Ocean Exploration and Research

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MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT

CRUISE EX-16-07: CAPSTONE Wake Island PRIMNM (*Telepresence 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-16-07, 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.

3. Cruise Objectives

EX-16-07 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 24 hour per day mapping operations focused on previously unmapped seamount areas around the Wake Island Marine National Monument (MNM), a part 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 Kwajalein, Marshall Islands on August 25, and concluded in Honolulu, Hawaii on September 11. 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.

The complete objectives for this cruise are detailed in the EX-16-07 Project Instructions, archived in the NOAA Central Library.

4. Summary of Mapping Results

EX-16-07 mapped 43,979 square kilometers of seafloor during the 19 days at sea. An overview of the multibeam bathymetry data collected west of 180 degrees longitude is shown in Figure 1, and an overview of data collected east of 180 degrees longitude is shown in Figure 2. Focus maps showing coverage obtained within the Wake Island Marine National Monument and the Johnston Atoll Marine National Monument are provided in Section 7 of this report.

Cruise Overview Map

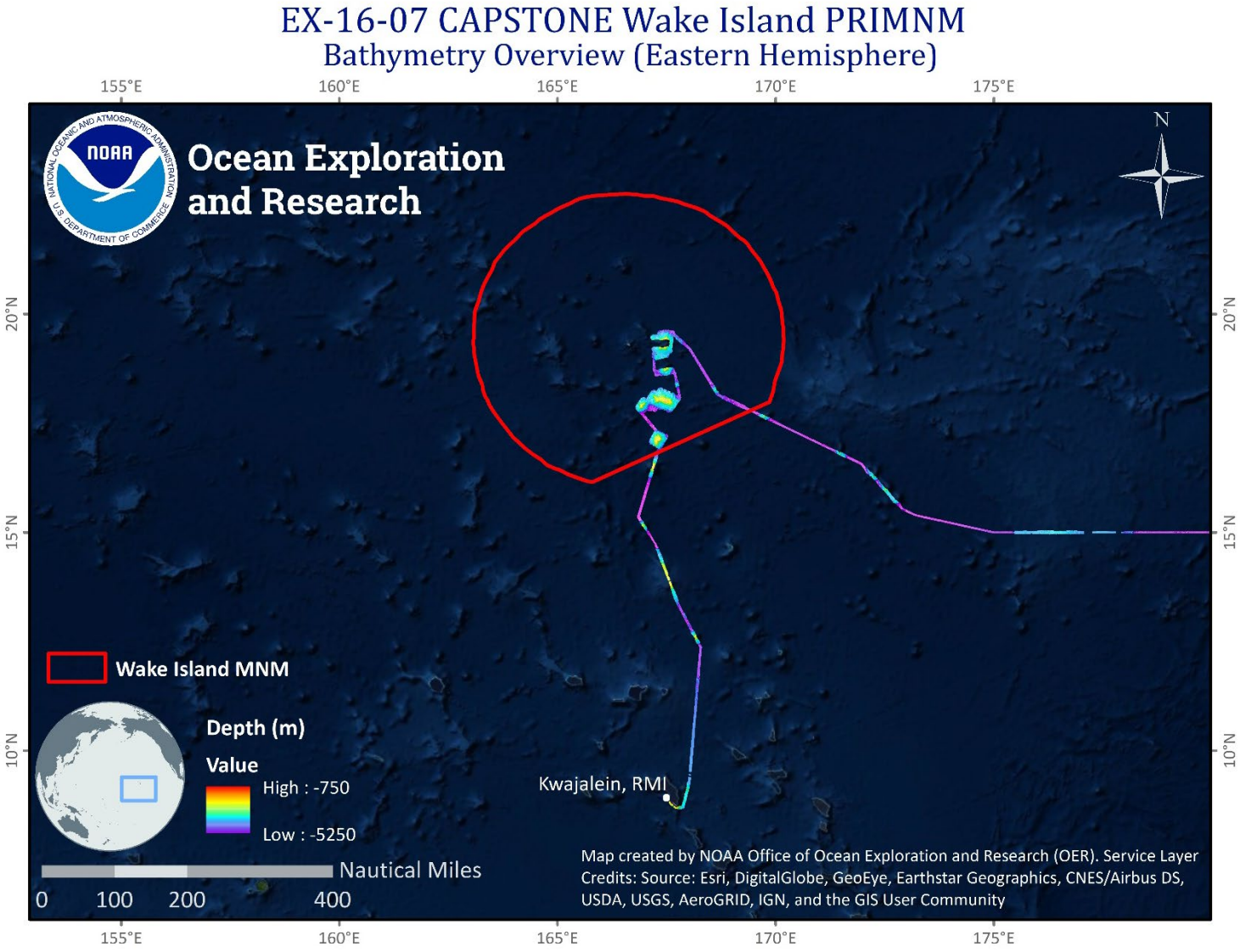

Figure 1. Overview of bathymetric mapping coverage completed west of 180 degrees longitude during the CAPSTONE Wake Island Atoll PRIMNM expedition (EX-16-07). Map generated in ArcMap.

