Ocean Exploration and Research

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MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT

CRUISE EX-16-05 Leg 1: 2016 Deepwater Exploration of the Marianas (*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 expedition EX-16-05 Leg 1, and to present a summary of the overall mapping results and mapping related cruise activities. The complementary cruise report that includes remotely-operated vehicle (ROV) operations can be found in the NOAA Central Library with the title "2016 Deepwater Exploration of the Marianas EX-16-05 Leg 1 Cruise Report," doi:10.7289/V5/CR-OER-EX1605L1. 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-16-05 Leg 1 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 Commonwealth of the Northern Mariana Islands (CNMI) and the Marianas Trench Marine National Monument (MTMNM). 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 April 20, 2016 and concluded in Saipan, CNMI on May 11, 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.

The complete objectives for this cruise are detailed in the EX-16-05 Leg 1 Project Instructions, archived in the NOAA Central Library.

4. Summary of Mapping Results

EX-16-05 Leg 1 mapped 19,657 square kilometers of seafloor during the 22 days at sea. An overview of the multibeam bathymetry data collected is shown in Figure 1 and Table 1 below.

Cruise Overview Map

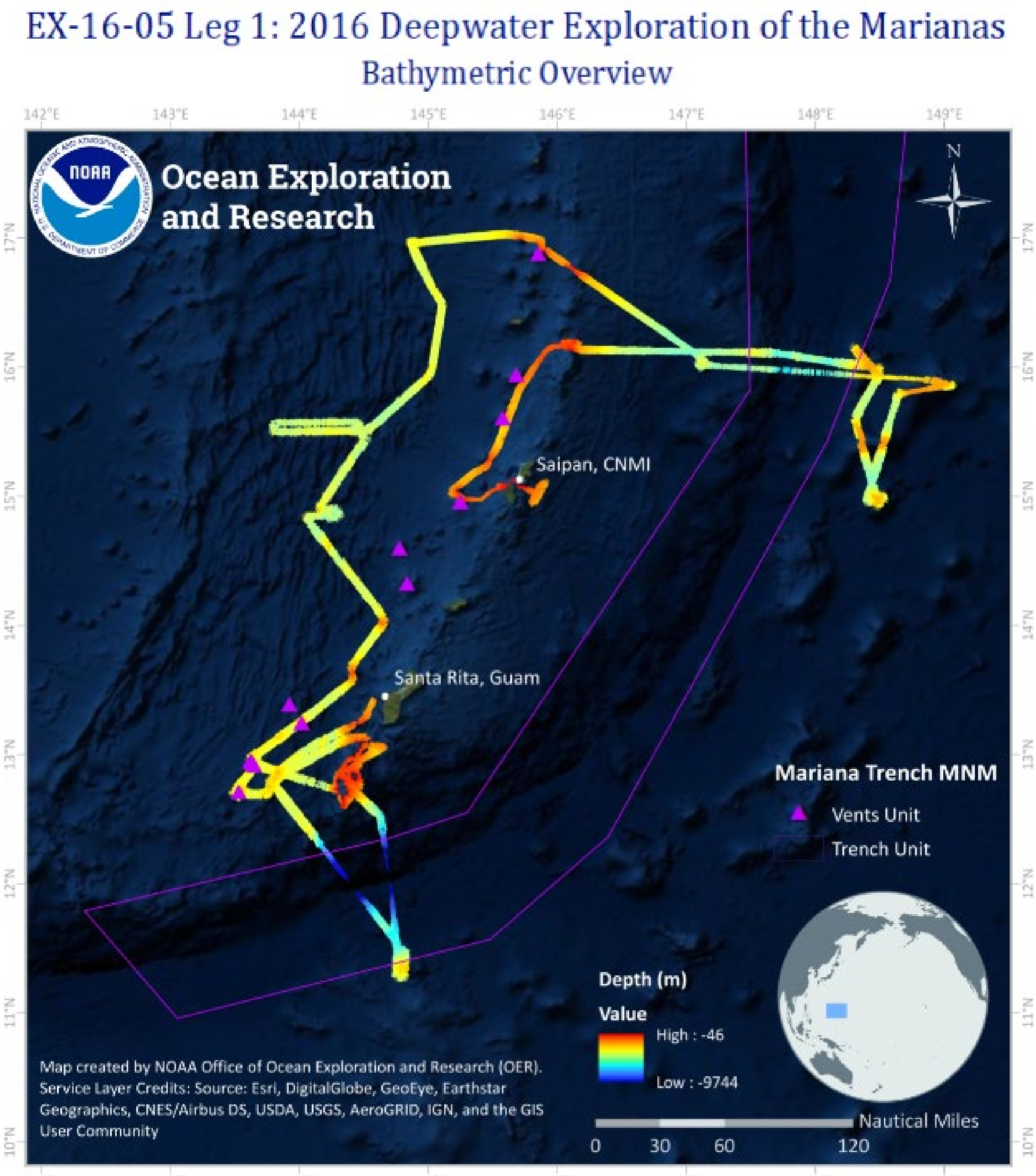

