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MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT

CRUISE EX-16-05 Leg 3: 2016 Deepwater Exploration of the Marianas

June 17 – July 10, 2016

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1. Introduction

The NOAA Office of Ocean Exploration and Research and the NOAA Ship *Okeanos Explorer*

Commissioned in August 2008, the NOAA Ship *Okeanos Explorer* is the nation's only federal vessel dedicated to ocean exploration. With 95% of the world's oceans left unexplored, the ship's combination of scientific and technological tools uniquely positions it to systematically explore new areas of our largely unknown ocean. These exploration cruises are explicitly designed in collaboration with the broad science community to provide a foundation of publicly accessible baseline data and information to support science and management needs. This baseline information often leads to further more detailed investigations by other parties.

The unique combination of mission capabilities including a high-resolution multibeam sonar deep water remotely operated vehicles, telepresence technology, and integrated data management system quicken the scientific discovery and dissemination process. These systems enable us to identify new targets in real time, dive on those targets shortly after initial detection, and then send this information back to shore for immediate near-real-time collaboration with scientists and experts at Exploration Command Centers around the world. The integrated data management system provide for the quick dissemination of information-rich products to the scientific community. This ensures that discoveries are immediately available to experts in relevant disciplines for research and analysis.

Through the operation and maintenance of the mission capabilities, NOAA's Office of Ocean Exploration and Research (OER) provides the nation with unparalleled capacity to discover and investigate new oceanic regions and phenomena, conduct the basic research required to document discoveries, and seamlessly disseminate data and information-rich products to a multitude of users. OER strives to develop technological solutions and innovative applications to critical problems in undersea exploration and to provide resources for developing, testing, and transitioning solutions to meet these needs.

Okeanos Explorer Management – a unique partnership within NOAA

The *Okeanos Explorer* mode of operations systematic telepresence-enabled exploration, requires a robust with shore-based high speed network and infrastructure. The ship is operated, managed and maintained by NOAA's Office of Marine and Aviation Operations, which includes commissioned officers of the NOAA Corps and civilian wage mariners. OER owns and is responsible for operating and managing the cutting-edge ocean exploration systems on the vessel (ROV, mapping and telepresence) and ashore including Exploration Command Centers and terrestrial high speed networks. The ship and shore-based infrastructure combine to be the only federal program dedicated to systematic telepresence-enabled exploration of the planet's largely unknown ocean.

Table of Contents

2. Report Purpose

The purpose of this report is to briefly highlight the mapping data collection and processing methods used during the cruise.

This report focuses on the mapping data collected during exploration expedition EX-16-05 Leg 3. The complementary cruise report that includes remotely-operated vehicle (ROV) operations (2016 Deepwater Exploration of the Marianas: EX-16-05 Leg 3 Cruise Report) can be found in the NOAA Central Library.

3. Cruise Objectives

Operations for this cruise included ROV, mapping, and telepresence-based remote participation operations. The expedition commenced in Santa Rita, Guam with operations beginning on June 17th and concluding in Santa Rita, Guam on July 10th. Operations used the ship's deep water mapping systems (Kongsberg EM302 multibeam sonar, EK60 split-beam fisheries sonars, ADCPs, and Knudsen 3260 chirp sub-bottom profiler sonar), NOAA's two-body 6000 m remotely operated vehicle (ROVs *Deep Discoverer* and *Seirios*), and the ship's high-bandwidth satellite connection for real-time ship-to-shore communications. ROV dives were conducted during the day to collect high-resolution visual surveys and limited rock and biological specimen sampling. Mapping operations were conducted during overnight transits and when the ROVs were on deck. Exploration operations for the cruise focused on deep-water areas around the Commonwealth of the Northern Mariana Islands (CNMI) and the Mariana Trench Marine National Monument (MTMNM). 4,878 linear kilometers were surveyed by the ship with the EM302 multibeam sonar, resulting in a cumulative multibeam survey coverage area of 27,764 square kilometers during this expedition (Figure 1). All mapping operations were completed within the United States Exclusive Economic Zone (EEZ). Much of the mapping work was done during transits between daily ROV dive operations. Figures 2, 3, and 4 highlight a few of the larger continuous seafloor bathymetry surveys that were able to be completed without long distance transits between ROV dives.

This expedition helped establish a baseline of information in the region to catalyze further exploration, research and management activities. The specific objectives for this cruise were defined in EX-16-05 Leg 3 Project Instructions, which are archived in the NOAA Central Library.

4. Summary of Mapping Results

Cruise Overview Map

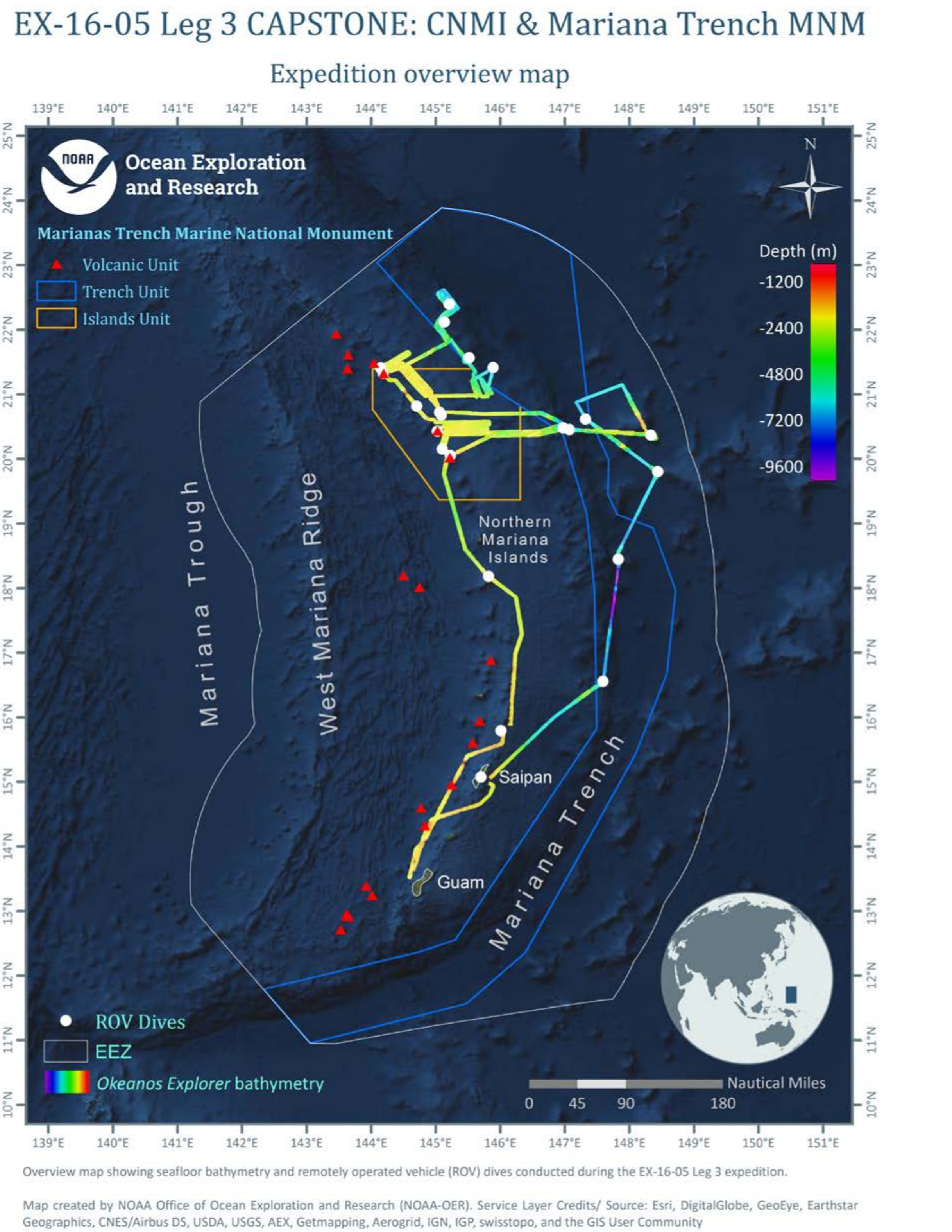

Figure 1. Cruise map showing overall EX-16-05 Leg 3 operations. Map generated in ArcMap.

