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EX-15-04 Leg 1
CAPSTONE NWHI & Johnston Exploration Mapping

Cruise Report

Mapping Exploration of the
Johnston Atoll Unit of the
Pacific Remote Islands Marine
National Monument

July 10, 2015 to July 24, 2015

Pearl Harbor, HI to Pearl Harbor, HI

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Abstract:

EX-15-04 Leg 1 was an exploratory mapping expedition that commenced on July 10, 2015 in Pearl Harbor, HI and concluded on July 24, 2015 in Pearl Harbor, HI. EX-15-04 Leg 1 focused on ocean mapping of the Johnston Atoll unit of the Pacific Remote Islands Marine National Monument (PRIMNM) for baseline characterization. The cruise was part of the multi-year Campaign to Address Pacific monument Science, Technology, and Ocean NEeds (CAPSTONE). NOAA priorities for the CAPSTONE campaign include a combination of science, education, outreach, and open data objectives that will support management decisions at multiple levels.

During the expedition approximately 31,377 square kilometers of seafloor area were mapped using the multibeam sonar, covering a linear track line distance of 5,308 km. The expedition focused on mapping along fracture zones during the transits to/from Pearl Harbor to the Johnston Atoll region (approximately three days of transit time each way), then spent the remaining survey time (eight days) mapping within the Johnston Atoll unit of PRIMNM. Inside the Monument boundary, mapping focused on Horizon Guyot, the Johnston Seamount chain, Hutchinson Seamount, and the Karin Seamount chain. All operations were conducted within US and international waters. Most of the areas mapped during this cruise had never been mapped in detail with ship-based echo sounders. This report presents an overview of the objectives of the cruise, the scientific sonar systems used for exploration, information about data acquisition, processing, and quality control, and a summary of some of the key findings.

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1. *Okeanos Explorer* Introduction

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 oceans. 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, 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 systems 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.

NOAA's Office of Ocean Exploration and Research (OER) provides the nation with an unparalleled capacity for ocean exploration. The missions of the program include: 1) to discover and investigate new oceanic regions and phenomena, 2) conduct baseline research required to document discoveries, and 3) 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.

2. Expedition Overview

EX-15-04 Leg I was an exploratory mapping expedition, and was the first cruise of a three year major effort (2015-2017) in the Pacific by the Office of Ocean Exploration and Research, entitled CAPSTONE (Campaign to Address Pacific monument Science, Technology, and Ocean NEeds). NOAA priorities for the 2015 CAPSTONE Expedition included a combination of science, education, outreach, and open data objectives to support management decisions at multiple levels.

During EX-15-04 Leg 1, mapping operations were conducted 24 hours per day. The expedition focused on mapping along fracture zones during the transits to/from Pearl Harbor to the Johnston Atoll region (approximately three days of transit time each way), then spent the remaining survey time (eight days) mapping within the Johnston Atoll Unit of the Pacific Remote Islands Marine National Monument (PRIMNM). Inside the Monument boundary, mapping focused on Horizon Guyot, the Johnston Seamount chain, Hutchinson Seamount, and the Karin Seamount chain. All operations were conducted within US and

international waters. Most of the areas mapped during this cruise had never been mapped in detail with ship-based echo sounders.

A. Rationale for Exploration

Originally created by Presidential Proclamation 8336 of January 6, 2009, Pacific Remote Islands Marine National Monument (PRIMNM) boundaries were expanded by Presidential Proclamation 9173, dated September 29, 2014. The expansion includes waters adjacent to Jarvis and Wake Islands, and Johnston Atoll. The central and western Pacific marine national monuments and national marine sanctuaries encompass over 742,000 square miles of emergent land, coral reef, ocean and maritime heritage resources. They contain some of the last relatively pristine marine ecosystems on the planet and harbor numerous protected species, as well as undiscovered shipwrecks and cultural landscapes sacred to the indigenous peoples of the Pacific. Their designation is unprecedented in terms of geographic scope, ecological value, and national symbolism for ocean conservation. However, their remoteness creates substantial challenges. Most deep-water areas remain poorly known and are of high interest to federal and state agencies with research and management responsibilities. The CAPSTONE campaign has been designed to provide a foundation of publicly accessible baseline data and information for U.S. marine protected areas in the central and western Pacific. The effort will also provide critical information relevant to emerging regional issues like deep-sea mining and the potential U.S. Extended Continental Shelf.

Understanding biogeographic patterns between and among the Pacific Monuments and Sanctuaries is a coordinating theme for CAPSTONE science priorities. Themes and objectives for the 2015 Expedition included:

- Acquiring data to support priority Monument and Sanctuaries science and management needs, including habitat surveys in recently expanded boundary areas;
- Identifying and characterizing vulnerable marine habitats - particularly high density deep sea coral and sponge communities;
- Characterization of seamounts within the Prime Crust Zone (PCZ). The PCZ is the area of the Pacific with the highest expected concentration of deep sea minerals, including rare metals and rare earth elements;
- Collecting information on the geologic history of Central Pacific Seamounts, including those that are or may be relevant to our understanding of plate tectonics and subduction zone biology and geology; and
- Providing a foundation of publicly accessible data and information products to spur further exploration, research, and management activities in the region.

Exploratory mapping within the Johnston Atoll unit of PRIMNM is a first step to baseline characterization and scientific discovery in this large and poorly studied marine protected area. Data gathered on this cruise is directly useful by managers to better understand the resources within this portion of the Monument. Figure 1 shows high quality multibeam data

coverage available in the Johnston Atoll unit of PRIMNM prior to this cruise.

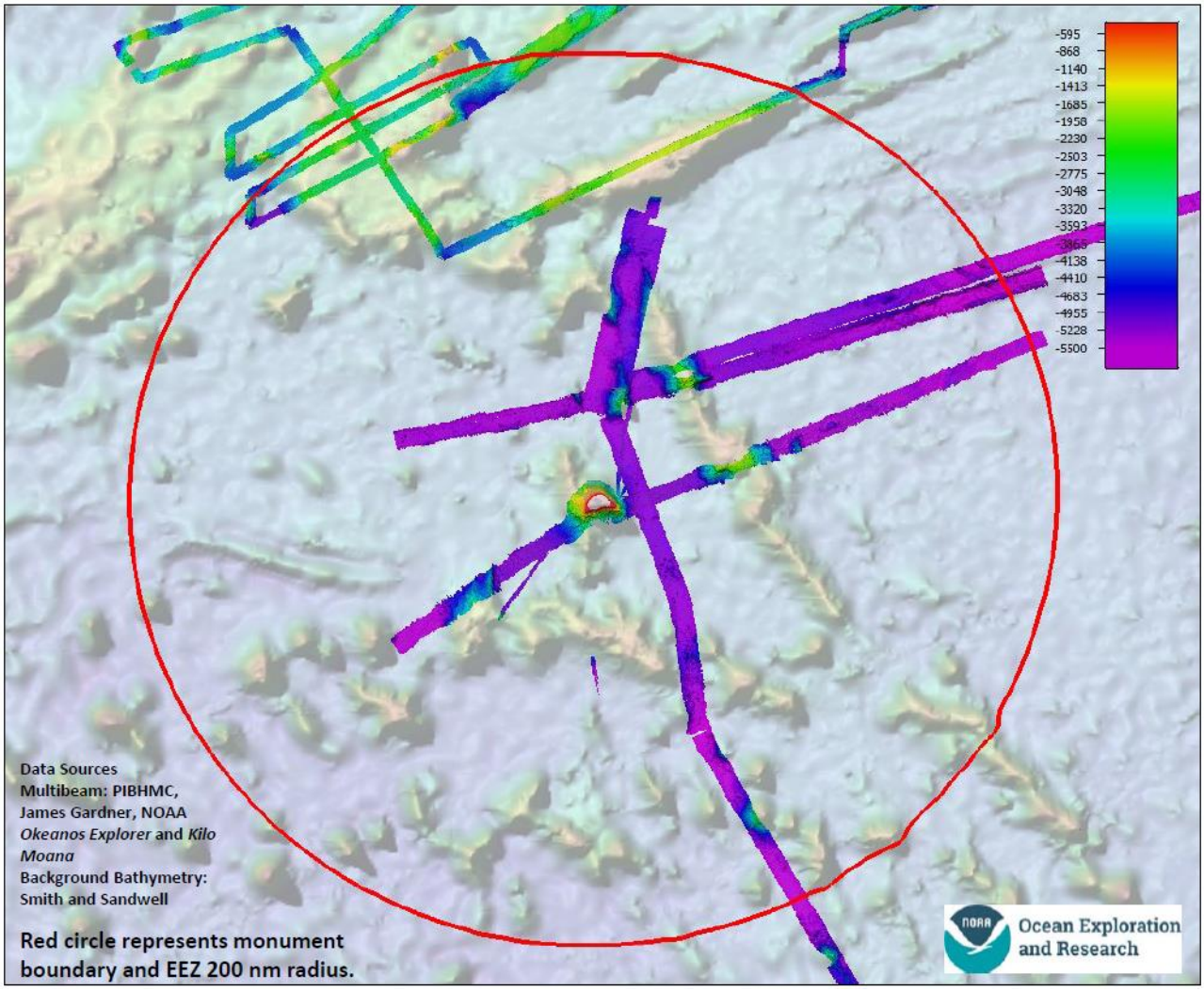

Figure 1. High quality publicly-available multibeam sonar data coverage of the seafloor within the Johnston Atoll unit of PRIMNM <u>prior</u> to EX-15-04 L1 shown with color-coded bathymetry shading. Background is satellite-derived bathymetry by Smith and Sandwell. Depth scale is in meters. Red circle represents the Monument boundary. Data in the northern region is data collected previously by the *Okeanos Explorer*. Other deep water multibeam data collected by Dr. James Gardner for the Extended Continental Shelf project in the region, and by transits of the RV *Kilo Moana*. Note the lack of existing multibeam sonar data coverage over most ridge and seamount features. During the EX-14-04 L1 expedition, the Okeanos Explorer collected 5308 linear kilometers of new EM302 multibeam sonar data covering 31,377 square kilometers.

