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MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT

CRUISE EX-16-06: CAPSTONE Wake Island Unit PRIMNM (*ROV & Mapping*)

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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 utilized during the mapping expedition EX-16-06, 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 documented in the 2016 NOAA Ship *Okeanos Explorer* Survey Readiness Report, available in the NOAA Central Library. A full description of Remotely Operated Vehicle (ROV) operations and sample collections completed during the cruise is available in a separate Expedition Report available in the NOAA Central Library with the title "Cruise EX-16-06—2016 Deepwater Wonders of Wake *(ROV/Mapping).*

3. Cruise Objectives

EX-16-06 was conducted in support of the **C**ampaign to **A**ddress **P**acific Monument **S**cience, **T**echnology, and **O**cean **NE**eds (CAPSTONE), a multi-year effort focused on the systematic collection of baseline information in support of scientific and management needs within and in the vicinity of monuments and marine protected areas in the central and western Pacific. This cruise consisted of ROV and mapping operations focused on deep water areas around the Wake Island Unit of the Pacific Remote Islands Marine National Monument (PRIMNM). This expedition helped establish a baseline of information in the region to catalyze further exploration, research and management activities.

The expedition commenced in Santa Rita, Guam on July 27, 2016 and concluded in Kwajalein, Marshall Islands on August 19, 2016. Mapping operations utilized the ship's deep water mapping systems (Kongsberg EM 302 multibeam sonar, EK 60 split-beam fisheries sonars, and Knudsen 3260 chirp sub-bottom profiler), as well as the ship's high-bandwidth satellite connection for daily transfer of incoming data to the awaiting shoreside mapping team and scientists. Mapping operations were conducted during transits and overnight following ROV operations. Exploration operations for this cruise focused on deep-water areas around Wake Island and along the transits from Guam to Kwajalein.

The complete objectives for this cruise are detailed in the EX-16-06 Project Instructions, archived in the NOAA Central Library.

4. Summary of Mapping Results

EX-16-06 mapped 33,000 square kilometers of seafloor during the 24 days at sea. An overview of the multibeam bathymetry data collected is shown in Figure 1. A focused map showing coverage obtained within the Wake Island Unit of the PRIMNM is provided in Section 7 of this report, Figure 2.

