection setting stayed in Manual Ping Mode/Extra Deep and the Along Direction at all times equaled 0. At 0600 the *Okeanos Explorer* reached the 7000m Sandwell and Smith contour line. The angular coverage mode was set at 30/30, the spike filter set at medium to eliminate artifacts, and the ship was transiting at 10kts. At this time the bottom detection was still very inconsistent. In an attempt to obtain higher data quality, the maximum port/starboard angles were brought in from 30/30 to 15/15 and the ship slowed down from 10kts to 8kts, then to 7kts. The EA600 (singlebeam) was turned on, and set to multi-pulse ping mode, which is the recommend setting for deep water because it provides higher accuracy data (EA600 operator manual, Kongsberg 2006). At 0626, after all of these changes, the bottom looked much better, especially at the outer beams. The range gate stayed narrow and expendable bathythermograph (XBT) #4 was applied to both the EA600 and the EM302 data. At 0644 and a depth of 7964m, nadir began to drop out

and created a hole in the bathymetry (Figure 2). SIS had reached its maximum depth of 8000m. The port side continued to acquire data until 0655 when it arrived at the depth of 8000m. The singlebeam and multibeam were close in depth, with a difference of approximately 50m. At this time pinging and logging were disabled, and a Built in System Test (BIST) was performed while the ship transited to the other side of the trench.

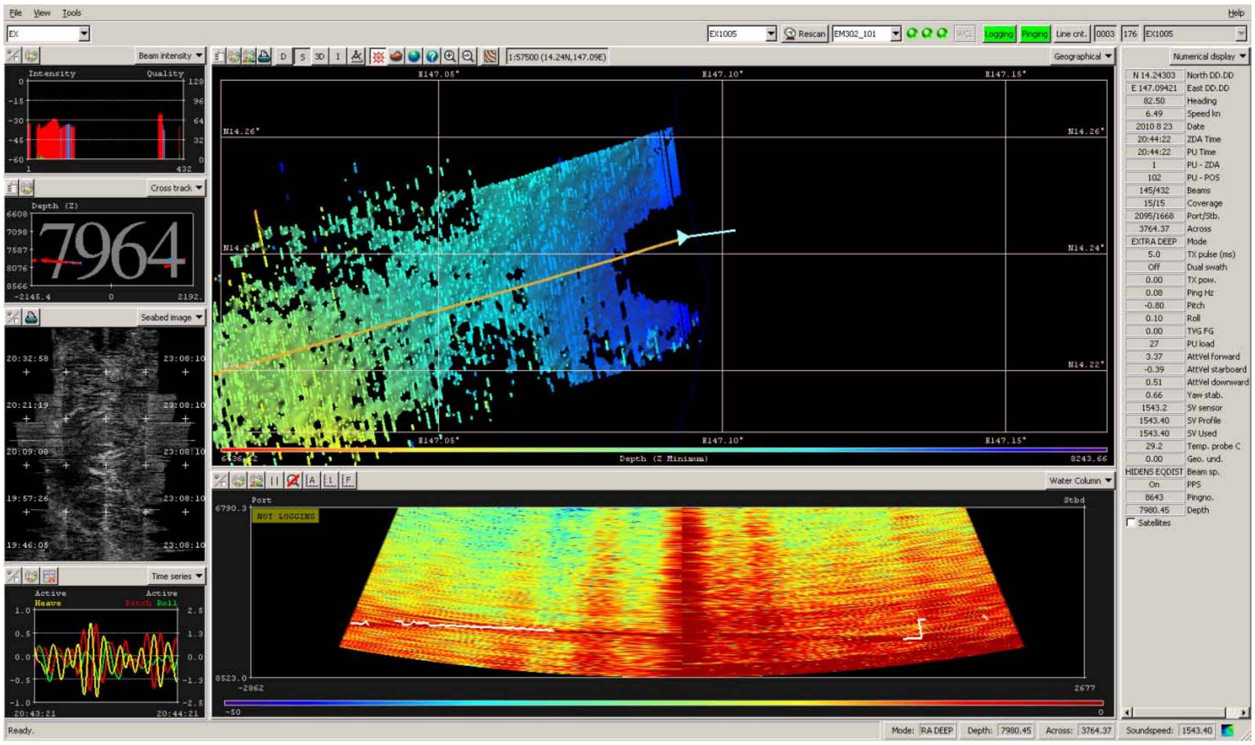


Figure 2: Screen capture of Kongsberg SIS Software showing the EM302 data creating a hole where nadir reached a depth of 7964m at 0644. On 24 August 2010.

As the *Okeanos Explorer* transited to the eastern side of the Mariana Trench, the EA600 was kept on to track the depth. At 0845, the EA600 reached a maximum depth of 9514m. As the ship approached the eastern 8000m Sandwell and Smith contour, the EM302 was restarted and both the singlebeam and the multibeam were pinging. The EM302 was not able to find bottom at this time. Concurrently, the ship was at a decreased speed of 5kts for Continuous Plankton Recorder (CPR) recovery. Since the settings going into the trench allowed quality data to be collected, the SIS collection settings were left at Manual Ping Mode/Extra Deep, Along Direction zero, and the port/starboard maximum angles of15/15. Force depth of 8000m was utilized to find the seafloor, and the first depth reading was achieved at 0849 at a depth of 8000m. Line number 04 began to be logged. Five minutes later the data quality was excellent, excluding outer-beam artifacts, with approximately a 4000m swath locked on the seafloor at 7900m (*Figure 3).*

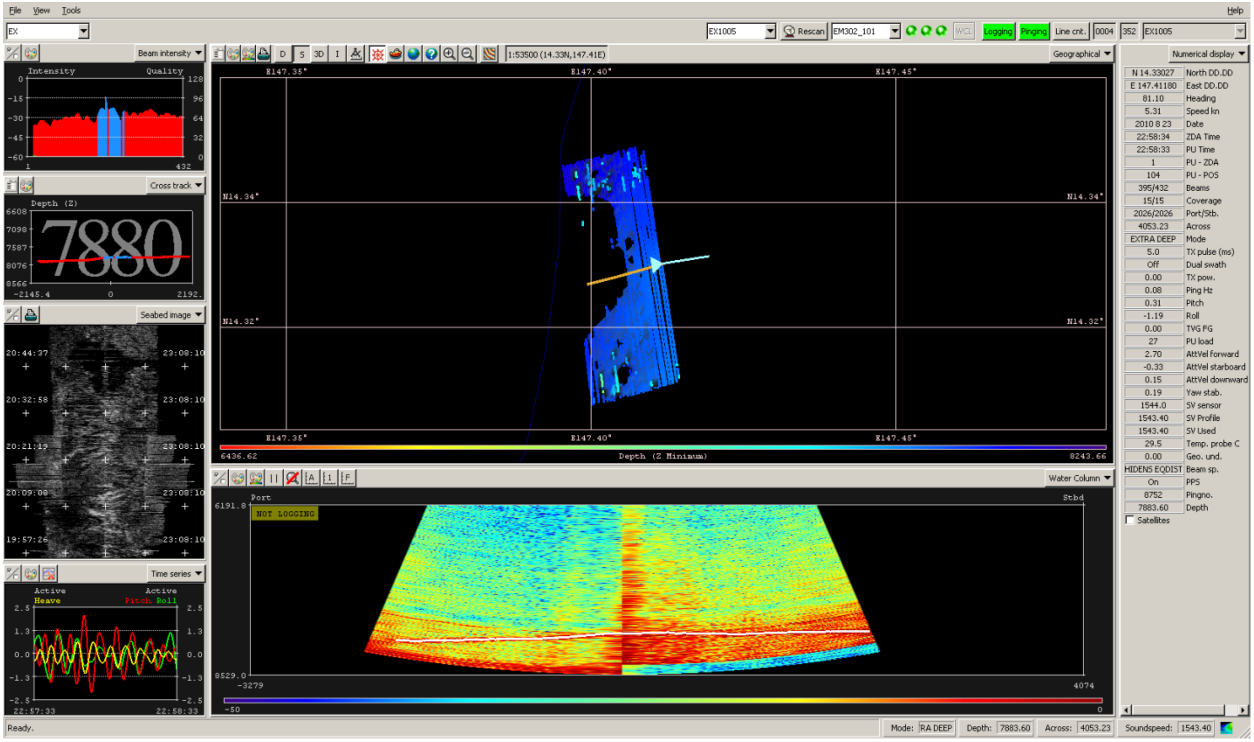


Figure 3: Screen capture of Kongsberg SIS Software showing the quality of data achieved by the EM302 exiting the trench at a depth of 7880m [2258 UTC, 25 August 2010].

In an attempt to rid the data of the outer-beam and nadir artifacts, the EA600 was turned off and the spike filter setting remained at medium. These changes seemed to improve the data. Since the EM302 was maintaining a lock on the bottom, the settings in SIS were manipulated in order to acquire a wider swath width on the seafloor and to observe what affect different settings had on the incoming data, with the ship at a speed of 5.5kts for CPR deployment. Between 0911 and 0918 the max angle port/starboard was increased to 20/20 and the minimum depth was decreased to 3000m. At 5.5kts neither of these changes caused deterioration in the data quality. Around 0950 and a depth of 7400m the ship speed increased to 7kts. Force depth was needed for the first time and continued to be used for the next ten minutes. The range was narrowed by changing the minimum depth to 5000m in order to focus the beams on the 7189m depth of the seafloor. With the ship up to full transit speed at 10.5kts the Ping Mode was set to Auto (Extra Deep), the max angle of coverage set to Auto (18/16 port/starboard), and the min/max depth to 6000m/7500m. Even with the ship at transit speed, high quality data was still acquired. The range and the angular coverage mode were gradually increased and the EM302 maintained quality data while exiting the Mariana Trench.

