



MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT

CRUISE EX-11-03 Leg 1: Galapagos Spreading Center (*Mapping, CTD, and Tow-yo*)

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1. Introduction

The NOAA Office of Ocean Exploration and Research is the only federal program dedicated to exploring our deep ocean, closing the prominent gap in our basic understanding of U.S. deep waters and seafloor and delivering the ocean information needed to strengthen the economy, health, and security of our nation.

Using the latest tools and technology, OER **explores** previously unknown areas of our deep ocean, making discoveries of scientific, economic, and cultural value. Through live video streams, online coverage, training opportunities, and real-time events, OER allows scientists, resource managers, students, members of the general public, and others to actively **experience** ocean exploration, expanding available expertise, cultivating the next generation of ocean explorers, and engaging the public in exploration activities. From this exploration, OER makes the collected data needed to **understand** our ocean publicly available, so we can maintain the health of our ocean, sustainably manage our marine resources, accelerate our national economy, and build a better appreciation of the value and importance of the ocean in our everyday lives.



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2. Report Purpose

The purpose of this report is to briefly describe the acoustic seafloor and water-column mapping data collection and processing methods used during the mapping expedition EX-11-03 Leg 1, and to present a summary of the overall mapping results and mapping related cruise activities. A detailed description of the *Okeanos Explorer's* mapping capabilities is available in the 2011 NOAA Ship *Okeanos Explorer* Survey Readiness Report, available in the NOAA Central Library.

3. Cruise Objectives

EX-11-03 Leg 1 is the first of two cruises comprising the Galapagos Rift Expedition (GALREX 2011), exploring the diverse and complex geological formations of the deep Galapagos region. This cruise focused on the collection of contemporary multibeam data over a portion of the Galapagos Rift axis where no prior bathymetric data exists, as well as utilizing CTD Tow-yo operations to sample the bottom 300 meters of the water column in an effort to identify and map dispersing neutrally buoyant hydrothermal plumes. Data from this cruise will be used to guide further exploration within this dynamic region, particularly during the second cruise of the GALREX 2011, EX-11-03 Leg 2.

The expedition commenced in San Diego, CA on June 11, 2011, and concluded in Puntarenas, Costa Rica on July 1, 2011. Operations utilized the ship's deep water mapping systems (Kongsberg EM 302 multibeam sonar), the CTD Tow-yo system developed by NOAA's Pacific Marine Engineering Laboratory (PMEL), and the ship's high-bandwidth satellite connection for daily transfer of incoming data to the awaiting shoreside mapping team and scientists.

The complete objectives for this cruise are detailed in the EX-11-03 Project Instructions, which are archived in the NOAA Central Library.



4. Summary of Mapping Results

EX-11-03 Leg 1 mapped 44,294 square kilometers (6,195 linear kilometers) of seafloor during the 23 days at sea (Figure 1 and Table 1).