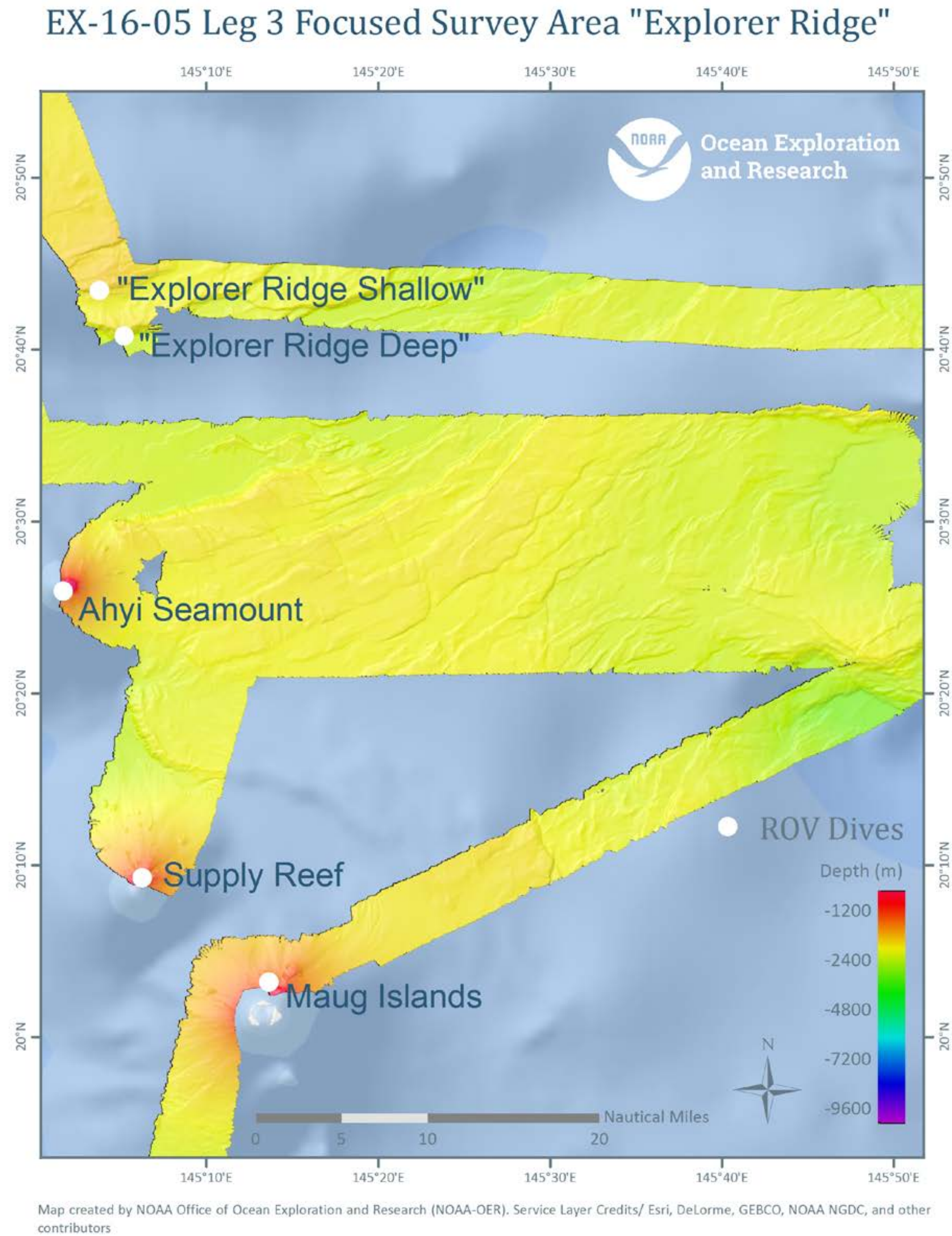

Figure 2 . Map showing new multibeam sonar data collected in the vicinity of five ROV dives sites near an area informally dubbed "Explorer Ridge". This focused survey area complemented survey coverage collected during EX-16-05 Leg 2, and highlights the extensive distinct fault patterns in the seafloor of the area. Map generated in ArcMap.

