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MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT

CRUISE EX-16-08: FY17 Ship and ROV Shakedown (ROV and Mapping)

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1. Introduction

The NOAA Office of Ocean Exploration and Research (OER) 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-16-08, and to present a summary of the overall mapping results and mapping related cruise activities. A detailed description of the NOAA Ship *Okeanos Explorer's* mapping capabilities is available in the 2016 NOAA Ship *Okeanos Explorer* Survey Readiness Report, available in the NOAA Central Library at https://doi.org/10.25923/9vs2-pw48. A separate cruise report detailing the ROV activities of the cruise is planned to be available in the NOAA Central Library.

3. Cruise Objectives

EX-16-08 was a telepresence-enabled cruise focused on ROV engineering trials in and around the Hawaiian Islands. The primary purpose of the cruise was to ensure full preparation of ship and mission systems to support fiscal year 2017 field season operations. The 2017 field season was the third year of the Campaign to Address Pacific monument Science, Technology, and Ocean NEeds (CAPSTONE) field effort to collect scientific data in deep water areas of U.S. marine protected areas in the central and western Pacific. The ship conducted 24-hour per day operations consisting of daytime ROV dives, ship shakedown items, and overnight mapping operations. Mapping operations included a patch test calibration of the EM 302 multibeam sonar, calibration of the POSMV positioning system via a GNSS Azimuth Measurement System (GAMS) calibration, and gathering data with the Acoustic Doppler Current Profilers (ADCPs) to determine transducer alignment angles. Data were collected by the multibeam, split-beam, and sub-bottom sonars onboard. The complete objectives for this cruise are detailed in the EX-16-08 Project Instructions, which are archived in the NOAA Central Library.

The expedition also completed a high profile public engagement event on December 7, 2016, on the 75th anniversary of the attack on Pearl Harbor. In solemn honor of this anniversary, a publicly-televised ROV dive was conducted on a Japanese mini submarine, five miles off the entrance to Pearl Harbor. The sub was sunk on the morning of December 7, 1941 - ninety minutes before Pearl Harbor was bombed by air. The sub was sunk by the destroyer USS *Ward*, marking the first U.S. shots fired and the country's entry into World War II in the Pacific.

4. Summary of Mapping Results

EX-16-08 operations were completed Dec 01 – Dec 08, 2016 and mapped 1,071 square kilometers (km) of seafloor in the vicinity of the Hawaiian Islands during the 8 days at sea (Figure 1 and Table 1). All of this area was mapped within the U.S. Exclusive Economic Zone in depths deeper than 200 meters (m). Multibeam bathymetry data coverage is shown in Figure 1.