Figure 1. Overview of bathymetric mapping coverage completed during the CAPSTONE CNMI & Marianas Trench MNM expedition (EX-16-05 Leg 1), starting in Santa Rita, Guam and ending in Saipan, CNMI. Map generated in ArcMap.

5. Mapping Statistics

Table 1. Summary statistics of exploration mapping work completed during EX-16-05 Leg 1.

Dates of cruise	April 20 – May 11, 2016
Ship's draft: Start of cruise (04/20/2016) End of cruise (05/11/2016)	Fore: 14' 3'', Aft STBD: 14' 9" Fore: 14' 0"; Aft STBD: 14' 3"
Linear kilometers of survey with EM 302	3,642
Square kilometers mapped with EM 302	19,657
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files (.all)	451 files/ 21.3 GB
Number / Data Volume of EM 302 water column multibeam files	451 files / 69.6 GB
Number / Data Volume of EK 60 water column split beam files (.raw)	439/ 27 GB
Number / Data Volume of sub-bottom sonar files (.segy, .kea, .keb)	355 / 3.6 GB
Number of XBT casts	19
Number of CTD casts (including test casts)	5

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 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-16-05 Leg 1. The calibration data from EX-16-01 are available at http://doi.org/10.7289/V5TD9VJM.

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. Data were collected by each sonar concurrently during mapping 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.

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

8. Multibeam Sonar Data Quality Assessment and Data Processing

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

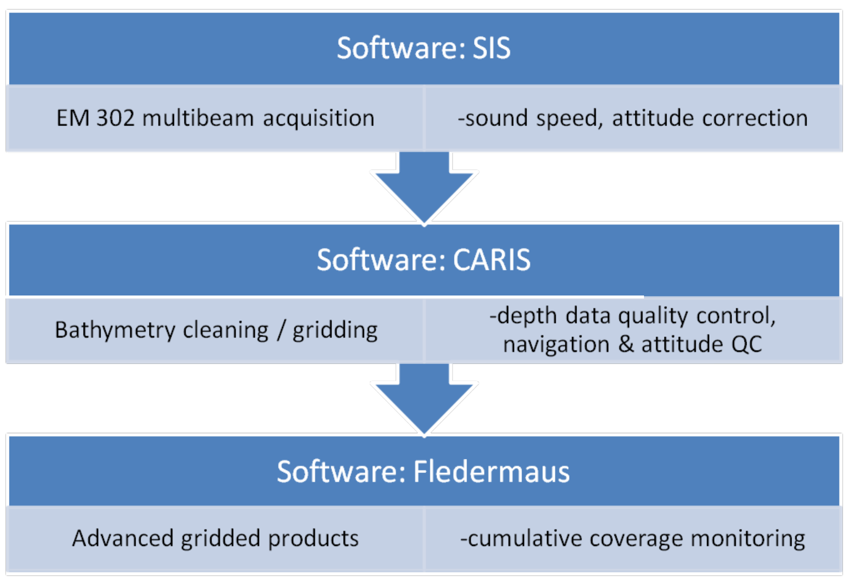

Figure 2. Shipboard multibeam data processing workflow.