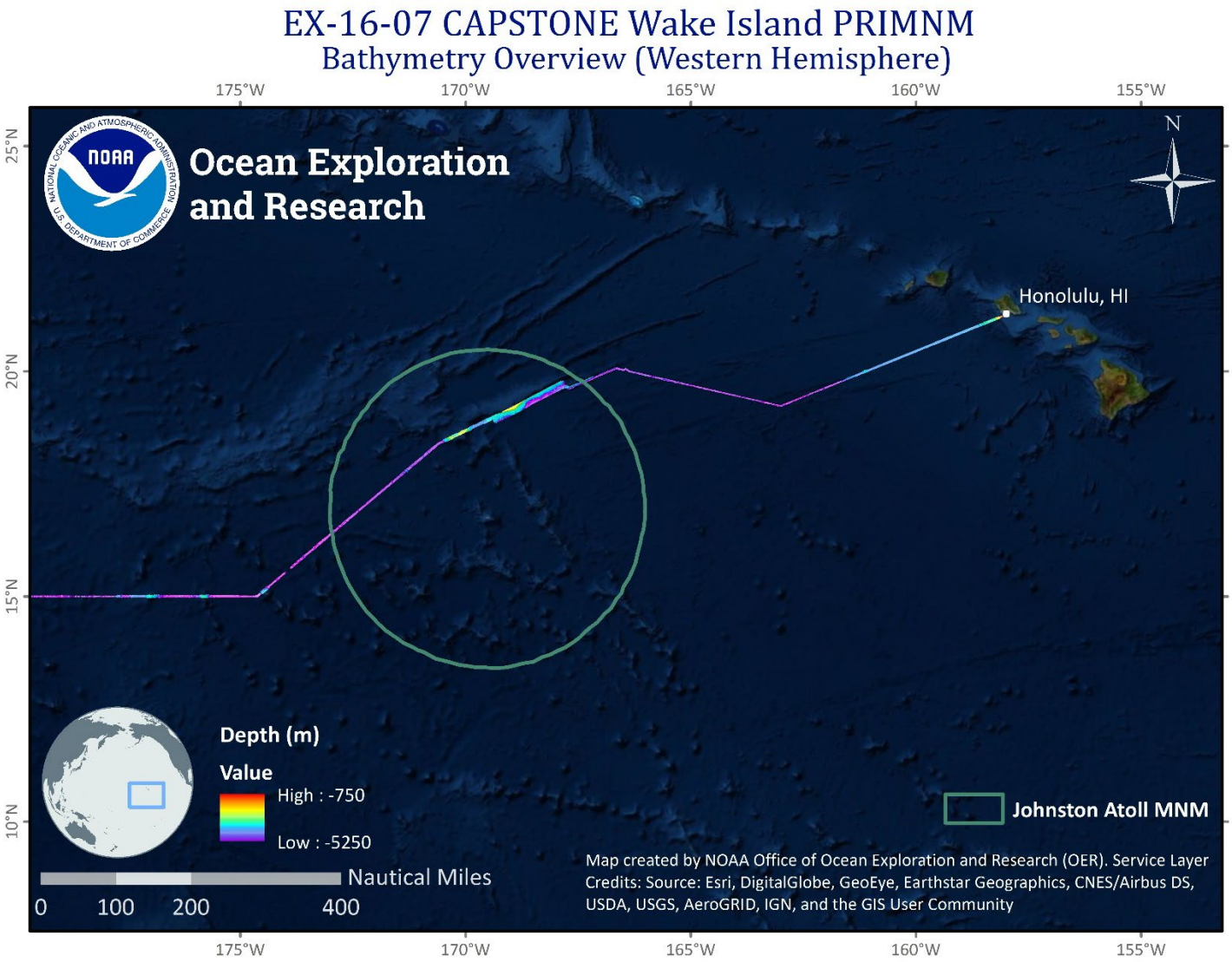

Figure 2. Overview of bathymetric mapping coverage completed east of 180 degrees longitude during the CAPSTONE Wake Island Atoll PRIMNM expedition (EX-16-07). Map generated in ArcMap.

5. Mapping Statistics

Table 1. Summary statistics of ocean mapping work completed during EX-16-07.

Dates of cruise	**August 25 – September 11, 2016**
Ship's draft: **Start of cruise (08/25/2016)** **End of cruise (09/11/2016)**	 **Fore: 14' 3'', Aft STBD: 14' 9"** **Fore: 14' 0"; Aft STBD: 14' 3"**
Linear kilometers of survey with EM 302	**7,382**
Square kilometers mapped with EM 302	**43,979**
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files (.all)	**499 files/ 27.8 GB**
Number / Data Volume of EM 302 water column multibeam files	**499 files / 105 GB**
Number / Data Volume of EK 60 water column split beam files (.raw)	**735 / 58.6 GB**
Number / Data Volume of sub-bottom sonar files (.segy, .kea, .keb)	**389 / 6.58 GB**
Number of XBT casts	**78**
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, 38 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-16-07. 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, 38, 70, 122, and 200 kHz) sonars, and Knudsen 3260 sub-bottom profiler. Data were collected by each sonar concurrently during operations.

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 Marine National Monument (Figure 3) and over the Horizon Guyot in the Johnston Atoll Marine National Monument (Figure 4).

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 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 (TSG) flow-through system as a quality assurance measure. The TSG was secured on September 7 for a period of approximately 12 hours while surveying the Horizon Guyot to perform necessary repairs on leaking plumbing. The RESON SVP-70 remained functional, and no adverse effects to data quality were observed.