Mapping activities focused on the following priorities:

1) conducting a patch test calibration of the EM302 multibeam sonar at the beginning of the expedition;

2) mapping along fracture zones during the transits to/from Pearl Harbor to the Johnston Atoll region; and
3) mapping the tops and higher flanks of seamount and ridge features located within the Johnston Atoll region of the Pacific Remote Islands Marine National Monument (PRIMNM). Top priority features included the Johnston Seamount group, Hutchinson Seamount, Karin Seamount Group, and Horizon Tablemount.

B. Objectives

Mission objectives for EX-15-04 Leg 1 included a combination of operational, science, education, outreach, and data management objectives:

1. Collect 24-hr/day deep water multibeam (EM 302), split beam (EK 60), and subbottom sonar data (MBES)
   a. Conduct 24-hour mapping operations for the duration of the cruise
   b. Collect bathymetric, seafloor backscatter, and water column backscatter data.
   c. Complement previously-gathered Extended Continental Shelf (ECS) surveying efforts around Johnston Atoll by mapping a key gap that may connect two ridge features
   d. Map a substantial portion of the Johnston Seamount, Hutchinson Seamount, and Karin Ridge features within the Johnston Atoll PRIMNM, with a focus on the summits and shallower flanks.
   e. Sub-bottom sonar 24-hr data collection will be at discretion of CO.

2. Conduct a patch test calibration for the EM 302 multibeam sonar. The patch test is needed after the recent dry dock to ensure system offsets are calibrated for optimum data quality. The patch test will be completed during the first day of the expedition prior to the long transit to Johnston Atoll, and should be accompanied by a CTD cast.

3. XBT operations
   a. XBT casts will be collected at regular intervals of no more than 6 hours

4. Train new personnel in all data collection and processing procedures (continuous throughout cruise)
   a. Training of new personnel in the Survey Department
   b. Train UCAR Explorers-in-Training
   c. Train UCAR mapping contractor new to the ship
   d. Train EPP mapping intern and interested visiting scientists

5. Continue testing new or modified mission hardware, software, and the mission UPS system.
   a. Mission computers recently upgraded to Windows 7
   b. Continue testing upgrades to Caris, Fledermaus, Hypack, and ArcGIS
   c. Assess performance of mission UPS following installation of new batteries

6. Telepresence (VSAT 5 mbps ship to shore; T1 shore to ship)

a. Maintain single live stream video from ship to shore with a focus on the multibeam mapping display.

7. CTD operations
   a. A CTD cast at the start of the patch test survey is planned.
   b. CTD rosette operations may be requested to obtain sound velocity profiles as a back-up for XBT operations, and thus the CTD should be mission-ready prior to the start of the expedition.
   c. Additional sensors typically mounted on the rosette including dissolved oxygen, light scattering sensor (LSS), and altimeter should be operationally tested and ready to perform exploration activities as the need arises should water column anomalies be discovered during the cruise.

8. The longstanding NASA marine aerosols network survey of opportunity will continue for the cruise.

9. Marine mammal observations
   Richard Hall, Fishery Policy Analyst for NOAA's NMFS Pacific Islands Region, will be onboard to lead marine mammal observations during the expedition. Data on observed marine mammal behavioral responses to the presence of the ship will be documented using the same methodology employed during the 2014 R/V *Falkor* expeditions within PMNM.

All cruise objectives were accomplished with the exception of objective 7. A CTD cast was not conducted, as an XBT was selected instead to gather a sound velocity profile in support of the multibeam sonar patch test. This decision was based primarily on the desire to save time. Multibeam patch test results indicated that no new offsets were necessary. While marine mammal observation watch standing was conducted during all daylight hours of the cruise (objective 9), no marine mammals were observed and thus the database was not populated with any new entries.

C. List of participants

At-sea participating mapping personnel:

Name (Last, First)	Role	Affiliation
Sowers, Derek	Expedition Coordinator/ Mapping Team Lead	OER/ERT Inc.
Meyer, Jason	Watch Lead	UCAR Contractor
Bittinger, Amanda	Watch Lead	UCAR Contractor
Miller, Joyce	Watchstander	HI Mapping Research Group
Heywood, Luan	Watchstander, Explorer-in-Training	UCAR
Tauriello, Dan	Watchstander, Explorer-in-Training	UCAR
Veazey, Lindsay	Watchstander, Explorer-in-Training	UCAR
Baechler, Neah	Watchstander, Explorer-in-Training	UCAR
Cooksey, Maria	Watchstander, Explorer-in-Training	EPP
CDR Wetzler, Mark	Commanding Officer	NOAA Corps.
LT Rose, Emily	Operations Officer	NOAA Corps.
Freitas, Daniel	Augmenting Survey Tech	NOAA OMAO
Hall, Richard	Mammal Observer	NMFS/PIRO

3. Methods

A. Operations Overview

During EX-15-04 Leg 1, mapping operations were conducted continuously throughout the cruise, 24 hours-a-day. Sonar data collection included a Kongsberg EM 302 multibeam (30 kHz), Simrad EK 60 split-beam (18 kHz), and Knudsen subbottom profile chirp (3.5 kHz) system.

Throughout the cruise, multibeam data quality was monitored in real-time by acquisition watch standers. Line spacing was planned to ensure 25-30% overlap between adjacent lines of multibeam sonar swaths. Cutoff angles in the multibeam acquisition software, Seafloor Information Software (SIS), were adjusted on both the port and starboard sides depending on ocean depth and prevailing weather conditions to optimize coverage and data quality. Angles were generally set between 40° and 70° on both the port and starboard sides. Survey and transit vessel speeds were typically maintained between 8.5-9 knots, and sea state and weather conditions were favorable for conducting ocean mapping work throughout the duration of the expedition.

Expendable bathythermograph (XBT) casts were conducted approximately every six hours during the cruise to ensure high quality multibeam sonar data. Sound velocity profiles were generally very stable throughout the survey, particularly once the ship was away from the main Hawaiian Islands.

All multibeam sonar data collected during the expedition was fully processed according to established onboard procedures and was archived with the National Center for Environmental Intelligence (NCEI, formerly NGDC). 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. Once per day, cleaned, gridded bathymetric data were exported to ASCII text files (y,x,z) at 50 meter cell size in WGS84 datum. The ASCII files were then used to create Fledermaus SD objects. These SD objects were then exported to geotiff and Google Earth KMZ files, which were copied to the shoreside FTP on a daily basis to support shoreside scientist participation.

During daylight hours, marine mammal observation watchstanders were present on the bridge looking for the presence of marine mammals or other protected species. Training on marine mammal observations was conducted prior to the start of the cruise at the NOAA Inouye Regional Center (IRC). Watchstanding shifts were led by Richard Hall, with mapping mission personnel rotating on and off duty every two hours to offer relief. Watchstanders were provided with data sheets and instructed to use compass units installed on the bridge wings to estimate bearing and distance from the ship. Datasheets contained fields for species, number of individuals, heading, and behavior. If the animals were close enough, watchstanders were also instructed to attempt to take a photo. Any data recorded was to be entered into an existing Microsoft Access database created to log marine mammal observations from 2014 *Falkor* cruises within Papahānaumokuākea Marine National Monument. Despite the rigorous efforts to observe and document marine mammals during this cruise, no observations were witnessed or recorded.

B. Equipment

Sonars

Okeanos Explorer has three scientific sonars that are operated simultaneously during mapping operations: a Kongsberg 30 kHz multibeam system, a Kongsberg 18 kHz split-beam fisheries sonar, and a Knudsen 3.5 kHz chirp sub-bottom profiler sonar. Mapping operations onboard *Okeanos Explorer* occur continuously throughout the day and night.

EM302
Okeanos Explorer's EM302 30 kHz multibeam sonar is used to collect seafloor bathymetry, seafloor backscatter, and water column backscatter. Backscatter represents the strength of the acoustic signal reflected from some target, whether the seafloor or bubbles in the water column. The EM302 is a deep water multibeam system designed to map in depths ranging from approximately 200-7,000 meters.

Split-Beam Sonar
The Kongsberg EK60 (18 kHz) single beam is used to collect information about the water column, such as gas plume or seep sites, and to obtain information about biomass. The EK60 split-beam sonar is used as a quantitative scientific echosounder to identify water column

acoustic reflectors - typically biological scattering layers, fish, or gas bubbles – providing additional information about water column characteristics and anomalies.

Subbottom Profiler
The primary purpose of the Knudsen Chirp 3260 (3.5 kHz) sonar is to provide echogram images of surficial geological sediment layers underneath the seafloor to a maximum depth of about 80 meters below the seafloor. The Subbottom profiler is normally operated to provide information about the sedimentary features and the bottom topography that is simultaneously being mapped by the multibeam sonar. The data generated by this sonar is fundamental in helping geologists interpret the shallow geology of the seafloor.

XBTs
Expendable bathythermographs (XBTs) were deployed to obtain sound velocity profiles to help calibrate the multi-beam system and ensure accurate bathymetric mapping. The XBT type is the Deep Blue probe produced by Lockheed Martin Sippican. Expendable bathythermographs were collected every three to six hours at an interval defined by prevailing oceanographic conditions to correct multibeam data for changes in sound speed in the water column, and were applied in real time using Seafloor Information Software (SIS). Sound speed at the sonar head was determined using a Reson SVP-70 probe, and salinity measurements near the transducers were taken using the ship's flow-through thermosalinograph (TSG).