Cruise Overview Map

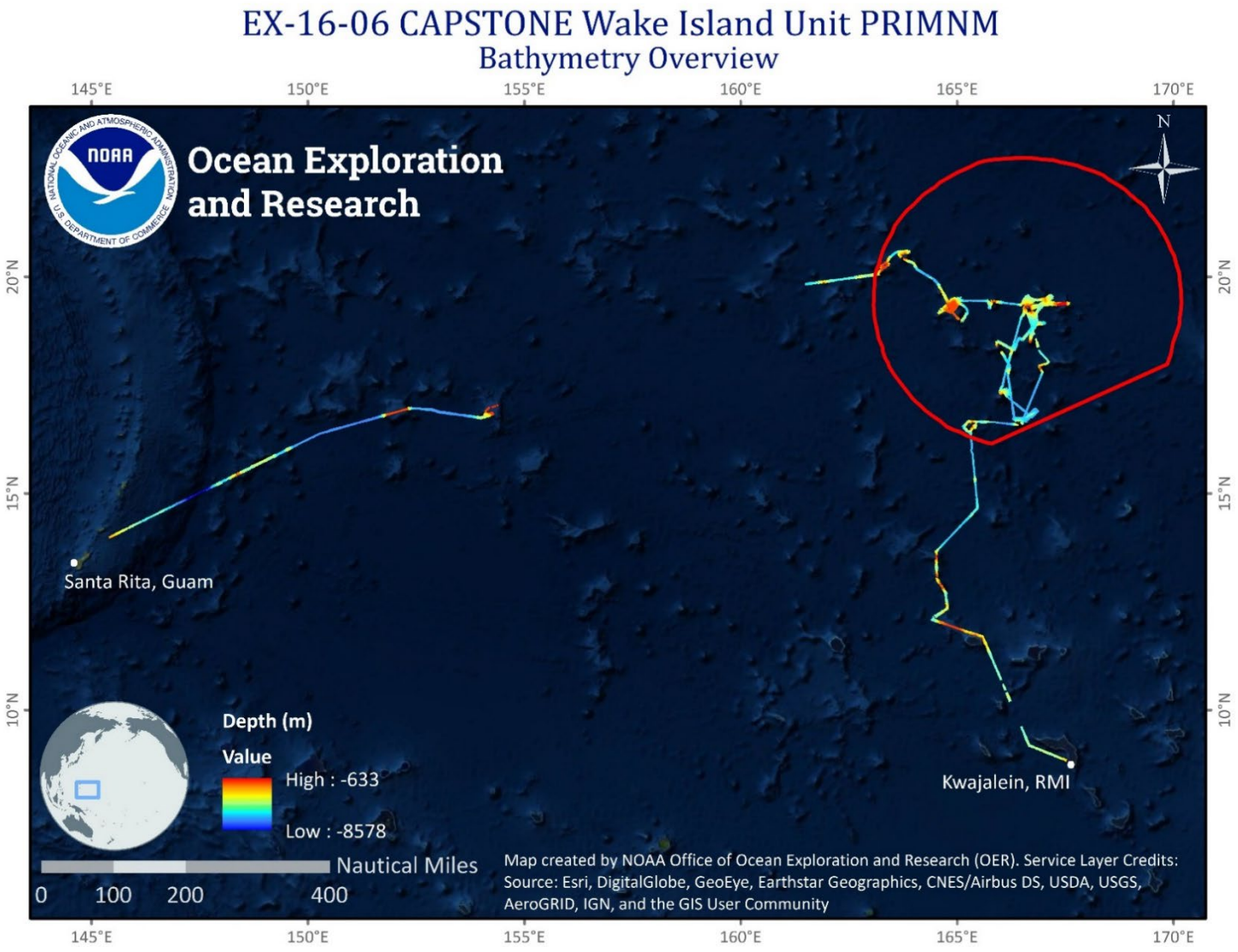

Figure 1. Overview of bathymetric mapping coverage completed during the CAPSTONE Wake Island Unit PRIMNM expedition (EX-16-06).

5. Mapping Statistics

Table 1. Summary statistics of ocean mapping work completed during EX-16-06.

Dates of cruise	July 27 – August 19, 2016
Ship's draft: Start of cruise (07/27/2016) End of cruise (08/19/2016)	 Fore: 14' 3'', Aft STBD: 14' 9" Fore: 14' 0"; Aft STBD: 14' 3"
Linear kilometers of survey with EM 302	6,120
Square kilometers mapped with EM 302	33,000
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files (.all)	459 files/ 21.7 GB
Number / Data Volume of EM 302 water column multibeam files	459 files / 80.5 GB
Number / Data Volume of EK 60 water column split beam files (.raw)	197 / 43.7 GB
Number / Data Volume of sub-bottom sonar files (.segy, .kea, .keb)	567 / 5.11 GB
Number of XBT casts	40
Number of CTD casts (including test casts)	0

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 2016 NOAA Ship *Okeanos Explorer* Mapping Systems Readiness Report is available in the NOAA Central Library.

Simrad EK 60 Split-beam Sonars

The ship operated four Simrad EK 60 split-beam fisheries sonars: 18 kHz, 70 kHz, 120 kHz, and 200 kHz. These sonars are quantitative scientific echosounders 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. These sonars were calibrated on the EX-16-01 cruise, and calibration values from that cruise were applied to the EK sonars for EX-16-06. The calibration data from EX-16-01 are available at http://doi.org/10.7289/V5TD9VJM. The 2016 EK 60 & EK Calibration Report is available in the NOAA Central Library.