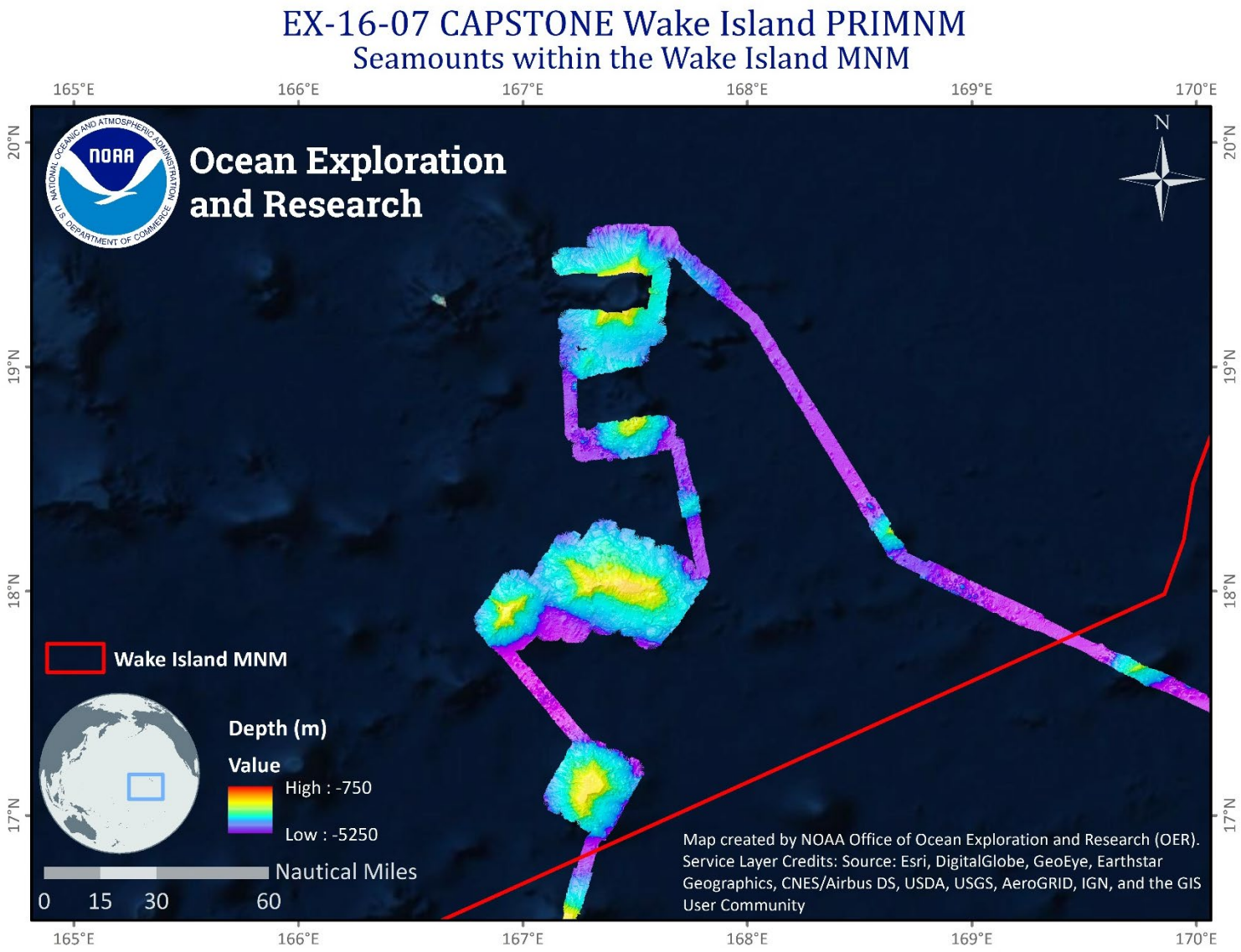

Figure 3. Overview of bathymetric mapping coverage acquired on unnamed seamounts within the Wake Island Marine National Monument (outlined in red). Map generated in ArcMap.