For more detailed information about the sonar systems, see 2016 *Okeanos Explorer* Readiness Report (http://doi.org/10.7289/V5FT8J2Z).

C. Survey of Opportunity

As part of an ongoing survey of opportunity partnership project with NASA, mission personnel collected aerosol optical depth measurements in order to provide data to the Maritime Aerosol Network component of AERONET. Data were collected with a Microtops II sun photometer device attached to a handheld GPS unit.

D. Operating Model

EX-15-04 Leg 1 was a telepresence-enabled exploration mapping cruise. No ROV operations took place during this cruise. For most of the cruise a single live video feed was broadcast to shore and streamed to the OER webpage. The live feed display featured the multibeam sonar SIS display throughout most of the cruise. This display enabled shoreside viewers to see the seafloor being mapped with the EM302 multibeam sonar in near real-time. The broadcast was interrupted due to technical issues several times during the cruise.

E. Permits/Clearances

Papahānaumokuākea Marine National Monument (PMNM) Research Permit: Mapping work inside PMNM was originally planned for this cruise, but was not pursued due to the cruise being shorter than originally planned. However, the permit was still secured in case weather was poor near Johnston Atoll. Prior to the start of the cruise on July 9, 2015 the crew and mission personnel attended the mandatory training sessions associated with the permit.

Endangered Species Act Section 7 Consultation: OER submitted an informal consultation request under Section 7 of the Endangered Species Act for CAPSTONE EX1504 Legs 1-4 to NOAA PIRO's Protected Resources Division. Prior to the start of the cruise, OER received a letter of concurrence from NMFS stating that the cruises were not likely to adversely affect ESA-listed marine species, and would have insignificant effects on designated or proposed critical habitat.

Hawaii Board of Land and Natural Resources (BLNR): Permission to conduct CTD Rosette Operations in state waters was received from the Hawaii BLNR. A hearing to review plans and receive permission to conduct ship operations in Hawaii state waters was held June 12, 2015. The permit from BLNR to conduct work in state waters was approved.

Categorical Exclusion: This project qualified for a categorical exclusion from the need to prepare a NEPA environmental assessment, as documented in a June 24, 2015 memorandum from NOAA OER.

4. Summary of Operations

EX-15-04 Leg 1 was originally scheduled to occur July 3-24, 2015. Due to the need for an emergency dry dock period to repair the ship's dynamic positioning thrusters, the start of the cruise was delayed by seven days. This resulted in dropping mapping objectives originally planned to occur within the Papahānaumokuākea Marine National Monument.

The cruise was successful in fulfilling the majority of cruise objectives defined in the final signed project instructions based on the reduced cruise dates of July 10-24. Exploratory mapping work was completed as planned, and no major problems were encountered. Transit mapping was completed between Honolulu and Johnston Atoll, with an emphasis on mapping a fracture zone feature along the way. Within the Johnston Atoll Unit of PRIMNM, focused survey mapping was completed over top priority areas on Horizon Tablemount, the Johnston Seamount Group, Hutchinson Seamount, and Karin Ridge. Figure 2 provides an overview of multibeam sonar data coverage completed during the cruise. Table 1 provides an overview of mapping accomplishment statistics.

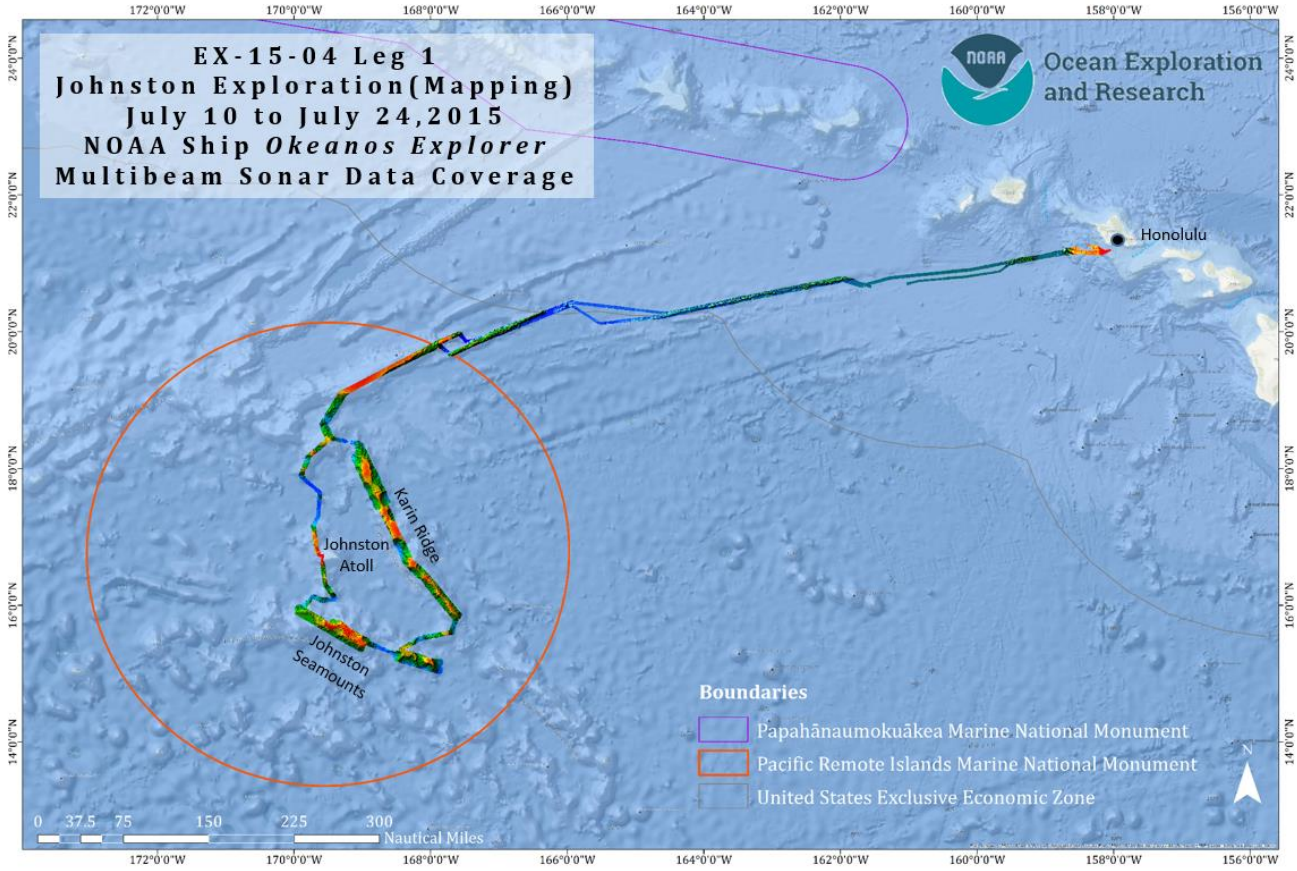

Figure 2. Map of multibeam sonar data coverage collected during EX-15-04 L1. Bathymetry data coverage shown with color-coded bathymetry shading. The boundary of the Johnston Atoll Unit of the PRIMNM is shown in red.

Table 1. Mapping Accomplishment Statistics from EX-15-04 L1

Dates	July 10-24, 2015
Days lost to weather	0 days
Total mapping days	15 days
Total non-mapping days	0 days
Unscheduled days alongside	0 days
Line kilometers of survey	5,308 km
Square kilometers of seafloor mapped	31,377 km^2
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files	410 files / 22.8 GB
Number / Data Volume of EM 302 water column multibeam files	410 files / 89 GB
Number / Data Volume of EK 60 water column singlebeam files	1,794 files / 4.13 GB
Number / Data Volume of subbottom sonar files	422 files / 4.61 GB
Number of XBT casts	61
Number of CTD casts (including test casts)	0
Beginning draft	Forward: 15'4"; Aft: 13'11.25"
Ending draft	Forward: 14'9"; Aft: 14'

This expedition provided hands-on ocean mapping experience to four Explorers-in-Training students and one NOAA Educational Partnership Program student. Valuable data for NASA about aerosols in the atmosphere was collected as feasible.

B. Calendar of Events

July 2015						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1	2	3	4
5	6	7	8	9	10 Departed Pearl Harbor at 1000 PDT, patch test completed	11 Transit mapping to Johnston Atoll, ship drills
12 Transit mapping of Horizon Tablemount	13 Transit mapping north of Johnston Atoll	14 Passed closely by Johnston Atoll, transit mapping	15 Ran survey lines over Johnston Seamount Group	16 Ran survey lines over Johnston Seamount Group	17 Transit mapping to Karin Ridge	18 Survey of Karin Ridge
19 Survey of Karin Ridge	20 Survey of Karin Ridge, begin transit to port	21 Transit mapping en route to Honolulu	22 Transit mapping en route to Honolulu	23 Transit mapping en route to Honolulu, post cruise meeting	24 Arrived in port at Pearl Harbor	25

C. Expedition Daily Log

All times listed are local ship time, which was equivalent to UTC time minus ten hours (UTC-10)

July 10, 2015
First sea day of EX-15-04 L1. The ship left the pier in Pearl Harbor at 1000. The multibeam failed TX Receiver BIST tests numerous times upon startup of the system. The failures where due to low voltage on certain transmit boards. After several restart attempts of SIS and the

TRU, three problematic transmit boards were re-seated to fix the problem. This fixed the problem. Mapping data quality appeared normal on all sonars. Completed short survey of interest area near Oahu for potential wrecks, followed by the multibeam patch test survey. We opted for an XBT cast in lieu of a CTD at the start of the patch test in order to save time. Patch test lines were completed around dinner time and the ship began the long multi-day transit to the Johnston Atoll of the Pacific Remote Islands Marine National Monument. Sea state was favorable all day. Marine mammal observations were conducted all day by Richard Hall, with training of additional observer watch standers getting underway. Best practices for managing potential interactions with marine mammals and other protected species were reviewed and posted on the bridge.