<u>Findings</u>

The *Okeanos Explorer* crossed the Mariana Trench twice in 2010, during EX1003 and EX1005. Between the two cruises, higher data quality was collected during EX1005 (*Figure4)*. One of the major factors that seemed to affect the quality of data was the speed at which the ship was traveling. The ship exiting the trench through the EX1005 cruise was already traveling at 5kts for another projects requirement, whereas the average speed of the ship during the EX1003 ship was around 8.25kts. The three knot difference might have allowed the EM302 to originally find the bottom easier. It also seems that starting with the system in manual mode over auto mode and having a narrower angular coverage allowed the EX1005 cruise to obtain greater data quality. Another major difference in the SIS settings during the transit was that unlike the EX1003 cruise where the Along Direction varied from -7 to 7, the Along Direction stayed at 0 throughout the entire crossing of the trench. During the EX1005 cruise, the SIS collection settings were gradually moved from narrow parameters to a more broad range of settings. This gradual change seemed to help the EM302 maintain a lock on the bottom while the ship slowly increased speed. A setting that has been observed to reduce “railroad track” artifacts is the penetration filter set to off (discovered after crossing the Mariana Trench in EX1003), which was also used for the EX1005 transit through the trench.

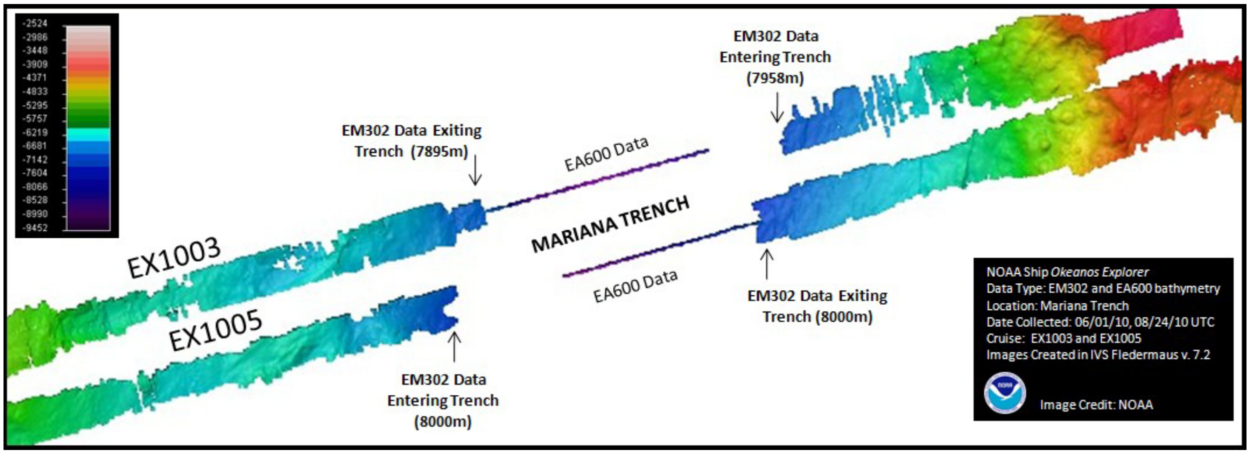


Figure 4: Screen capture of Fledermaus showing a comparison of flat EM302 and EA600 data collected during the EX1003 and the EX1005 cruises.

It was theorized during the EX1003 cruise that upon exiting the trench, the EM302 might have had to reestablish itself with the seafloor after pinging was disabled at 8000m. On August 24, 2010, the EM302 had no issue with reestablishing itself and immediately the seafloor was found with the ship traveling at 5kts. Therefore, this theory was most likely not the reason that the EM302 had issues with originally finding the seafloor when exiting the Mariana Trench.

Large railroad tracks and smiles were observed while exiting the trench on the EX1003 cruise. At this time the EA600 was turned on. During EX1005, when exiting the trench, artifacts were observed while both the multibeam and the singlebeam were pinging. Upon securing the singlebeam the outer-beam and nadir artifacts observed in SIS seemed to diminish. The EX1003 cruise established the possibility that the EA600 could in times help the EM302 collect better data. So, the question remains: did the EA600 help to cause the artifacts observed in the previous cruise, or was that due to not utilizing the penetration filter on the multibeam or the multi-pulse mode on the singlebeam as they were utilized on EX1005?

It is important to note that the two transits were traveling in opposite directions while crossing the trench and the bathymetry is different on either side (*Figure 5)*. Both cruises obtained better data when traveling over the steeper slope on the eastern wall of the trench, whether they were entering or exiting the trench. It has been observed on the *Okeanos Explorer* that the EM302 tends to collect better data when the seafloor has variable features and an acoustically reflective bottom. Therefore, it is possible that the type of bathymetry on the eastern side of the trench shaped the quality of data the EM302 gathered.

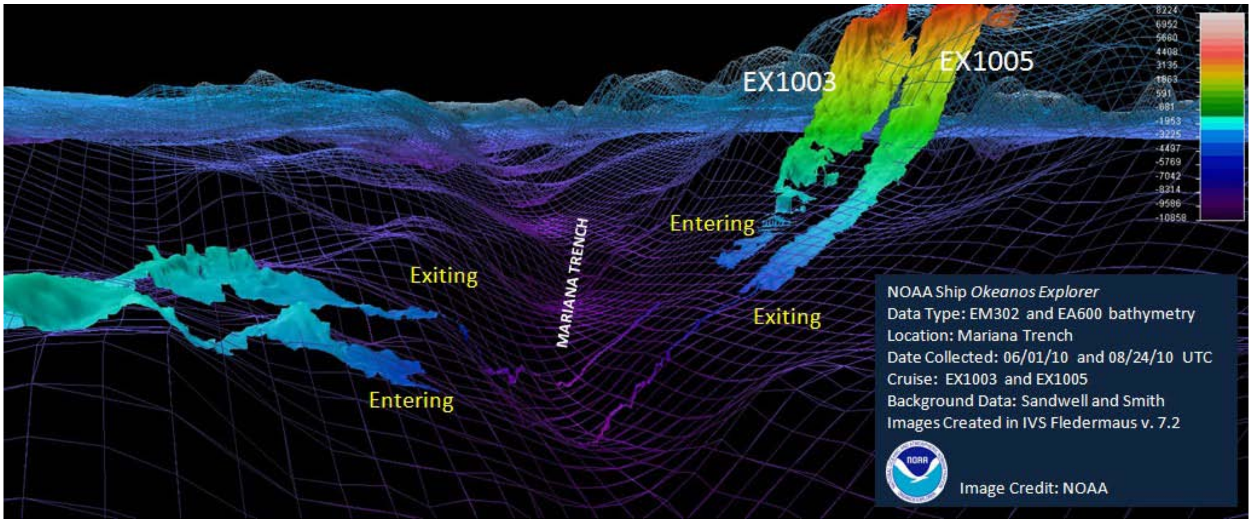


Figure 5: Screen capture of Fledermaus showing a comparison of EM302 and EA600 data collected during both the EX1003 and EX1005 cruises under lain with wireframe of Sandwell and Smith compiled data. Image credit: NOAA.

Depth	Coverage	Depth	Coverage	Depth	Coverage	Depth	Coverage
7900	4300	7250	5235	6620	3544	5400	6105
7900	4400	7200	5127	6620	3941	5240	6388
7840	4400	7150	4805	6580	4051	5100	6084
7760	4342	7100	4684	6520	4148	5000	8160
7700	5261	7100	4507	6420	4727	4760	6832
7675	5659	7040	3782	6420	4479	4600	6597
7640	5600	7040	3870	6360	4828	4400	7127
7580	5767	7020	4307	6275	5024	4100	7367
7540	5777	6960	3852	6230	4553	4000	8559
7480	5669	6920	3642	6040	5543	3800	8701
7420	5407	6880	3912	6000	5268	3650	8215
7400	5515	6860	4298	5880	5778	3500	7839
7380	5480	6800	3857	5800	6065	3200	7540
7340	4685	6780	3689	5700	5778	3020	7534
7300	5235	6720	3692	5600	6030	3000	7338
7300	5391	6660	3795	5550	5956	3000	6935

Table 1. Depth vs. Coverage of line 0004 as the EX transited out of the Mariana Trench.

Conclusions

Once more, while crossing the Mariana Trench, the EM302 was able to obtain data up to the 8000m Sandwell and Smith contour line. The EX1005 cruise achieved higher quality data than the EX1003 cruise. The major differences in acquisition setting were the ships speed (slower), the penetration filter (off) and the EA600 ping mode (multi-pulse). It is uncertain if any of these variables individually affected the data quality more than another or if it is the combination of settings that was most successful. The EX1005 data did not encounter the same anomalies in the backscatter; this is most likely due to using multi-pulse ping mode verses maximum ping mode, which is typically used. In the future it would be interesting to manipulate just the effect of the EA600 on the EM302 while leaving all other variables at a constant. Even after crossing the trench for a second time, it is apparent that there is still more to learn about the system operating in these depths.

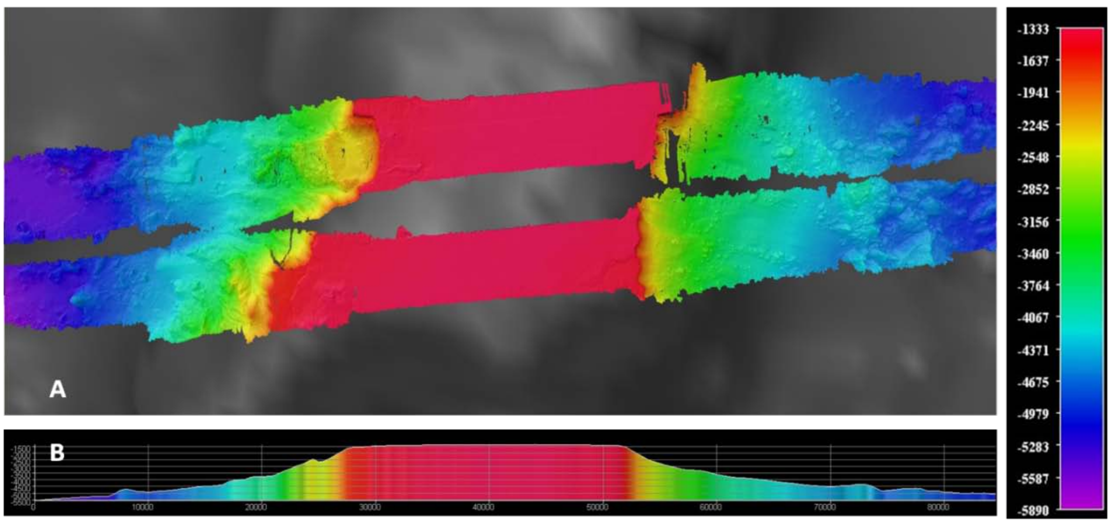
<u>Interesting Features detected by the EM302 during EX1005</u>
By Brian Shiro

D1. Landslides (15.57°N, 152.07°E)

(Lines 0066_20100531_180451_EX and 0009_20100825_00004_EX)

Both transits passed over a large flat-topped guyot about 500 km east of the Mariana Trench. The feature is about 20 km wide at the top and 50 km across at the base in the east-west direction. The steep-walled cliffs seem to have been shaped by numerous landslides. Large fault scarps, slump blocks, debris aprons and boulder fields are visible on both sides of the feature. Landslides are the second most common cause of tsunamis, so understanding the processes that lead to slope failure in the submarine environment could have important natural hazard implications.