Cruise Overview Map

EX-11-03 Leg 1 Galapagos Spreading Center Bathymetric Overview

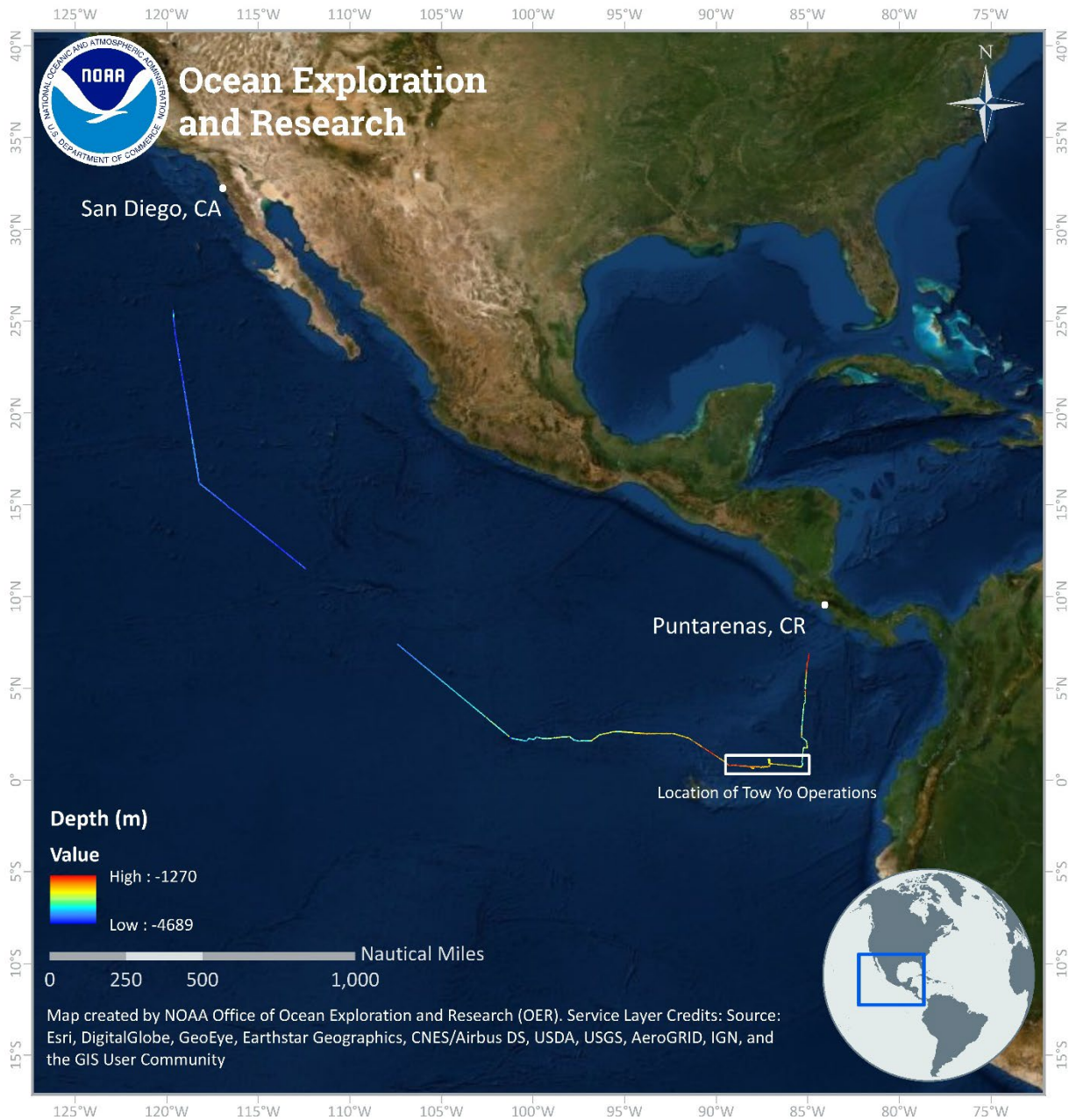


Figure 1. Overview of bathymetric mapping coverage completed during Galapagos Spreading Center expedition (EX-11-03 Leg 1). Map generated in ArcMap.

5. Mapping Statistics

Table 1. Summary statistics of ocean mapping work completed during EX-11-03 Leg 1.

Dates of cruise	June 11 – July 01, 2011
Ship's draft: Start of cruise (06/11/2011) End of cruise (07/01/2011)	Fore: 15' 0", Aft STBD: 14' 10.5" Fore: 14' 6"; Aft STBD: 14' 7"
Linear kilometers of survey with EM 302	6,195
Square kilometers mapped with EM 302	44,294
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files (.all)	93 files/ 29.43 GB
Number / Data Volume of EM 302 water column multibeam files	12 files / 11.0 GB
Number / Data Volume of EK 60 water column split beam files (.raw)	38 / 2.1 GB
Number of XBT casts	66
Number of CTD casts (including test casts)	9



6. Mapping Sonar Setup

Kongsberg EM 302 Multibeam Sonar

NOAA Ship *Okeanos Explorer* is equipped with a 30 kilohertz (kHz) Kongsberg EM 302 multibeam sonar capable of detecting the seafloor in up to 10,000 meters of water and conducting productive mapping operations in 8,000 meters of water. The system generates a 150° beam fan containing up to 432 soundings per ping in waters deeper than 3300 meters. In waters shoaler than 3300 meters the system is operated in dual swath mode, and obtains up to 864 soundings per ping by generating two swaths per ping cycle. The multibeam sonar is used to collect seafloor bathymetry, seafloor backscatter, and water column backscatter data. Backscatter represents the strength of the acoustic signal reflected from a target, such as the seafloor or bubbles in the water column. The system is patch tested annually and the results are reported in the annual readiness report. The 2011 NOAA Ship *Okeanos Explorer* Mapping Systems Readiness Report is available in the NOAA Central Library.