Knudsen 3260 Sub-bottom Profiler

The ship is equipped with a Knudsen 3260 sub-bottom profiler that produces a frequency-modulated chirp signal with a central frequency of 3.5 kHz. This sonar is used to provide echogram images of shallow geological layers underneath the seafloor to a maximum depth of approximately 80 meters below the seafloor. The sub-bottom profiler is normally operated to provide information about sub-seafloor stratigraphy and features. The data generated by this sonar are fundamental to helping geologists interpret the shallow geology of the seafloor.

Teledyne ADCPs

The ship utilizes a 38 kHz Teledyne RDI Ocean Surveyor Acoustic Doppler Current Profiler (ADCP), with a ~1000 meter range; and a 300 kHz Teledyne RDI Workhorse Mariner ADCP, with a ~70 meter range. The ADCPs gather data prior to ROV deployments in order to assess currents at the dive site in support of safe operations. They are kept running throughout the ROV dives. The ADCPs are typically not run concurrently with the other sonars during mapping operations due to interference issues.

7. Data Acquisition Summary

Mapping operations included data collection via the EM 302 multibeam sonar, EK 60 split-beam (18, 70, 122, and 200 kHz) sonars, and Knudsen 3260 sub-bottom profiler. Due to a malfunction with the EM 302 TRU, multibeam data were not collected for periods of time between July 30 and August 1. During this time only EK 60 and sub-bottom data were collected. At all other times data were collected by each sonar concurrently.

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. Focused operations occurred over unsurveyed seamounts in the Wake Island Unit of the Pacific Remote Marine National Monument (Figure 2).

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 ¼ swath width overlap between lines. Cutoff angles in the multibeam acquisition software Seafloor Information 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 probe 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 continuously compared against secondary derived sound speed values from the ship's onboard thermosalinograph (TSG) flow-through system as a quality assurance measure.