Figure 1: Screen capture of Fledermaus showing Plan (A) and Profile (B) views of the guyot. EX1003



transit swath above and EX1005 transit swath below. Image credit: NOAA.

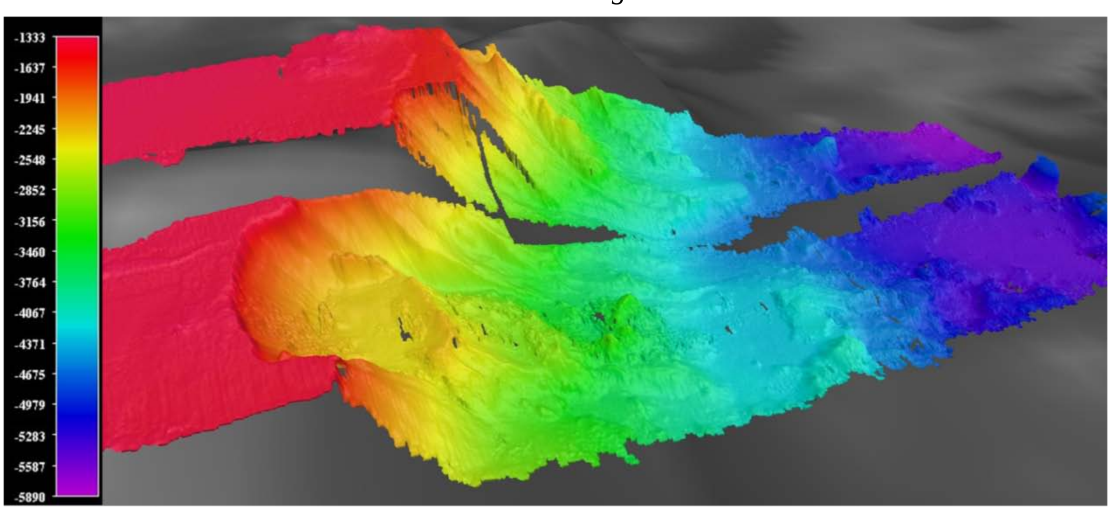


Figure 2: Screen capture of Fledermaus showing a landslide in a perspective view looking towards the southwest on the west face, vertical exaggeration 3. Image credit: NOAA.

D2. Volcano (18.68°N, 166.85°E)

(Line 0029_20100828_180749_EX)

On the EX1005 leg, we discovered a small cinder cone with a well-defined central crater. The cone rises about 500 m above the local 4900 m surface. This feature is not visible in the Sandwell and Smith bathymetry and may be a new discovery. The cone's high degree of symmetry and lack of obvious erosional modification may indicate it is still active. Submarine hot spots that produce volcanoes also form hydrothermal vents that support diverse ecosystems, so this may be worth further study.

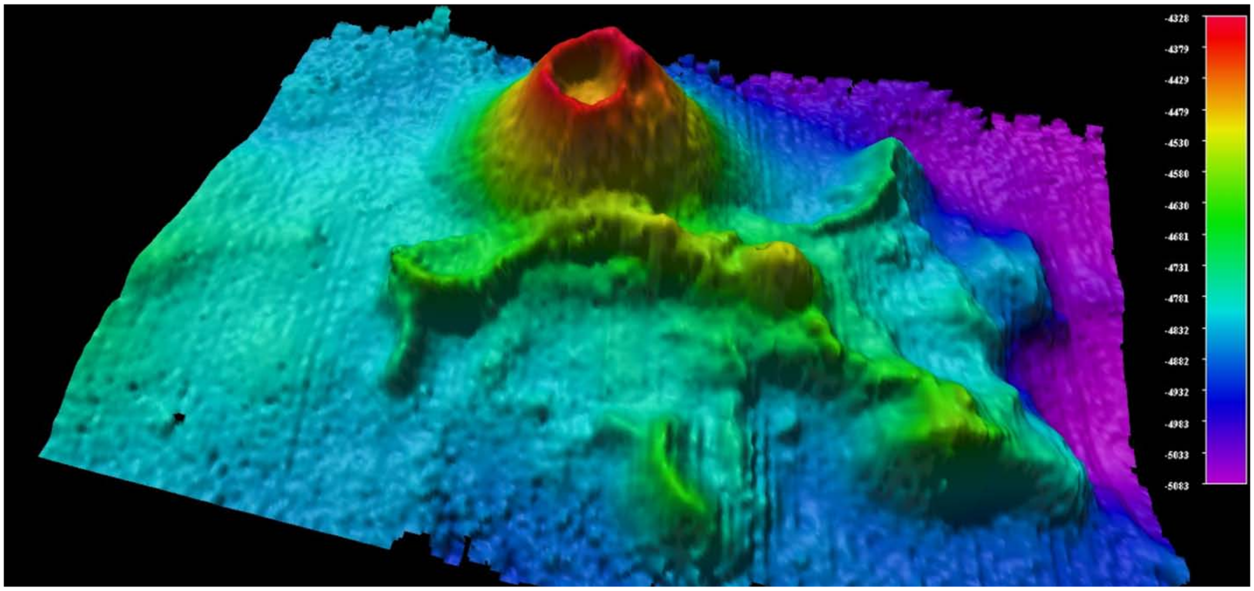


Figure 3: Screen capture of Fledermaus showing a cinder cone perspective view towards the northwest, vertical exaggeration 3. Image credit: NOAA.

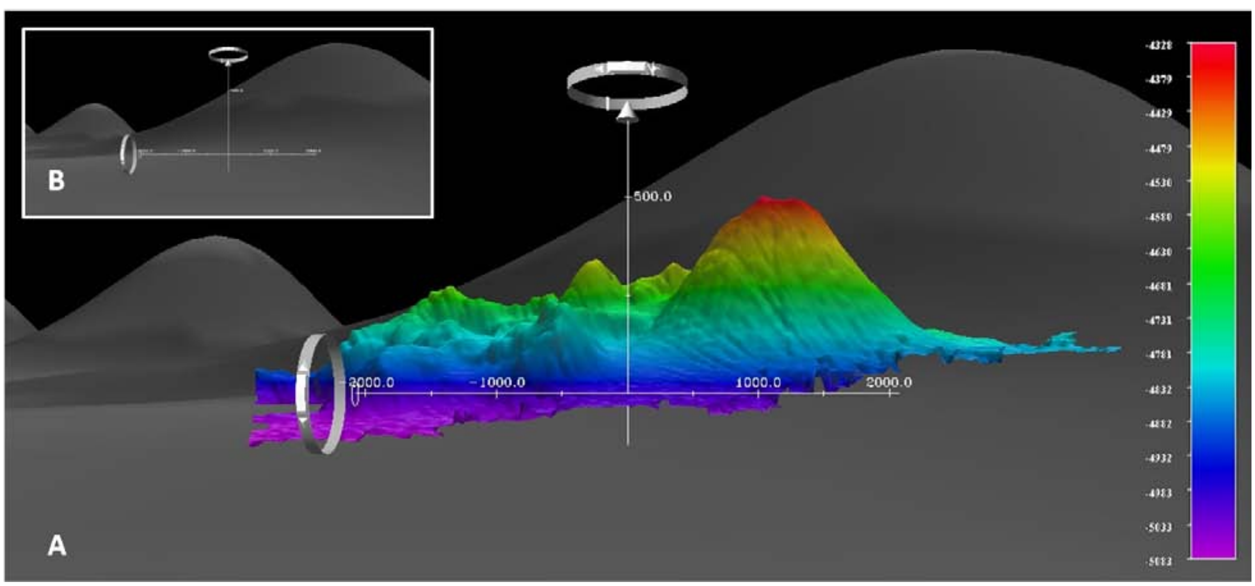


Figure 4: Screen capture of Fledermaus showing a side view of the cone looking south (A) compared to Sandwell and Smith bathymetry (B), vertical exaggeration 3. Image credit: NOAA.

D3. Paleoshorelines (19.50°N, 171.60°E)

(Lines 0033_30100829_180726_EX, 0034_20100830_00007_EX and 0042_20100527_013410_EX

About midway through the transit, we crossed the Mid-Pacific Mountains which is a rise containing a large number of seamounts, guyots and former islands. A chain of up to six horizontal benches spanning 2-4 km each is evident along the western edge of one guyot. They are separated by distinct vertical drops of 200-300 meters at the 5100, 4700, 4500, 4200, 3900 and 3500 m levels. These appear to be former shorelines that record the sinking of the former island. The paleoshorelines observed here likely represent the rise in sea level during the end of the last ice age; studying them provides clues to how climate change has happened in the past.

Figure 5: Screen capture of Fledermaus showing Plan (A) and Profile (B) views of the paleoshorelines.