9. Data Archival Procedures

All mapping data collected by the NOAA Ship *Okeanos Explorer* are archived and publicly available within 90 days of the end of each cruise via the National Centers for Environmental Information (NCEI) online archives. The complete data management plan (which describes the raw and processed data formats produced for this cruise) is available as an appendix in the EX-16-05 Leg 1 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)

Simrad EK split-beam water column dataset:

- Mapping watch stander log
- Weather log

Knudsen 3260 Sub-bottom Profiler dataset:

- Mapping watch stander log
- Weather 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)

EM 302 water column data is directly available at http://doi.org/10.7289/V5G73BWS and EK 60 water column data at http://doi.org/10.7289/V5KW5D8S.

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). For any challenges accessing SBP data, send an inquiry to ncei.info@noaa.gov requesting access to EX-16-05 Leg 1 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 01/21/2020).

10. Cruise Calendar

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

April - May 2016

Sun	Mon	Tues	Wed	Thur	Fri	Sat
17	18	19 Mission personnel arrive to ship.	20 Depart Guam, mapping ops commenced outside of Guam harbor. Evening CTD conducted.	21 Daytime ROV dive, overnight mapping.	22 Daytime ROV dive, overnight mapping.	23 Daytime ROV dive, overnight mapping.
24 Daytime ROV dive, ROV recovery with ADCPs on, no bathymetric mapping conducted.	25 Transit mapping.	26 Morning CTD ops, daytime ROV dive, overnight mapping.	27 Morning CTD ops, daytime ROV dive, overnight mapping.	28 Daytime ROV dive, overnight mapping.	29 Daytime ROV dive, overnight mapping.	30 Daytime ROV dive, overnight mapping.
1 Daytime ROV dive, overnight mapping.	2 Daytime ROV dive, overnight mapping.	3 Daytime ROV dive, overnight mapping.	4 Daytime ROV dive, overnight mapping focused on sub-bottom lines.	5 Daytime ROV dive, overnight mapping focused on sub-bottom lines.	6 Daytime ROV dive, overnight mapping focused on sub-bottom lines.	7 Daytime ROV dive, overnight mapping.
8 Daytime ROV dive, overnight mapping.	9 Daytime ROV dive, overnight mapping focused on water column data collection.	10 Daytime ROV dive, overnight mapping focused on Underwater Cultural Heritage (UCH).	11 Morning UCH mapping, pulled into port in Saipan.	12 Demobilization.	13 Mission personnel depart.	14

11. Daily Cruise Log Entries

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

April 20-21

NOAA Ship *Okeanos Explorer* departed Guam at approximately 1000 to commence the 2016 Deepwater Exploration of the Marianas Expedition. Mapping operations were started following the departure from Guam harbor, and continued en route to Fina Nagu Caldera A where CTD operations were conducted. An electrical failure occurred during CTD "pogo" operations, and mapping operations were conducted overnight. Mission personnel spent the day getting familiar with ship systems and operations, and preparing for the first ROV dives.

April 22

Continued overnight mapping around the Santa Rosa reef attempting to capture the 400m contour. The command was not comfortable mapping anywhere lacking existing multibeam bathymetry due to shallow reef pinnacles that might not be charted. Data quality was high on all sonars. New watch-standers are up to speed on mapping procedures and daily products are being made and pushed to shore. XBTs are only being collected once a night because no sound speed artifacts are being detected. Casts will be conducted more frequently if needed.

April 23

During overnight mapping to the next dive site, Enigma Seamount, the ship crossed over the Mariana Trench. The EK 60s timed out due to the deep depths so they were secured in water deeper than ~6000 meters (m). Over the trench transit speeds were 8-9 knots and the EM 302 had a difficult time tracking bottom. The deepest depth measured was ~9,825 m. Upon arrival at the Enigma Seamount, two-thirds of the seamount were mapped prior to arriving on the dive site in the morning. Data quality was high on all sonars in depths <5000 m. Data have been collected on both the 38 kHz and 300 kHz ADCPs during the ROV dives.

April 24

No mapping operations. ROV recovery extended into the early morning hours of 4/25. Following recovery, the ship remained on station in DP until 1600 to enable the deck department and engineering team to safely disassemble, assess and reassemble the flag sheave. ADCP data were collected throughout the entirety of the repairs.