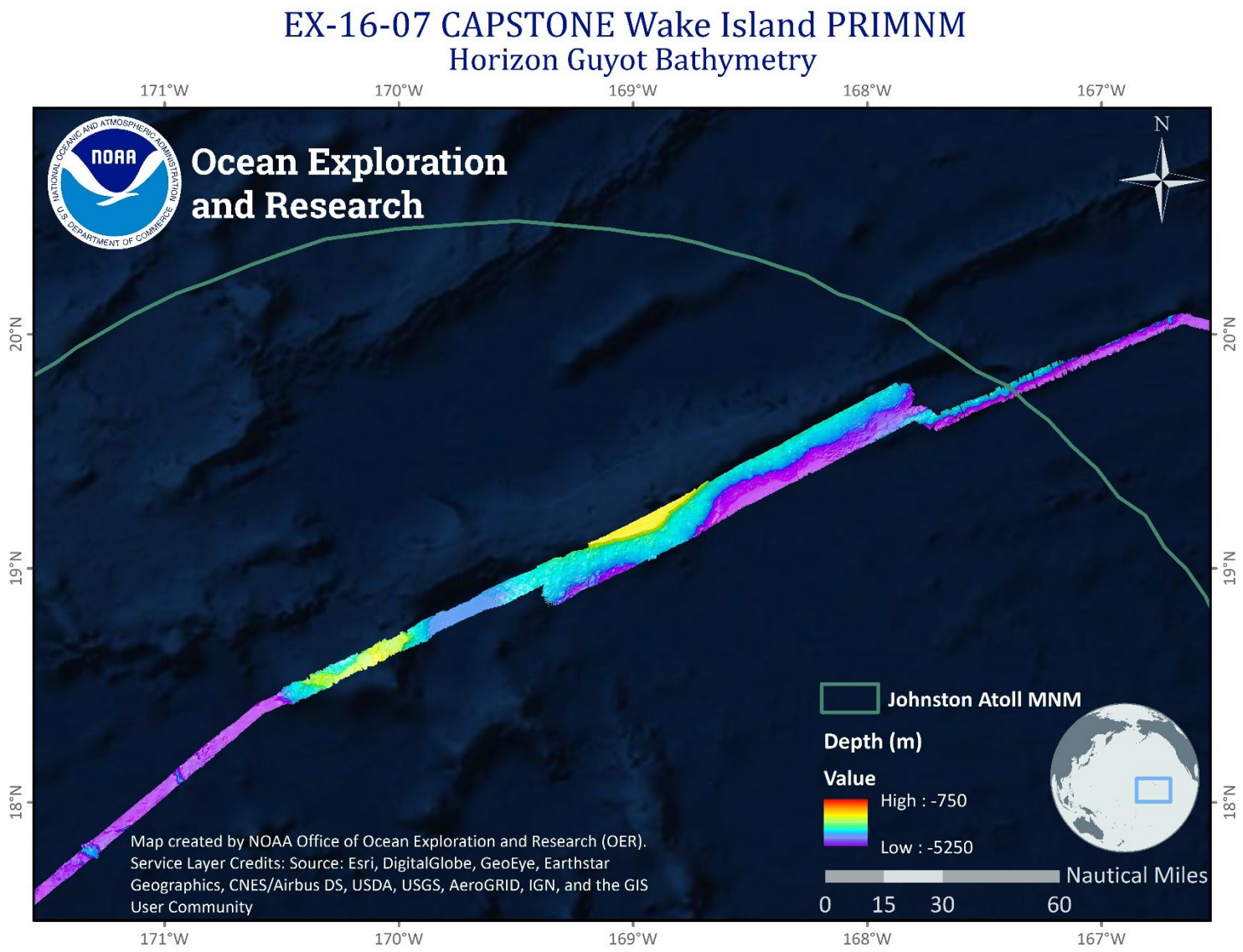

Figure 4. Overview of bathymetric mapping coverage acquired over the Horizon Guyot within the Johnston Atoll Marine National Monument (outlined in green). Map generated in ArcMap.

8. Multibeam Sonar Data Quality Assessment and Data Processing

Figure 5 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).

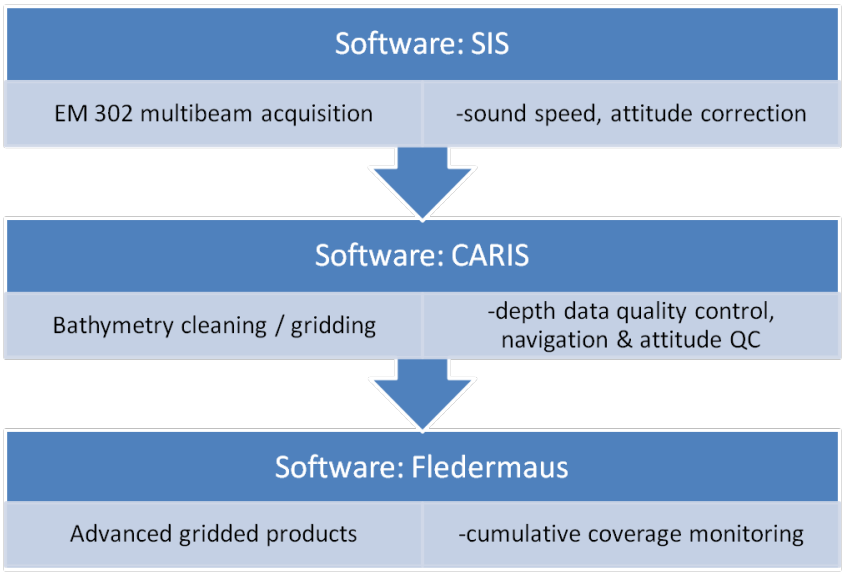

Figure 5. Shipboard multibeam data processing workflow.

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 in the EX-16-07 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

Knudsen 3260 Sub-bottom Profiler dataset:

- Mapping watch stander log
- Weather log
- Sub-bottom 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 01/02/2020).

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 01/02/2020).

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 01/02/2020).

10. Cruise Calendar

All times listed are local ship time, which was UTC +12 hours at the beginning of the cruise. Gradual changes to shift to Hawaii time throughout the cruise are noted in bold below.