July 11, 2015
Continued mapping operations during transit to Johnston Atoll region of the Pacific Remote Islands Marine National Monument. Sea state was favorable all day and data quality was mostly high. There are several developing tropical storm systems in the region that we are monitoring closely for predicted track of the storms and possible interaction with our planned trackline. So far we are proceeding with the planned transit line. Yesterday's patch test data were evaluated using the patch test calibration tools in Caris software. No adjustment of currently applied offsets are needed, which means that overall the multibeam is calibrated and working as expected. There are some persistent minor artefacts in the multibeam bathymetry that can largely be managed right now through adjusting filter settings. Training of new mapping personnel took place throughout the day. We moved from UTM zone 4N to 3N.

July 12, 2015
Continued mapping operations during transit to Johnston Atoll region of the Pacific Remote Islands Marine National Monument. Sea state was favorable most of the day, but picked up somewhat from yesterday. Data quality was good all day. The tropical storm system with potential to cross our trackline instead veered west to the south of Johnston Atoll and is no longer a concern. We spent the day mapping a minor fracture zone and abyssal plain. Tomorrow we will be mapping part of the top of the Horizon Tablemount. Training of new personnel continued. We mapped an interesting isolated caldera-like feature 2.5 kilometers across with 300 m vertical relief from the abyssal plain. Marine mammal observations were conducted all day with interns rotating to help with two hour shifts. No cetaceans or turtles were spotted. Sun photometer measurements were taken every two hours during the day when the sun was unobstructed.

July 13, 2015
Today's operations focused on mapping along the top of Horizon Tablemount, a long flat-topped ridge feature in the northern region of Johnston Atoll MNM. Sea conditions were mild and mostly following, so mapping data quality on all three sonars was very good throughout the day. We are expecting to be just offshore of Johnston Atoll itself by mid-afternoon tomorrow. Survey operations went smoothly today, and the features on the approaches and flanks of Horizon Tablemount were interesting. We have noticed the subbottom seems to jump around too much on auto phase shifting – we are doing phase shifts manually with better results and monitoring the sonar carefully to ensure data does not get clipped. Auto

gain has also been problematic on the Knudsen, as it periodically will ramp up the gain until the echogram is just all noise. Gain is therefore being manually adjusted. Marine mammal observations were conducted all day with interns rotating to help with two hour shifts. No cetaceans or turtles were spotted.

July 14, 2015
Today we mapped a series of seamounts extending south from Horizon Tablemount, passed Johnston Atoll, and began mapping the apparent ridge gap between Johnston Atoll and Johnston Seamount to complement Extended Continental Shelf (ECS) work in the region. The close pass by Johnston Atoll was a highlight of the day, as everyone was interested in glimpsing this seldom visited place. Sea state picked up a little since yesterday, but conditions were still favorable for high quality mapping data on all sonars. Tomorrow we begin focused survey operations on the Johnston Seamounts. The weather has been mostly sunny, with sporadic clouds. The water masses here seem to have very stable sound velocity profiles, and thus we have been conducting XBTs approximately every five hours, and there are never any sound velocity warnings in SIS. Marine mammal observations were conducted all day with interns rotating to help with two hour shifts. No cetaceans or turtles were spotted. Many birds were observed near Johnston Atoll – mostly brown boobies, along with a few terns and frigate birds.

July 15, 2015
Mapping of the Johnston Seamounts began today with favorable sea state and good quality on the sonars. The seamount has very complex terrain with terraced levels, many pinnacle features, and numerous smaller volcanic-looking cones. We will map in this seamount group for the next few days, breaking the area into two distinct focus survey areas naturally divided by a deep gap previously mapped by Jim Gardner for ECS purposes. Given that we don't have time to complete the mapping of all the Johnston Seamount Group and Karin Ridge, we are splitting our mapping time roughly in half between these two areas and concentrating on the flanks and tops of the features. There will be plenty to map at night during the Leg 4 ROV cruise to add to the mapping coverage. We have noticed occasional multi-ping gaps in the multibeam occurring between the middle and outer beams. They often seem to correlate with areas of very low backscatter, so may be due to volume scattering of our signal at oblique incidence angles. Sometimes changing to a deeper mode seems to help with this issue. Changing to a shallower mode will also be experimented with. Overall data quality has been quite good and data cleaning on the multibeam is light. Water column processing has begun. Marine mammal observations conducted during all daylight hours – nothing to report today. Sun photometer measurements being taken when sunny.

July 16, 2015
Mapping of the Johnston Seamounts continued throughout the day, with good data quality on all sonars. The eastern half of the first seamount we mapped in the Johnston Seamount group has a flat top studded with numerous cones or pinnacle features. Both Joyce Miller and Chris Kelley have commented that the only other place they recall seeing similar features was near Kingman Reef. Our mapping time in the Johnston Seamount group will end tomorrow morning, at which time we will transit to focus our remaining survey time on Karin Ridge before transiting back to port. Water column and bottom backscatter data processing are

ongoing. No water column anomalies have been discovered thus far. Marine mammal observations conducted during all daylight hours – nothing to report today. Sun photometer measurements being taken when sunny.

July 17, 2015
Mapping operations on the Johnston Seamounts group concluded today in order to break away and begin mapping of Karin Ridge with the remaining time we have for focused survey work. It has been hard to leave after mapping only half of these fascinating seamounts. We mapped part of a smaller, but interesting, lone seamount while transiting to Karin. Most of the seamounts and ridges in the area have fairly flat tops, but are consistently studded with the small cone features. We began surveying very long lines along the main axis of Karin Ridge. We have time to survey about 3 lines on the southern half and 5 lines on the northern half. Overall data quality has been quite good. The multibeam occasionally has trouble tracking bottom at nadir, but using a strong penetration filter setting usually quickly resolves the issue. There are areas of very low backscatter interspersed among the cone features and on the tops of the guyots. Water column and bottom backscatter data processing are ongoing.

July 18, 2015
Today was spent mapping along Karin Ridge, an approximately 170 nm NW-SE trending ridge feature located east of Johnston Atoll. Sea state picked up throughout the day, with 4-6' seas, rain, 30 knot winds, and lightning storms by midnight. Data quality was good in the morning and fair by the end of the day. Fire and abandon ship drills were conducted mid-afternoon. We plan to map in the Karin Ridge area until the evening of July 20th, at which time we will depart for the approximately 3.5 day transit back to Honolulu mapping another line on the Horizon Tablemount on our way out. Surveying of Karin Ridge is going well, with the first multibeam line revealing the top main axis of the ridge. Stormy conditions and lightning in the evening required slowing the survey speed down to 7-7.5 knots to keep data quality reasonable. Bubble sweep-down was an issue impacting bottom tracking on the multibeam at higher speeds. Lightning storms prohibited us from making an XBT for 10 hours, but no sound velocity problems were observed in SIS or in the multibeam data.

July 19, 2015
Surveying of Karin Ridge continued all day. Sea state relaxed somewhat overnight, with data quality returning to good on all sonars. Surveying operations went smoothly today. There is a small re-occurring issue with bottom detections near outer beam sector boundaries in the multibeam that results in small periodic holes in the bathymetry coverage. We have experimented with many different filter and mode settings and have not found a conclusive solution yet. Marine mammal observations ongoing – nothing to report. There is an issue on the low resolution feed that needs to be fixed – EC has requested shoreside OER assistance on troubleshooting.

July 20, 2015
We finished our survey efforts on Karin Ridge at 2000, and began the 3.5 day, 753 nm transit journey back to Honolulu. We were able to complete five multibeam lines on the northern region of Karin Ridge, and three lines on the middle and southern region. Sea state was mild, with swells of 2-4', making for high quality sonar data collection. Kongsberg support has

been sent information about the minor bottom tracking issue we have been seeing periodically. We noticed that in some cases where it appeared the multibeam was not collecting data, there was data when the lines were imported and processed with Caris. The data had been flagged by SIS, but some of these flagged soundings were actually acceptable. Watch leads have been helping to QC the data at the end of each watch to help separate good soundings from noise. These minor issues are being worked on, but overall data quality has been good.

July 21, 2015
The day was spent transit mapping as we make our way back to port. Another line of multibeam data on Horizon Tablemount was matched with the one collected earlier on the cruise. Sea state was mild again, with swells of 2-4'. We are on schedule for a mid-morning arrival back to Ford Island on Friday July 24th. Overall data quality on the sonars was good. The multibeam had some trouble tracking the bottom at nadir while surveying over the very steep slope of Horizon Tablemount.

July 22, 2015
Transit mapping went smoothly today. Much of the day was over flat abyssal plain until reaching the fracture zone that we partially mapped during the transit to Johnston. We are edge matching our earlier line to finish mapping the fracture feature. The EC and Joyce Miller gave a science talk today about the mission, geological context of the region, enigmatic science questions about the region, and an overview of the multibeam data collected during the cruise. The talk was well attended by the crew. Kongsberg was sent an image of the receive stave array as part of the correspondence to see if we can fix the minor outer beam sector bottom tracking issue seen on this cruise. As part of this, we may turn the multibeam off temporarily tomorrow and re-seat the BSP 67B cards on the TRU, as advised by technical support. This will be done in a featureless area during transit. All of the water column data files have been processed by Dan Tauriello. So far there has been just one file with potential water column anomalies. Marine mammal observations ongoing – still nothing to report.