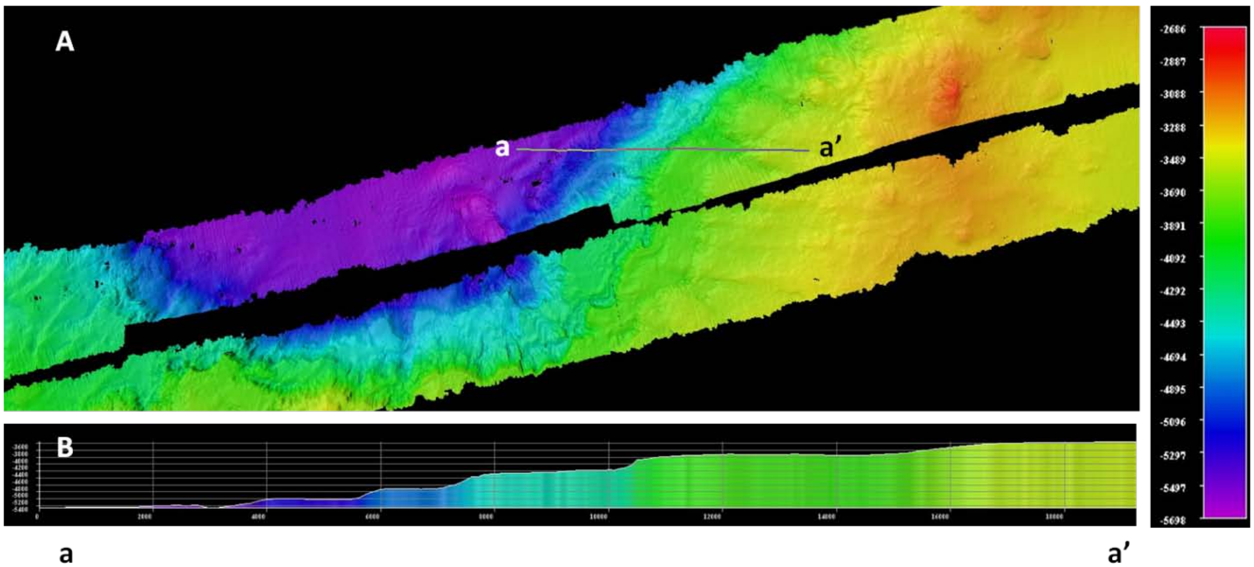
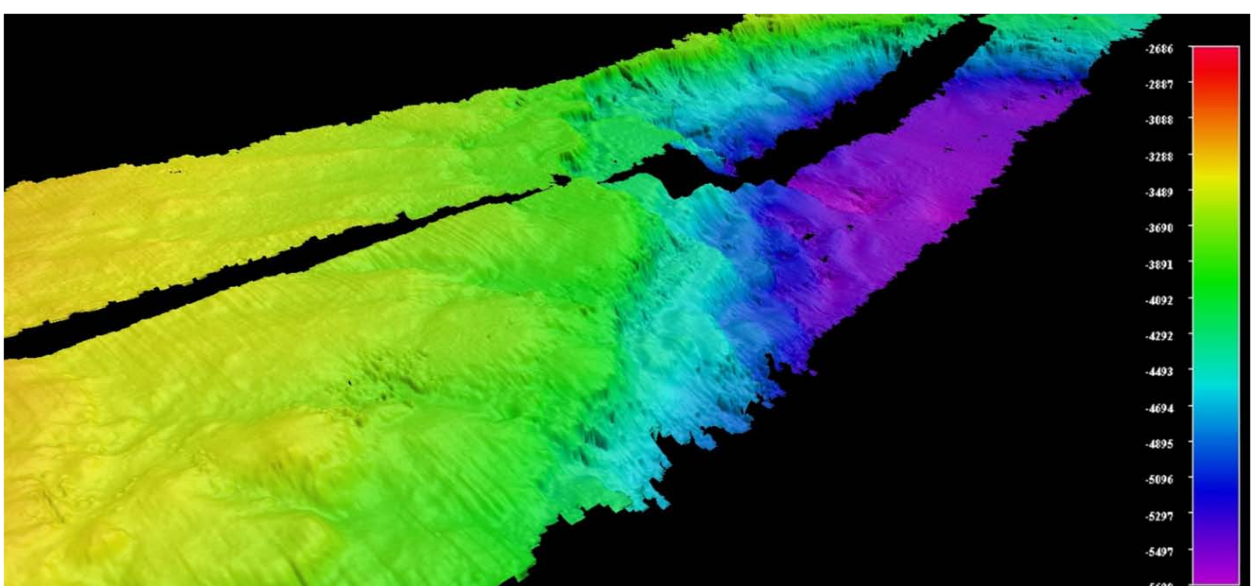


Image credit: NOAA.

Figure 6: Screen capture of Fledermaus showing paleoshorelines in a perspective view looking towards the southwest, vertical exaggeration 2.5. Image credit: NOAA.



Necker Ridge Analysis

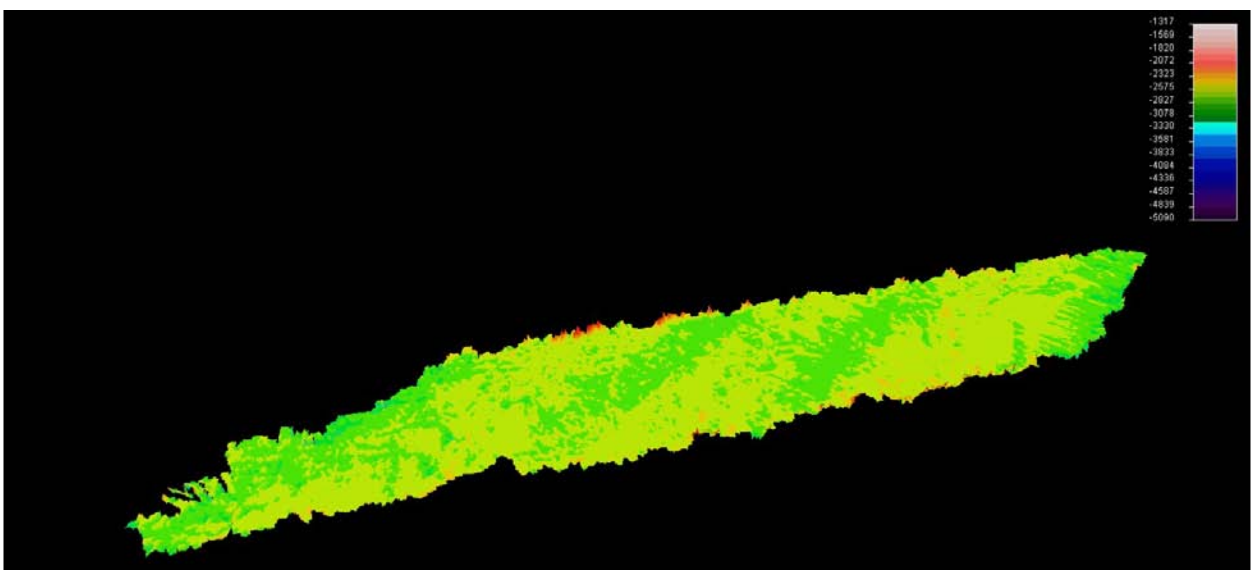
A Comparison of Line 54 crossing Necker Ridge, Data Collected by the EM302 during EX0909 Legs 1 and 2 and EX1005

By Jack Payette

Data Quality Assessment

On September 3, 2010, during EX1005 the ship crossed Necker Ridge. Necker Ridge and the surrounding area were mapped during previous cruises; EX0909 Legs 1, 2 and 3. Here a statistical analysis is performed on the datasets obtained during EX1005 and from the EX0909 Necker Ridge cruises using the surface difference functionality in Fledermaus. The results are expected to be very similar to the surface difference analysis performed earlier this year on Necker Ridge datasets from the EX1003 and EX0909 cruises. The azimuths of the lines compared from EX1005 and EX0909 cruises were not perfectly perpendicular or completely overlapping nevertheless a comparison was still made. The area of data overlap was gridded at a 50 meter cell size, with a precision of 6 in CARIS HIPS 6.1, and exported to ASCII xyz. Fledermaus v.6 sd objects were then created out of each dataset's ASCII xyz file after some processing using both the IVS Avggrid and Dmagic programs. The Fledermaus sd objects from EX1005 and EX0909 were compared and difference plotted (see Figure 1). The comparison depths were made from approximately 2500 to 5000 meters, across the width of Necker Ridge. The surface difference statistical analysis (see Figure 2) showed an average difference of 6.8 meters and a standard deviation of 13.7 meters. The largest observed difference of up to 219.7 meters was probably due to degraded data quality in extreme outer beams. The average and Median surface differences were 7.5, and 7.1 meters respectively. Overall the comparison showed even greater precision of the EX multibeam systems than that made between EX1003 and the Necker Ridge data.

Figure 1. Screen capture of Fledermaus showing the difference surface comparing multibeam data of



Necker Ridge mapped by the EX in 2009 and 2010. Note: depth color bar shows bathymetry depth values, not depth difference comparison values. Image credit: NOAA.