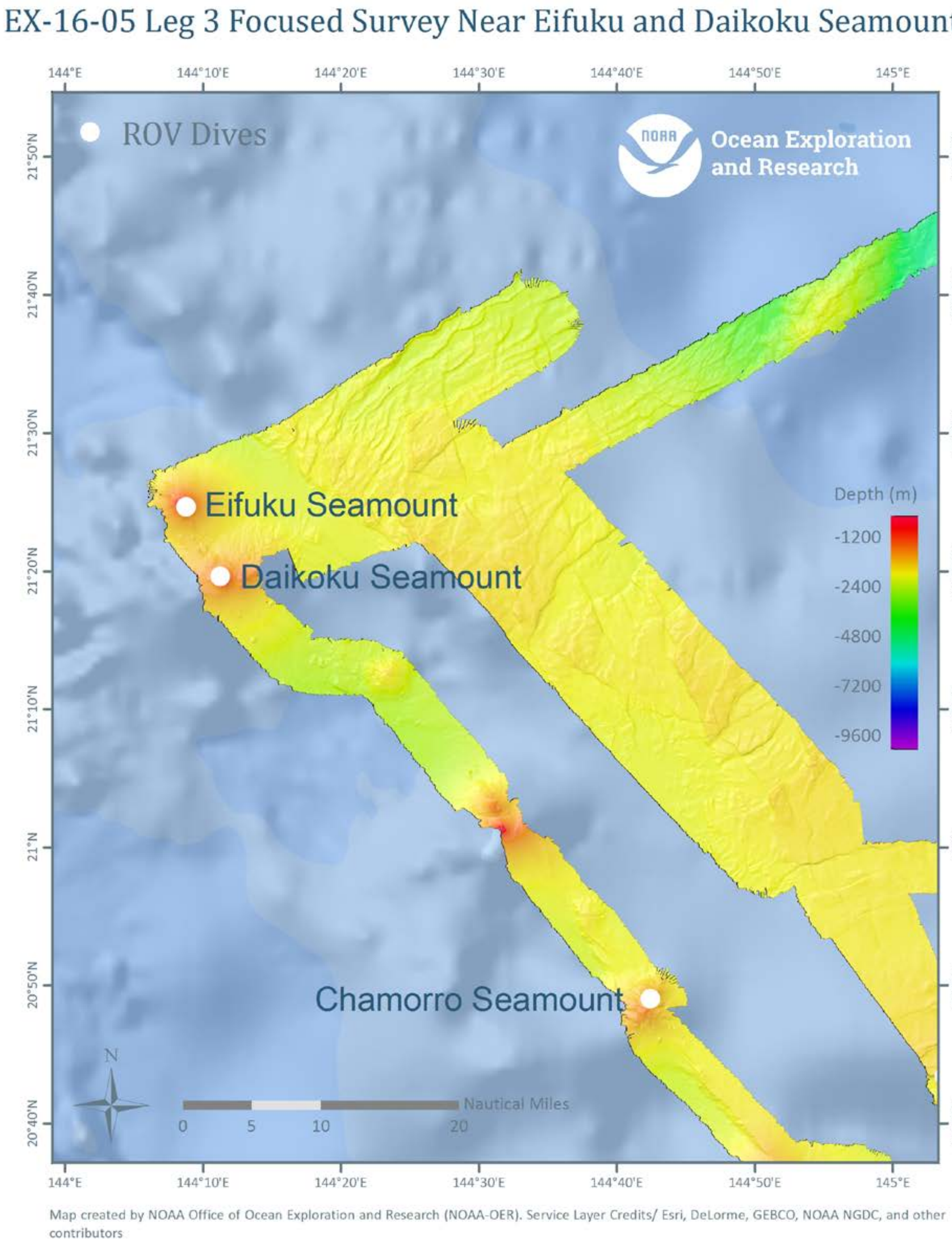

Figure 3. Map showing new multibeam sonar data collected in the vicinity of Eifuku and Daikoku seamounts. Note the distinct fault patterns in the seafloor of the area. New data collected on this expedition confirmed that the seafloor near the summit of Daikoku had changed since the last mapping survey, and analysis of water column data confirmed the presence of active bubble plumes. Map generated in ArcMap.

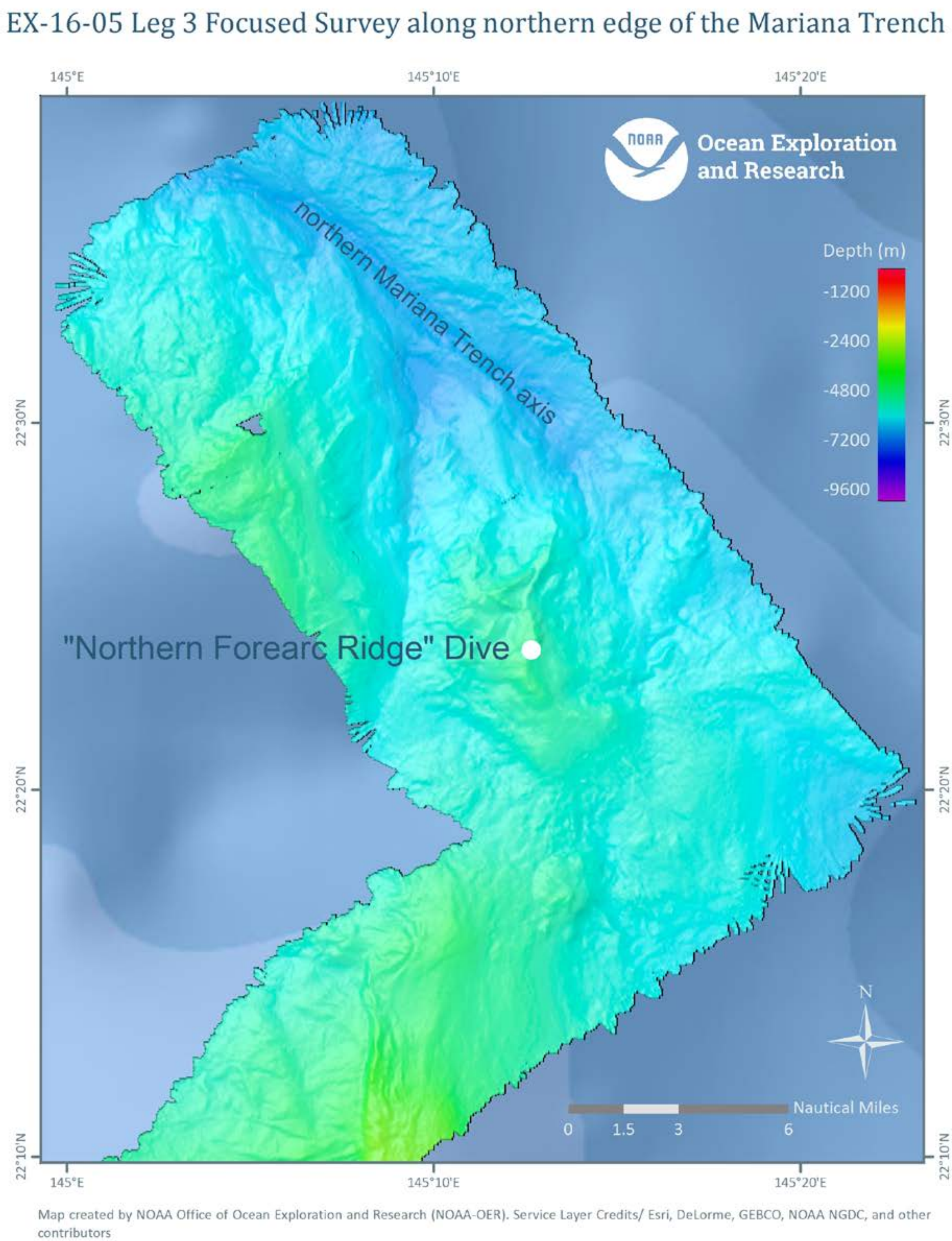

Figure 4. Map showing new multibeam sonar data collected along the northern edge of the Mariana Trench axis. This was the northernmost extent of mapping work on the expedition. The "Northern Forearc Ridge" dive site was originally thought to be a potential site of a mud volcano, but mapping data and ROV investigations on the cruise determined that it was not. Map generated in ArcMap.

5. Mapping Statistics

Dates	6/17/16 - 7/10/16
Line kilometers of survey	4,878
Square kilometers mapped	27,764
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files	369 files / 21.2 GB
Number / Data Volume of EM 302 water column multibeam files	369 files / 82 GB
Number / Data Volume of EK 60 water column singlebeam files	480 files / 33.7 GB
Number / Data Volume of subbottom sonar files	409 files / 4.15 GB
Number of XBT casts	48
Number of CTD casts (including test casts)	0
Beginning draft	Forward:15'3”; Aft:14'0"
Ending draft	Forward:14'4"; Aft:14'3”

6. Mapping Sonar Setup

The NOAA Ship *Okeanos Explorer* is equipped with a 30 kHz Kongsberg EM 302 multibeam sonar capable of mapping the seafloor in 0 to 8000 meters of water. The system generates a 150° beam fan containing up to 432 soundings per ping in waters deeper than 3000 meters. In waters less than 3000 meters, the system is operated in multiping, or dual swath mode, and obtains up to 864 soundings per ping, by generating two swaths per ping cycle.

The ship is also equipped with four Kongsberg EK 60 split beam fisheries sonars, 18, 70, 120, and 200 kHz. The 18 kHz transducer transmits a 7° beam fan.

Additionally the ship is equipped with a Knudsen 3260 sub-bottom profiler that produces a 3.5 kHz chirp signal. A 38 kHz Teledyne RDI Ocean Surveyor Acoustic Doppler Current Profiler (ADCP), with a ~1000 m range, and a 300 kHz Teledyne RDI Workhorse Mariner ADCP, with a ~70 m range.