Simrad EK 60 Split-beam Sonars

The ship operated an 18 kHz Simrad EK 60 split-beam fisheries sonar. This sonar is a quantitative scientific echosounder calibrated to identify the target strength of water column acoustic reflectors - typically biological scattering layers, fish, or gas bubbles – providing additional information about water column characteristics and anomalies. This sonar was installed just prior to this cruise, and was not calibrated until EX-11-05 in the Gulf of Mexico, however some uncalibrated opportunistic data was collected over the Galapagos Spreading Center during this cruise.



7. Data Acquisition Summary

Mapping operations included data collection via the EM 302 multibeam sonar and Knudsen 3260 sub-bottom profiler. Data were collected by each sonar concurrently during the transits, with the exception of areas within the Mexican EEZ and the French EEZ in the vicinity of Clipperton Island when all scientific sensors were secured.

Survey lines were planned to either maximize edge matching of existing bathymetric data, or to fill data gaps in areas with existing bathymetric coverage. In regions with no existing data, lines were planned to optimize potential exploration discoveries.

Throughout the cruise multibeam data quality was monitored in real time by acquisition watchstanders. Ship speed was adjusted to maintain data quality as necessary, and line spacing was planned to ensure at least $\frac{1}{4}$ swath width overlap between lines. Cutoff angles in the multibeam acquisition software Seafloor Acquisition System (SIS) were generally left wide open for maximum exploration data collection and routinely adjusted on both the port and starboard side to ensure the best data quality and coverage.

Multibeam data received real time surface sound velocity corrections via the RESON SVP-70 at the sonar head, as well as through profiles generated from Expendable Bathythermographs (XBTs) conducted at intervals no greater than 6 hours, as dictated by local oceanographic conditions. RESON sound velocity values were constantly compared against secondary derived sound speed values from the ship's onboard thermosalinograph flow-through system as a quality assurance measure.



8. Multibeam Sonar Data Quality Assessment and Data Processing

Figure 2 shows the multibeam data processing workflow for this cruise. EM 302 Built-in Self Tests (BISTs) were run throughout the cruise to monitor multibeam sonar system status and are available as ancillary files in the sonar data archives. Raw multibeam bathymetry data files were acquired in SIS, then imported into CARIS HIPS for processing. In CARIS, the attitude and navigation data stored in each file were checked, and erroneous soundings were removed using Swath Editor and Subset Editor. Final bathymetry QC was completed post-cruise onshore at the Center for Coastal and Ocean Mapping at the University of New Hampshire. With the vast majority of surveying completed in deep water, depth measurements were not adjusted for tides, as they are an essentially insignificant percent of the overall water depth. Data cleaning projects were in UTM zone projections for the operations area. Final data products were exported and archived as field geographic WGS84 coordinate reference frame (i.e., unprojected).

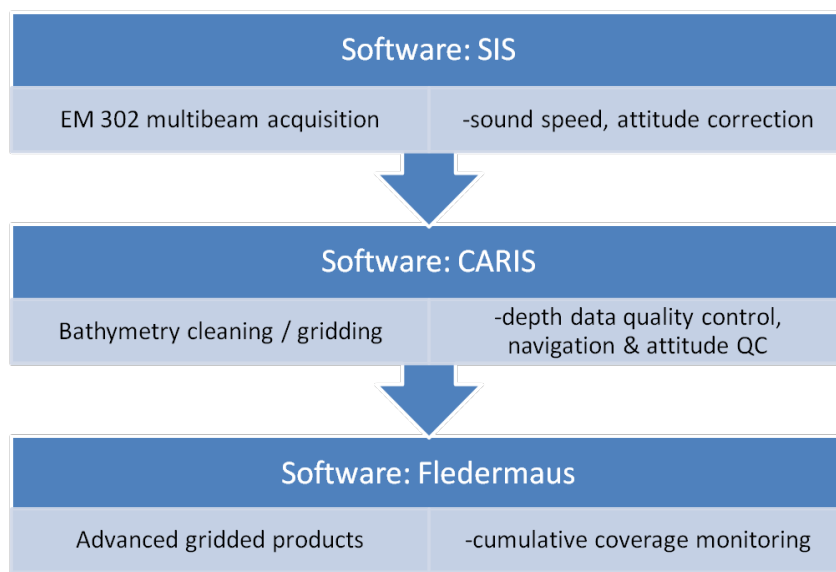


Figure 2. Shipboard multibeam data processing workflow.



