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MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT

CRUISE EX-15-04 Leg 2: Hohonu Moana 2015: Exploring the Deep Waters off Hawaii *(ROV and 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 used during the remotely operated vehicle (ROV) and mapping expedition EX-15-04 Leg 2, 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 2015 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 Report: EX-15-04 L2, Hohonu Moana 2015: Exploring the Deep Waters off Hawai'i (ROV & Mapping).*"

3. Cruise Objectives

EX-15-04 Leg 2 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 was the second of four legs comprising the "Hohonu Moana: Exploring the Deep Water off Hawai'i" expedition, focusing on collection of critical baseline data to address NOAA Science and management needs within the Papahānaumokuākea Marine National Monument (PMNM). This region is also commonly referred to as the Northwest Hawaiian Islands (NWHI).

EX1504L2 was a combined mapping/ROV cruise to PMNM that took place between July 31, 2015 and August 23, 2015. The expedition commenced and concluded in Honolulu, Hawaii, with mapping operations occurring during all transits and overnight following ROV deployments and recoveries. Eighteen ROV dives were conducted, including the deepest dive ever conducted inside PMNM, to a depth of 4,829 meters. Mapping operations utilized the ship's deep water mapping systems (Kongsberg EM 302 multibeam sonar, EK 60 split-beam fisheries sonar, 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-15-04 Leg 2 Project Instructions, which are archived in the NOAA Central Library.

4. Summary of Mapping Results

EX-15-04 Leg 2 mapped 29,923 square kilometers of seafloor during the cruise (Figure 1 and Table 1). Multibeam bathymetry data coverage is shown in Figure 1. The locations of all ROV dives are shown in Figure 2.

Cruise Overview Map

Figure 1. Overview of bathymetric mapping coverage completed during EX-15-04 Leg 2.