July 23, 2015
Today was the last full day of mapping operations on the cruise. Transit mapping was conducted all day. After finishing mapping of the fracture zone in the morning, we temporarily turned off the multibeam over a large area of flat seafloor to re-seat BSP67 boards in the TRU as recommended by Kongsberg technical support. This led to the multibeam not working for 3.5 hours until we could restore it. The lost data was over an area of flat seafloor. Mapping for the rest of the cruise was normal. The ship was dockside at Ford Island at approximately 10 AM local time. EM302 troubleshooting work was in response to our inquiry about trying to fix the minor bottom tracking problem at sector boundaries in outer beams. After the EC and Chief ET reseated the BSP67 boards, we tried to bring the multibeam back up but there were a host of BIST test failures. After 3 complete system restarts we pinged the sonar before running BISTs, then ran BISTs and all passed. Upon inspection of the passed BIST results the same board/band combinations that were out of spec in earlier BISTs were still out of spec, so it does not appear to have changed anything. Will follow up with Kongsberg, but for now recommend running EM302 as is and living with the periodic gaps. Derek suspects the problem is more with TX boards that are not

functioning at quite 100%. All transit lines to Johnston were processed in FMGT and have backscatter mosaics available. The major seamount features and Karin Ridge within the Monument also have completed backscatter mosaics to aid dive planning during EX1504L4.

July 24, 2015
At 1000m Powered down Knudsen, at 500m meters powered down EK60 and EM302. Arrived in Pearl Harbor.

5. Summary of Findings

During the expedition approximately 31, 377 square kilometers of seafloor area were mapped using the multibeam sonar, covering a linear track line distance of 5,308 km. Nine of the days at sea were spent within the Johnston Atoll Unit of the Pacific Remote Islands Marine National Monument.

The expedition resulted in mapping many of the flat-topped seamounts (guyots) and ridges submerged around Johnston Atoll, and discovering that many of these features were dotted with distinct pinnacle-shaped mounds with typical heights of 100-300 meters. The flat-topped guyots provide evidence that these mountains were previously at sea level in their geologic past, while the pinnacles protruding from the surface provide evidence of secondary volcanism at some point after the guyot tops submerged under the surface.

The following general observations were noted during this mapping expedition:

- There was a surprising lack of marine mammal sightings during the expedition - only one group of about 6 dolphins near Oahu was spotted. No other marine mammal observations were noted during the rest of the trip despite dedicated spotters during daylight hours.
- No sea turtles or sharks were observed.
- Very few other ships were observed on radar or via AIS contacts.
- The seafloor terrain on the seamounts and guyots within the Monument is complex and fascinating - the many flat-topped seamounts were likely above sea level at some point, but some of them are dotted all over with what appear to be volcanic domes that likely formed during a different period.
- There do not appear to be water column anomalies (e.g. bubble seeps) in the region surveyed, as initial analysis of multibeam sonar water column data did not reveal anything of note.
- Multibeam sonar seafloor backscatter mosaics were completed for most of the trackline we mapped, including all of the major seamounts within the Monument. These mosaics are useful for insights into substrate hardness and texture and have been archived with the raw data.
- In addition to the multibeam sonar mapping data, the ship collected EK60 water column sonar data showing biological layers of interest and sub-bottom sonar data that provides insights into the shallow (i.e. 80m or less below the seafloor surface) geology of the region.

The trackline of the ship is shown in Figure 3, which shows all tracklines where water column sonar data was collected using the ship's EK60 split-beam and EM302 multibeam sonars.

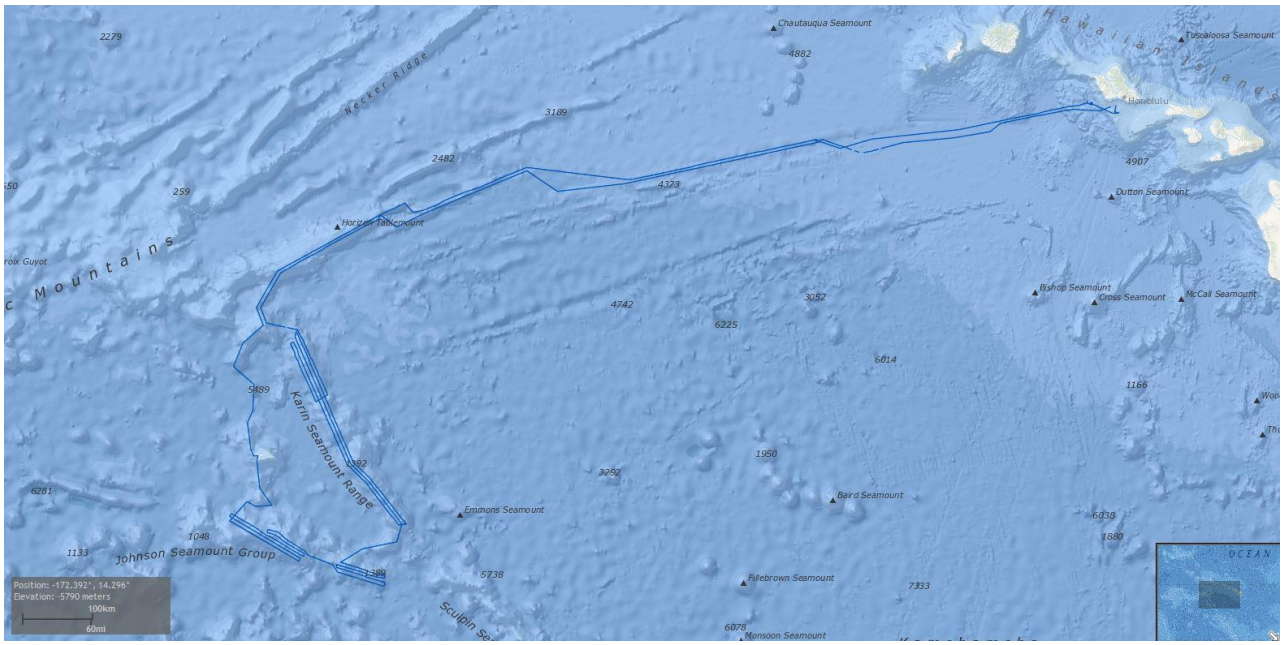

Figure 3. Shiptrack of the *Okeanos Explorer* during EX-15-04L1 (dark blue trackline). Map generated by the Water Column Sonar Data online mapping service maintained by the National Center for Environmental Information (NCEI). The scale bar on the map represents 100 km.

Example Highlight Features Within the Johnston Atoll Unit of the Pacific Remote Islands Marine National Monument (PRIMNM)

The seamount and ridge features partially mapped during the cruise are clearly among the most prominent features within this unit of the Monument. This section of the report briefly highlights some of the interesting seafloor mapping data collected during the cruise. Figure 4 shows exaggerated 3-D bathymetry of the Hutchinson Seamount within the Johnston Seamounts group.

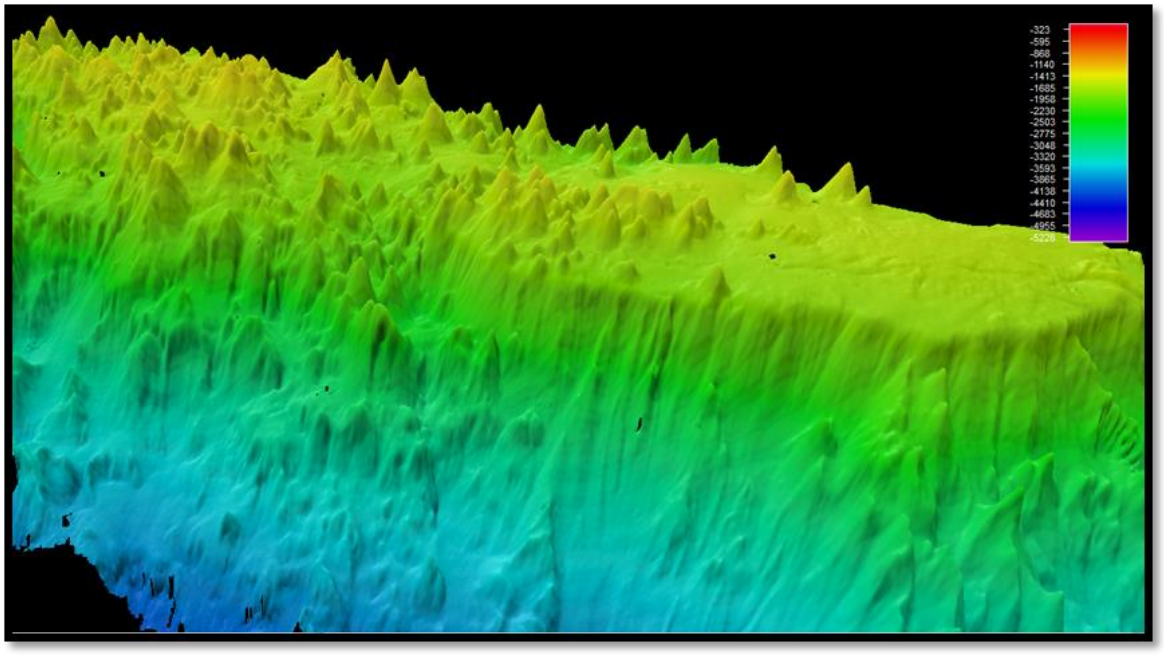

Figure 4. Multibeam bathymetry of a Hutchinson Seamount within the Johnston Seamount Group showing numerous pinnacles dotting the guyot surface. Depth scale is in meters and bathymetry shown at 5x vertical exaggeration. The depth scale color bar ranges from approximately 300 to 5300 meters.