August-September 2016

Sun	Mon	Tues	Wed	Thur	Fri	Sat
						20 Mission personnel arrive in Kwajalein.
21 Alongside, port of Kwajalein.	22 Passdown from EX1605L3 Mapping Lead. Alongside port of Kwajalein.	23 Additional mission personnel arrive. Ship tours 9am-2pm. Alongside port of Kwajalein.	24 EX1607 conference call with EC. Ship tours 9am-2pm. Alongside port of Kwajalein.	25 Depart Kwajalein. Transit mapping to Wake Island.	26 Transit mapping to Wake Island.	27 Transit mapping to Wake Island. Arrived at Seamount 1.
28 Mapping Seamount 1. **+1hr time change to UTC +11.**	29 Mapping Seamount 2 and 3.	30 Mapping Seamount 3 and 4.	31 Mapping Seamount 4.	1 Mapping Seamount 5.	2 Transit mapping towards Honolulu via 15N.	3 Transit mapping towards Honolulu via 15N.
4 Transit mapping towards Honolulu via 15N. -1 day due to crossing international dateline.	5 Transit mapping towards Honolulu. NE transit toward original trackline.	6 Transit mapping towards Honolulu. Focused mapping at Horizon Guyot.	7 Focused mapping at Horizon Guyot.	8 Focused mapping at Horizon Guyot. Resume transit mapping towards Honolulu.	9 Transit mapping towards Honolulu via adjusted trackline. **+1hr time change to UTC +10.**	10 Transit mapping towards Honolulu via adjusted trackline.
11 Arrive at Pearl Harbor Pier, Ford Island, Honolulu, HI.	12 EX1607 mission personnel depart ship.					

11. Daily Cruise Log Entries

All times listed are local ship time, which was UTC +12 hours at the beginning of the cruise. Gradual changes to shift to Hawaii time throughout the cruise are noted in bold below.

August 23-24, 2016 (ship time UTC +12 hrs)
The ship was alongside at the port of Kwajalein, with all mission personnel onboard. A conference call was held with the Expedition Coordinator onshore and shipside mission personnel. Ship tours were conducted by officers with the help of mission personnel in the control room. Sailing was delayed until 1400 August 25, 2016 to allow for the arrival of a new crew member.

August 25, 2016
The ship was alongside at the port of Kwajalein. Mission personnel readied sonar for transit mapping starting at 0730. The EM 302 passed on the first BIST. Following an on-time 1400 departure, mapping operations commenced in the Kwajalein shipping channel to the offshore trackline toward Wake Island MNM over a previously unmapped route at 10 knots (kts). Seas 1 to 3 feet. Data quality is high.

August 26, 2016
Transit mapping from Kwajalein to Wake Island MNM continued. Seas 1 to 3 feet. Data quality is high.

August 27, 2016
Transit mapping from Kwajalein to Wake Island MNM continued. Arrived at the Seamount 1 location at approximately 2015 to begin focused mapping using the EM 302, EK 60 and sub-bottom profiler at 8.5 to 9.0 kts for complete coverage of the geographic rise. Seas 2 to 4 feet. Data quality is high.

August 28, 2016
Focused mapping of Seamount 1 was completed. Some patches of high attenuation coupled with multibeam dropouts were seen in the vicinity of the plateau of the seamount. Transit to Seamount 2 was at 10 kts, with focused mapping conducted at 8.5 kts over the seamount. East wind, seas 3 to 5 feet. Data quality is high.

August 29, 2016 (UTC +11 hrs)
Focused mapping continued. Seamount 2 coverage was completed and Seamount 3 coverage was started. XBT system failures increased over the last 24 hours. West wind, seas 4 to 6 feet. Data quality is high.

August 30, 2016
Focused mapping continued. Seamount 3 coverage completed. Seamount 4 focused mapping started. West wind, seas 4 to 6 feet. Data quality is high. EiTs are compiling seamount projects with bathymetry, backscatter and trackline data.

August 31, 2016
Focused mapping continued. Seamount 4 coverage completed. Seamount 5 focused mapping started. Wind (southwest 10 to 15 kts) and seas (5 to 7 feet) have increased gradually since leaving Kwajalein, however data quality remains high. Swaths up to 9400 meters (m) were acquired in 4000 m of water.

Local network problems observed during the night watch.

September 1, 2016
Focused mapping continued. Seamount 5 coverage completed. Transit mapping began about 1330 in a southeastern direction toward 15°N 175°E to avoid tropical storm Madeline. A top layer of sediment can be seen in the sub-bottom data over the southeastern transit between Seamount 5 and Seamount 7. One pass over Seamount 7 was made along the transit.