7. Data Acquisition Summary

Background data used to guide exploration mapping included multibeam data collected on previous *Okeanos Explorer* cruises, R/V *Falkor* expeditions¸ the Extended Continental Shelf project, and Sandwell and Smith satellite altimetry bathymetric data. Some dive planning was conducted using bathymetry grids created using all available bathymetry achieved with NCEI using NCEI’s Auto Grid online tool.

The schedule of operations included overnight transit mapping and mapping whenever the ROV was on deck. Lines were planned to maximize either edge matching of existing data or data gap filling in areas where existing bathymetry coverage existed. In regions with no existing data, exploration transit lines were planned to optimize potential discoveries. The shiptrack for the expedition is shown in Figure 5. Long transits were completed at the beginning and end of the cruise. Clustering of ROV dive sites in the middle of the cruise enabled focused survey operations in several priority areas within, and adjacent to, the Marianas Trench Marine National Monument (within both the Trench and Islands Units – see figures 2-4).

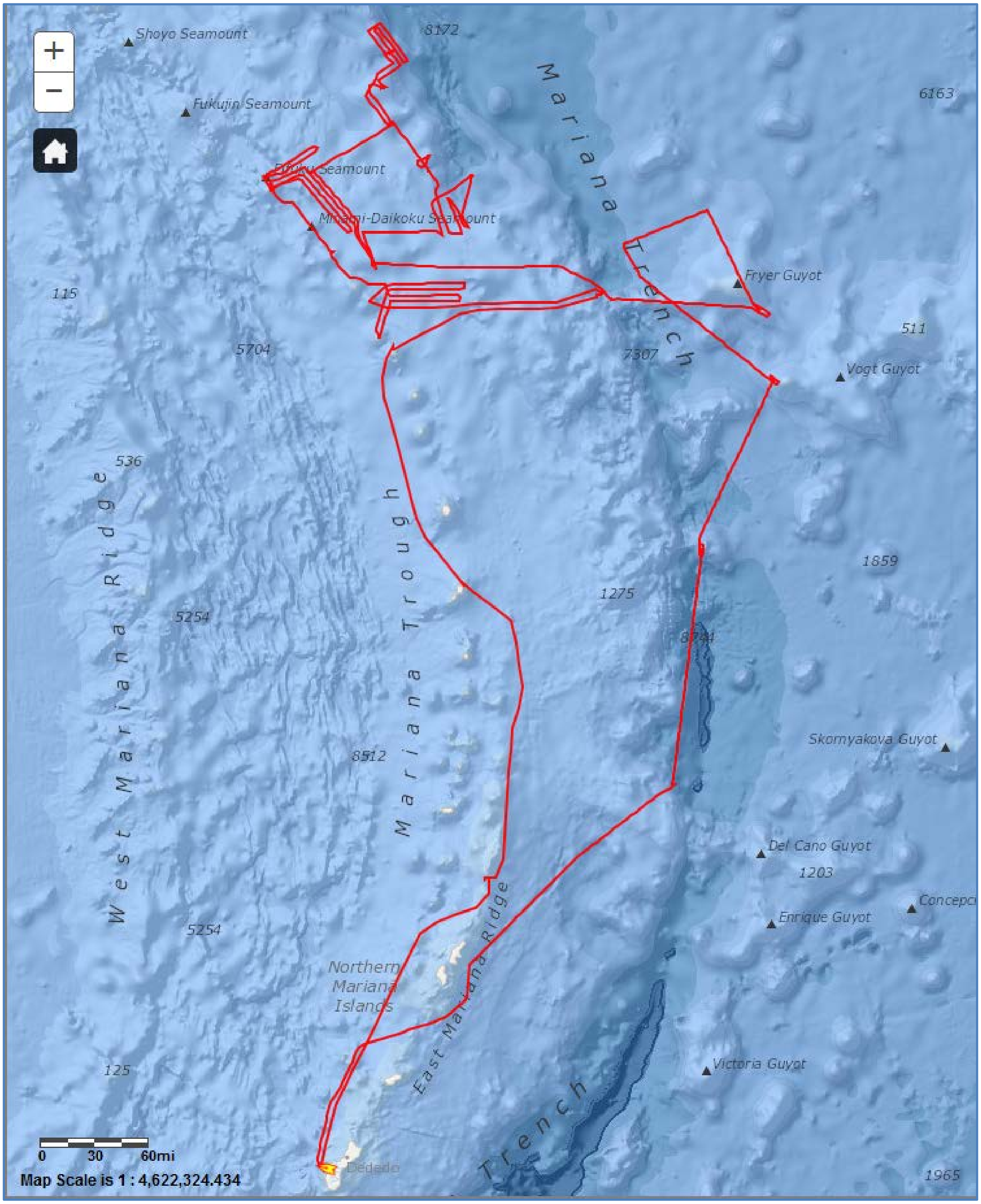

Figure 5. Shiptrack of the Okeanos Explorer during EX-16-05L3. Map generated by the Okeanos Explorer Atlas online mapping service maintained by the National Center for Environmental Information (NCEI). Beginning and ending port was in Guam.

Mapping operations included EM 302 multibeam, EK 60 split beam, Knudsen sub-bottom profiles, and ADCP data collection. Expendable bathythermographs (XBTs) were collected every 6 hours and applied in real time using Seafloor Information System (SIS) software. Sound speed at the sonar head was determined using a Reson SVP-70 probe and the thermosalinograph (TSG).

Throughout the cruise, multibeam data quality was monitored in realtime by acquisition watchstanders. Ship speed was adjusted to maintain data quality as necessary. Much of the mapping was conducted along transit lines to ROV dive sites, however in places time allowed focused surveying over areas lacking multibeam data. In these focus areas line spacing was generally planned to ensure ¼ overlap between lines at all times. Cutoff angles in SIS were generally adjusted on both the port and starboard side to ensure the best balance between data quality and coverage.

The ADCPs were always turned off for general mapping operations due to noticeable interference with the bottom tracking performance of the EM302. It is unknown why the interference with the 300 kHz ADCP occurred, but the issue was well documented during the 2016 field season. The interference was tested during EX-16-05 Leg 1 in Medium, Deep, Very Deep, and Extra Deep depth modes with CW, Mix, and FM transmit modes. The interference pattern was noticeable in all modes, so for subsequent mapping the 300 kHz ADCP was turned off.

During normal mapping operations data were collected with the EM302, EK60s, and subbottom profiler. During daytime ROV operations, the 38 and 300 kHz ADCPs were turned on to provide information on currents in the vicinity of the dive site. EK60s were also run on several dives where mid-water exploration transits with the ROVs were conducted. This data shows what appears to be a very clear avoidance behavior of organisms in the water column in response to the presence of the ROVs (figure 6).