Cruise Overview Map

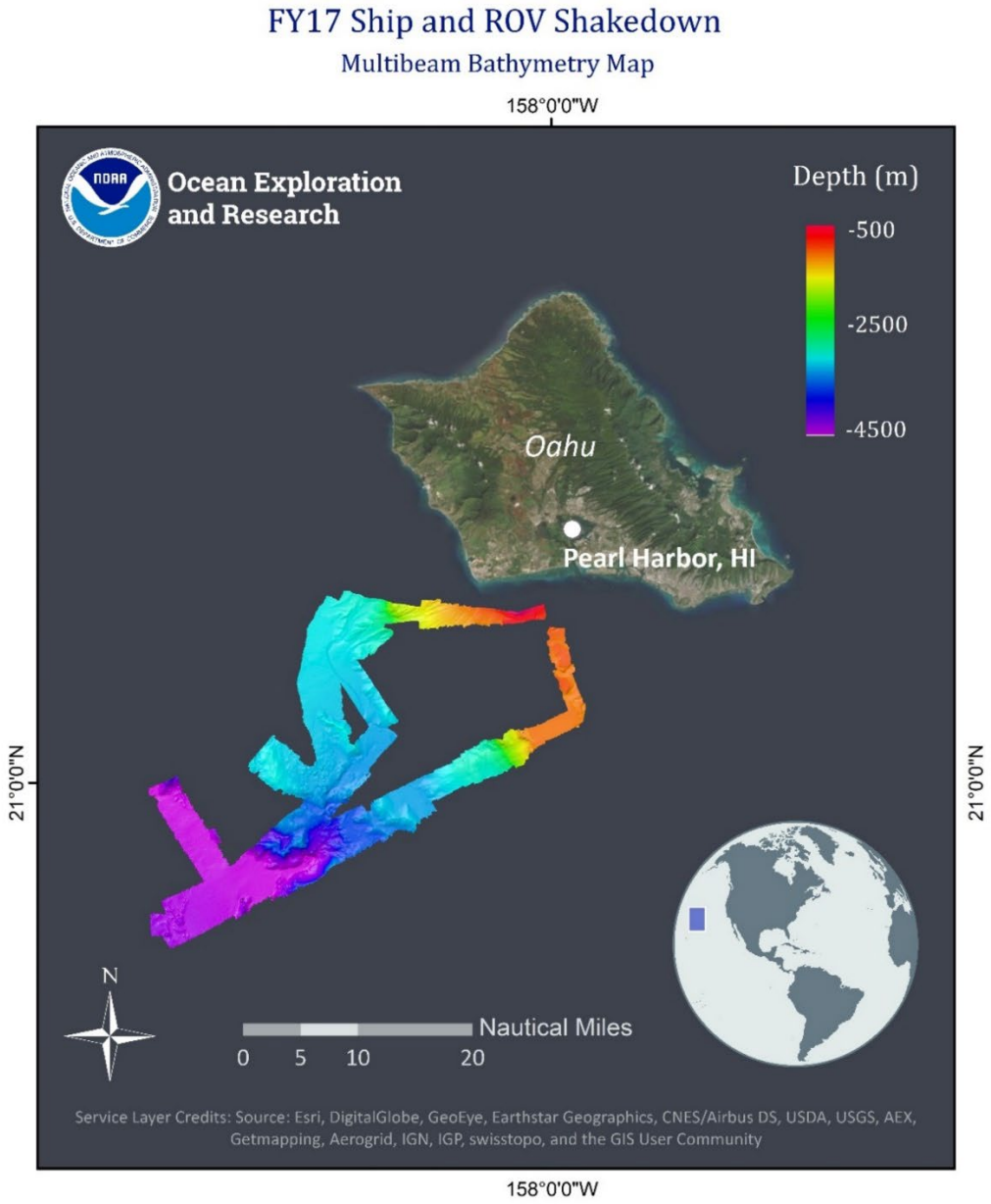

Figure 1. Overview of multibeam bathymetric mapping coverage completed during EX-16-08.

5. Mapping Statistics

Table 1. Summary statistics of ocean mapping work completed during EX-16-08.

Dates of cruise	**December 1-8, 2016**
Linear kilometers of survey with EM 302	**416**
Square kilometers mapped with EM 302	**1,071**
Square kilometers mapped with EM 302 within U.S. EEZ deeper than 200 meters	**1,071**
Number / data volume of EM 302 raw bathymetric / bottom backscatter multibeam files (.all)	**81 files / 3.56 GB (some files restricted from public release)**
Number / data volume of EM 302 water column multibeam files	**81 files / 11.52 GB (some files restricted from public release)**
Number / data volume of EK60 water column split-beam files (.raw)	**9 / 1.03 GB**
Number / data volume of sub-bottom sonar files (.segy, .kea, .keb)	**21 / 0.15 GB**
Number of XBT casts	**9**
Number of CTD casts (including test casts)	**4**

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 shallower 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 calibrated with a multibeam sonar patch test 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 at https://doi.org/10.25923/9vs2-pw48..