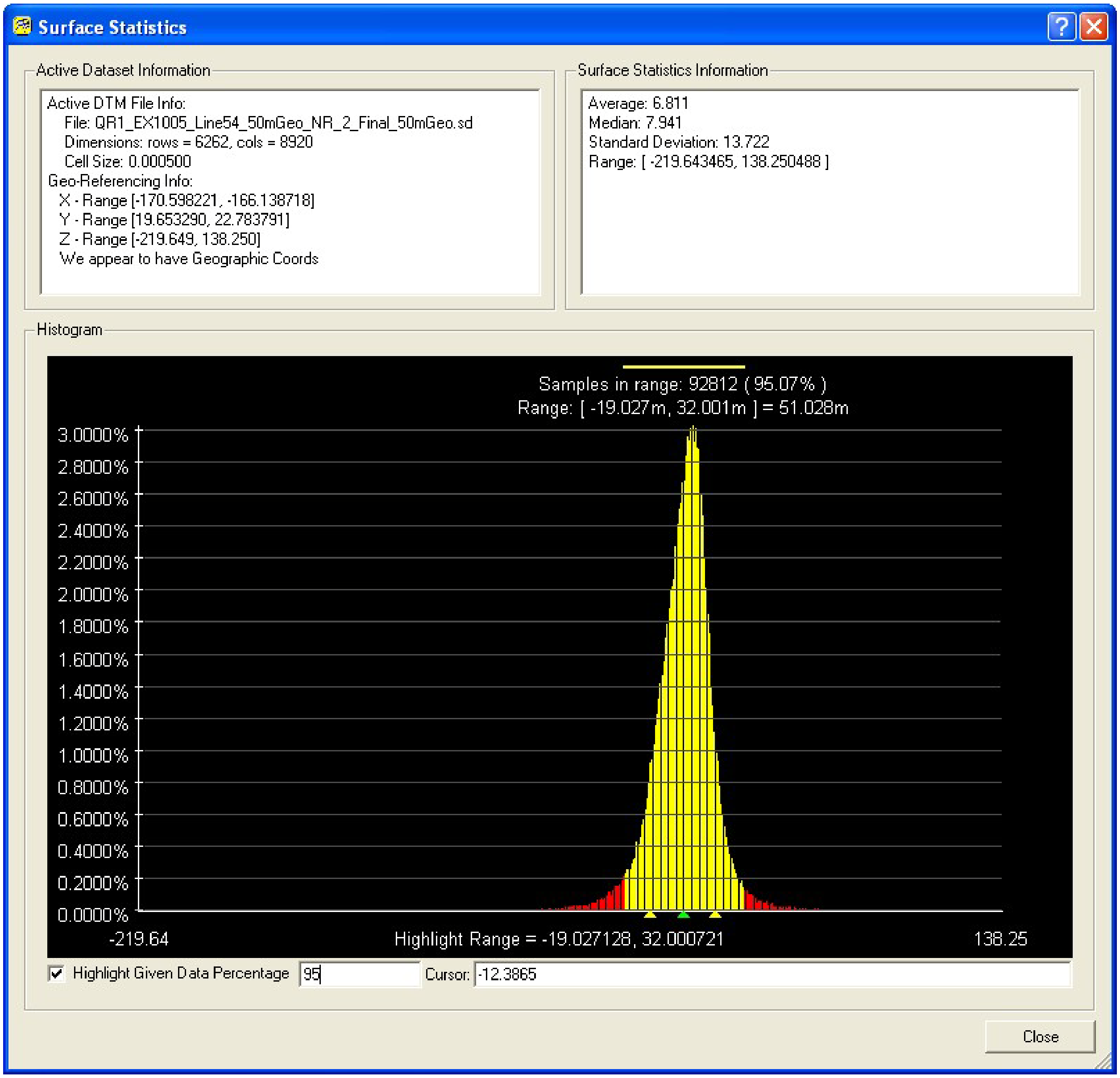


Figure 2. Screen capture of Fledermaus showing the Statistical Analysis results of 2009 vs. 2010 Necker Ridge multibeam data. Image credit: NOAA.

Appendix B: Tables of Files Collected

Multibeam File Log

EX1005 MULTIBEAM FILE LOG		
Julian Day	**Date (GMT)**	**MB Line Filename**
235	08/23/2010	0000_20100823_042851_EX.all
235	08/23/2010	0001_20100823_060234_EX.all
235	08/23/2010	0002_20100823_113952_EX.all

235	08/23/2010	0003_20100823_173952_EX.all
235	08/23/2010	0004_20100823_225029_EX.all
236	08/24/2010	0005_20100824_000950_EX.all
236	08/24/2010	0006_20100824_060943_EX.all
236	08/24/2010	0007_2010824_120955_EX.all
236	08/24/2010	0008_20100824_181002_EX.all
237	08/25/2010	0009_20100825_000004_EX.all
237	08/25/2010	0010_20100825_060001_EX.all
237	08/25/2010	0011_20100825_120002_EX.all
237	08/25/2010	0012_20100825_140350_EX.all
237	08/25/2010	0013_20100825_200350_EX.all
238	08/26/2010	0014_20100825_235959_EX.all
238	08/26/2010	0015_20100826_060000_EX.all
238	08/26/2010	0016_20100826_074323_EX.all
238	08/26/2010	0017_20100826_134320_EX.all
238	08/26/2010	0018_20100826_194322_EX.all
*	DNE	0019
*	DNE	0020
238	08/26/2010	0021_20100826_215128_EX.all
239	08/27/2010	0022_20100827_000003_EX.all
239	08/27/2010	0023_20100827_060510_EX.all
239	08/27/2010	0024_20100827_120512_Ex.all
239	08/27/2010	0025_20100827_180517_EX.all
240	08/28/2010	0026_20100828_000005_EX.all
240	08/28/2010	0027_20100828_060752_EX.all
240	08/28/2010	0028_20100828_120753_EX.all
240	08/28/2010	0029_20100828_180749_EX.all
241	08/29/2010	0030_20100829_000007_EX.all
241	08/29/2010	0031_20100829_060723_EX.all
241	08/29/2010	0032_20100829_120727_EX.all
241	08/29/2010	0033_20100829_180726_EX.all
242	08/30/2010	0034_20100830_000007_EX.all
242	08/30/2010	0035_20100830_060010_EX.all
242	08/30/2010	0036_20100830_120006_EX.all
242	08/30/2010	0037_20100830_131046_EX.all
242	08/30/2010	0038_20100830_191045_EX.all
243	08/31/2010	0039_20100831_000005_EX.all
243	08/31/2010	0040_20100831_060007_EX.all
243	08/31/2010	0041_20100831_120052_EX.all
243	08/31/2010	0042_20100831_180047_EX.all
244	09/01/2010	0043_20100901_000008_EX.all
244	09/01/2010	0044_20100901_042011_EX.all
244	09/01/2010	0045_2010901_061812_EX.all
244	09/01/2010	0046_2010901_121814_EX.all
244	09/01/2010	0047_20100901_181817_EX.all
245	09/02/2010	0048_20100902_000003_EX.all
245	09/02/2010	0049_20100902_060513_EX.all
245	09/02/2010	0050_20100902_120510_EX.all
245	09/02/2010	0051_20100902_180511_EX.all
246	09/03/2010	0052_20100903_000003_EX.all
246	09/03/2010	0053_2010903_060008_EX.all
246	09/03/2010	0054_2010903_093504_EX.all
246	09/03/2010	0055_20100903_153511_EX.all
246	09/03/2010	0056_20100903_213512_EX.all
247	09/04/2010	0057_20100904_000001_EX.all
247	09/04/2010	0058_20100904_060814_EX.all
247	09/04/2010	0059_20100904_120809_EX.all
247	09/04/2010	0060_20100904_180815_EX.all
248	09/05/2010	9061_20100905_000008_EX.all
248	09/05/2010	0062_20100905_055949_EX.all
248	09/05/2010	0063_20100905_115949_EX.all
248	09/05/2010	0064_20100905_175949_EX.all
248	09/05/2010	0065_20100905_235948_EX.all
248	09/05/2010	0066_20100906_000003_EX.all

Sound Velocity Profile Log

EX1005 SVP FILE LOG			
DATE (GMT)	**TIME (GMT)**	**XBT/CTD FILE NAME**	**LAT/LONG (WGS84)**
8/23/2010	04:43:03	XBT_082310_01.asvp	13 32.16943N 144 35.85742E
8/23/2010	10:26:52	XBT_082310_02.asvp	13 47.60181N 145 26.09375E
8/23/2010	14:13:12	XBT_082310_03.asvp	13 57.02527N 146 2.5166E
8/23/2010	20:18:03	XBT_082310_04.asvp	14 13.62646N 147 2.29883E
8/24/2010	02:35:12	XBT_082410_05.asvp	14 28.48962N 147 55.95703E
8/24/2010	08:43:58	BAD CAST	-
8/24/2010	08:49:05	XBT_082410_07.asvp	14 45.78589N 148 58.44238E

8/24/2010	14:35:04	XBT_082410_08.asvp	15 1.7627N 149 56.21484E
8/24/2010	20:33:39	XBT_082410_09.asvp	15 15.9721N 150 55.1710E
8/25/2010	02:40:06	XBT_082510_10.asvp	15 30.22144N 151 54.9375E
8/25/2010	08:42:36	XBT_082510_11.asvp	15 44.00024N 152 52.83984E
8/25/2010	14:25:46	XBT_082510_12.asvp	15 57.31982N 153 48.85352E
8/25/2010	19:34:10	XBT_082510_13.asvp	16 9.11572N 154 38.5176E
8/26/2010	01:47:19	XBT_082610_14.asvp	16 23.75439N 155 40.1875E
8/26/2010	07:49:24	XBT_082610_15.asvp	16 38.54504N 156 42.62207E
8/26/2010	13:35:42	XBT_082610_16.asvp	16 51.74133N 157 38.34668E
8/26/2010	19:34:55	XBT_082610_17.asvp	17 4.15295N 158 30.85547E
8/27/2010	2:13:59	XBT_082710_18.asvp	17 18.20898N 159 30.46191E
8/27/2010	7:55:01	XBT_082710_19.asvp	17 29.9260N 160 25.7744E
8/27/2010	13:30:34	XBT_082710_20.asvp	17 40.0575N 161 21.22168E
8/27/2010	19:32:09	XBT_082710_21.asvp	17 51.4734N 162 23.6416E
8/28/2010	1:38:02	XBT_082810_22.asvp	18 3.13806N 163 27.48438E
8/28/2010	7:49:55	XBT_082810_23.asvp	18 14.79102N 163 31.37109E
8/28/2010	13:31:20	XBT_082810_24.asvp	18 25.4476N 165 29.8633E
8/28/2010	19:31:59	XBT_082810_25.asvp	18 36.6710N 166 31.5059E
8/29/2010	1:34	XBT_082910_26.asvp	18 47.9574N 167 33.6354E
8/29/2010	7:46:48	XBT_082910_27.asvp	19 0.001N 168 39.900E
8/29/2010	13:28	XBT_082910_28.asvp	19 11.4600N 169 42.9300E
8/29/2010	19:31	XBT_082910_29.asvp	19 20.6940N 170 49.2712E
8/30/2010	1:36	XBT_083010_30.asvp	19 28.185N 171 49.2294E
8/30/2010	7:43:13	XBT_083010_31.asvp	19 36.050N 172 52.260E
8/30/2010	13:39:19	XBT_083010_32.asvp	19 43.745N 173 53.88672E
8/30/2010	18:37:30	XBT_083010_33.asvp	19 50.3055N 174 46.5117E
8/31/2010	0:39:29	XBT_083110_34.asvp	19 58.02258N 175 48.47266E

