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EX-16-04
CAPSTONE Wake Island PRIMNM (Preliminary Mapping)

Cruise Report

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

March 23, 2016 to April 13, 2016

Kwajalein, Republic of the Marshall
Islands to Guam

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Abstract:

EX-16-04 was an exploratory mapping expedition that commenced on March 23, 2016 in Kwajalein Atoll in the Marshall Islands and concluded on April 13, 2016 in Guam. EX-16-04 focused on ocean mapping of the Wake Island unit of PRIMNM for exploratory 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 42,519 square kilometers of seafloor area were mapped using the multibeam sonar, covering a linear track line distance of 7,517 km. The vast majority of this work was completed in areas un-mapped with multibeam sonars. Ten days at sea were spent inside the boundaries of the Wake Atoll Unit of the Pacific Remote Islands Marine National Monument (PRIMNM), providing new high resolution bathymetry and backscatter data for over 19,176 square kilometers of seafloor inside the Monument. Ten of the seamounts within the Monument were mapped in their entirety, with an additional six seamounts partially mapped. Including transit mapping to/from the Monument, portions of 37 individual seamounts were mapped during the cruise.

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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-16-04 was an exploratory mapping expedition that commenced on March 23, 2016 in Kwajalein Atoll in the Marshall Islands and concluded on April 13, 2016 in Guam. EX-16-04 focused on ocean mapping of the Wake Island unit of PRIMNM for exploratory baseline characterization. Wake Island is the northernmost atoll in the Marshall Islands geological ridge, and according to the US Fish & Wildlife Service, is perhaps the oldest living atoll in the world. 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. The Wake Island Unit of PRIMNM contains 406,307 km^2 of ocean area within the US Exclusive Economic Zone. Very little multibeam data previously existed in this region, and this cruise was therefore undertaken to explore and characterize this very large US

marine protected area. The vast majority of areas mapped during the cruise had never been mapped in detail with ship-based echo sounders. Mapping the tops and higher flanks of seamount and ridge features was a top priority of the cruise both during transits to/from the Monument, as well as within the Monument boundaries.

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.

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 Wake 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.

B. Objectives

During EX-16-04 multibeam data was collected 24 hours a day, almost entirely over previously unexplored regions. This mapping work provided essential baseline mapping and reconnaissance of the region prior to EX-16-06, enabling ROV dive locations to be planned partially in advance. The following were cruise objectives for EX-16-04:

1. Collect 24-hr/day deep water multibeam (EM 302), split-beam (EK60), and sub-bottom sonar data (Knudsen 3260).
   a. Conduct 24-hour mapping operations for the duration of the cruise
   b. Collect bathymetric, seafloor backscatter, and water column backscatter data.
   c. Sub-bottom sonar 24-hr data collection will be at the discretion of the CO.

2. Conduct emergency drills. Drills may include some or all of the following as determined by CO:
   a. Fire/Damage Control
   b. Abandon Ship
   c. Man-Over-Board
   d. Steering Casualty
   e. Oil Spill/ Hazmat spill

3. Data management objectives:
   a. Ensure expected data products are transferred from the ship to the Inner Space Center at URI.
   b. Work with Mapping Team to improve data management process documentation and SOPs as they relate to mapping products

4. Conduct water column sound velocity profile measurements via UCTD or XBT.
   a. Test the UCTD and refine SOP. UCTD will be the preferred method to collect sound velocity casts once the SOP is refined and personnel have been adequately trained in its use. XBT casts will be conducted as needed.
   b. Water column sound velocity casts will be collected at regular intervals ofno more than 6 hours in support of multibeam sonar operations
   c. CTD rosette operations may be requested to obtain sound velocity profiles as a back-up for XBT and UCTD operations, and thus the CTD should be mission-ready prior to the start of the expedition. 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.

5. Train personnel in data collection and processing procedures as needed (continuous throughout cruise).

a) Train Explorers-in-Training
b) Train EPP mapping intern
c) Train augmenting Survey Tech or newly hired Survey Tech

6. Map a large section of area within the Wake Island Unit of PRIMNM. Survey mapping will focus on mapping the large seamount features within the unit. This mapping work will form a foundational basis of information on which top priority ROV dive operations can be planned for subsequent exploration expeditions.

7. Telepresence (VSAT 4.7 mbps ship to shore; 1.54 mbps shore to ship)
   a) Maintain single live stream video from ship to shore with a focus on the multibeam mapping display

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

9. As a partnership survey of opportunity, recover an existing High-frequency Acoustic Recording Package (HARP) mooring, and deploy new HARP mooring near Wake Island.

10. Search for Underwater Cultural Heritage (UCH) sites associated with WWII battles in the region. Specific search targets are too be determined. NOAA OER's UCH policies will be followed to guide the management of data associated with sites found intentionally or unintentionally.

11. Test new QPS Qimera software for importing, cleaning, and making products from multibeam sonar data.

All cruise objectives were accomplished. The only significant challenge during the cruise was the loss of the UCTD dummy probe due to the winch line breaking upon probe recovery. The reason for the line breakage was unknown.