Figure 5 is a multibeam sonar backscatter intensity mosaic image (plan view) of the Hutchinson Seamount. Figure 6 highlights a close up 3-D view and profile of typical cone features mapped on top of this seamount.

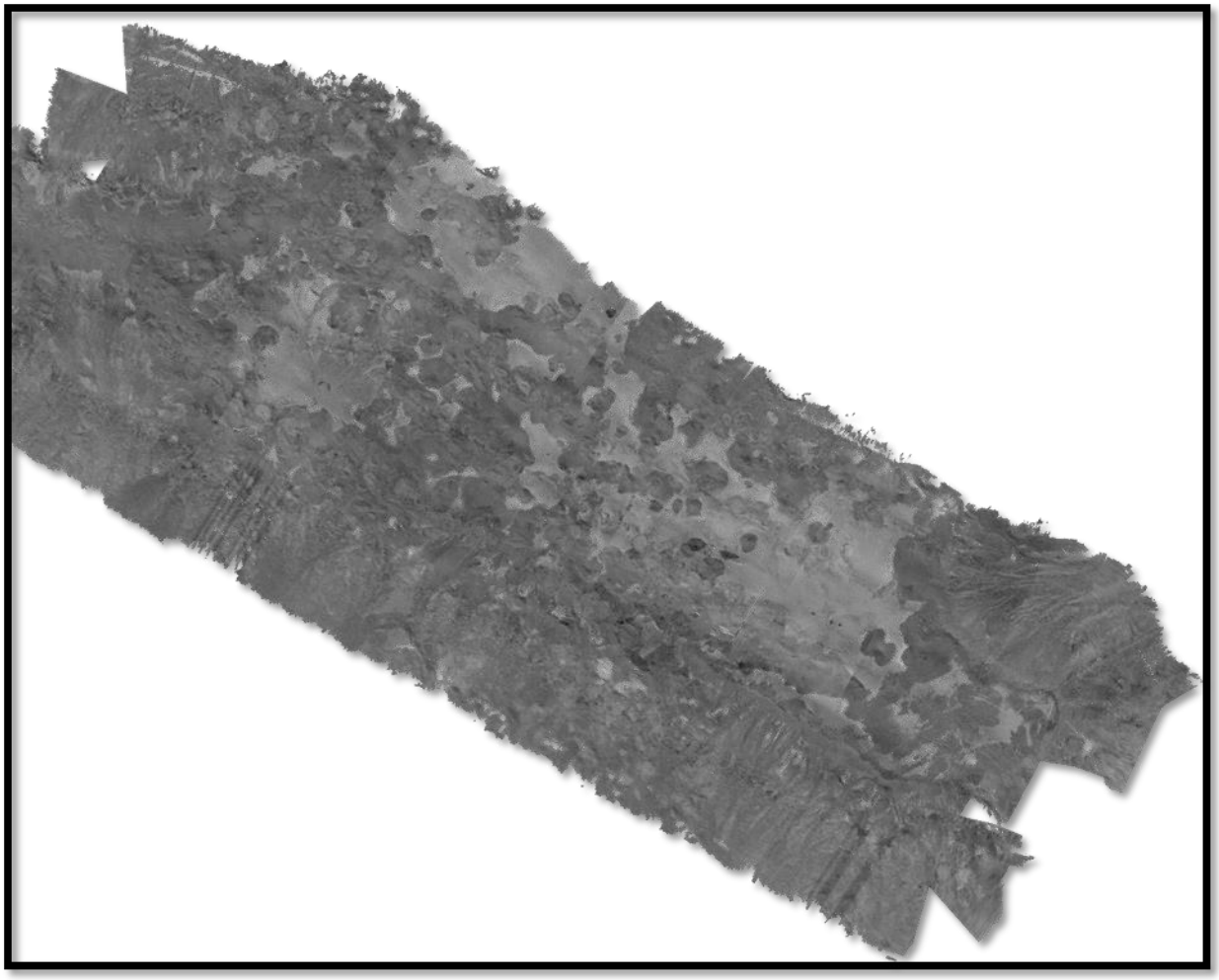

Figure 5. Image of multibeam sonar seafloor backscatter intensity from the first of the Johnston Seamounts mapped on this cruise. Circular cone-shaped features along the top of the seamount stand out from the surrounding sediment. In this mosaic lighter colors indicate lower reflectivity (softer sediment), while darker colors indicate higher backscatter intensity and thus harder substrate.

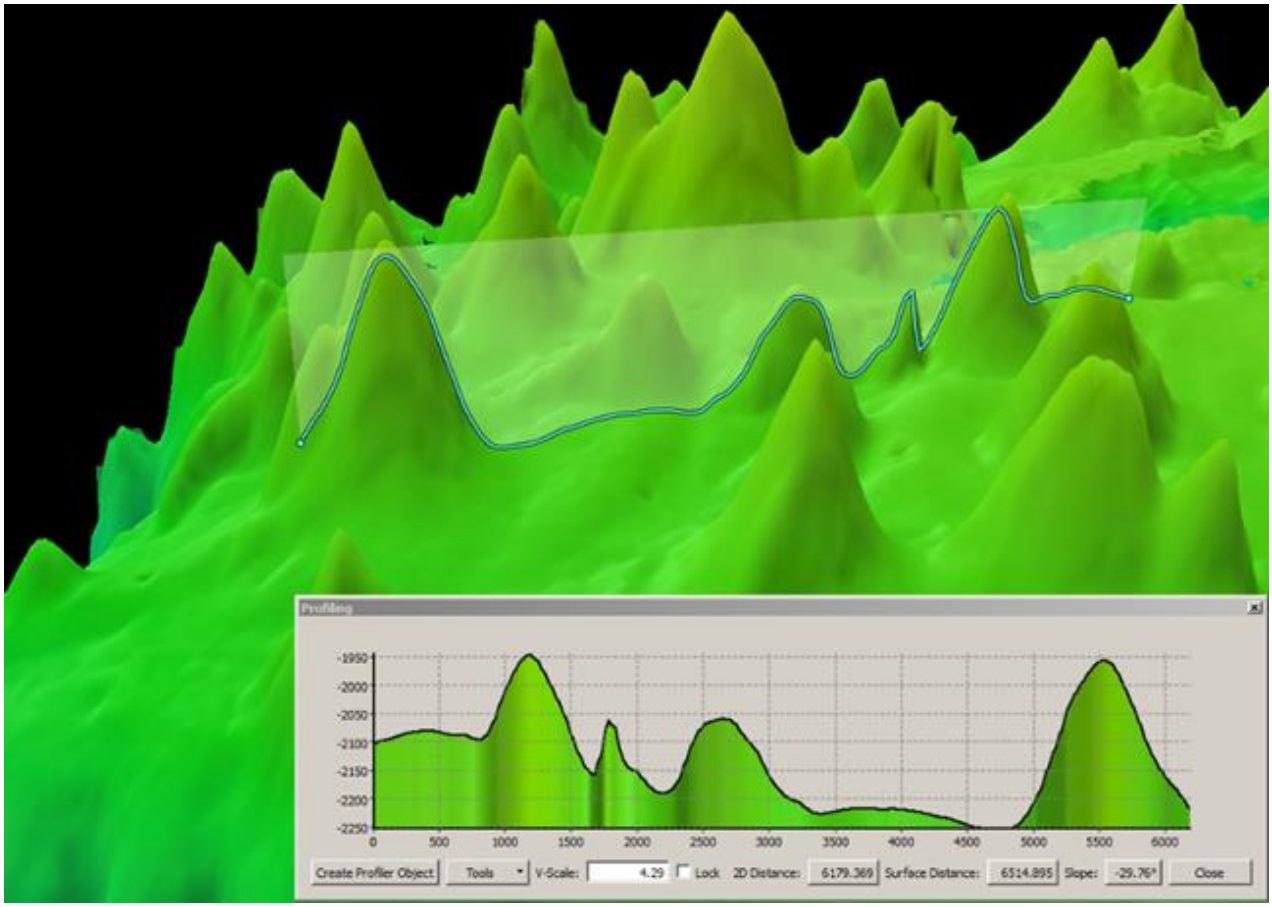

Figure 6. Close up view and profile of cone features on top of Hutchinson Seamount. Typical cone heights protrude 100-300 m from surrounding seafloor. Vertical exaggeration 5x.

Figure 7 highlights an unexpected discovery of a dramatic single pinnacle feature on an otherwise rounded unnamed seamount located directly in between the Johnston and Karin Seamount ranges.