Simrad EK60 Split-beam Sonars

The ship had five operational Simrad EK60 split-beam fisheries sonars onboard during the cruise: 18, 38, 70, 120, 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 during the EX-16-01 cruise, and calibration values from that cruise were applied to the EK60 sonars for EX-16-08.

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 an approximately 1000 meter range; and a 300 kHz Teledyne RDI Workhorse Mariner ADCP, with an approximately 70 meter range. The ADCPs gather data prior to ROV deployments 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, EK60 split-beam (18, 38, 70, 120, and 200 kHz) sonars, and Knudsen 3260 sub-bottom profiler. Data were collected by each sonar concurrently during the transits. Apart from transits, most of the mapping time on this cruise was dedicated to completing the patch test calibration of the multibeam sonar. Multibeam lines 13-30 were restricted due to Underwater Cultural Heritage protocols. There was a failed positioning system calibration that resulted in a heading bias in multibeam lines 31-48. The operational area was mostly already well mapped by previous surveys and most of the mapping work needed for this cruise focused on testing and calibrating sonar systems onboard. 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 adjusted to minimize poor data on the outer beams of the swath.

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 secondarily derived sound speed values from the ship's onboard thermosalinograph flow-through system as a quality assurance measure.

Simrad EK60 split-beam water column sonar data were collected during mapping operations. Data were monitored in real time for quality but were not post-processed. Knudsen 3260 sub-bottom profiler data were also collected during a portion of the cruise.

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 Seafloor Information System (SIS), then imported into QPS Qimera for processing. In Qimera, the attitude and navigation data stored in each file were checked, and erroneous soundings were removed using 2-D and 3-D editors. Gridded digital terrain models were exported utilizing QPS Fledermaus software and posted to the ship's File Transfer Protocol (FTP) site for daily transfer to shore. Final bathymetry quality control (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. The coordinate system for the data cleaning projects was set to the appropriate Universal Transverse Mercator (UTM) zone for the operational area. Final data products were exported and archived as field geographic WGS84 coordinate reference frame (i.e., unprojected).

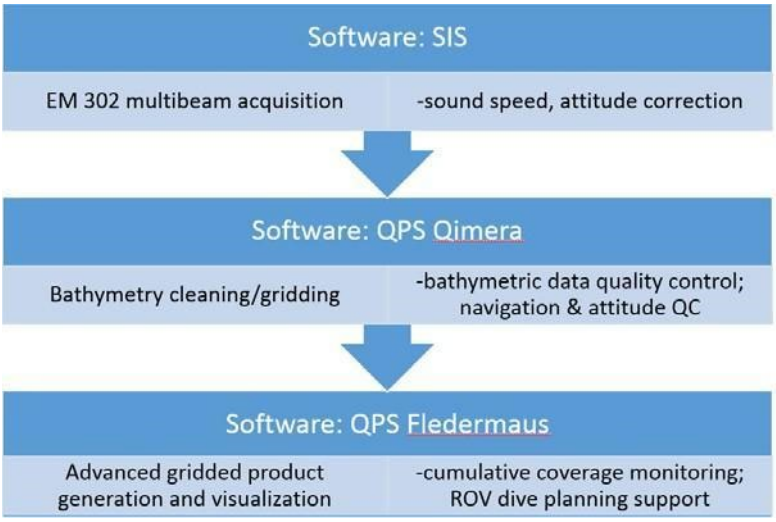

Figure 2. Shipboard multibeam data processing workflow.

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. A short crossline was run on December 2, 2016 as shown in Figure 3. Crossline analysis was completed using the Crosscheck Tool in QPS Qimera software to evaluate the data against standards set by the International Hydrographic Organization. The results are shown below.