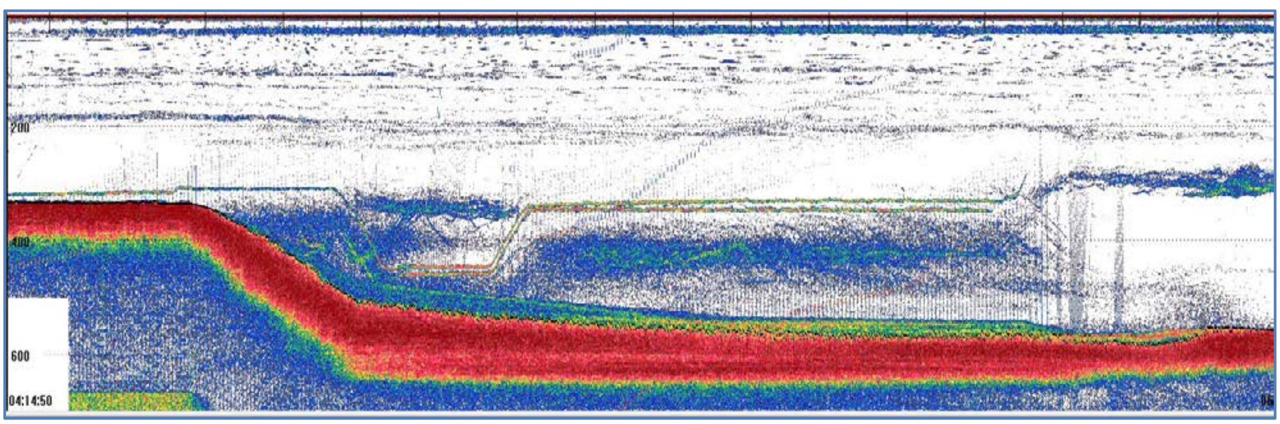

Figure 6. EK60 18 kHz echogram from the Maug ROV dive site showing apparent avoidance by organisms to the presence of the ROVs. Red area is the seafloor. Solid lines in the water column represent the dual-body ROVs conducting transects. Note how the blue scattering layers of biology physically separate from the area in the vicinity of the ROVs.

The ROV dive site at Daikoku had active hydrothermal vents at a depth of 410 m. Prior to the dive, two lines of sonar data were collected over the summit of the volcano. Data were analyzed for signs of bubble plumes since this site had previously been documented to release CO2 bubbles associated with sulfur pools (OER-funded Submarine Ring of Fire 2014 – Ironman expedition). EK60 and the EM302 water column data clearly showed the bubble plume (figures 7 and 8). The active bubble plumes were well documented with video footage during the ROV dive at this site (figure 9).

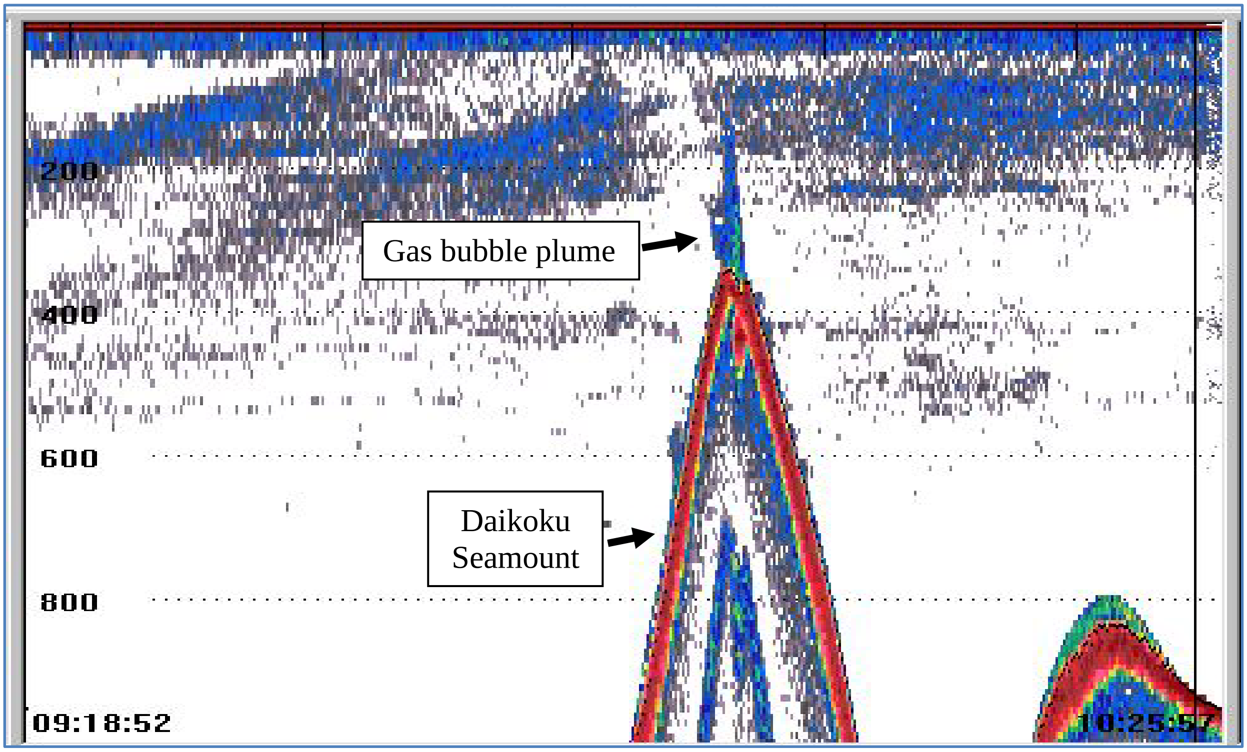

Figure 7. Echogram image from the 18 kHz EK60 split-beam sonar clearly showing a bubble plume emanating from near the summit of Daikoku Seamount. The red color represents the seafloor, while blue represents strong sound scatterers in the water column.

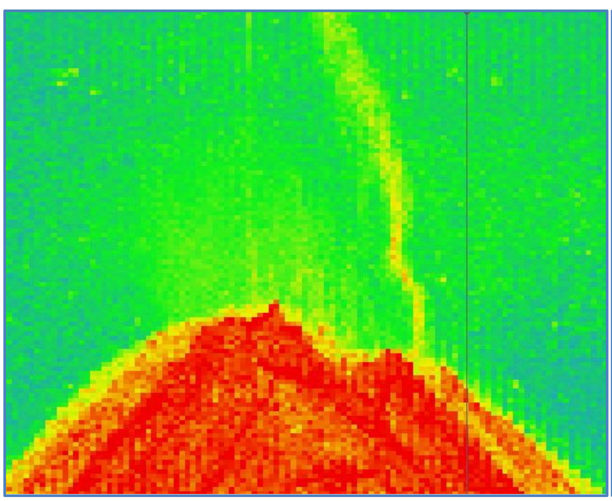

Figure 8. Image showing EM302 mulitibeam water column data processed with QPS Fledermaus Midwater software showing the bubble plume (yellow) coming from an area below the summit of Daikoku Seamount (red feature). Data processing and imagery by Jason Meyer.

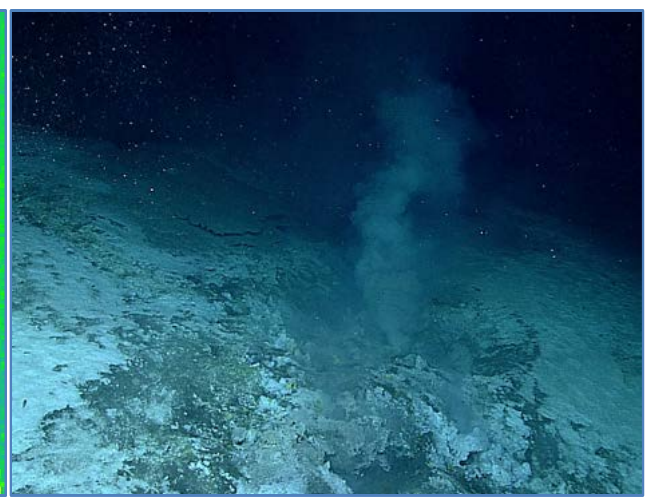

Figure 9. Example image from the *Deep Discoverer* ROV showing one of many sources of bubble and fluid expulsion from the seafloor in the vicinity of the Daikoku Seamount sulfur pools at approximately 410m depth.