8/31/2010	7:04	XBT_083110_35.asvp	20 6.43909N 176 56.07227E
8/31/2010	12:35	XBT_083110_36.asvp	20 13.6748N 177 54.23047E
8/31/2010	18:32	XBT_083110_37.asvp	20 21.4749N 178 56.9688E
8/31/2010	0:34:47	XBT_090110_38.asvp	20 29.10364N 179 58.42383E
9/1/2010	6:44	XBT_090110_39.asvp	20 33.33484N 178 58.67383W
9/1/2010	12:27:27	XBT_090110_40.asvp	20 37.8784N 177 58.59961W
9/1/2010	18:34:09	XBT_090110_41.asvp	20 41.6826N 176 51.7676W
9/2/2010	0:35:34	XBT090210_42.asvp	20 45.97412N 175 46.56445W
9/2/2010	6:42:04	XBT_090210_43.asvp	20 50.52854N 174 41.41602W
9/2/2010	11:25:06	XBT_090210_44.asvp	20 5.6343N 173 49.7129W
9/2/2010	17:37:18	XBT_090210_45.asvp	20 58.0130N 172 43.0117E
9/2/2010	23:33:23	XBT_090210_46.asvp	21 2.18555N 171 39.46094W
9/3/2010	5:51:20	XBT_090310_47.asvp	21 6.53174N 170 33.1543W
9/3/2010	11:35:30	XBT_090310_48.asvp	21 8.88916N 169 31.1543W
9/3/2010	17:33:44	XBT_090310_49.asvp	21 9.3115N 168 24.9356W
9/3/2010	23:33:48	XBT_090310_50.asvp	21. 9.72998N 167 18.7832W
9/4/2010	5:42:38	BAD CAST	-
9/4/2010	5:48:07	XBT_090410_52.asvp	21 10.13647N 166 13.38867W
9/4/2010	11:29:24	XBT_090410_53.asvp	21 10.51636N 165 13.55469W
9/4/2010	16:32:09	XBT_090410_54.asvp	21 10.8586N 164 23.0117W
9/4/2010	22:36:46	XBT_090410_55.asvp	21 11.23926N 163 20.30762W
9/5/2010	4:45:28	XBT_090510_56.asvp	21 11.6062N 162 22.3388W
9/5/2010	10:20:46	XBT_090510_57.asvp	21 11.95361N 161 27.75293W
9/5/2010	16:36:38	XBT_090510_58.asvp	21 12.3442N 160 26.4981W
9/5/2010	22:34:48	XBT_090510_59.asvp	21 11.52344N 159 24.89355W

Appendix C: List of Acronyms

BIST – Built In System Test

CDR - Commander

CO – Commanding Officer

CPR – Continuous Plankton Recorder

CTD – conductivity temperature and depth (equipment)

CW – continuous wave

dB – decibels

deg - degree

DGPS –Differential Global Positioning System

EEZ –Exclusive Economic Zone

ET – Electronics Technician

EX – NOAA Ship *Okeanos Explorer*

ft – feet

FM – frequency modulation

FOO – Field Operations Officer

Hdg - heading

Km – kilometers

KM – Kongsberg Maritime AS

Kt(s) – knots

LT – lieutenant

LTJG – lieutenant junior grade

MBES – multibeam echosounder

NMFS – National Marine Fisheries Service

NOAA – National Oceanic and Atmospheric Administration

OER – Office of Ocean Exploration and Research

OMAO – Office of Marine and Aviation Operations

SIS – Seafloor Information System – Kongsberg proprietary software

SST – Senior Survey Technician

stbd - starboard

TRU – transmit and receive unit

UNH-CCOM/JHC – University of New Hampshire Center for Coastal and Ocean Mapping / Joint Hydrographic Center

UPS – uninterruptable power supply

WD – water depth

XBT – expendable bathythermograph

Appendix D: EM302 description and operational specs

EM 302 : Ideal for Ocean Exploration

There are several features of the Okeanos Explorer's 30 kHz multibeam that make it an excellent tool for ocean exploration. The following is a brief description of these features.

Depth Range

The system is designed to map the seafloor in water depths of 10 to 7000 meters. This leaves only the deepest parts of the deeper ocean trenches out of the EM 302's reach. Moreover, operational experience on the *Okeanos Explorer* has shown consistent EM 302 bottom detection at depth ranges in excess of 8000m.

High Density Data

In multibeam data, the denser the data, the finer resolution maps you can produce. The system can operate in dual swath, or multiping mode, which results in increased along track data density. This is achieved by detecting two swaths per ping cycle, resulting in up to 864 beams per ping.

The Okeanos Explorer mapping team typically operates the multibeam in high density equidistant ping mode, which results in up to 864 soundings on the seafloor per ping.

Full Suite of Data Types Collected

The system collects seafloor backscatter data, which provides information about the character of the seafloor in terms of bottom type.

The system also collects water column backscatter data, which has the ability to detect gaseous plumes in the water column. The full value of this feature is still being realized.

FM chirp mode is utilized in water depths greater than 1000 meters, and allows for the detection of the bottom further out from nadir than with previous 30 kHz systems.

Multibeam Primer

The area of the seafloor covered, or ensonified, by a single beam within a pulse of sound, or ping, is called the beam footprint. This beam footprint is defined in terms of the across track and along track values. Both of these values are dependent on water depth and the beam width at which the sound pulse is transmitted and received. The across track beam width value is also dependent on the receive angle, or "listening" angle, of the system, and the angle from nadir which it is received from. The receive angle for the receive transducer on the Okeanos Explorer EM302 is 1°, which is the smallest possible angle currently available for the EM302 system. The further out from nadir a sounding occurs, the larger the footprint will be. For example, as seen in Table 1 below, in 2000 meters of water, a beam footprint will have a radius of 18 meters at nadir but 25 meters by the time it hits the seafloor at an angle 140 degrees out from nadir.

Calculated acrosstrack acoustic beam footprint for EM 302 (high density ping mode, 432 soundings/profile)				
Water depth (m)	**Angle from nadir**			
50	1 deg RX center	90 deg	120 deg	140 deg
100	1	0.5	1	1
200	2	1	2	3
400	4	2	3	5
1000	7	4	6	10
2000	18	9	16	25
4000	35	19	32	-
6000	70	37	-	-
7000	105	56	-	-

Table 2. Calculated across track EM 302 beam footprint. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 17.

Calculated acrosstrack sounding density for EM 302 (high density ping mode, 432 soundings/profile)			
Water depth (m)	**Swath Width**		
50	90 deg	120 deg	140 deg
100	0.2	0.4	0.9
200	0.5	0.8	1.7
400	0.9	1.6	3.5
1000	1.9	3.2	6.9
2000	4.6	8.1	17.4
4000	9.3	16.2	-

Table 3. Calculated across track EM 302 sounding density. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 17.

Acrosstrack sounding density describes the spacing between individual soundings on the seafloor in the acrosstrack direction. The maximum swath of the EM 302 is 150 degrees. At this swath, the sounding density will be the least dense, since the beams will be spread out over a larger horizontal distance over the seafloor. As the swath angle (width) is decreased, the sounding density will increase, as the same number of beams are now spread out over a smaller horizontal distance over the seafloor.

Calculated ping rate and alongtrack resolution for EM 302

140 deg swath, one profile per ping					
			Alongtrack distance between profiles (m)		
Water depth (m)	**Swath Width (m)**	**Ping Rate (pings/second)**	**@4 kts**	**@8 kts**	**@12 kts**
50	275	3.2	0.7	1.2	1.9
100	550	1.8	1.1	2.2	3.3
200	1100	1	2.1	4.2	6.3
400	2200	0.5	4.1	8.2	12.2
1000	5500	0.2	10	20	30
2000	8000	0.1	15.2	30.5	45.7
4000	8000	0.06	19.2	38.5	57.7
6000	8000	0.04	24.5	49	73.4

Table 4. Calculated ping rate and along track EM 302 sounding density, one profile per ping. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 15.

Calculated ping rate and alongtrack resolution for EM 302					
140 deg swath, two profiles per ping					
			Alongtrack distance between profiles (m)		
Water depth (m)	**Swath Width (m)**	**Ping Rate**	**@4 kts**	**@8 kts**	**@12 kts**
50	275	3.2	0.3	0.6	0.9
100	550	1.8	0.6	1.1	1.7
200	1100	1	1.1	2.1	3.2
400	2200	0.5	2	4.1	6.1
1000	5500	0.2	5	10	15
2000	8000	0.1	7.6	15.2	22.8

Table 5. Calculated ping rate and along track EM 302 sounding density, two profiles per ping. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 15.

Reference: Kongsberg Product Description: EM 302 multibeam echosounder

Appendix E: EM302 Processing Parameters

#// Database Parameters

#// Seafloor Information System
#// Kongsberg Maritime AS
#// Saved: 2010.08.31 11:59:25

#// Build info:
#* SIS: [Version: 3.6.4, Build: 174 , DBVersion 16.0 CD generated: Mon Mar 30 2009 14:00:00]
[Fox ver = 1.6.29]
[db ver = 16, proc = 16.0]
[OTL = 4.0.-95]
[ACE ver = 5.5]
[Coin ver = 2.4.4]
[Simage ver = 1.6.2a]
[Dime ver = DIME v0.9]
[STLPort ver = 513]
[FreeType ver = 2.1.9]
[TIFF ver = 3.8.2]
[GeoTIFF ver = 1230]
[GridEngine ver = 2.3.0]

#* Language [3] #// Current language, 1-Norwegian, 2-German,3-English, 4-Spanish

#* Type [302]
#* Serial no. [101]
#* Number of heads [2]
#* System descriptor [50331648]
#// 03000000

#// ***

#// Installation parameters

#{ Input Setup #// All Input setup parameters

#{ COM1 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#* Baud rate: [9600]
#* Data bits [8]
#* Stop bits: [1]
#* Parity: [NONE]
#} Com. settings

#{ Position #// Position input settings.
#* None [1] [0]
#* GGK [1] [0]
#* GGA [1] [1]
#* GGA_RTK [1] [0]
#* SIMRAD90 [1] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [0] [0]
#* MK39 Mod2 Attitude, [0] [0]
#* ZDA Clock [1] [1]
#* HDT Heading [0] [0]
#* SKR82 Heading [0] [0]
#* DBS Depth [1] [0]
#* DBT Depth [1] [0]
#* EA500 Depth [0] [0]
#* ROV. depth [1] [0]
#* Height, special purp [1] [0]
#* Ethernet AttVel [0] [0]
#} Input Formats