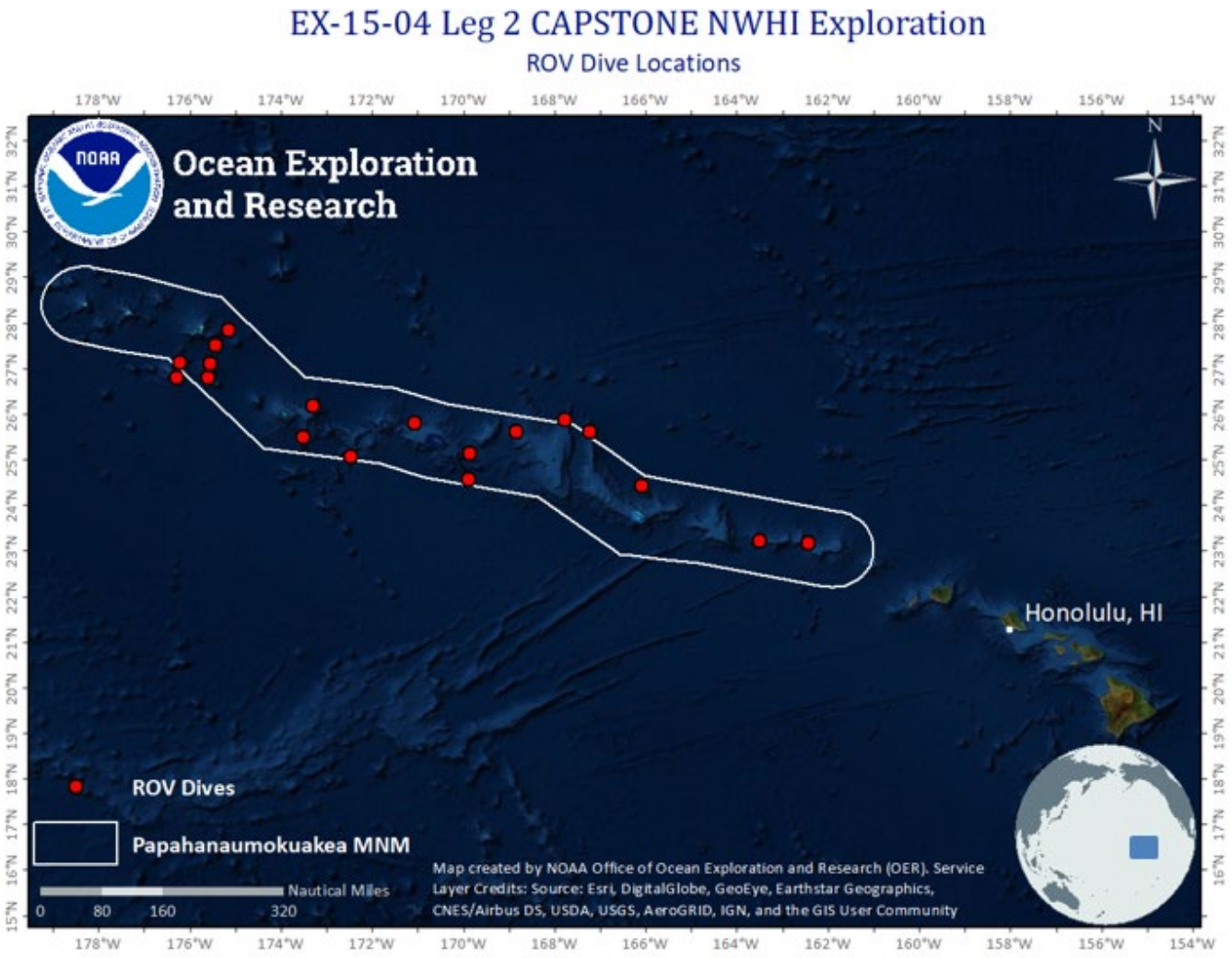

Figure 2. Overview of ROV dive locations during EX-15-04 Leg 2.

5. Mapping Statistics

Table 1. Summary statistics of ocean mapping work completed during EX-15-04 Leg 2.

Dates of cruise	July 31 – August 23, 2015
Ship's draft: Start of cruise (07/31/2015) End of cruise (08/23/2015)	 Fore: 15' 6'', Aft STBD: 14' 3" Fore: 14' 9"; Aft STBD: 14' 7"
Linear kilometers of survey with EM 302	6,211
Square kilometers mapped with EM 302	29,923
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files (.all)	481 files/ 23.5 GB
Number / Data Volume of EM 302 water column multibeam files	481 files / 88.6 GB
Number / Data Volume of EK 60 water column split beam files (.raw)	569 / 4.1 GB
Number / Data Volume of sub-bottom sonar files (.segy, .kea, .keb)	807 / 5.06 GB
Number of XBT casts	39
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 2015 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. 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.

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.

7. Data Acquisition Summary

Mapping operations included data collection via the EM 302 multibeam sonar, EK 60 split-beam sonar, and Knudsen 3260 sub-bottom profiler. Data were collected by each sonar concurrently during the transits.

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 ¼ 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 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 constantly compared against secondary derived sound speed values from the ship's onboard thermosalinograph flow-through system as a quality assurance measure.

Simrad EK 60 split-beam water column sonar data were collected throughout the majority of the cruise, including during ROV dives while the multibeam was not acquiring data (Figure 3). Data were monitored in real time for quality but were not post-processed.

Knudsen 3260 subbottom profiler data were also collected throughout the majority of the cruise. See Figure 4 for an overview of subbottom coverage.

Figure 3. Simrad EK60 spit-beam sonar tracklines (in green) collected during EX-15-04 Leg 2.