Crossline file:

0004_20161202_091346_EX1608_MB.all

Mainscheme line files:

0003_20161202_090832_EX1608_MB.all

Statistic	Value (depths in meters)
Number of points of comparison	7680
Grid Cell Size	75
Difference Mean	-0.103
Difference Median	-0.338
Difference Std. Dev	10.042
Difference Range	[-139.797, 60.615]
Mean + 2*Stddev	20.187
Median + 2*Stddev	20.422
Data Mean	-4226.55
Reference Mean	-4226.45
Data Z-Range	[-4284.370, -4088.537]
Reference Z-Range	[-4276.319, -4090.140]
Order 1 Error Limit	54.9461
Order 1 # Rejected	50
Order 1 P-Statistic	0.00651042
Order 1 Survey	ACCEPTED

These results confirm that the data collected meet International Hydrographic Organization (IHO) Order 1 specifications for data quality.

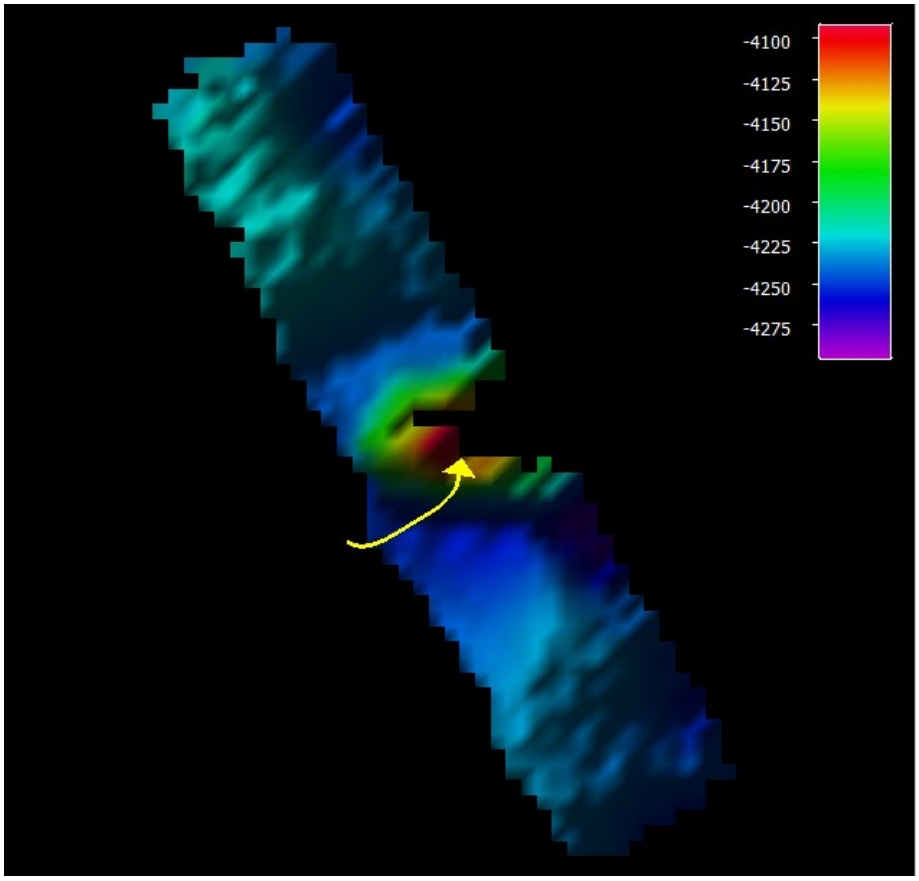

Figure 3. EX-16-08 crossline (shown in yellow) used for comparison against the bathymetric grid generated via the intersecting multibeam survey line.

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-16-08 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

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

All sonar data is permanently discoverable at https://www.ngdc.noaa.gov/.

EM 302 and EK60 water column data, supporting data, and informational logs are available in the NCEI Water Column Sonar Archives:

- EM 302 water column data can be found here: http://doi.org/10.7289/V5NS0S3S
- EK60 water column data can be found here: https://doi.org/10.7289/v5x63k5z

Sub-bottom data, supporting data, and informational logs are available in the NCEI Trackline Geophysical Data portal at https://maps.ngdc.noaa.gov/viewers/geophysics/ (last accessed 4/8/2020). For assistance in accessing sub-bottom profiler data, send an inquiry to ncei.info@noaa.gov requesting access to EX-16-08 Knudsen 3260 sub-bottom profiler 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 4/8/2020).