#} COM1

#{ COM2 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#* Baud rate: [19200]
#* Data bits [8]
#* Stop bits: [1]
#* Parity: [NONE]
#} Com. settings

#{ Position #// Position input settings.
#* None [0] [1]
#* GGK [0] [0]
#* GGA [0] [0]
#* GGA_RTK [0] [0]
#* SIMRAD90 [0] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [1] [1]
#* MK39 Mod2 Attitude, [0] [0]
#* ZDA Clock [0] [0]
#* HDT Heading [0] [0]
#* SKR82 Heading [0] [0]
#* DBS Depth [0] [0]
#* DBT Depth [0] [0]
#* EA500 Depth [0] [0]
#* ROV. depth [0] [0]
#* Height, special purp [0] [0]
#* Ethernet AttVel [0] [0]
#} Input Formats

#} COM2

#{ COM3 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#* Baud rate: [4800]
#* Data bits [8]
#* Stop bits: [1]
#* Parity: [NONE]
#} Com. settings

#{ Position #// Position input settings.
#* None [1] [1]
#* GGK [1] [0]
#* GGA [1] [0]
#* GGA_RTK [1] [0]
#* SIMRAD90 [1] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [0] [0]
#* MK39 Mod2 Attitude, [0] [0]
#* ZDA Clock [0] [0]
#* HDT Heading [1] [1]
#* SKR82 Heading [0] [0]
#* DBS Depth [1] [0]
#* DBT Depth [1] [0]
#* EA500 Depth [0] [0]
#* ROV. depth [1] [0]
#* Height, special purp [1] [0]
#* Ethernet AttVel [0] [0]
#} Input Formats

#} COM3

#{ COM4 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#* Baud rate: [9600]
#* Data bits [8]
#* Stop bits: [1]
#* Parity: [NONE]
#} Com. settings

#{ Position #// Position input settings.
#* None [1] [1]
#* GGK [1] [0]
#* GGA [1] [0]
#* GGA_RTK [1] [0]
#* SIMRAD90 [1] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [0] [0]
#* MK39 Mod2 Attitude, [0] [0]
#* ZDA Clock [0] [0]
#* HDT Heading [0] [0]
#* SKR82 Heading [0] [0]
#* DBS Depth [1] [0]
#* DBT Depth [1] [0]
#* EA500 Depth [0] [0]
#* ROV. depth [1] [0]
#* Height, special purp [1] [0]
#* Ethernet AttVel [0] [0]
#} Input Formats

#} COM4

#{ UDP2 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#// N/A
#} Com. settings

#{ Position #// Position input settings.
#* None [1] [1]
#* GGK [1] [0]
#* GGA [1] [0]
#* GGA_RTK [1] [0]
#* SIMRAD90 [1] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [0] [0]
#* MK39 Mod2 Attitude, [0] [0]
#* ZDA Clock [0] [0]
#* HDT Heading [0] [0]
#* SKR82 Heading [0] [0]
#* DBS Depth [0] [0]
#* DBT Depth [0] [0]
#* EA500 Depth [1] [0]
#* ROV. depth [0] [0]
#* Height, special purp [0] [0]
#* Ethernet AttVel [0] [0]
#} Input Formats

#} UDP2

#{ UDP3 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#// N/A
#} Com. settings

#{ Position #// Position input settings.
#* None [0] [1]
#* GGK [0] [0]
#* GGA [0] [0]
#* GGA_RTK [0] [0]
#* SIMRAD90 [0] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [0] [0]
#* MK39 Mod2 Attitude, [0] [0]
#* ZDA Clock [0] [0]
#* HDT Heading [1] [0]
#* SKR82 Heading [0] [0]
#* DBS Depth [1] [0]

#* DBT Depth [1] [0]
#* EA500 Depth [0] [0]
#* ROV. depth [1] [0]
#* Height, special purp [1] [0]
#* Ethernet AttVel [0] [0]
#} Input Formats

#} UDP3

#{ UDP4 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#// N/A
#} Com. settings

#{ Position #// Position input settings.
#* None [0] [1]
#* GGK [0] [0]
#* GGA [0] [0]
#* GGA_RTK [0] [0]
#* SIMRAD90 [0] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [1] [0]
#* MK39 Mod2 Attitude, [0] [0]
#* ZDA Clock [0] [0]
#* HDT Heading [1] [0]
#* SKR82 Heading [0] [0]
#* DBS Depth [1] [0]
#* DBT Depth [1] [0]
#* EA500 Depth [0] [0]
#* ROV. depth [1] [0]
#* Height, special purp [1] [0]
#* Ethernet AttVel [0] [0]
#} Input Formats

#} UDP4

#{ UDP5 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#// N/A
#} Com. settings

#{ Position #// Position input settings.
#* None [0] [0]
#* GGK [0] [0]
#* GGA [0] [0]
#* GGA_RTK [0] [0]
#* SIMRAD90 [0] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [0] [0]
#* MK39 Mod2 Attitude, [0] [0]
#* ZDA Clock [0] [0]
#* HDT Heading [0] [0]
#* SKR82 Heading [0] [0]
#* DBS Depth [0] [0]
#* DBT Depth [0] [0]
#* EA500 Depth [0] [0]
#* ROV. depth [0] [0]
#* Height, special purp [0] [0]
#* Ethernet AttVel [1] [1]
#} Input Formats

#{ Attitude Velocity settings #// Only relevant for UDP5 on EM122, EM302 and EM710, currently
#* Attitude 1 [1] [1]
#* Attitude 2 [1] [0]
#* Use Ethernet 2 [1] [1]
#* Port: [5602]
#* IP addr.: [192.168.2.20]
#* Net mask: [255.255.255.0]
#} Attitude Velocity settings

#} UDP5

#{ Misc. #// Misc. input settings.
#* External Trigger [1] [0]
#} Misc.

#} Input Setup

#{ Output Setup #// All Output setup parameters

#* PU broadcast enable [1] [1]
#* Log watercolumn to s [1] [1]

#{ Host UDP1 #// Host UDP1 Port: 16100

#{ Datagram subscription #//
#* Depth [0] [0]
#* Raw range and beam a [0] [0]
#* Seabed Image [0] [0]
#* Central Beams [0] [0]
#* Position [0] [0]
#* Attitude [0] [0]
#* Heading [0] [0]
#* Height [0] [0]
#* Clock [0] [0]
#* Single beam echosoun [0] [0]
#* Sound Speed Profile [0] [1]
#* Runtime Parameters [0] [1]
#* Installation Paramet [0] [1]
#* BIST Reply [0] [1]
#* Status parameters [0] [1]
#* PU Broadcast [0] [0]
#* Stave Display [0] [0]
#* Water Column [0] [0]
#* Internal, Range Data [0] [0]
#* Internal, Scope Data [0] [0]
#} Datagram subscription

#} Host UDP1

#{ Host UDP2 #// Host UDP2 Port: 16101

#{ Datagram subscription #//
#* Depth [1] [1]
#* Raw range and beam a [1] [1]
#* Seabed Image [1] [1]
#* Central Beams [1] [0]
#* Position [1] [1]
#* Attitude [1] [1]
#* Heading [1] [1]
#* Height [1] [1]
#* Clock [1] [1]
#* Single beam echosoun [1] [1]
#* Sound Speed Profile [0] [1]
#* Runtime Parameters [0] [1]
#* Installation Paramet [0] [1]
#* BIST Reply [1] [1]
#* Status parameters [0] [1]
#* PU Broadcast [1] [0]
#* Stave Display [0] [1]
#* Water Column [0] [1]
#* Internal, Range Data [1] [0]
#* Internal, Scope Data [1] [0]
#} Datagram subscription

#} Host UDP2

#{ Host UDP3 #// Host UDP3 Port: 16102

#{ Datagram subscription #//
#* Depth [0] [1]
#* Raw range and beam a [0] [0]
#* Seabed Image [0] [0]
#* Central Beams [0] [0]
#* Position [0] [0]
#* Attitude [0] [1]
#* Heading [0] [0]
#* Height [0] [1]
#* Clock [0] [0]
#* Single beam echosoun [0] [1]
#* Sound Speed Profile [0] [1]
#* Runtime Parameters [0] [0]
#* Installation Paramet [0] [1]
#* BIST Reply [0] [0]
#* Status parameters [0] [0]
#* PU Broadcast [0] [0]
#* Stave Display [0] [0]
#* Water Column [0] [0]
#* Internal, Range Data [0] [0]
#* Internal, Scope Data [0] [1]
#} Datagram subscription

#} Host UDP3

#{ Host UDP4 #// Host UDP4 Port 16103

#{ Datagram subscription #//
#* Depth [1] [1]
#* Raw range and beam a [1] [0]
#* Seabed Image [1] [0]
#* Central Beams [1] [0]
#* Position [1] [0]
#* Attitude [1] [0]
#* Heading [1] [0]
#* Height [1] [0]

#* Clock [1] [0]
#* Single beam echosoun [1] [0]
#* Sound Speed Profile [1] [0]
#* Runtime Parameters [1] [0]
#* Installation Paramet [1] [0]
#* BIST Reply [1] [0]
#* Status parameters [1] [0]
#* PU Broadcast [1] [0]
#* Stave Display [1] [0]
#* Water Column [1] [0]
#* Internal, Range Data [1] [0]
#* Internal, Scope Data [1] [0]
#} Datagram subscription

#} Host UDP4

#{ Watercolumn #// Host UDP4 Port 16103

#{ Datagram subscription #//
#* Depth [1] [1]
#* Raw range and beam a [1] [1]
#* Seabed Image [1] [1]
#* Central Beams [1] [0]
#* Position [1] [1]
#* Attitude [1] [1]
#* Heading [1] [1]
#* Height [1] [1]
#* Clock [1] [1]
#* Single beam echosoun [1] [1]
#* Sound Speed Profile [1] [1]
#* Runtime Parameters [1] [1]
#* Installation Paramet [1] [1]
#* BIST Reply [1] [1]
#* Status parameters [1] [1]
#* PU Broadcast [1] [0]
#* Stave Display [1] [0]
#* Water Column [1] [1]
#* Internal, Range Data [1] [0]
#* Internal, Scope Data [1] [0]
#} Datagram subscription

#} Watercolumn

#} Output Setup

#{ Clock Setup #// All Clock setup parameters

#{ Clock #// All clock settings.
#* Source: [1] #// External ZDA Clock
#* 1PPS Clock Synch. [1] [1]
#* Offset (sec.): [0]
#} Clock

#} Clock Setup

#{ Settings #// Sensor setup parameters

#{ Positioning System Settings #// Position related settings.