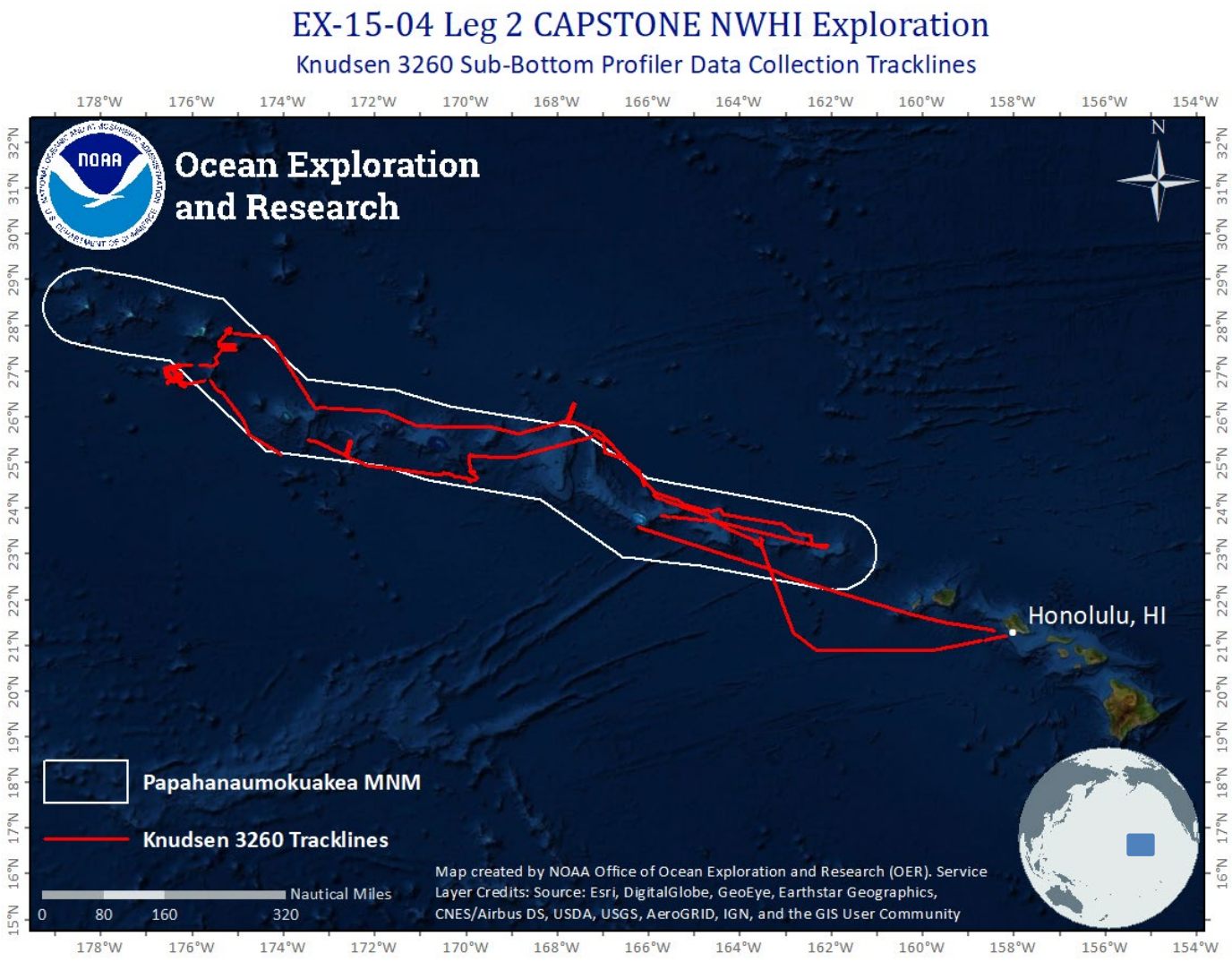

Figure 4. Knudsen 3260 subbottom profiler tracklines (in red) collected during EX-15-04 Leg 2.

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 by SIS, and were imported into CARIS. In CARIS, attitude and navigation data stored in each file were checked, and erroneous soundings were manually removed using CARIS Swath Editor and Subset Editor. 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).