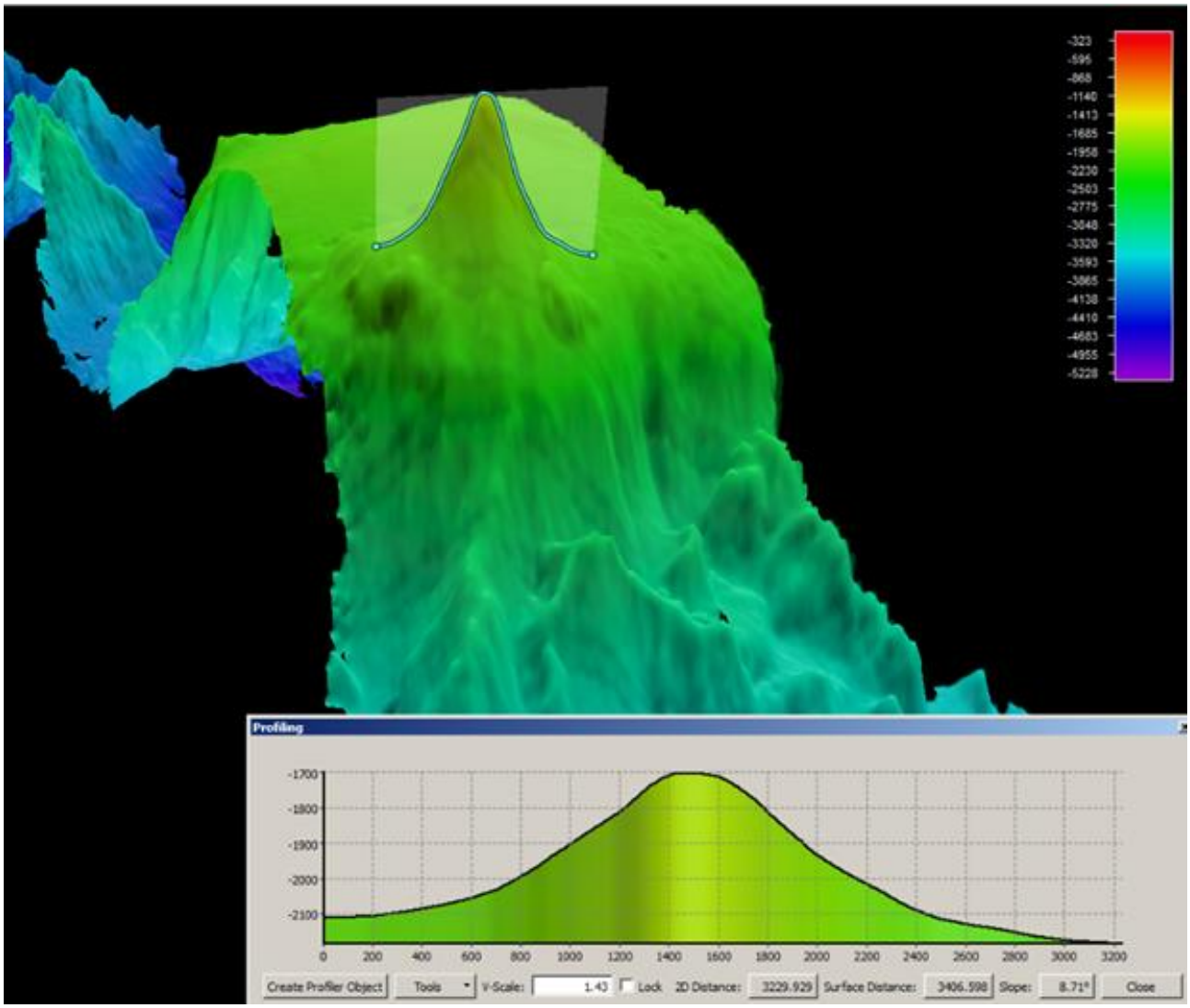

Figure 7. Unexpected pinnacle feature on top of an otherwise gently domed un-named seamount mapped during transit between Johnston Seamount group and Karin Ridge. The presence of this 400m pinnacle was not hinted at by the existing NOAA chart for the region or by the Smith and Sandwell predicted bathymetry layer. Vertical exaggeration 5x. The depth scale color bar ranges from approximately 300 to 5300 meters.

Figures 8, 9, and 10 showcase the bathymetric complexity, roughness, and steepness of features mapped within the impressive Karin Ridge area. Figure 10 provides a strong example of how ship-based mapping provides extraordinary detail about seafloor features that cannot be resolved via satellite mapping methods.

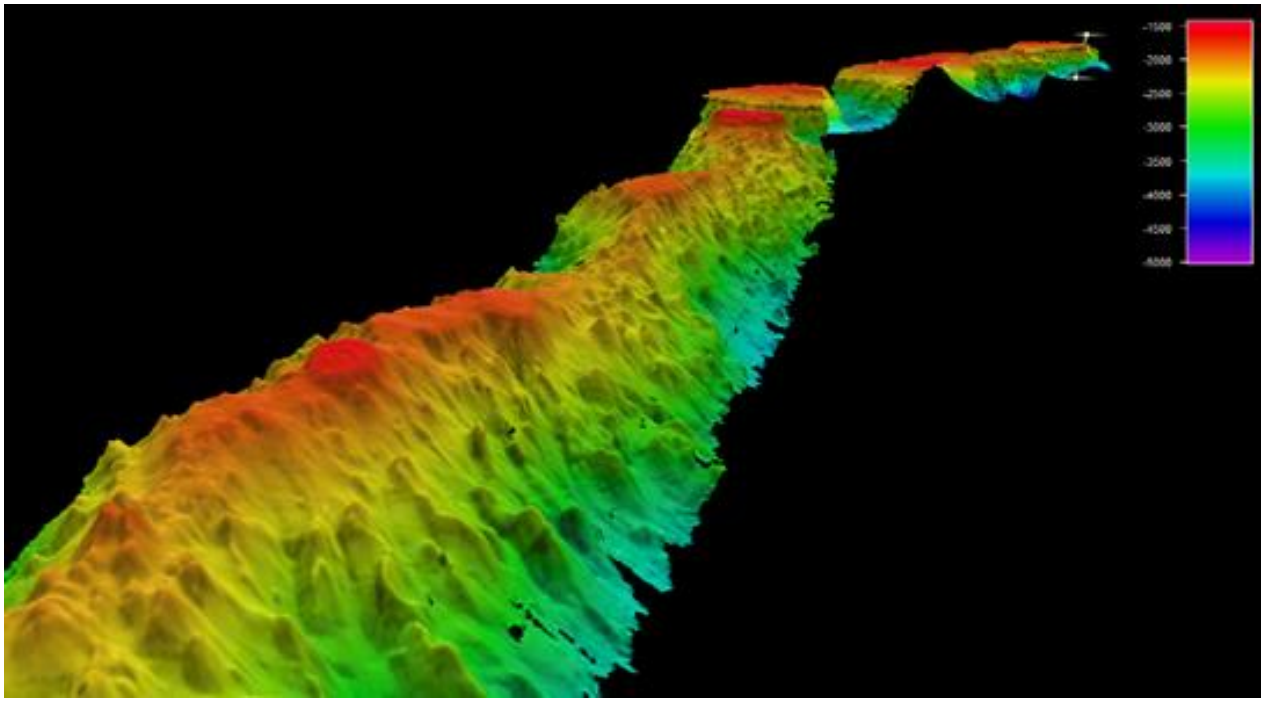

Figure 8. Overview of Karin Ridge bathymetry looking from the south to the north. Note the many flat-topped summits along the ridge. 3x vertical exaggeration. The depth scale color bar ranges from approximately 1500 to 5000 meters.

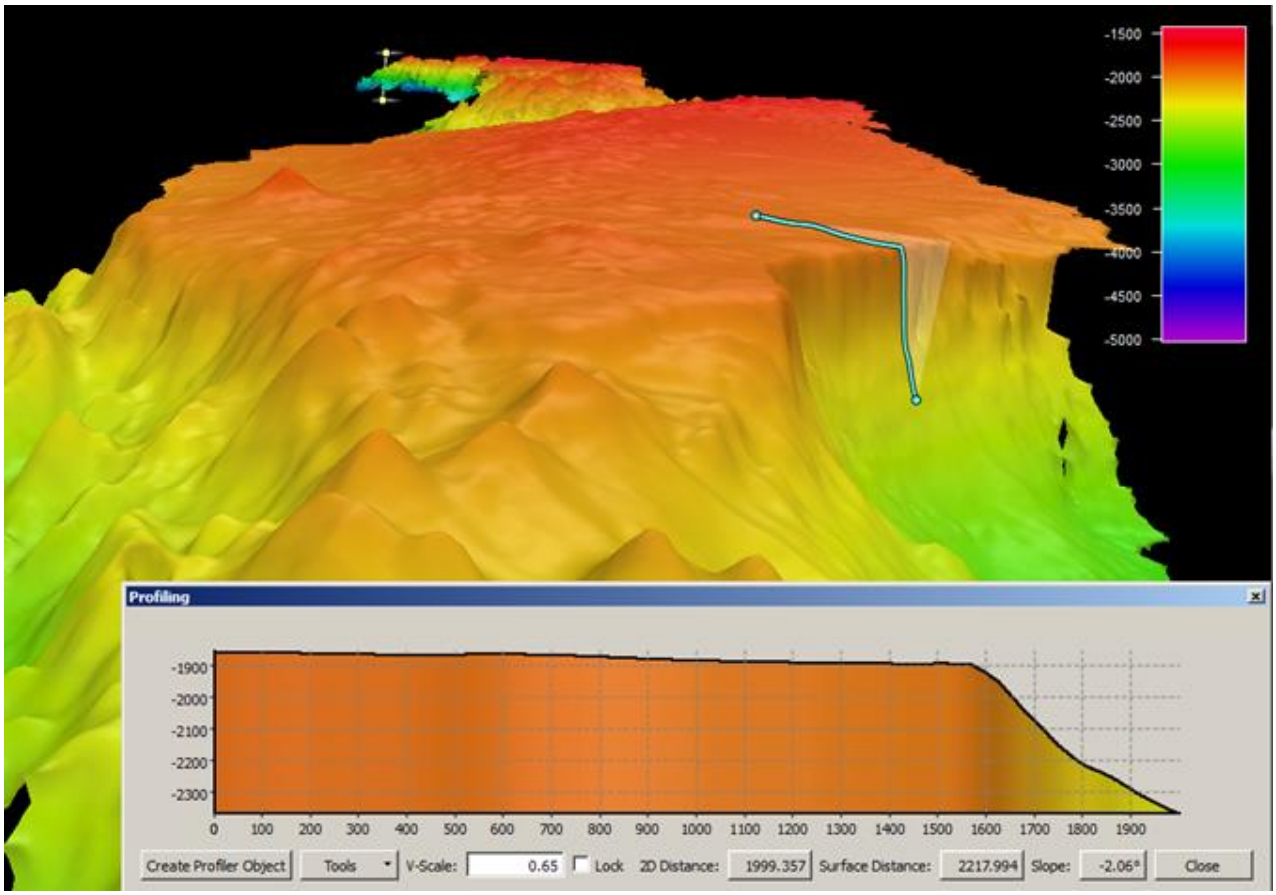

Figure 9. Dramatic scarp feature at the edge of a summit plateau. Slopes up to 60 degrees. Vertical exaggeration 3x. View perspective is looking from north to south. The depth scale color bar ranges from approximately 1500 to 5000 meters.