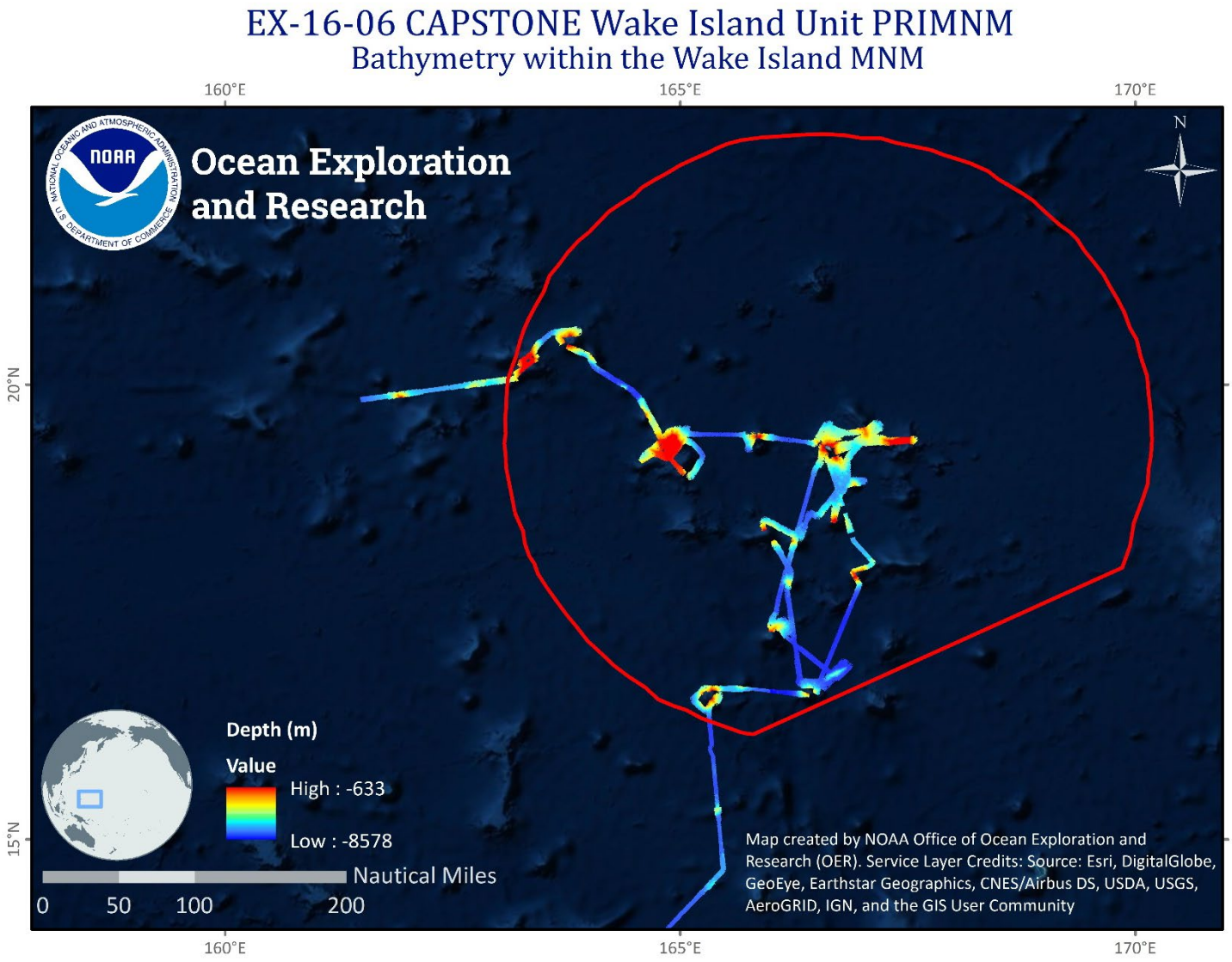

Figure 2. Overview of bathymetric mapping coverage acquired during the cruise within the Wake Island Unit of the Pacific Remote Island Marine National Monument (PRIMNM) extents of PRIMNM are shown in red.

8. Multibeam Sonar Data Quality Assessment and Data Processing

Figure 3 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).

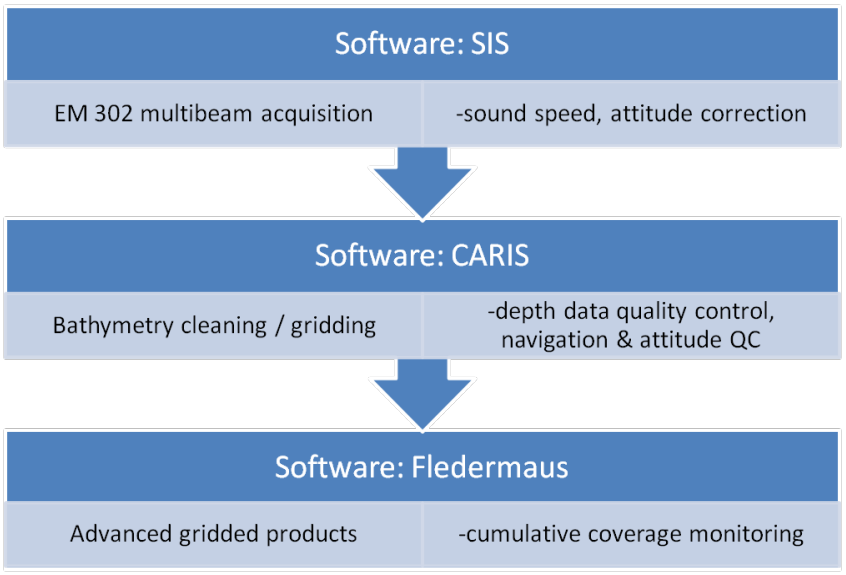

Figure 3. Shipboard multibeam data processing workflow.