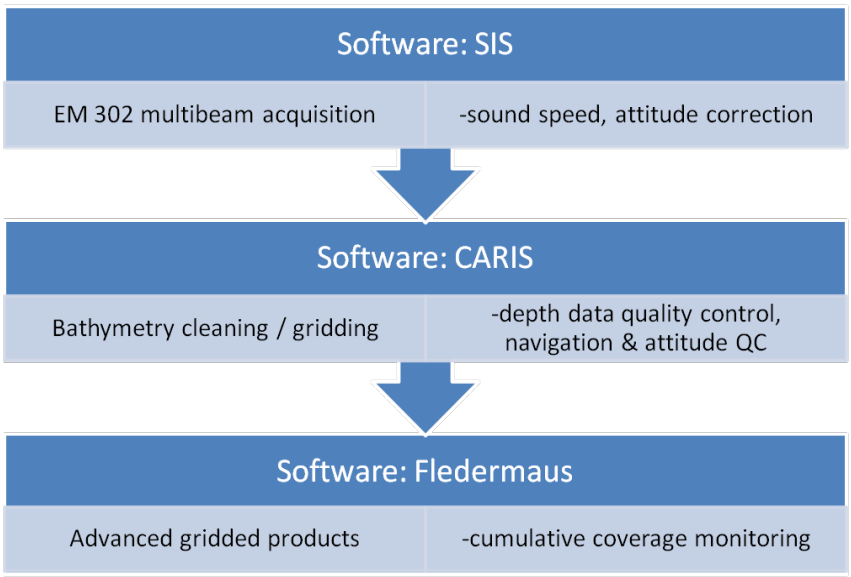

Figure 5. Shipboard multibeam data processing workflow.

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. Two crosslines were collected opportunistically during transits as shown in Figure 6. Crossline analysis was completed using the Crosscheck Tool in QPS Qimera software. The results are shown below and confirm that the data meet International Hydrographic Organization (IHO) Order 1 specifications for data quality.

Crossline files:

0374_20150819_140156_EX1504L2_MB

0449_20150822_195129_EX1504L2_MB

Mainscheme line files:

0077_20150804_085437_EX1504L2_MB

0425_20150821_175447_EX1504L2_MB

Statistic	Value
Number of points of comparison	123960
Grid Cell Size	100 m
Difference Mean	0.533
Difference Median	0.422
Difference Std. Dev	4.77
Difference Range	[-109.34, 100.38]
Mean + 2*Stddev	10.06
Median + 2*Stddev	9.95
Data Mean	-4916.24
Reference Mean	-4916.78
Data Z-Range	[-5108.33, -3986.01]
Reference Z-Range	[-5095.99, -4079.50]
Order 1 Error Limit	63.92
Order 1 # Rejected	171
Order 1 P-Statistic	0.001379
Order 1 Survey	**ACCEPTED**