9. Data Archival Procedures

All mapping data collected by the NOAA Ship *Okeanos Explorer* are archived and publicly available within 90 days of the end of each cruise via the National Centers for Environmental Information (NCEI) online archives. The complete data management plan (which describes the raw and processed data formats produced for this cruise) is available as an appendix to the EX-11-03 Project Instructions, available in the NOAA Central Library. Ancillary and supporting files are archived with the sonar datasets. These include:

EM 302 Multibeam bathymetry and bottom backscatter dataset:

- Mapping watch stander log
- Weather log
- Sound velocity profile log
- Multibeam acquisition and processing log
- Built-In-System-Tests (BISTs)
- Processor Unit Parameters
- Text files of telnet sessions on the EM 302 transceiver unit (TRU)

Simrad EK split-beam water column dataset:

- Mapping watch stander log
- Weather log
- EK data log

EM 302 Multibeam water column dataset:

- Mapping watch stander log
- Weather log
- Sound velocity profile log
- Multibeam acquisition and processing log
- Built-In-System-Tests (BISTs)
- Processor Unit Parameters
- Text files of telnet sessions on the EM 302 transceiver unit (TRU)
- Multibeam water column data review log if data were reviewed for presence of seeps in Fledermaus MidWater



EM 302 water column data are available in the NCEI Water Column Sonar Archives:
https://www.ngdc.noaa.gov/maps/water_column_sonar/index.html (last accessed
01/07/2020).

EM 302 bathymetry data, supporting informational logs, and ancillary files are available in
the NCEI Data Archives accessible at <https://www.ngdc.noaa.gov/> (last accessed
01/07/2020).



10. Cruise Calendar

All times listed are local ship time, -8 hours from UTC unless otherwise noted.

June – July 2011

Sun	Mon	Tues	Wed	Thur	Fri	Sat
5 Expedition coordinator arrived to ship.	6 Remaining mission personnel arrived to ship.	7 Alongside in San Diego. Harbor Acceptance Testing of EK 60 completed.	8 Fueling occurred. Sailing delayed one day due to mechanical issue.	9 Departed from San Diego. Mapping sensors secured within Mexican EEZ.	10 Mapping sensors secured within Mexican EEZ.	11 Mapping sensors enabled after exiting Mexican EEZ at 1000 PDT.
12 Transit mapping.	13 Transit mapping.	14 Transit mapping.	15 Transit mapping.	16 Transit mapping. Mapping sensors secured within French EEZ at 0600.	17 Mapping sensors enabled after exiting French EEZ at 1800.	18 Transit mapping.
19 Transit mapping.	20 Transit mapping.	21 Transit mapping. Time change to -6 UTC.	22 Arrived at tow-yo transect line at 1100. Commenced 24-hr tow-yo operations.	23 24-hr tow-yo operations.	24 24-hr tow-yo operations.	25 24-hr tow-yo operations.
26 24-hr tow-yo operations.	27 24-hr tow-yo operations.	28 24-hr tow-yo operations.	29 Concluded tow-yo operations at 1400. Transit mapping.	30 Transit mapping.	1 Transit mapping.	2 Ship anchored outside of Puntarenas, Costa Rica.



11. Daily Cruise Log Entries

Generated from the daily expedition situation reports. All times listed are in local ship time (-8 hours from UTC unless otherwise noted).

June 5, 2011

Expedition Coordinator / Mapping Team Lead Meme Lobecker arrives to the ship at 32nd St. Naval Station, San Diego, CA.

June 6, 2011

The following mission personnel arrive to the ship: Elizabeth “Libby” Chase, Vincent Howard, Thomas Kok, Nicholas Kraus, Christopher Pinero, Sharath Ravula, Brendan Reser.

June 7, 2011

The ship prepared for the four-week cruise and departure from US waters. The ship will not return to a US port until August 18, when she pulls into Key West, Florida, at the end of EX-11-04.

The EK 60 GPT was installed and connected to the new 18 kHz transducer that was installed during the recent San Diego emergency dry-dock period. Permission to ping the sonar at the dock after 1800 local time was obtained, and a successful harbor acceptance test (HAT) was performed by the Kongsberg technician and the mapping team lead. System performance will be evaluated as time allows during the cruise.