Crosslines

Comparing depth values from orthogonal survey lines is a standard hydrographic quality control measure to evaluate the consistency of the multibeam sonar data collected during a cruise. Crosslines were run on August 8, 2016 as shown in Figure 4. Crossline analysis was completed using the Crosscheck Tool in QPS Qimera software to confirm that the survey meets the requirements for an International Hydrographic Order 1 survey. The results are shown below.

Crossline files:

0241_20160808_024806_EX1606_MB

Mainscheme line files:

0233_20160807_211906_EX1606_MB

0238_20160808_010742_EX1606_MB

0244_20160808_040847_EX1606_MB

Statistic	Value
Number of points of comparison	122,627
Grid Cell Size	100.000
Difference Mean	-1.621
Difference Median	-1.621
Difference Std. Dev	12.634
Difference Range	[-77.51, 85.80]
Mean + 2*Stddev	27.290
Median + 2*Stddev	27.290
Data Mean	-4944.917
Reference Mean	-4943.296
Data Z-Range	[-5659.02, -3859.68]
Reference Z-Range	[-5648.39, -3874.07]
Order 1 Error Limit	64.265
Order 1 # Rejected	86
Order 1 P-Statistic	0.000701
Order 1 Survey	**ACCEPTED**

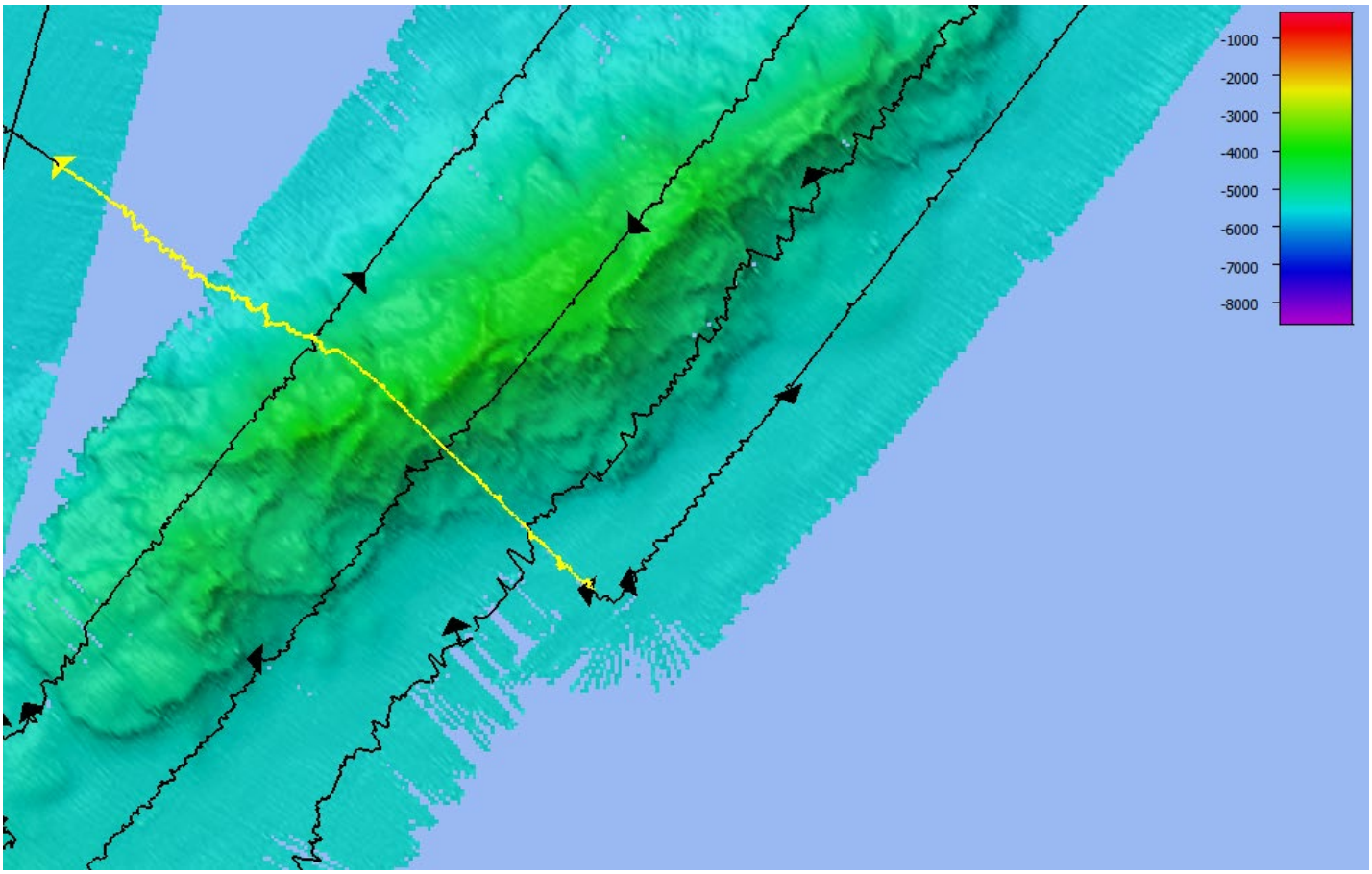

Figure 4. EX-16-06 crossline (shown in yellow) used for comparison against the 100-meter bathymetric grid generated via orthogonal multibeam survey line.

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 in the EX-16-06 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 watchstander log
- Weather log
- Sound velocity profile log
- Multibeam acquisition and processing log
- Built-In-System-Tests (BISTs)

Simrad EK split-beam water column dataset:

- Mapping watchstander log
- Weather log

Knudsen 3260 Sub-bottom Profiler dataset:

- Mapping watchstander log
- Weather log

EM 302 Multibeam water column dataset:

- Mapping watchstander log
- Weather log
- Sound velocity profile log
- Multibeam acquisition and processing log
- Built-In-System-Tests (BISTs)

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 01/21/2020).

Sub-bottom data, supporting data, and informational logs are available in the NCEI Data Archives accessible at https://maps.ngdc.noaa.gov/viewers/geophysics/ (last accessed 01/21/2020).