#{ COM1 #// Positioning System Ports:
#* P1T [0] #// System
#* P1M [0] #// Enable position motion correction
#* P1D [0.000] #// Position delay (sec.):
#* P1G [WGS84] #// Datum:
#* P1Q [1] #// Enable
#* Pos. qual. indicator [] #//
#} COM1

#} Positioning System Settings

#{ Motion Sensor Settings #// Motion related settings.

#{ COM2 #// Motion Sensor Ports:
#* MRP [RP] #// Rotation (POSMV/MRU)
#* MSD [0] #// Motion Delay (msec.):
#* MAS [1.00] #// Motion Sensor Roll Scaling:
#} COM2

#} Motion Sensor Settings

#{ Active Sensors #//
#* APS [0] [COM1] #// Position:
#* ARO [2] [COM2] #// Motion:
#* AHE [2] [COM2] #// Motion:
#* AHS [3] [COM3] #// Heading:
#} Active Sensors

#} Settings

#{ Locations #// All location parameters

#{ Location offset (m) #//

#{ Pos, COM1: #//
#* P1X [0.00] #// Forward (X)
#* P1Y [0.00] #// Starboard (Y)
#* P1Z [0.00] #// Downward (Z)
#} Pos, COM1:

#{ Pos, COM3: #//
#* P2X [0.00] #// Forward (X)
#* P2Y [0.00] #// Starboard (Y)
#* P2Z [0.00] #// Downward (Z)
#} Pos, COM3:

#{ Pos, COM4/UDP2: #//
#* P3X [0.00] #// Forward (X)
#* P3Y [0.00] #// Starboard (Y)
#* P3Z [0.00] #// Downward (Z)
#} Pos, COM4/UDP2:

#{ TX Transducer: #//
#* S1X [6.147] #// Forward (X)
#* S1Y [1.822] #// Starboard (Y)
#* S1Z [6.796] #// Downward (Z)
#} TX Transducer:

#{ RX Transducer: #//
#* S2X [2.497] #// Forward (X)
#* S2Y [2.481] #// Starboard (Y)
#* S2Z [6.790] #// Downward (Z)
#} RX Transducer:

#{ Attitude 1, COM2: #//
#* MSX [0.00] #// Forward (X)
#* MSY [0.00] #// Starboard (Y)
#* MSZ [0.00] #// Downward (Z)
#} Attitude 1, COM2:

#{ Attitude 2, COM3: #//
#* NSX [0.00] #// Forward (X)
#* NSY [0.00] #// Starboard (Y)
#* NSZ [0.00] #// Downward (Z)
#} Attitude 2, COM3:

#{ Waterline: #//
#* WLZ [1.838] #// Downward (Z)
#} Waterline:

#} Location offset (m)

#} Locations

#{ Angular Offsets #// All angular offset parameters

#{ Offset angles (deg.) #//

#{ TX Transducer: #//
#* S1R [0.00] #// Roll
#* S1P [0.00] #// Pitch
#* S1H [359.98] #// Heading
#} TX Transducer:

#{ RX Transducer: #//
#* S2R [0.00] #// Roll
#* S2P [0.00] #// Pitch

#* S2H [0.03] #// Heading
#} RX Transducer:

#{ Attitude 1, COM2: #//
#* MSR [0.00] #// Roll
#* MSP [-0.80] #// Pitch
#* MSG [0.00] #// Heading
#} Attitude 1, COM2:

#{ Attitude 2, COM3: #//
#* NSR [0.00] #// Roll
#* NSP [0.00] #// Pitch
#* NSG [0.00] #// Heading
#} Attitude 2, COM3:

#{ Stand-alone Heading: #//
#* GCG [0.00] #// Heading
#} Stand-alone Heading:

#} Offset angles (deg.)

#} Angular Offsets

#{ ROV. Specific #// All ROV specific parameters

#{ Depth/Pressure Sensor #//
#* DSF [1.00] #// Scaling:
#* DSO [0.00] #// Offset:
#* DSD [0.00] #// Delay:
#* DSH [NI] #// Disable Heave Sensor
#} Depth/Pressure Sensor

#} ROV. Specific

#{ System Parameters #// All system parameters

#{ System Gain Offset #//
#* GO1 [0.0] #// BS Offset (dB)
#} System Gain Offset

#{ Opening angles #//
#* S1S [0] #// TX Opening angle:
#* S2S [1] #// RX Opening angle:
#} Opening angles

#} System Parameters

#// ***
#// Runtime parameters

#{ Sounder Main #//

#{ Sector Coverage #//

#{ Max. angle (deg.): #//
#* MPA [70] #// Port
#* MSA [70] #// Starboard
#} Max. angle (deg.):

#{ Max. Coverage (m): #//
#* MPC [5000] #// Port
#* MSC [5000] #// Starboard
#} Max. Coverage (m):

#* ACM [1] #// Angular Coverage mode: AUTO
#* BSP [2] #// Beam Spacing: HIDENS EQDIST

#} Sector Coverage

#{ Depth Settings #//
#* FDE [4400] #// Force Depth (m)
#* MID [1000] #// Min. Depth (m):
#* MAD [6000] #// Max. Depth (m):
#* DSM [0] #// Dual swath mode: OFF
#* PMO [0] #// Ping Mode: AUTO
#* FME [1] #// FM enable
#} Depth Settings

#{ Stabilization #//
#* YPS [1] #// Pitch stabilization
#* TXA [3] #// Along Direction (deg.):

#{ Yaw Stabilization #//
#* YSM [2] #// Mode: REL. MEAN HEADING
#* YMA [300] #// Heading:
#* HFI [1] #// Heading filter: MEDIUM
#} Yaw Stabilization

#} Stabilization
#} Sounder Main

#{ Sound Speed #//

#{ Sound Speed at Transducer #//
#* SHS [2] #// Source PROFILE
#* SST [15000] #// Sound Speed (dm/sec.):
#* Sensor Offset (m/sec [0] #//
#* Filter (sec.): [5] #//
#} Sound Speed at Transducer

#} Sound Speed

#{ Filter and Gains #//

#{ Filtering #//
#* SFS [1] #// Spike Filter Strength: WEAK
#* PEF [0] #// Penetration Filter Strength: OFF
#* RGS [0] #// Range Gate: SMALL
#* SLF [1] #// Slope
#* AEF [1] #// Aeration
#* STF [1] #// Sector Tracking
#* IFF [1] #// Interference
#} Filtering

#{ Absorption Coefficient #//
#* ABC [5.767] #// 31.5 kHz
#} Absorption Coefficient

#{ Normal incidence sector #//
#* TCA [6] #// Angle from nadir (deg.):
#} Normal incidence sector

#{ Mammal protection #//
#* TXP [0] #// TX power level (dB): Max.
#* SSR [0] #// Soft startup ramp time (min.):
#} Mammal protection
#} Filter and Gains

#{ Data Cleaning #//
#* Active rule: [STANDARD] #//
#{ STANDARD #//
#* PingProc.maxPingCountRadius [10]
#* PingProc.radiusFactor [0.050000]
#* PingProc.medianFactor [1.500000]
#* PingProc.beamNumberRadius [3]
#* PingProc.sufficientPointCount [40]
#* PingProc.neighborhoodType [Elliptical]
#* PingProc.timeRule.use [false]
#* PingProc.overhangRule.use [false]
#* PingProc.medianRule.use [false]
#* PingProc.medianRule.depthFactor [0.050000]
#* PingProc.medianRule.minPointCount [6]
#* PingProc.quantileRule.use [false]

#* PingProc.quantileRule.quantile [0.100000]
#* PingProc.quantileRule.scaleFactor [6.000000]
#* PingProc.quantileRule.minPointCount [40]
#* GridProc.minPoints [8]
#* GridProc.depthFactor [0.200000]
#* GridProc.removeTooFewPoints [false]
#* GridProc.surfaceFitting.surfaceDegree [1]
#* GridProc.surfaceFitting.tukeyConstant [6.000000]
#* GridProc.surfaceFitting.maxIteration [10]
#* GridProc.surfaceFitting.convCriterion [0.010000]
#* GridProc.surfaceDistanceDepthRule.use [false]
#* GridProc.surfaceDistanceDepthRule.depthFactor [0.050000]
#* GridProc.surfaceDistancePointRule.use [false]
#* GridProc.surfaceDistancePointRule.scaleFactor [1.000000]
#* GridProc.surfaceDistanceUnitRule.use [false]
#* GridProc.surfaceDistanceUnitRule.scaleFactor [1.000000]
#* GridProc.surfaceDistanceStDevRule.use [false]
#* GridProc.surfaceDistanceStDevRule.scaleFactor [2.000000]
#* GridProc.surfaceAngleRule.use [false]
#* GridProc.surfaceAngleRule.minAngle [20.000000]
#* SonarProc.use [false]
#* SonarProc.gridSizeFactor [4]
#* SonarProc.mergerType [Average]
#* SonarProc.interpolatorType [TopHat]
#* SonarProc.interpolatorRadius [1]
#* SonarProc.fillInOnly [true]
#} STANDARD

#{ Seabed Image Processing #//
#* Seabed Image Process [1] [0]
#} Seabed Image Processing
#} Data Cleaning

#{ Advanced param. #//
#} Advanced param.

Appendix F: Software versions in use

Software	Version	Purpose
CARIS HIPS and SIPS	6.1 Service Pack 2	Multibeam processing
ECDIS		Ship line keeping
Fledermaus	6.7.0h Build 419 Professional	Multibeam QC
Fledermaus	7.2	Multibeam QC / products
Hypack	9.0.0.22	Survey planning
Hypack	9.0.4.0	Real-time monitoring
Kongsberg SIS (installed 2/12/10)	3.6.4 build 174	EM302 data acquisition
Velocipy (NOAA)	10.7 (r2982)	XBT processing