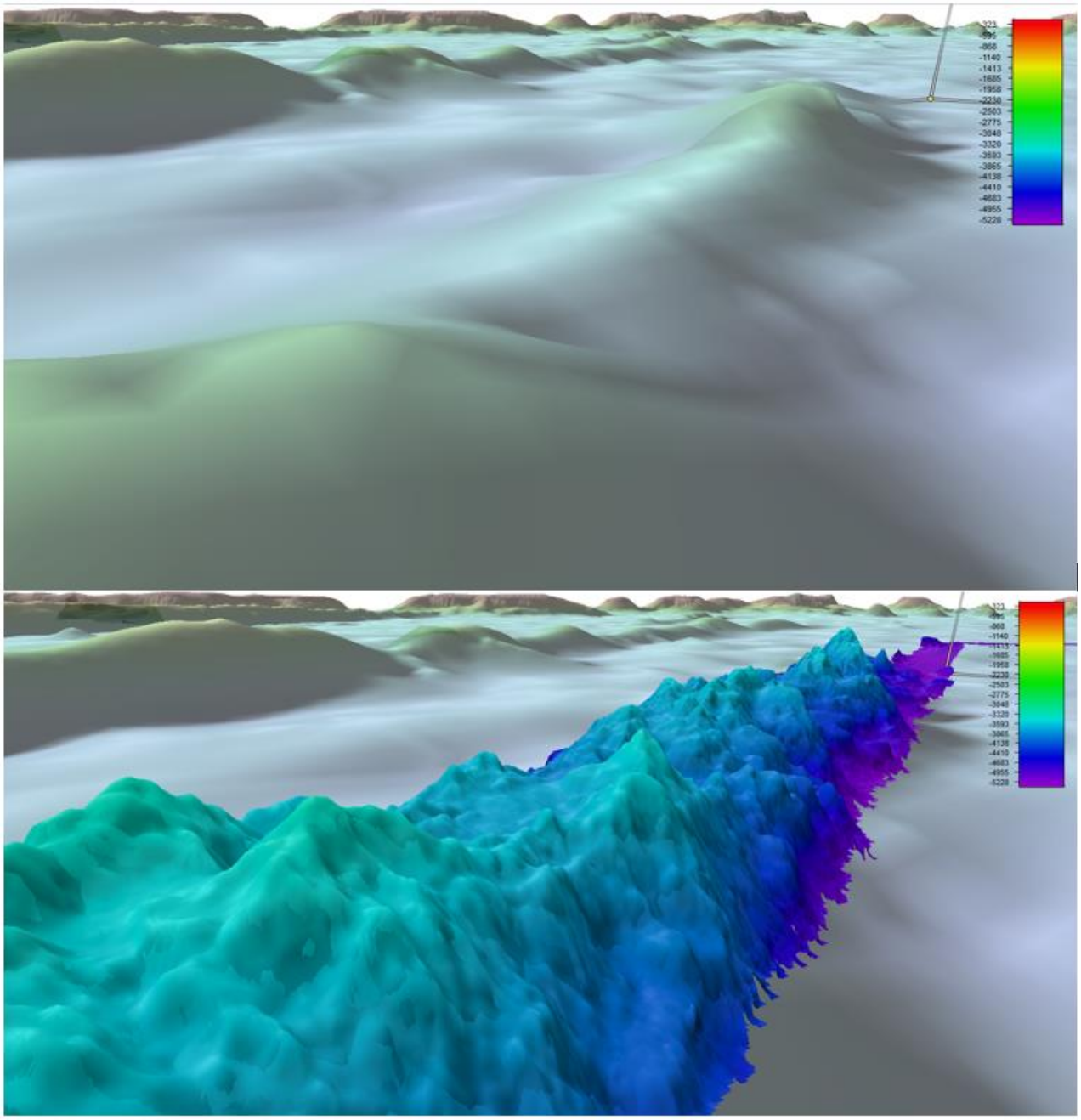

Figure 10. Before and after comparison of satellite-derived predicted bathymetry layer (Smith and Sandwell, top image) to EM302 multibeam bathymetry gridded to 50 m resolution (bottom image) following transit mapping over this unnamed ridge feature east of Horizon Tablemount. 3x vertical exaggeration. The depth scale color bar ranges from approximately 300 to 5300 meters.

6. Sonar Data Quality Assessment

EM 302 Multibeam Crossline Analysis

Within CARIS software, 75 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 0.2 m (Figure 11). This result indicates that in survey water depths ranging from 1800-3900 meters, the mainscheme and crossline multibeam tracks surveyed in orthogonal directions at different times obtained seafloor depths that agreed with each other within 0.2 meters (on average), with a standard deviation of 8.7 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>
0297_20150720_223439_EX1504L1_MB
0298_20150720_233437_EX1504L1_MB

<u>The mainscheme lines used:</u>
0235_20150718_152811_EX1504L1_MB
0250_20150719_050234_EX1504L1_MB
0283_20150720_102532_EX1504L1_MB

	Points Compared	Max Value	Minimum Value	Mean Difference	Standard Deviation
Crossline	17,550	139.7 meters	-105 meters	0.2 meters	8.7 m

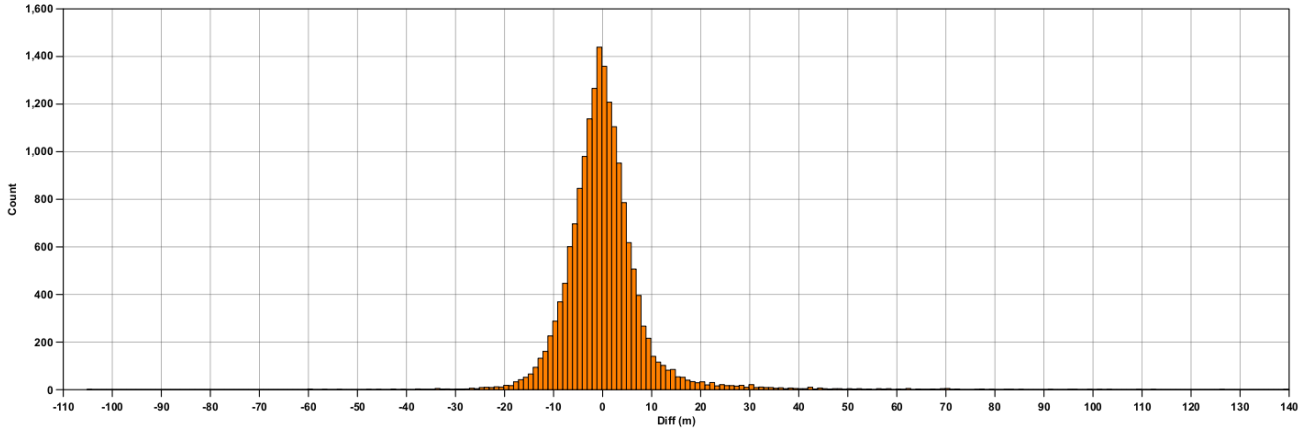

Figure 11. Summary statistics and a histogram plot of the differences between the mainscheme and crossline bathymetric surfaces.

7. 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.

A. OER Data Discoverability Tools

OER data can be accessed via the following websites:

- OER Digital Atlas at http://www.ncddc.noaa.gov/website/google_maps/OE/mapsOE.htm
- OER ROV Data Archives at http://service.ncddc.noaa.gov/rdn/oer-rov-cruises

Additional data requests are handled through the NOAA Ocean Exploration and Research Program Data Access Request Form which can be found here: https://docs.google.com/a/noaa.gov/forms/d/1pU3jbcV5ffunMKUbYgnA2OK-ZT9qj2Dh6JgZ79TTORM/viewform?formkey=dHAycC1MYndJb0hTdGRaYXAzVTVBdWc6MA&fromEmail=true

B. Sonar Data

Sonar data collected onboard *Okeanos Explorer* undergoes QA/QC after a cruise and is then made publicly available through the OER Data Discoverability Tools, the National Archives, and the following websites:

- NGDC Interactive Bathymetry Data Viewer at http://maps.ngdc.noaa.gov/viewers/bathymetry/
- NGDC Interactive Multibeam Data Viewer at http://maps.ngdc.noaa.gov/viewers/multibeam/
- Place holder for ADCP archives
- NGDC Interactive Water Coulmn Data Viewer at http://maps.ngdc.noaa.gov/viewers/water_column_sonar/

8. References

The following references are for background data used throughout the cruise:

Becker, J. J., D. T. Sandwell, W. H. F. Smith, J. Braud, B. Binder, J. Depner, D. Fabre, J. Factor, S. Ingalls, S-H. Kim, R. Ladner, K. Marks, S. Nelson, A. Pharaoh, G. Sharman, R. Trimmer, J. vonRosenburg, G. Wallace, P. Weatherall., Global Bathymetry and Elevation Data at 30 Arc Seconds Resolution: SRTM30_PLUS, Marine Geodesy, 32:4, 355-371, 2009.

Smith, W. H. F., and D. T. Sandwell, Global seafloor topography from satellite altimetry and ship depth soundings, Science, v. 277, p. 1957-1962, 26 Sept., 1997.