April 25

Overnight mapping consisted of a straight transit line to the next CTD launch location, Fina Nagu Caldera C. The ship had to maintain higher speeds (9-9.5 kts) to get on station in time, so data over the Mariana Trench was poor. The EM 302 did not track bottom deeper than 9,500 m. The

18 kHz and 70 kHz EK 60s were set to passive mode in the trench because they were timing out. Once in waters shoaler than 6000 m, tracking improved on all sonars. Data quality was fair in >5000 m of water (due to high speed) and good in waters shoaler than 5000 m. Several passes were made over the Fina Nagu Caldera D dive site with the EM 302, as the ship arrived on station earlier than expected due to CTD operations being aborted mid-cast.

April 26

Mapping operations focused on the Toto caldera last night, which is a known area of active venting and part of the MTMNM Vents Unit. Several passes were made over the caldera at 6-7 knots. Watch standers monitored the EM 302 and 18 kHz EK 60 for water column anomalies. No anomalies were visible in the water column. Data quality on all sonars was high.

April 27

Overnight mapping focused on the Santa Rosa north box. There was no existing bathymetry over the area mapped, so mapping proceeded very carefully due to shallow reefs in the area. The EM 302, EK 60s, and Knudsen were run during overnight mapping and data quality was high.

April 28

Overnight mapping focused on the Santa Rosa north box. The EM 302, EK 60s, and Knudsen were run during overnight mapping and data quality was high.

April 29

Overnight transit mapping to the next dive site included data collection over three monument vent units. No anomalies were noted in the water column over these sites. Upon arrival to the dive site, mapping operations focused on a portion of the NW Guam Seamount. Data quality was high on all the sonars. Overnight, the survey watch lead was able to do some interference testing with the ADCPs while seas were quite calm. Interference was noted with the 38 kHz, but no interference was noted with the 300 kHz. This confirms that the 38 kHz will have to be put on a sync with the other sonars if it is to run simultaneously.

April 30

Overnight mapping operations were conducted in an area with no existing multibeam bathymetry. Data quality on all sonars was good, considering the > 4000 m depths. Additional testing was conducted with the 300 kHz ADCP, with interference observed in the outer most sectors of the EM 302 in the deepest two ping modes.

May 1

Transit mapping edge matched some existing EM 302 EV *Falkor* data. The data quality on all sonars was high.

May 2

After the ROV dive on the hydrothermal vents, mapping operations were conducted over the first vent with all sonars except the ADCPs. A clear signal was observed in the water column in the EK 60 data (Figure 3). Four passes were done over the first vent, and two passes were done over the third waypoint vent 100 m to the east. The signal in the data was consistent and repeatable with each pass.