10. Cruise Calendar

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

December 2016

Sun	Mon	Tues	Wed	Thur	Fri	Sat
				1 First day of the cruise. Ship was fueled and departed Ford Island. Transit mapping and testing of multibeam.	2 Dynamic positioning testing. Small boat transfer. Multibeam testing and overnight mapping.	3 ROV engineering dive 1 completed south of Oahu. CTD test casts. GAMS calibration attempt. First multibeam sonar patch test effort completed.
4 ROV engineering dive 2 completed. Overnight mapping with ADCP reciprocal lines for transducer alignment.	5 ROV engineering dive 3 completed. Second multibeam sonar patch test successfully completed.	6 ROV engineering deep water test dive completed (dive 4). Multibeam survey and patch test validation line completed.	7 ROV dive on Japanese mini-submarines completed as major public engagement event. Ship transited to port in Pearl Harbor in the evening.	8 ROV mission team demobilization. Ship preparing for the follow-up mapping system shakedown cruise EX-16-09.		

11. Daily Cruise Log Entries

Generated from the daily expedition situation reports. All times listed are local ship time, which was -10 hours from UTC

December 1, 2016

The NOAA Ship *Okeanos Explorer* got underway on time and moved over to the fuel pier. After taking on 80 thousand gallons of fuel the ship departed for sea. When we tried to bring the multibeam online we were not receiving any data from the Sound Velocity Probe. The thermosalinograph (TSG) is being utilized for calculating sound speed at the multibeam transducer face instead of the probe.

The focus of mapping operations was testing the multibeam after troubleshooting and part replacement work conducted by Kongsberg while alongside the previous day. All of the Ethernet cables connecting all boards in the multibeam transmit/receive unit (TRU) were replaced, all firmware on the TRU was updated, and three faulty transmit (TX36) boards were replaced with spares. One faulty receive (RX32) board was replaced from spares. SIS operating software was upgraded to 4.3.2, which is the latest version. After these improvements, the TRU boots quickly and cleanly and all Built-in Self Tests (BISTs) pass.

December 2, 2016

The ship commenced dynamic positioning (DP) testing at 0600 and continued testing until lunch time. Modification to the DP system were successful. After lunch a small boat transfer was conducted to pick up visiting scientists and the compass adjuster. Most of the afternoon was spent adjusting the magnetic compass. Once that was complete the ship turned to sea and commenced overnight mapping operations. Throughout the day several issues came up and are currently being worked on. The ADCPs are not behaving correctly, and there are still some integration problems with transitioning from the C-Nav positioning system to the new MarineStar system.

The EM 302 pinged continuously for 13 hours with no errors. Data were collected from 700 m to around 4000 m. No errors, warnings, or ping failures occurred and the system has been deemed in good condition for the field season. Evening and overnight mapping operations focusing on gathering new multibeam data over four dive targets planned for the remotely-operated vehicles (ROVs) on this cruise. The multibeam worked without any problems. ROV dive background maps were made. Successfully completed a GNSS Azimuth Measurement System (GAMS) calibration on the POSMV antennas. This was necessary since all antennas had been removed for mast

preservation work. Results indicated GAMS solutions pre-calibration were still of high quality, with only about a 2 millimeter adjustment to the antenna separation distance post-calibration.

Following the GAMS calibration, ADCP testing work was conducted for the rest of the night. The OS38 deck unit was disconnected from power, but was fixed in the morning. The WH300 ADCP was run all night to gather test data and characterize currents in the area. At 3 AM the ADCP stopped putting out a video signal and it was not possible to stop the survey without a hard reset. Assistance was provided by partners at the University of Hawaii (UH). Detailed instructions were also received for gathering ADCP data to test ADCP alignment angles, and agreed on a testing plan.