June 8, 2011

In the morning, the ship moved from the 32nd Street Naval Base, Quay Wall North, Pier 8 in San Diego, to Pier 180 Navy Fuel Pier, Point Loma, San Diego, CA, to take on fuel. Due to a no-sail level problem with the oily water separator, the ship delayed sailing until June 9, at 1300. In order to make up for lost time at the dock, the cruise track was adjusted to transit directly through the Mexico EEZ, reducing the transit time south by approximately 1.5 days. Multibeam data will not be collected through the Mexico EEZ. At 1610, the ship moved to the cruise ship terminal for overnight dockage.

The survey department conducted ship introduction and training meetings throughout the day. Expectations and roles of watchstanders were discussed. The cruise plan and other background information were reviewed.

It was discovered that only four sensors at a time can be used on the CTD rosette frame due to limited availability of Y-cables. Additional Y-cables are being ordered and will be available onboard by EX-11-03 Leg 2. The Niskin bottles were removed from the rosette since water sampling will not occur during EX-11-03 Leg 1. The deck department continues to work on fabricating mounting brackets for new sensor configuration on the rosette.



The telepresence lead was onboard this week to prepare the telepresence system prior to ship departure. The VSAT is performing well at the dock.

Brendan Reser from the National Coastal Data Development Center (NCDDC) is onboard this cruise to gain exposure to systems data collection, onboard data management, and automatic data transfer operations.

June 9, 2011

The oily water separator was repaired prior to departure, and the ABS test passed. The ship departed the San Diego cruise ship terminal at 1300. The ship transited approximately 12 miles offshore, then turned south at 1715 to begin transit through the Mexico EEZ. All SCS sensors were disabled except for the navigation and met sensors.

The EM 302 multibeam will remain secured until the ship crosses out of the Mexico EEZ in ~2 days. Watchstanders acclimated to their schedules, and reviewed cruise documentation, including the cruise plan, system manuals, and background papers.

The EM 302 and EK 60 were briefly powered on and operated for ~2 hours before the ship entered the Mexico EEZ, over water depths ~400-1200 meters. Initial observations include the following: interference was observed in water depths > ~900m, which was expected, as the trigger to sync the two sonars has not yet been configured. Simultaneous bottom depth detections between the two sonars were roughly estimated to be within 1% of water depth of each other.

At 1600 at the CO's instruction and in preparation for entering the Mexico EEZ, the SSTs disabled all SCS sensors except for met and CNAV. The only scientific data currently being transmitted to shore are for shiptracker and webship. When the ship crosses over into international waters outside the Mexico EEZ, full SCS data logging and transmission to shore will be enabled.

A test CTD will be conducted after the ship exits the Mexico EEZ and enters international waters. The newly acquired light scattering sensors (LSS) and oxygen reduction potential (ORP) sensors will be tested at that time.

June 11, 2011

The ship crossed out of the Mexico EEZ at 1000. An XBT was conducted, applied to the EM 302, and multibeam logging was enabled.

June 12, 2011

To make the fastest transit to the Galapagos Spreading Center, the ship is maintaining 9.5 – 10.5 kts speed at full speed on 2 generators and at 150 RPMs. 24 hour EM 302 multibeam survey continued and data quality remains high. Swath width in 4000m is still approximately 2x water depth. The first batch of daily multibeam products were generated according to the data management plan and placed on the FTP.



Nav files of the ship's track through the Mexico EEZ were sent via email to NCDDC to facilitate trackline generation for the Okeanos Explorer Digital Atlas (http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm), which provides daily data collection updates for all Okeanos Explorer cruises.

June 13, 2011

24 hour EM 302 multibeam survey continued during southward transit through international waters towards the Galapagos Spreading Center.

Cumulative multibeam products continue to be provided daily via the Okeanos Explorer FTP. Mapping data quality remains high, with 2x water depth swath width in 4000 m water

June 14, 2011

24 hour EM 302 multibeam survey continued during the southward transit through international waters towards the Galapagos Spreading Center.

A CTD cast was conducted to 4000m water depth to test the new CTD sensors (LSS (main, secondary), ORP, altimeter).