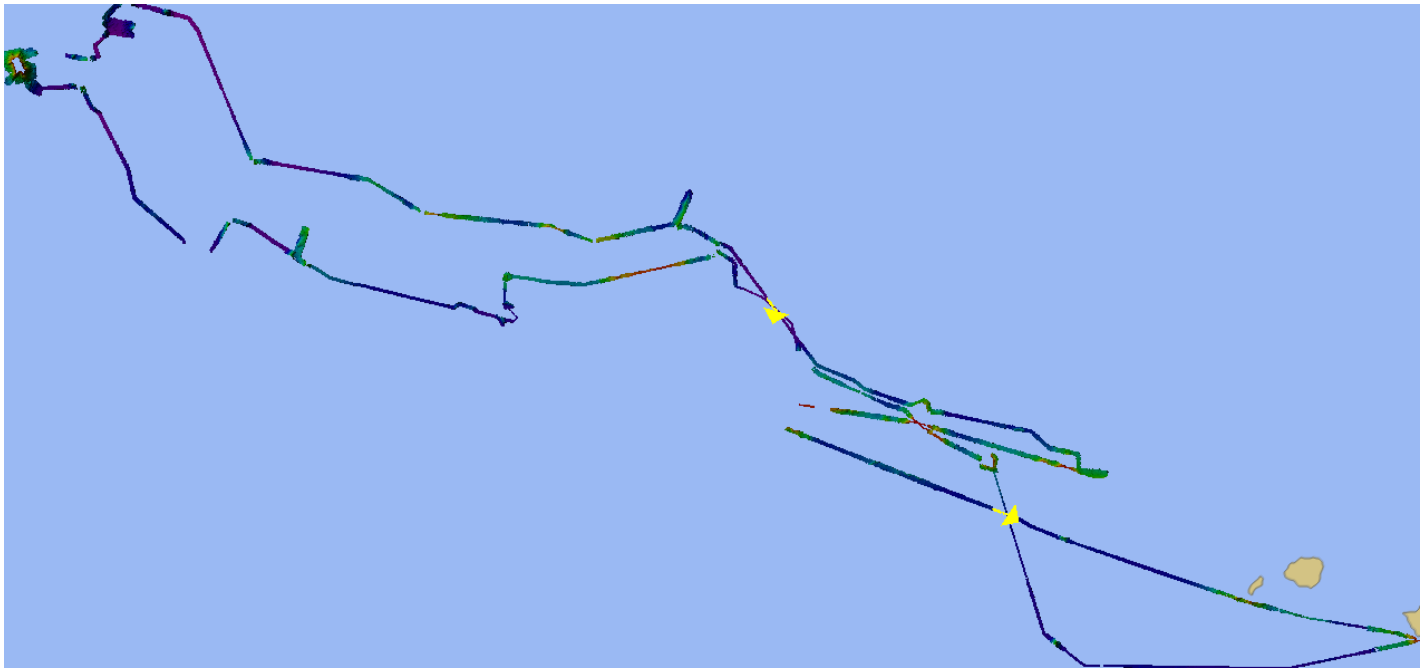

Figure 6. EX-15-04 Leg 2 crosslines (shown in yellow) used for comparison against the bathymetric grid generated via orthogonal multibeam survey lines.

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-15-04 Leg 2 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:

- Sound velocity profile log
- Multibeam acquisition and processing log

Simrad EK split-beam water column dataset:

- Mapping watch stander log

Knudsen 3260 Sub-bottom Profiler dataset:

- Mapping watch stander log

EM 302 Multibeam water column dataset:

- Sound velocity profile log
- Multibeam acquisition and processing log

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).

- EK 60 water column data can be found directly here: doi:10.7289/V5B85644
- EM 302 water column data can be found directly here: doi:10.7289/V56H4FFV

Sub-bottom data, supporting data, and informational logs are available in the NCEI Data Archives accessible at https://maps.ngdc.noaa.gov/viewers/geophysics/. For assistance in accessing SBP data, send an inquiry to ncei.info@noaa.gov requesting access to EX-15-04 L2 Knudsen 3260 sub-bottom raw and processed data.

EM 302 bathymetry data, supporting informational logs, and ancillary files are available in the NCEI Data Archives accessible at https://maps.ngdc.noaa.gov/viewers/bathymetry/ (last accessed 01/02/2020).

10. Cruise Calendar

All times listed are local ship time, -10 hours from UTC

July - August 2015

Sun	Mon	Tues	Wed	Thur	Fri	Sat
					31 Ship departed Pearl Harbor, Oahu at 0930. Transit Mapping.	1 Transit mapping.
2 Transit mapping.	3 Transit mapping.	4 Transit mapping.	5 Sub-bottom data collection over Maro Crater. Multibeam gap filling lines.	6 Transit mapping.	7 Transit mapping. Focused mapping of western side of North Hampton Seamount.	8 Transit mapping.
9 Focused mapping over Salmon Bank.	10 Focused mapping over Salmon Bank.	11 Focused mapping over Salmon Bank.	12 Focused mapping east of Pearl and Hermes Atoll.	13 Sub-bottom data collection over unnamed seamount.	14 Transit mapping.	15 Transit mapping.
16 Transit mapping.	17 Focused mapping of the rift zone at Gardner Pinnacle.	18 Transit mapping.	19 Transit mapping.	20 Transit mapping. Diversion to Tern Island to rescue scientists.	21 Transit mapping.	22 Transit mapping.
23 Transit mapping. Alongside in Pearl Harbor at 1830.						

11. Daily Cruise Log Entries

Generated from the daily expedition situation reports. All times listed are in local ship time (-10 hours from UTC)

July 31
The ship departed Pearl Harbor, Oahu at approximately 0930 to commence Leg 2 of the EX-15-04 Hohonu Moana Expedition. The EM 302 TRU booted cleanly after a 10 minute warm up period. The results were recorded to a telnet session. Two Built-in Self Tests (BISTs) passed overall, with three channels of the receive boards failing, which is not new and of which Kongsberg is aware and monitoring with the mapping team. Data quality on all sonars was acceptable for 10-12 kt transit speeds in deep water. Once the ship exited the Oahu platform, most data were collected over the abyssal plain with exceptions of basalt at the southern edge of Kauai and one small abyssal hill < 350 m high.