December 3

Following the ROV dive, we moved directly into Conductivity Temperature Depth (CTD) deployment practice. Two test casts were conducted. The second one yielded useful CTD data. The Survey Department is updating the standard operating procedure (SOP) for CTD casts. The ship moved to the CTD cast site for the multibeam patch test, and a successful cast was completed to 2500 m. Salinity and temperature data was "jumpy" past about 800 meters, but still seemed reasonable after thinning and smoothing of the profile. An XBT cast was completed in the same area immediately after CTD recovery for comparison purposes. Casts were nearly identical in the upper 500 m of the water column, with some differences below that, but no greater than 2 m/s. The CTD cast was applied to the multibeam computer for use during the patch test lines. Patch test operations were planned for all night until transiting to the "Omaha" dive site.

December 4

The patch test lines were completed overnight. In the morning, the ROV team reported they noticed a 15 degree difference between the POSMV heading and the heading from the ship's gyros. This indicated there was some major bias of the POSMV that must have resulted from the GAMS calibration attempt on December 2. This finding meant that the patch test lines gathered the previous night would have to be re-done once the heading issue was fixed. The GAMS values were reset to the pre-calibration values, which fixed the problem. The calibration was redone in the evening using a manual calibration routine instead of the auto calibration tried the first time. This time a successful calibration was conducted with good results that matched closely to the heading numbers from the ship's gyros. An updated SOP is being generated to ensure that we use the better procedure next time, as there were two Applanix procedures that differed in approach. The multibeam, EK60, and sub-bottom sonars were all run together as normal for a mapping cruise to generate test datasets to send to the onshore data warehouse. The rest of the night was dedicated to running reciprocal lines with both ADCPs on to gather data needed by UH to evaluate the existing transducer alignment angles of the ADCPs and see if any adjustments are needed.

December 5

The mapping watch was dedicated to completing the multibeam patch test lines and mapping on the way to the 3000 m ROV dive site. Patch test calibration was completed in CARIS, with no additional offsets deemed necessary to roll, pitch, yaw, or latency aspects of the multibeam system. Occasional transient dropouts of data feeds from the TRU to SIS were noted, with associated warning messages in SIS. The problem self-resolves within a few seconds, and is thought to be a network interruption or dropped data packets. This issue will be monitored, but did not appear to have any impact on data quality. ADCPs are being run prior to, and during, all ROV dives.

December 6

Following the ROV 3000 m dive recovery, all three usual sonars were run over a nearby area that had somewhat poor existing data quality. Transit mapping was then done to get a validation crossline over the patch test area before transiting towards the mini-sub dive sites for an 0300 arrival.

December 7

The multibeam, sub-bottom, and EK60 sonars were run until the ship was close to the dive site for the Japanese mini-submarines. This dive site was selected as part of the 75th anniversary commemoration of the attack on Pearl Harbor. The dive was broadcast live and consumed operations for the rest of the day. At the conclusion of the dive the ADCPs were run until entering Pearl Harbor. The ship pulled into port at Ford Island.

December 8

The mission team demobilized, with the ROVs secured in anticipation of the following mapping systems shakedown cruise.

12. References

The 2016 NOAA Ship *Okeanos Explorer* Survey Readiness Report can be obtained in the NOAA Central Library at https://doi.org/10.25923/9vs2-pw48.

The EX-16-08 Project Instructions can be obtained from the NOAA Central Library. The EX-16-08 Data Management Plan is an appendix of the project instructions.

The 2016 Mapping Systems Readiness Report can be obtained in the NOAA Central Library at http://doi.org/10.7289/V5FT8J2Z.

NOAA Nautical Charts

Various datasets downloaded from the NCEI archives via NOAA AutoChart.