Cumulative multibeam products continue to be provided daily via the Okeanos Explorer FTP. Mapping data quality remains high, with 2x water depth swath width in 4000 m water. An EM 302 built-in-system-test (BIST) was run while the ship was on station conducting the test CTD. All RX sound levels were in the 40-50 dB range (expected low as the ship was stationary) and all TX and RX boards are functional.

June 15, 2011

24 hour EM 302 multibeam survey continued during southward transit through international waters towards the Galapagos Spreading Center.

A second test vertical CTD cast was conducted to 4000m water depth to test the new CTD sensors (LSS (main, secondary), ORP, altimeter).

The ship will pass into the French EEZ around Clipperton Island ~0600 tomorrow (6/16). Scientific sensors will be secured. Navigational information will be provided to OMAO/NOAA Shiptracker and NCDDC/Digital Atlas to continue ship progress track plots. The ship will bring the third generator online to pick up ~1 kt speed during this dead-head transit.

June 16, 2011

The multibeam and SCS systems were secured prior to entering the French Exclusive Economic Zone (EEZ) around Clipperton Island. The ship passed into the EEZ just after 0600, and should reenter international waters at ~1800 on 6/17. Navigational information is being provided to OMAO/NOAA Shiptracker and NCDDC/Digital Atlas to continue ship progress track plots. The ship is making 11 knots on three generators during the EEZ transit.



Today Ecuador granted permission to conduct marine scientific research in the Ecuadorian EEZ during EX-11-03 Leg 1 without an observer onboard. Plans are now underway to revert to executing the original cruise plan dated June 07 2011.

June 17, 2011

The multibeam and SCS systems were secured throughout the day while transiting through the French Exclusive Economic Zone around Clipperton Island. The ship exited the French EEZ at 1800 and multibeam and SCS sensors were enabled and data logging commenced.

The ship conducted safety drills in the afternoon, including steering casualty, fire, and abandon ship.

June 18, 2011

EM 302 multibeam data collection continued throughout the day. A few minor incidents of interference were observed while a tuna fishing boat was nearby.

Prior to today, there was a consistent following sea of 4-6 ft for the majority of the cruise. In the morning, the weather began to come from the south. The winds built throughout the day and were 25 kts by dinner time, and as a result the ship slowed to 8-9 kts.

June 19, 2011

EM 302 multibeam data collection continued throughout the day.

By the early morning, the ship had slowed to 7.5-8.5 kts due to heading into heavy seas. The swell was 4-8 ft throughout the day, with waves 3-7 ft, and winds 20-23 kts. The weather was from 170-190° and the ship's heading was 130. In the evening, the seas were still up, but the wind had decreased to 15 kts.

The ship will arrive at the precise mapping line ~0200 6/20.

June 20, 2011

The precise multibeam mapping line continued throughout the day, with data quality remaining high.

Following the unofficial permission to work in Ecuadorian waters during Leg 1 with no escort onboard, the ship is carrying out the cruise plan dated June 7 2011. Expected time the ship will cross the Ecuador EEZ border is 6/22 0030. Expected time the ship will complete the precise multibeam mapping line is 6/22 ~0600.

A successful 1000 meter CTD cast was conducted to test the LSS sensor rewiring.

June 21, 2011

The precise multibeam mapping line continued throughout the day, with data quality remaining high in terms of bottom detection and swath coverage.



The ship changed time zones in the late evening. Ship time is now UTC -6 hours.

The formal clearance for marine scientific research was received onboard at 1130 ship time from the Director General of the Maritime Interests of Ecuador, Admiral Angel Sarzosa Aguirre. The ship will carry out the cruise plan dated June 7 2011. The ship crossed into the Ecuador EEZ border at 1653. The precise multibeam mapping line was completed 6/22 at 0108. Transit to the tow-yo ops line commenced. Estimated arrival to start of tow-yo exploration line is 6/23 ~0900.

The seas laid down to 4-6-foot swell, 1-2-foot chop and 11-16 kt winds from the south. On 170 – 175 RPMs throughout the day, the ship was able to maintain speed of 10 – 11 kts throughout the day while maintaining multibeam data quality.

During the science planning call at 0900, it was decided that Paramount Seamounts will not be explored during EX-11-03 Leg 1. When the ship completes the precise mapping line, at ~0600 on 6/22, the ship will head to the start of the tow-yo line at waypoint 42 from the cruise plan (0° 47.305'N, 89° 19.809'W). From there, work will continue east on the tow-yo line at 1.7 kts, covering as much of the planned line as possible, while leaving enough time to run lines over the Inca Spreading Zone during the transit to Puntarenas.