August 1
24-hour mapping occurred during the transit to the first ROV dive site. Data quality was good for transit speed and depth. ROV team helped with watch standing during the day. The EM 302 had difficulty tracking the bottom over an unnamed seamount. Enabling the sector tracking and penetration filters appeared to help. A collapsed caldera was also mapped in the vicinity of the seamount. Two holiday fill lines over existing synthesis data were run overnight en route to the ROV dive site.

August 2
Transit/holiday mapping continued in the morning to ROV dive site 02. Mapping data quality was high on all sonars, with the exception of sub-bottom profiler bottom tracking over sections of steep terrain. Transit/mapping commenced in the evening en route to ROV dive site 03. XBT casts with all three launchers have shown severe spikes in data using probes from different batches, likely indicating a connectivity issue of the larger system. Fantail box plug was cleaned by the ET, but this did not fix the issue. The system continues to be troubleshot.

August 3
Transit mapping continued through the morning until reaching ROV dive site 03. Data collection included holiday fill and transit lines. XBT system continues to be troubleshot. ROV ascent CTD cast was applied to MB data for the 11 hrs of data collection, as the XBT system is still not providing good data and continues to be troubleshot by the survey team. No significant SVP artifacts have been observed in the data.

August 4
Overnight mapping consisted of transit and synthesis holiday fill lines. Data quality on all sonars was high. The XBT system continues to be troubleshot. The test probe was used on two launchers, with one launcher getting a successful test, however when a real XBT was conducted with it spikes occurred in the data. The ROV CTD was used for the first half of overnight data collection. A second XBT cast was conducted later in the night and minor spikes occurred and were cleaned out so the cast could be interpolated and applied.

August 5
Overnight mapping included sub-bottom data collection over Maro crater at request of the shore based science team, and holiday fill lines were conducted over existing synthesis data, including over deep sections of two volcanic rift zones. Chief Electronics Technician (CET) re-terminated two XBT launchers. XBT troubleshooting next steps are test launchers and use alternate MK21 rack unit.

August 6
Overnight mapping consisted of transit holiday fill lines on the ridge extending southeast off Maro Reef / Maro Seamount. Data quality was good on all sonars with exception of sub-bottom tracking over slopes at high transit speeds (10+ kts). A successful XBT cast was conducted using one handheld launcher and the older MK21 USB rack unit. Ascent CTD data from D2 were still applied to multibeam data for the first half of night ops.

August 7
Overnight mapping operations initially focused on completing a section of mapping on the western side of North Hampton Seamount in order to define the 4000m depth curve, followed by transit mapping through the night en route to the ROV dive site. Two of the three XBT launchers are now producing good casts with the older USB rack unit.

August 8
Overnight mapping was conducted at 10-11 kt transit speed after the ship exited the monument to dispose of waste water. Data quality was good with the exception of on steep slopes which are difficult for the multibeam and sub-bottom to track at high transit speeds. Where possible, data collection focused on complementing existing synthesis data. 10 BISTs have been conducted thus far and all have passed. EM 302 transmit-receive unit (TRU) is left powered on during the daytime ROV operations. Sub-bottom power is secured in the rack room. 10-20 second fly-through visualizations are being created for ROV dives for use as discussion points during the morning science dive planning call. XBTs have been good two nights in a row. CTD data from ROV ascents continue to be applied to MBES data.

August 9
Overnight mapping focused on developing coverage over the Salmon Bank area in preparation for the ROV dive on 8/11. Data quality was good on all three sonars.

August 10
Overnight mapping focused on unmapped areas of Salmon Bank in preparation for the next morning's ROV dive. Data quality on all sonars was high. SIS stopped painting to the geographical display grid in real-time, possibly due to the large geographic area of the survey.