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 01/21/2020).

10. Cruise Calendar

All times listed are local ship time, which was UTC +12 hours.

July - August 2016

Sun	Mon	Tues	Wed	Thur	Fri	Sat
24	25	26 Mission personal arrive.	27 Depart Guam, commence transit mapping.	28 Transit mapping.	29 Transit mapping.	30 First ROV dive, TRU trouble-shooting.
31 Continued TRU troubleshooting and transit to next dive.	1 Transit mapping.	2 Delayed daytime ROV dive, evening mapping.	3 Daytime ROV dive, evening mapping.	4 Canceled dive, daytime and evening mapping.	5 Daytime ROV dive, evening mapping.	6 Daytime ROV dive, evening mapping.
7 Weather day, no dive, transit mapping.	8 Weather day, no dive, focused mapping in southern tip of monument.	9 Daytime ROV dive, evening mapping.	10 Daytime ROV dive, evening mapping.	11 Daytime ROV dive, evening mapping.	12 Daytime ROV dive, evening mapping.	13 Daytime ROV dive, evening mapping.
14 Daytime ROV dive, evening mapping.	15 Daytime ROV dive, evening mapping.	16 Daytime ROV dive, evening mapping.	17 Transit mapping.	18 Transit mapping.	19 Arrive in Kwajalein.	20 Demobilization.
21 Demobilization.	22 Mission personnel depart.	23	24	25	26	27

11. Daily Cruise Log Entries

Generated from the daily expedition situation reports. All times listed are in local ship time (UTC +12).

July 27
The ship got underway from Santa Rita, Guam. The EM 302 TRU was energized in the morning after switching to ship power. The TRU and SIS connected easily and the first BIST had no failures. About 20 minutes into operations an issue with the EM 302 prevented the sonar from pinging. A BIST showed the transmit (TX) board 08 had a failure. The TRU was restarted, letting it warm up for about 20 minutes. The next BIST showed no failures with the TX boards, but all the receive (RX) boards had failed. The TRU was secured and left idle for 20 minutes, then allowed to warm up for 1 hour. This seemed to clear up all issues. Mapping continued through the night, but data quality was only fair to good due to maintaining 9.5 to 10.5 knots to get on the first ROV site in time.