Closer to Tinian and Saipan, focused surveys were conducted nearshore in support of Underwater Cultural Heritage assessment work. The ROV dive completed in this area discovered a B-29 Superfortress resting upsidedown on the seafloor. This is the first B-29 crash site found of over a dozen American B-29s lost in the area while flying missions during World War II.

All sonar data and sound velocity data files collected and products created during the cruise are provided as ancillary archived files.

8. Sonar Data Quality Assessment and Data Processing

EM 302 Multibeam Bathymetry Data

The multibeam data processing workflow is shown in Figure 10. 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 removed using CARIS Swath Editor and Subset Editor.

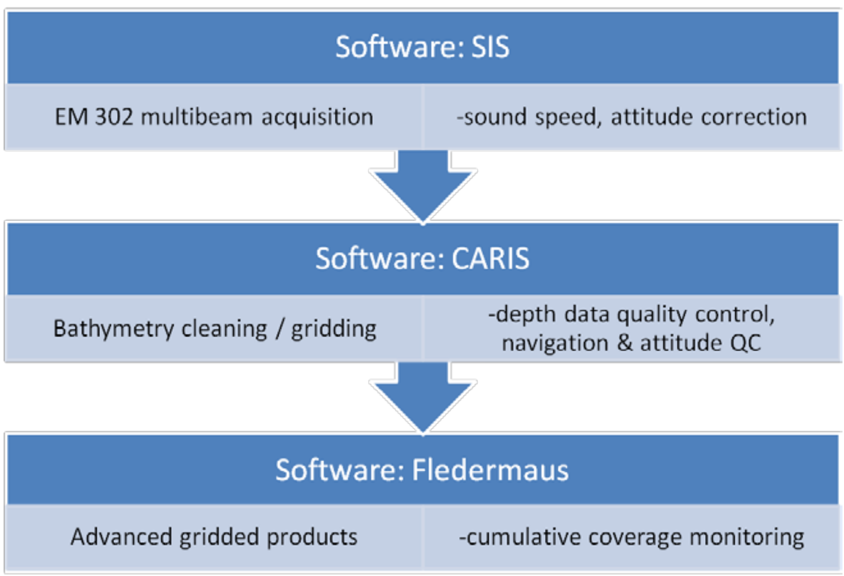

Figure 10. Shipboard multibeam data flow.

EM 302 Multibeam Water Column Backscatter Data Processing

Water column data was reviewed as time allowed during the cruise to examine for the presence of seeps and other water column anomalies.

EM 302 Built In System Tests (BISTs)

BISTs were run throughout the cruise to monitor multibeam sonar system status and are available as ancillary files in the sonar data archives.

EM 302 Multibeam Crossline Analysis

Within CARIS software, sixty meter resolution grid surfaces were generated separately for a mainscheme area and for an orthogonally oriented crossline for comparison. Mainscheme and crossline surfaces were then compared using the "surface differencing" tool in CARIS. The results show a normally distributed result, with the mean difference between the two surfaces being 0 m. This result indicates that in survey water depths ranging from 2000-2300 meters, the mainscheme and crossline multibeam tracks surveyed in orthogonal directions at different times obtained seafloor depths that agreed with each other (on average), with a standard deviation of only 4.1 m. Figure 11 displays summary statistics and a histogram plot of the differences between the mainscheme and crossline. These results provide strong validation of the quality of the multibeam bathymetry data.

<u>The crossline used:</u>
0072_20160621_183657_EX1605L3_MB (287°)

<u>The mainscheme lines used:</u>
0091_20160623_061124_EX1605L3_MB (17°)

	Points Compared	Max Value	Minimum Value	Average Difference	Standard Deviation
Crossline	7,483	19 meters	-32.2 meters	0 meters	4.1 m

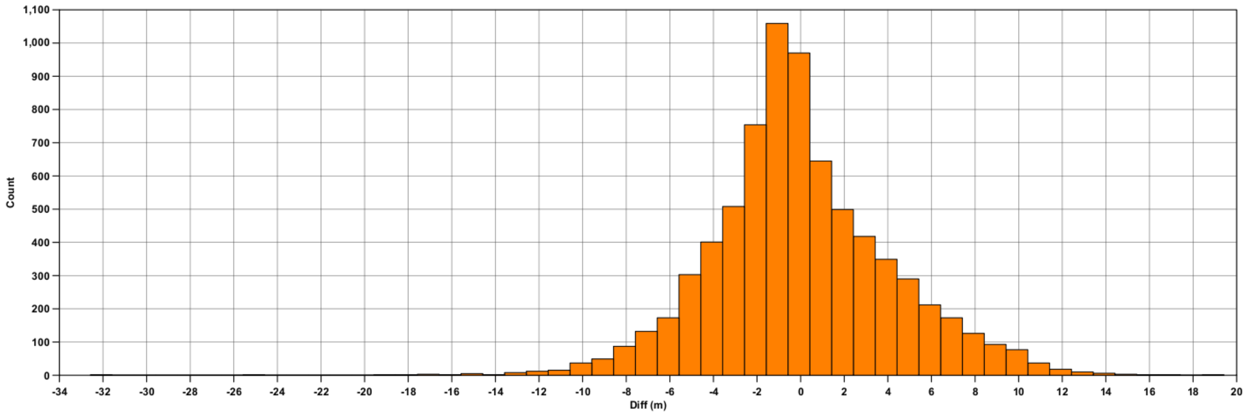

Figure 11. Summary statistics and a histogram plot of the differences between the mainscheme and crossline bathymetric surfaces.

9. Data Archival Procedures

All mapping data collected by *Okeanos Explorer* are archived and publically 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 raw and processed data formats produced for this cruise is available as an appendix in the project instructions.

EM 302 and EK60 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 7/3/2019).

Sub-bottom data, supporting data, and informational logs are available in the NCEI Data Archives accessible at https://www.ngdc.noaa.gov/ (last accessed 7/3/2019).

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 7/3/2019)

10. Cruise Calendar

All times listed are in local time on the ship. Local ship time was +12 hours from UTC. Names in quotes were given to dive sites lacking official names.

June / July 2016						
Sun	**Mon**	**Tues**	**Wed**	**Thur**	**Fri**	**Sat**
					17 Depart port in Guam 1000	18 ROV dive at Farallon de Medinilla
19 ROV dive at Pagan Island	20 ROV dive at Maug Island	21 ROV dive at “Hadal Ridge”	22 ROV dive at Ahyi Seamount	23 ROV dive at Supply Reef	24 ROV dive at Chamorro Seamount	25 ROV dive at Eifuku Seamount
26 ROV dive at Daikoku Seamount	27 ROV dive at “Stegosaurus” Ridge	28 ROV dive at “North Forearc Ridge”	29 ROV dive at “Unnamed Forearc Seamount”	30 ROV dive at “Twin Peaks”	1 ROV dive at “Explorer Ridge – Deep”	2 ROV dive at “Explorer Ridge – Shallow”
3 ROV dive at “Subducting Guyot 1”	4 ROV dive at Fryer Seamount	5 ROV dive at “Petite-spot Volcano”	6 ROV dive at Vogt Guyot	7 ROV dive at “Subducting Guyot 2”	9 ROV dive near Saipan and Tinian	10 Return to port in Guam

11. Daily Cruise Log

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

June 17, 2016
Mapping operations began as soon as leaving port in Guam. The EM302 passed all BIST tests and operated normally, producing high quality data in favorable seas. EK60 and sub-bottom sonars also operated normally, with high data quality. ADCPs were both run in Apra Harbor and for a short period of time after leaving port. SCS and the TSG were started by Chief ET Blessing and the new ST Wilkins. Derek provided several hours of training to the new ST, and overnight mapping watch was established.