August 11
Overnight mapping efforts focused on eastern and northern flanks of Salmon Bank. Sub-bottom data were collected over the NW Salmon Bank area. Data quality on all sonars was generally high, with the exception of when the sub-bottom profiler had trouble tracking up slope despite the ship's slowed speed of 6 knots.

The TRU dropped the 1 PPS feed at the same time as the heading accuracy was going out of tolerance specifications on the POSMV. Both systems were power cycled and rebooted cleanly.

August 12
Overnight mapping focused on filling a 700 sq km gap in multibeam data coverage east of Pearl and Hermes Atoll. Data quality was good on all sonars.

August 13
EK 60 data were collected during the water column exploration portion of the ROV ascent, during which time the ship and ROV traveled at 0.2 knots for approximately 1.5 hours collecting video data for 10 minutes at each 200m depth interval from 1200m to 600m. Overnight mapping focused on sub-bottom data collection over the unnamed potentially Cretaceous seamount which is the location of the 8/14 dive. Due to the availability of existing multibeam and water column data in the vicinity, multibeam and split-beam sonars were secured for this portion of the evening to allow greater alongtrack data density for the sub-bottom profiler. The "Process Shift" setting, when set to 1, was found to help with tracking the sub-bottom profiler on the steep flanks of the seamount.

August 14
Overnight mapping consisted of a 10 knot transit en route to the next dive site via a path that diverted outside monument boundaries to accommodate waste water disposal. An uncharted seamount was mapped within the monument boundary. The seamount does appear in the satellite-derived bathymetry but was found to be 1500 meters higher than predicted.

August 15
Overnight mapping operations consisted of transit mapping over unmapped areas between ROV Dive 13 and 14. Data quality was high on all sonars with the exception of occasional minor side lobe artifacts on flats areas in depths > 5000m between seamounts. All ancillary systems including XBT, CNAV, POSMV, and the Reson SVP 70 probe are performing well.

August 16
Overnight mapping consisted of straight transit mapping between dive sites, with no time for holiday fill deviations from the direct transit track. The EM 302 data showed what looked like interference for ~2 hrs while climbing one side of a seamount. The morning BIST showed several hard failures. The system was shut down for the day and will be troubleshot at the end of the ROV dive. It is suspected a reboot will resolve the failures.

August 17
Overnight mapping focused on developing coverage of the rift zone at Gardner Pinnacle which extends outside of the monument bounds. The multibeam TRU required two restarts before booting properly, then performed well all night. The daily BIST passed. Data quality on all sonars was high.

August 18
Transit mapping to the ROV dive site for 8/20 commenced and will continue through 8/19 into the morning of 8/20. The trackline is planned to collect data complementary to the existing synthesis data. EK 60 data were collected during the water column transect during ROV ascent.

August 19
Transit mapping continued through the day and into the morning of 8/20. Data quality on all sonars was high to acceptable at high transit speeds.

August 20
In the early evening, holiday fill lines were conducted between dive sites 18 and 19. NOAA OMAO leadership ordered the NOAA Ship *Okeanos Explorer* to divert course from her planned return to Pearl Harbor, Oahu, and instead transit west to Tern Island, French Frigate Shoals to rescue four scientists conducting research for NOAA's Hawaiian Monk Seal Research Program. During the transit to French Frigate Shoals, mapping operations transitioned to exploration transit mapping. Data quality on all sonars was high.

August 21
Transit exploration mapping continued throughout the day and evening with a skeleton mapping crew. The EK 60 was secured so the survey team could focus on multibeam and sub-bottom data collection. One half hour of data was accidentally collected in the monument in waters shallower than 250 m. Monument permitting representatives were contacted with the details for guidance on how to handle the data.

August 22
24-hour transit mapping continued. A slight course deviation was made to map a portion of an uncharted seamount within the monument boundaries. Data quality on all sonars was generally high.

August 23
Transit mapping continued until reaching the Pearl Harbor sea buoy. Data quality on all sonars was fair in heavier seas at 10+ kt transit speeds.

12. References

The 2015 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-15-04 Leg 2 Project Instructions can be obtained from the NOAA Central Library. The EX-15-04 Leg 2 Data Management Plan is an appendix of 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