The second LSS cable was rewired to provide higher sensitivity and connected to the CTD. The CTD package is now ready for tow-yo operations.

June 22, 2011

Mapping operations continue while transiting to the tow-yo exploration transect. Estimated arrival to start of tow yo exploration line is 6/23 ~0900.

June 23, 2011

The ship arrived at the start of the tow-yo exploration transect at 1100. The CTD was deployed at 1210 and 24-hr tow-yo operations commenced. The deployment location was .79N, 89.32W. 24 hour multibeam mapping operations continue. At midnight, the ship's location was 0.8N, 89.02W.

June 24, 2011

The ship continued 24 hour CTD tow yo and multibeam mapping operations. The second LSS cable failed in the early morning. The CTD was recovered, the cables for both LSS sensors were troubleshoot, and the CTD was redeployed within ~1hr.

At 1900, significant spikes were seen with both LSS sensors, indicating possible presence of hydrothermal activity. These spikes were seen for the rest of the evening.

June 25, 2011

The ship continued CTD tow yo and multibeam mapping operations until 0900, when CTD recovery commenced for the scheduled battery recharge. Multibeam mapping continued in the vicinity over previously unmapped areas during the recharge time. The second LSS was outfitted with a re-pinned cable during the battery recharge. The CTD was redeployed at the



same location along the tow line at 1617 hours. LSS possible plume detections continued to be observed through the morning.

June 26, 2011

The ship continued 24 hr CTD tow yo and multibeam mapping operations. There did not appear to be any significant plume detections in the LSS or ORP data. As of 1600, 199km of tow-yo ops had been conducted. Since leaving San Diego, the ship has mapped 4,595 linear kilometers, covering 33,692 square kilometers of the seafloor.

June 27, 2011

The ship continued 24 hr CTD tow yo and multibeam mapping operations. There did not appear to be any significant plume detections in the LSS or ORP data. The CTD altimeter battery was recharged after tow-yo Line 1 was completed. With a full battery, Tow Yo Line 2 commenced.

June 28, 2011

Multibeam operations continue in tandem with tow yo operations. XBTs are being conducted during meal breaks. The XBT normally conducted at 0000 will not be conducted until tow yo operations cease. Data quality remains high. Venting activity was not observed in the EM 302 data. EM 302 and EK 60 water column data are both recorded 24 hours a day for later review and possible correlation to vent activity. Minor interference is observed in the outer beams of the EM 302 data.

June 29, 2011

Through the morning and early afternoon, the ship continued CTD tow yo and multibeam mapping operations. The altimeter battery failed at 1400, just shy of the 48-hour mark since the last recharge. The ship's position was 00 45.010N, 085 44.28 W, almost spot on waypoint 63 from the cruise plan. A total of 398 km of continuous tow yo ops data were collected.

June 30, 2011

24-hour multibeam mapping operations continued. The lines over the Inca Fracture Zone were completed. A 3 meter sounding on the charts was investigated and disproven. Transit to Puntarenas continues.

July 1, 2011

24-hour multibeam mapping operations continued. Transit to Puntarenas continues. Crew days of rest are July 3, 4, and 6. The pilot is scheduled for ~0800 tomorrow.

July 2, 2011

The ship dropped anchor outside of Puntarenas, Costa Rica.

July 6, 2011

A science planning meeting was conducted onboard to plan for Leg 2 ROV dives based on the data collected during Leg 1.



12. References

The 2011 NOAA Ship *Okeanos Explorer* Survey Readiness Report can be obtained in the NOAA Central Library or by contacting the NOAA OER mapping team at oar.oer.exmappingteam@noaa.gov.

The EX-11-03 Project Instructions can be obtained from the NOAA Central Library at <https://doi.org/10.25923/1mhs-8w28>. The EX-11-03 Data Management Plan is an appendix to the Project Instructions.

The following were used for reference throughout the cruise:

Sandwell, D. T., and W. H. F. Smith, Global marine gravity from retracked Geosat and ERS-1 altimetry: Ridge Segmentation versus spreading rate, J. Geophys. Res., 114, B01411, doi:10.1029/2008JB006008, 2009.

NOAA Nautical Charts