June 18, 2016
Some multibeam data gaps were filled during the transit to the first dive site, including a large apparent data gap on the south side of Farallon de Medinilla. UCTD parts have been received on the ship and will be ready for testing as time allows.

June 19, 2016
Overnight mapping operations in transit to the Pagan dive site went smoothly. Data quality has been excellent even with transit speeds of 10.5-11 knots. The first daily product was produced and posted to the FTP site. The new ST Charlie Wilkins has been receiving training from Derek, Jason, and Chief ET Blessing and he is learning the position responsibilities quickly and doing

well. He is proficient in Caris and familiar with SIS and Hypack. Additional training/practice in SCS and CTD cast software is needed.

June 20, 2016
Overnight mapping operations were conducted during the transit to Maug and data quality was very good. New data was acquired in transit over several areas lacking data. Transit speeds varied between 9.5-11 knots. We received several useful high resolution bathymetry datasets from Bill Chadwick to use as backgrounds for planned dive sites. All sonars operating as expected. The ADCPs are being run to inform ROV dives and may be used to substitute pre-dive drift tests. We ran the EK60 sonars during the last 2 hours of the dive at Maug in order to help inform the mid-water transect completed at the end of the dive. 450 meters was selected as the initial target depth for maximizing our chances of seeing biology in the water column. Upon reaching this depth and transiting for a bit, it appeared that a shallower layer looked more promising and we moved the vehicles up to approximately 340 meters. Again, the biology seemed to disperse near the ROV. When the vehicles ascended to the surface, the scattering layer at 340m reappeared. It therefore appears clear from the EK60 data that water column biology is actively avoiding the ROVs. While we were able to image some interesting organisms in the water column, we are very likely scaring away much of it and therefore heavily biasing our exploration insights in these areas.

June 21, 2016
Overnight mapping operations were conducted for the transit to the Hadal Ridge dive site at the western edge of the Mariana Trench. Transit times between dives have not allowed for additional survey mapping yet. Data quality was good, and seas were 2-4'. Sun photometer measurements commenced following replacement of dead GPS batteries.

June 22, 2016
Daily BISTs are being run on the multibeam prior to surveying - all BISTs have passed without issue and the sonar is running well. Overnight transit mapping from the Mariana Trench edge to the dive site at Ahyi Seamount was completed. This starts to add coverage to the "Explorer Ridge" area that was mapped during Leg 2. This coverage will be built upon over the next two nights of survey operations. Mapping data was very good given the high transit speeds. Weather continues to support high quality data. The multibeam data used for the Hadal Ridge dive was from ECS mapping, and the accuracy of this data was verified by the ROV finding the seafloor almost exactly where expected. The knudsen had some trouble tracking the trench wall at deeper depths, but otherwise operated normally. New ST Wilkins was given a tour of the sonar closet and IMU equipment, and training is ongoing.

Overnight mapping focused on continuing to add coverage to the "Explorer Ridge" area started during Leg 2. Data quality was excellent. Surveying ended at the Ahyi dive site. Ahyi had existing bathymetry data from a *Roger Revelle* cruise in 2014. The selected dive site was on an apparent volcanic crater near the summit of the seamount. Upon diving on the feature, it was discovered that the actual seafloor was 100 m shallower than shown on the bathymetry. We concluded that the crater feature in the bathymetry was an artifact in the dataset that had not been properly removed. This example highlighted the importance of trying to obtain EX bathymetry prior to dives when possible. All mapping systems are working as expected.

June 23, 2016
Survey work focused on continuing to build coverage within the "Explorer Ridge" area, then quickly transiting over to the dive site at Supply Reef, which had good existing bathymetry and did not need to be re-mapped. Mapping quality was excellent. Survey Tech training continues.

June 24, 2016
The transit from Supply Reef to Chamorro Seamount was done at high speed to finish filling in the "Explorer Ridge" focused survey area as well as map Chamorro just prior to diving on the feature. Mapping quality was very good, although slightly degraded by high transit speeds needed to cover the desired mileage in time. Existing maps of Chamorro showed a summit crater, but it was poorly resolved. The EX bathymetry provided better resolution of the features, and enabled us to do some last minute revisions to the planned dive track and ROV waypoints to maximize efficiency and the opportunity to explore the most promising parts of the summit crater.

June 25, 2016
The EM 302 failed two BIST tests and would not ping normally at the start of survey operations. We re-booted the TRU and all BISTs passed - multibeam worked normally for the rest of the day. Data quality was very good on all sonars. We transited from Chammoro directly to re-survey the summits of Daikoku and Eifuku Seamounts in order to get better maps for the dives on the next two days. We generated 10m resolution maps of the summits and associated craters. We had time to do 2 survey lines on a small unexplored area prior to getting to the dive site on Eifuku. Midwater multibeam data was processed to locate a major gas plume mapped over Daifoku.

June 26, 2016
After ROV recovery at Eifuku, we proceeded directly over the summit of Daifoku to do a visual survey for hazards, gather another line of multibeam midwater data over the gas plume, and gather ADCP data over the seamount to assess currents - all to inform safe dive operations on the next day. When we tried to re-start the multibeam (after being idled for the ADCPs), it would not work and we failed two BIST tests. We restarted TRU twice and SIS operator machine once to finally get EM302 working normally again. We then mapped 2 survey lines of data over an un-mapped region of the Monument, prior to returning to the Daikoku dive site. Water column data processing located the gas plume, and we pinpointed the location of origin on the seafloor. This location coincided very closely with the location of sulfur pools provided to us by Bill Chadwick, and we planned to visit this location during the ROV dive.

June 27, 2016
Overnight mapping was conducted between the Daikoku dive site and the “Stegosaurus Ridge” dive site. The line plan edge-matched existing EX and other multibeam to map areas completely lacking multibeam data. Data quality was very good.

June 28, 2016
Following the dive on Stegosaurus Ridge, mapping work edge-matched existing multibeam datasets and mapped new terrain to the north as we made our way to the northernmost dive of the

expedition: North Forearc site. There was time to map to survey lines north of the dive site along the western wall of the Mariana Trench, which is a top priority mapping priority for Monument science and management. Data quality was good on all sonars. Patty Fryer suspected this area might have a mud volcano feature to dive on, but instead we found a very steep ridge feature that also made a good dive target. An early morning review of the newly acquired multibeam in this area was held to finalize the dive site for the day. We planned a dive track up the steepest scarp up to the ridge crest, then along the crest. ADCPs are run prior to, and throughout the dive, then secured for multibeam surveying. The SMD software is being used to make realtime backscatter mosaics of the multibeam data.

June 29, 2016
Sea state was a bit rougher for surveying today and water depths were deep for much of the night. Thus, we experienced smaller swath widths and moderate to good data quality. Survey speed was kept to about 8.5 knots in order obtain good quality multibeam. We edge matched existing data as we transited south to the Unnamed Forearc dive site. This transit data filled in a last gap between Leg 2 coverage and a western boundary of the Mariana Trench MNM. Mapping for the next two nights will consist of focused surveys within priority boxes defined for Leg 2, and will help link continuous coverage for a large area.