July 28
The ship continued to steam towards the first dive site. Mapping data quality was good. An issue with the generators led to the reduction in speed overnight to between 9 and 9.5 kts.

July 29
Continued transit mapping to the first dive site. Data quality was good despite fast transit speeds and deep depths. Arrived on the dive site early and added 60 km of mapping lines over Alba Guyot. The POSMV position accuracy exceeds the accuracy threshold each evening around 1800-2000. The number of satellites tracked drops to 9, and several of the satellites are very low on the horizon.

July 30
Mapping data was good until 2030 ship time, when the EM 302 stopped pinging. After multiple restarts and initial troubleshooting the system had not come back online. BIST tests returned various problems showing TX and RX board and channel failures. Troubleshooting is ongoing.

July 31
Transit mapping continued with the EK 60s, Knudsen, and ADCPs while EM 302 troubleshooting was ongoing. Several TX36 boards and all three power supply units were replaced with spares. BIST results and telnet sessions were sent to Kongsberg for analysis.

August 1
TRU troubleshooting continued in the afternoon, once the ship's power issues were resolved. The TRU had a clean boot and for the first BIST test, all tests passed. The system was restarted,

and the boot failed. Guidance from Kongsberg was to reboot again, and this time there was a clean boot with successful BISTs. The EM 302 began pinging, but the system had a very difficult time finding and tracking bottom and the data quality looked very poor. At one point pinging failed completely and the entire system (TRU and SIS) had to be restarted. A few hours into pinging the Mapping Lead and SST went down to check the ADCP sonars, which were still pinging. When the control room had a power failure, the ADCP computer shut off, and could not be restarted. It was thought that the sonars had also stopped pinging, but they had not. The power switches on the ADCP sonars were secured, and the interference in the multibeam stopped. EM 302 logging was started, as well as the EK 60s and Knudsen. Transit mapping continued during the overnight transit, and data quality was good.

August 2
Overnight mapping began immediately following the ROV dive. Coverage was added over two seamounts that were mapped during EX-16-04. The EM 302 passed all pre-mapping BIST tests and started pinging normally. A few hours into mapping the TRU stopped pinging. Pinging was restarted, but a few minutes later another failure was experienced. Pinging was restarted again and continued without issue.

Data quality was good on the EM 302, EK 60s, and Knudsen sonars. Over a region of flat seafloor, during a transit between seamounts, interference was observed in the EM 302 data. The watchstanders realized the Knudsen triggering had been switched to internal, rather than external. This was switched back and the interference dissipated.

August 3
Overnight mapping continued with the EM 302, EK 60s, and Knudsen. The transit line to the next dive site edge matched an existing line that was collected on EX-16-04. Coverage was completed over two small seamounts. At one point in the middle of the night, the EM 302 stopped pinging. The watchstanders were able to get the system pinging again without restarting SIS or the TRU, but the system does seem to randomly stop pinging.

August 4
Due to the extended time to map, coverage was added to what was collected on EX-16-04 over the McDonnell seamount. During a loss of power all mapping systems were shut down gracefully and restarted around noon to continue mapping. The TRU did not boot cleanly at first but started up fine after a reboot. The multibeam only lost pinging once during the 18 hours of mapping, the watchstanders were able to get the system pinging again by just starting and stopping pinging in SIS. The data quality was fair to good on all sonars, with some data dropouts due to pitching in rougher weather.