Data processing was halted about 6 hours until local processing was implemented. The irregular local network outages were resolved that evening. Data was still backed up during "up" periods.

September 2, 2016
Transit mapping toward 15°N 175°E. EM 302 data contains artifacts at the junction of sectors one and two when mapping along flat bottoms at 5400 m (650 m swath) reducing data quality. EK 60 and Knudson sub-bottom data remains high quality. Sub-bottom in 5400 m flat areas contains an approximately 15 meter top layer of sediment. South wind 5-15 kts with seas of 3 to 5 feet.

September 3, 2016
Transit mapping continued with the EM 302, EK 60 and sub-bottom. Data quality was moderate to high with a decrease in EM 302 starboard artifacts at the junction between sectors one and two. Sea states and wind slowly increased to cause the ship to slow in average speed to 9.5 kts along 15°N to avoid impending tropical storms.

September 4, 2016
Transit mapping continued. The EM 302 lost the ability to ping in the morning and was quickly resolved, but with diminished data quality. Ship tracks were heading directly into the wind and seas causing slower transit speeds and pitching, which also affected data quality in the EM 302 as well as the EK 60 and sub-bottom data. EM 302 swath coverage was about 5000 m in 4400 m of water. Seas 4 to 6 feet, east winds 10 to 15 kts. **The ship crossed the dateline at midnight and September 4 was repeated onboard**.

September 4, 2016
Transit mapping continued. The EM 302, EK 60 and sub-bottom profiler had difficulty maintaining bottom tracking due to the sea state. The EM 302 range gates and max angles were minimized to maximize along track data continuity. Data quality is poor with reduced swaths of 6000 m in 4700 m of water.

Tropical storm Madeline dissipated and tropical storm Lester turned north, however sea states remained 5 to 7 feet.

September 5, 2016
Transit mapping continued. With the passing of tropical storms Madeline and Lester the ship adjusted course northeastward to converge with the original trackline north of Johnston Atoll at position 18° 23.6N,170° 34.1W. EM 302 data quality remains poor. Seas 5 to 7 feet, wind 12 kts.

Caris processing was migrated back to the network.

September 6, 2016
Transit mapping continued. EM 302 data quality significantly improved overnight. The ship reached the Horizon Guyot area near the NE boundary of Johnston Atoll. Seas 3 to 5 feet, east wind 10kts.

September 7, 2016
Began the additional 24 hours of survey on the Horizon Guyot at 8.5 to 9 knots. EM 302 data quality was high and maintained along-track pinging. Swath widths were 8100m in 4000m of water. Some interference due to weather was indicated in the EK 60, though had subsided from previous days. Seas 5 to 7 feet, wind 10 to 15 knots.

September 8, 2016
Completed focused mapping in the Horizon Guyot area. EM 302, EK 60 and sub-bottom data deteriorated to poor quality with numerous dropouts due to weather conditions. The ship resumed transit mapping to Honolulu. The transit was adjusted to accommodate the new boundary for the Papahanaumokuakea Marine National Monument, because the ship did not have a permit to transit to Hawaii via the Monument. A permit must be requested 72 hours in advance. Seas 4 to 6 feet, wind 10 to 15 knots.

September 9, 2016 ***(UTC +10 hrs)***
Transit mapping continued. EM 302 data was poor with numerous dropouts along-track due to weather conditions. A one-hour time change to Hawaii Time zone (+10 UTC) occurred during the early morning. Seas 4 to 6 feet, east winds 10 to 15 knots.

September 10, 2016
Transit mapping continued. Seamount at approximate position 19° 59.75N, 161° 07.28W was acquired along the transit. Data quality improved to moderate with minimal dropouts. Swath widths are narrower than expected. Seas 3 to 6 feet, wind 10 knots.

September 11, 2016
Transit mapping occurred until the sonars were secured at the sea buoy. The ship arrived to the sea buoy at 0700; and it was alongside the pier at Foxtrot 10 on Ford Island at 0800.

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-16-07 Project Instructions can be obtained from the NOAA Central Library. The EX-16-07 Data Management Plan is an appendix of the project instructions.

EX-16-07 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 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