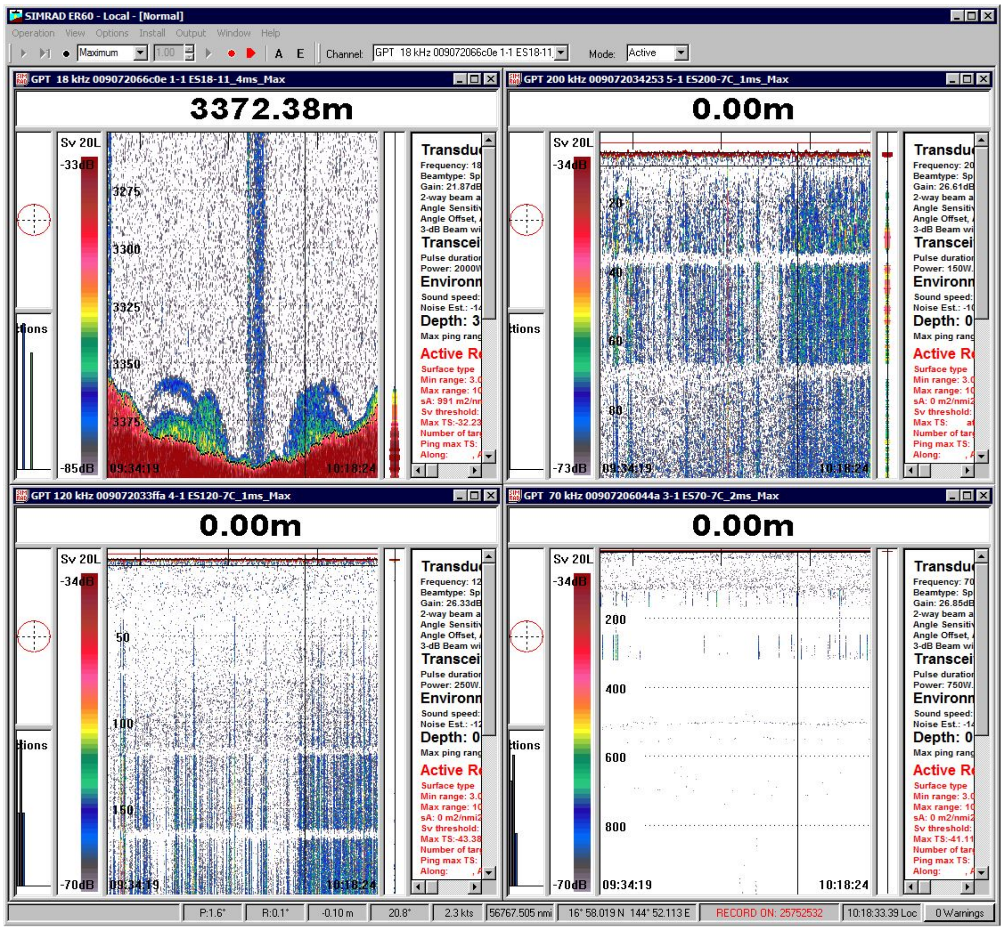

Figure 3. EK 60 data displaying the water column signal corresponding with the presence of hydrothermal vent activity.

May 3-4

The last two nights of mapping were primarily straight transits to the next dive sites. On May 3-4 the summit of the mud volcano was mapped prior to the dive. No water column anomalies were noted in the EM 302 or the EK 60 data. Data quality hovered between good to fair as the sea state picked up and the ship's heading was not ideal for the wind and wave direction. The transit to Pigafetta Guyot (May 4-5) was quite slow, as transit direction was directly into the prevailing surface current and wind. The ship barely made 8 knots all evening.

Arrival to the dive site was over an hour late, so the team was unable to map the ridge prior to the dive. Due to deteriorating weather and running into the currents and wind, the sonar data quality was fair, with many drop outs due to heavy pitching and induced bubble sweep down. Forcing the EM302 into a deeper ping mode seemed to help track the bottom, but resulted in a narrower swath than expected for the depths. No XBT was conducted the evening of May 4-5 due to rough sea conditions.

May 5, 6, 7

Overnight mapping focused on transiting to the next dive site and collecting good sub-bottom over the middle of the guyots. The dive site was mapped in the morning, improving upon the 100 m grid used to plan. Seas were still somewhat heavy, so data quality was dependent on the direction of transit.

May 8, 9, 10

After the FDM dive on 5/8, focused mapping occurred directly north of the dive site. Once the focused mapping was completed transit mapping was conducted to the Esmerelda Bank dive target. Data quality on all sonars was high. Following the Esmerelda Bank dive, mapping operations focused on the Esmerelda Crater. There was a distinct layer visible in the EK 60 sonars, visible on all four frequencies, but best on the 18, 70, and 120 kHz. The layer was about 120 m thick, from ~200 to 320 m deep, and had strong scattering, most visible around the rim.

May 11

Overnight mapping focused on a cultural heritage site over suspected downed WWII era B-29 planes on the west side of Tinian. A tight grid was run over a search area focusing on backscatter. The seafloor in the search area was covered in dense coral with high backscatter returns, so it was very difficult to make out any cultural features. Additional mapping operations were conducted to the east of Saipan and Tinian where little to no mapping data existed prior to arrival in port in the morning. Data quality was good on the west side of the islands but deteriorated on the east side due to the swell direction. The Knudsen was secured for some of the night due to poor data quality. All the sonars were secured before heading into port.

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-16-05 Leg 1 Project Instructions can be obtained from the NOAA Central Library. The EX-16-05 Leg 1 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