August 5
Mapping operations over the McDonnell seamount were concluded prior to the transit to the next dive. The EM 302, Knudsen, and EK 60s were running all night. Some dropouts were observed in the multibeam over steep slopes of the McDonnell seamount, particularly in the depth range where the ping mode switches from Deep to Very Deep. Forcing the sonar into a deeper depth and adjusting the along direction angle to -1 or -2 degrees helped improve bottom tracking. The ship arrived on the dive site a little early, so an additional line of mapping was collected on the western side of the unnamed seamount for the Aug 06 dive.

August 6
During overnight mapping the ship transited to the next dive site and expanded on existing multibeam coverage to the north of Wake Island. Data quality on all sonars was good to fair, and started to deteriorate as the weather got worse. The EM 302 did not lose pinging at all during the night, and BISTs continue to pass all tests. Collected 20 minutes of each individual EK 60 frequency, for mapping team testing purposes.

August 7
Weather was too rough for an ROV dive, so transit mapping operations were conducted most of the day with some targeted work on a few seamounts. Data ranged from fair to good depending on the heading.

August 8
Weather was too rough for an ROV dive, mapping coverage was extended in the southern tip of the monument. Surveyed a seamount feature on the southern end of the monument. MBES data was poor to fair depending on the heading of the line. SBP data were not logged because it could not track the bottom and XBTs were less frequent due to the weather.

August 9
Conducted a 130 nm straight transit line to the next dive site. Collected data with EM 302, Knudsen, and EK 60s. Data quality was fair to good, as seas were still a bit high and the ship was transiting as fast as possible.

August 10
After the dive the ship moved outside of 12 nautical miles from Wake Island and conducted mapping operations. Data quality was good on all sonars.

August 11
Overnight mapping went well. Coverage was added to some ridge features just south of Wake Island, as well as coverage over a seamount 27 nm south of Wake Island. Data quality continues to improve as the sea lays down. The ADCPs are still not functional despite a significant effort from UH and the GFOE data group to repair the damage caused from the rack room power failure.

August 12
Mapping operations continue as planned. Overnight transit mapping added to existing coverage in and around Wake Island. Data quality was good to excellent and there were no issues with the sonars.

August 13
Transit mapping continued. All systems were working well until about 0530 when the EM 302 stopped pinging. Pinging was restored without having to restart the TRU. A few copies of telnet sessions have been sent to Kongsberg to diagnose why the EM 302 intermittently and randomly loses pinging.

August 14
No major mapping updates. Overnight data quality on some headings was fair at times due to pitching into the seas and heavy winds; on other headings the data quality was good.

August 15
Overnight mapping went well. There is a minor issue with the XBTs, a few times this cruise the casts have canceled at 50 m and then upon recast, canceled at 200-300 m. The initial assumption is that the copper wire was hitting the ship as the casts were conducted at night in very windy conditions. This happened again yesterday evening when it was light enough out to see the copper wire, and it was clearly not hitting the ship. This has not had any noticeable negative effects on the data yet.

August 16
Conducted transit mapping overnight. Data quality was fair due to sea state.

August 17
Transit mapping to Kwajalein continued. Experienced problems with XBTs prematurely terminating and the multibeam occasionally refusing to ping. Troubleshooting is ongoing.

August 18
Transit mapping to Kwajalein continued.

August 19
Transit mapping to Kwajalein continued. The ship pulled in to Kwajalein.

12. References

The 2016 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-16-06 Project Instructions can be obtained from the NOAA Central Library. The EX-16-06 Data Management Plan is an appendix of the project instructions.

The EX-16-06 EK 60 Calibration Report can be obtained in the NOAA Central Library or by contacting the NOAA OER mapping team at oar.oer.exmappingteam@noaa.gov

The following data were used as background data throughout the expedition:

- Tozer, B. , D. T. Sandwell, W. H. F. Smith, C. Olson, J. R. Beale, and P. Wessel, Global bathymetry and topography at 15 arc seconds: SRTM15+, Accepted Earth and Space Science, August 3, 2019. https://doi.org/10.1029/2019EA000658
- NOAA Nautical Charts
- Various datasets downloaded from the NCEI archives via NOAA AutoChart.