June 30, 2016
Overnight mapping on the way to the Twin Peaks dive site allowed us to edge match existing multibeam data and fill in a wedge gap between the two large areas surveyed during Leg 2. Survey speeds were kept to 8.5-9 and data quality was good. The multibeam had no problems getting going, and the two hour pre-mapping warmup routine for the TRU has been working well. We switched XBT launchers and last night and have not had any further problems with occasional data spikes in the profile data. Leg 2 mapping data was used for the last two dive planning calls since the dives were chosen utilizing that dataset. Photometer measurements are being taken several times per day.

July 1, 2016
Overnight mapping edge-matched existing multibeam and built up coverage for the "Explorer Ridge" survey area started during Leg 2. Data quality was very good for most of the night. Sea state picked up a bit this morning to 3-5' and gusts up to 20 knots. Inventory was take of XBTs onboard, with 384 left in the cold storage room in addition to a full Vidmar cabinet.

July 2, 2016
For overnight mapping the ship transited northwest over existing multibeam coverage from Leg 2 then mapped two survey lines over a sizeable area lacking any multibeam data. Wind and waves were rougher today and data quality was moderate. Multibeam BIST test failed RX noise and RX spectrum tests, but it thought this was likely due to the ADCP and USBL being on during the test. We turned those sonars off and pinged the EM302 - it then worked normally. We have been able to get underway quickly on mapping once the ROVs are recovered on deck. Sun photometer measurements continue to be taken daily. The quality and useful of the mapping products are frequently complimented by onboard Science Leads.

July 3, 2016

Overnight mapping was a largely straight transit eastward to the next dive location at Subducting Guyot 1. We were able to gather mapping data over a long stretch of seafloor lacking in modern multibeam information. The dive site itself is within previously collected ECS mapping data coverage. The transit path required us to move largely against the swell waves a steady 15-20 knot wind, so pitching issues degraded data quality somewhat to moderate-good. Because the ship has requested that mission does not do back to back long dive days, some of our transits between dive sites are not efficient for mapping purposes.

July 4, 2016
For overnight mapping the ship transited eastward over most of Fryer Guyot, then gathered high resolution data over the dive site on a ridge crest extending off the SE flank of the seamount. The improved map was delivered to the ROV Team just prior to the dive. Data quality was good overall. The area covered has already been mapped by ECS efforts, so there was no nearby area that lacked multibeam. Tomorrow's transit will enable mapping about 35 nm of previously unmapped seafloor.

July 5, 2016
Overnight mapping involved transiting largely over existing ECS bathymetry data to get to the Petite-spot volcano dive site. However, there was time to map a 45-mile trackline of seafloor that appeared to lack any previously collected multibeam data. Transit speed average 8.7 knots and data quality was good to excellent. The seafloor over Fryer Guyot is highly reflective of sound and full swath angle coverage was obtained.

July 6, 2016
Overnight mapping was a straight transit from Petite-spot dive site to Vogt Seamount dive spot, with a detailed survey directly over the dive location. The new map was gridded to 25m and was a major improvement over the existing bathymetry available. The dive track was modified with this new information, and it was decided to take the vehicles up along the very edge of the extremely steep slope to the east of the dive site ridge. Data quality was very good. Caris fatally crashed on MBPROC1, as it has on earlier cruises this year. Thanks to good documentation of troubleshooting tips, we were able to correct the problem. ST Wilkins received a Fledermaus tutorial today.

July 7, 2016
Following the highly successful dive at Vogt, a long straight mapping transit line was completed to the next dive site at "Subducting Guyot 2". The dive site area was surveyed in high resolution with two passes and slow ship speeds. A new high resolution map was provided to the ROV team based on this survey. The waypoints determined the night before ended up being in a great location straight up a very steep wall of the scarp which was the focus of the dive. Draping the waypoints on the new bathymetry resulted in making the distance over bottom a little longer than originally anticipated. Data quality was good overall. Transit plans for the rest of the cruise were completed.

July 8, 2016
Overnight mapping was a straight transit from the "Subducting Guyot 2" dive site to the "Hadal Wall" dive site. This trackline surveyed along a portion of the Mariana Trench axis reaching

depths of up to 8,491 meters, with most of the trackline deeper than 6,000 m. Data quality was moderate to good overall considering the extreme depths involved. The EK60 timed out in depths over 6,000 meters. We followed the SOP for logging the EK60 in very deep waters, but the sonar timed out and would not record data even with the 18 and 70 kHz frequencies switched into passive mode. Therefore the EK60 was secured for most of the night. The Knudsen machine required a reboot as it locked up after the remote desktop session with the EK60 computer was ended. The Knudsen struggled to track bottom on steep slopes descending into the trench, but collected good data when the terrain flattened out and logged data most of the night.

July 9, 2016
UCH policies for mapping were followed within the 7 mile buffer from the B29 site. ADCPs were run throughout the dive to watch for tidal current changes.

July 10, 2016
Mapping operations were conducted en route to Guam with some extra time being traded for 2 extra ROV dive hours. Data holidays were filled and edge matching to Leg 1 and 2 data was completed as possible during approach to Guam

12. References

The 2016 Survey Readiness Report can be obtained by contacting NOAA Ship *Okeanos Explorer* at oar.oer.exmappingteam@noaa.gov.

The following data was used as background data throughout the cruise:
1) 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.

2) NOAA Nautical Charts in S-57 format.

13. Ancillary Files

Ancillary data files are archived with the sonar dataset. These include:

- Project Instructions
- EM 302 Processing Parameters in use during the cruise
- EM 302 Built In System Test (BIST) Results
- Tables of Data File Logs
- Daily Watchstander Log
- Weather Log

Appendix A: Acronyms

AERONET – Aerosols Robotic Network
AHB – Atlantic Hydrographic Branch
ASCII – American Standard Code for Information Interchange
AUV - autonomous underwater vehicle
BIST – built in system test
CDR – Commander
CO – Commanding Officer
CTD – conductivity, temperature, depth
dB - decibel
DNP – do not process
EEZ - Exclusive Economic Zone
ERT – Earth Resources Technology Corp.
ET – Electronics Technician
EX – NOAA Ship Okeanos Explorer
FM – frequency modulated / modulation
FTP – file transfer protocol
FV - free vehicle
GB - gigabytes(s)
KB - kilobytes(s)
kHz – kilohertz
km – kilometer
kts – knots
LT – Lieutenant
LSS - light scattering sensor
m - meters
MAN – Maritime Aerosols Network
MB – multibeam sonar
MB – megabytes(s)
ms – millisecond
NASA – National Aeronautics and Space Agency
NCDDC – National Coastal Data Development Center
NCEI - National Center for Environmental Intelligence
NCCOS - National Centers for Coastal Ocean Science
NGDC – National Geophysical Data Center
NMEA – National Marine Electronics Association
NOAA – National Oceanic and Atmospheric Administration
NODC – National Oceanographic Data Center
OER – NOAA Office of Ocean Exploration and Research
OMAO – NOAA Office of Marine and Aviation Operations
OPS – Operations Officer
PRT - Puerto Rico Trench
ROV – remotely operated vehicle
SBP – subbottom profiler
SCS – scientific computer system
SIS – Seafloor Information System

SST - Senior Survey Technician
SVP – sound velocity profile
TRU – transceiver unit
TSG - thermosalinograph
TX – transmit
UCAR - University Corporation for Atmospheric Research
UPRM - University of Puerto Rico, Mayaguez
USGS – United States Geological Survey
W - watt
XBT – expendable bathythermograph
XO – Executive Officer