C. List of Participants

At-sea participating mapping personnel and vessel liaisons:

Name (Last, First)	Role	Affiliation
Sowers, Derek	Expedition Coordinator/ Mapping Team Lead	OER/ERT Inc.
Freitas, Daniel	Watch Lead	UCAR Contractor
Bittinger, Amanda	Watch Lead	UCAR Contractor
Potts, Walter	Augmenting Survey Tech	NOAA OMAO
Atta, Calder	Watchstander, Explorer-in-Training	UCAR
Price, Melissa	Watchstander, Explorer-in-Training	UCAR
Grenier, Briana	Watchstander, Explorer-in-Training	UCAR
Ruby, Caitlin	Watchstander, Explorer-in-Training	UCAR
Martinez-Rivera, Stephanie	Watchstander, Explorer-in-Training	NOAA Educational Partnership Program
CDR Wetzler, Mark	Commanding Officer	NOAA Corps
XO Brinkley, James	Executive Officer	NOAA Corps
JO Pestone, Bryan	Acting Operations Officer	NOAA Corps

3. Methods

A. Operations Overview

During EX-16-04, 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 sonars (18, 70, 120, 200 kHz), and Knudsen subbottom profile chirp (3.5 kHz) system. The ship's 38 kHz and 300 kHz ADCPs were not used on this cruise because they interfered with the multibeam.

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. Survey and transit vessel speeds were typically maintained between 8.5-9 knots. Sea state and weather conditions were favorable for conducting ocean mapping work during most of the expedition, with rough seas being limited primarily to 4/4/16-4/6/16.

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 expedition, with no yellow or red sound velocity

warning lamps indicated within SIS. Sound speed at the sonar head was determined using a Reson SVP-70 probe and the thermosalinograph. Data from these two systems was monitored for consistency throughout the cruise. The Reson SVP-70 was applied to the multibeam data throughout the cruise.

All multibeam sonar data collected during the expedition were fully processed according to established onboard procedures and were 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 100 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, ArcGIS asc files, and Google Earth KMZ files, which were copied to the shoreside FTP on a daily basis to support shoreside scientist participation. Thus, daily products in a variety of formats (xyz, geotiff, kmz, sd, and asc) were produced each day in order to provide cumulative multibeam data coverage information to shoreside users.

The sub-bottom profiler was run during all survey operations in > 500 m of water. Raw sub-bottom profiler sonar data were processed during the cruise into file formats more useful for interpretation by end users of the profile imagery. The free software SEGYJp2 V1 developed by the Geological Survey of Canada was used to convert raw SEGY format files into jpeg images of sub-bottom profiles. ArcGIS shapefiles were also generated to show navigational tracklines of the ship for each sub-bottom sonar datafile collected during the cruise. The raw data, jpeg images, and shapefiles were all submitted to the NCEI archive.

EK 60 data were collected continuously throughout the cruise, with the exception of the deepest areas the ship crossed over the Mariana Trench while transiting from Wake Atoll to port in Guam. Raw data was recorded to the files.

A detailed data acquisition digital log was maintained constantly by mapping watchstanders. This log notes sonar acquisition setting changes, unusual events, troubleshooting notes, and other information that may be useful context for future users of the data collected during the expedition. This acquisition log was submitted to NCEI to be archived as an ancillary file along with the cruise datasets.

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.

Sub-bottom 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 Sub-bottom 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 approximately every 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 the 2016 Okeanos Explorer Readiness Report, which can be obtained by contacting the Mapping Team for NOAA Ship *Okeanos Explorer* at oar.oer.exmappingteam@noaa.gov.

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-16-04 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 at: http://oceanexplorer.noaa.gov/okeanos/media/exstream/exstream.html. The live feed display featured the multibeam sonar SIS display throughout most of the cruise. This display enables shoreside viewers to see the seafloor being mapped with the EM302 multibeam sonar in near real-time.

E. Permits/Clearances

Most of the expedition took place in US and International waters. The start of the expedition was in the Republic of the Marshall Islands (RMI), and diplomatic clearances were provided by RMI prior to the start of the cruise. A permit was not needed for operations undertaken with the Wake Atoll Unit of PRIMNM during this cruise. This project was provided a Categorical Exclusion consistent with the requirements of the National Environmental Policy Act. A copy of the Categorical Exclusion is available within the Project Instructions document for this cruise.

Endangered Species Act Section 7 Consultation: Prior to the start of the cruise, OER received a letter of concurrence from NMFS stating that the cruise was not likely to adversely affect ESA-listed marine species, and would have insignificant effects on designated or proposed critical habitat.

4. Summary of Operations

A. Mapping Operations

EX-16-04 was successful in fulfilling the cruise objectives defined in the final signed project instructions. Exploratory mapping work was completed as planned, and no major problems were encountered. Transit mapping was completed between Kwajalein Atoll in the Marshall Islands and Guam, with an emphasis on partially mapping as many seamount features as possible along the way. Within the Wake Atoll Unit of PRIMNM, focused survey mapping was completed over top priority (un-named) seamounts in the southwest, central, and northwest regions of the marine protected area. In addition to providing an initial characterization of the area, mapping work completed on this expedition was used to identify top priority remotely operated vehicle (ROV) dive locations for expeditions planned for later in the 2016 Field Season. Figure 1 provides an overview of multibeam sonar data coverage completed during the cruise. Table 1 provides an overview of mapping accomplishment statistics.

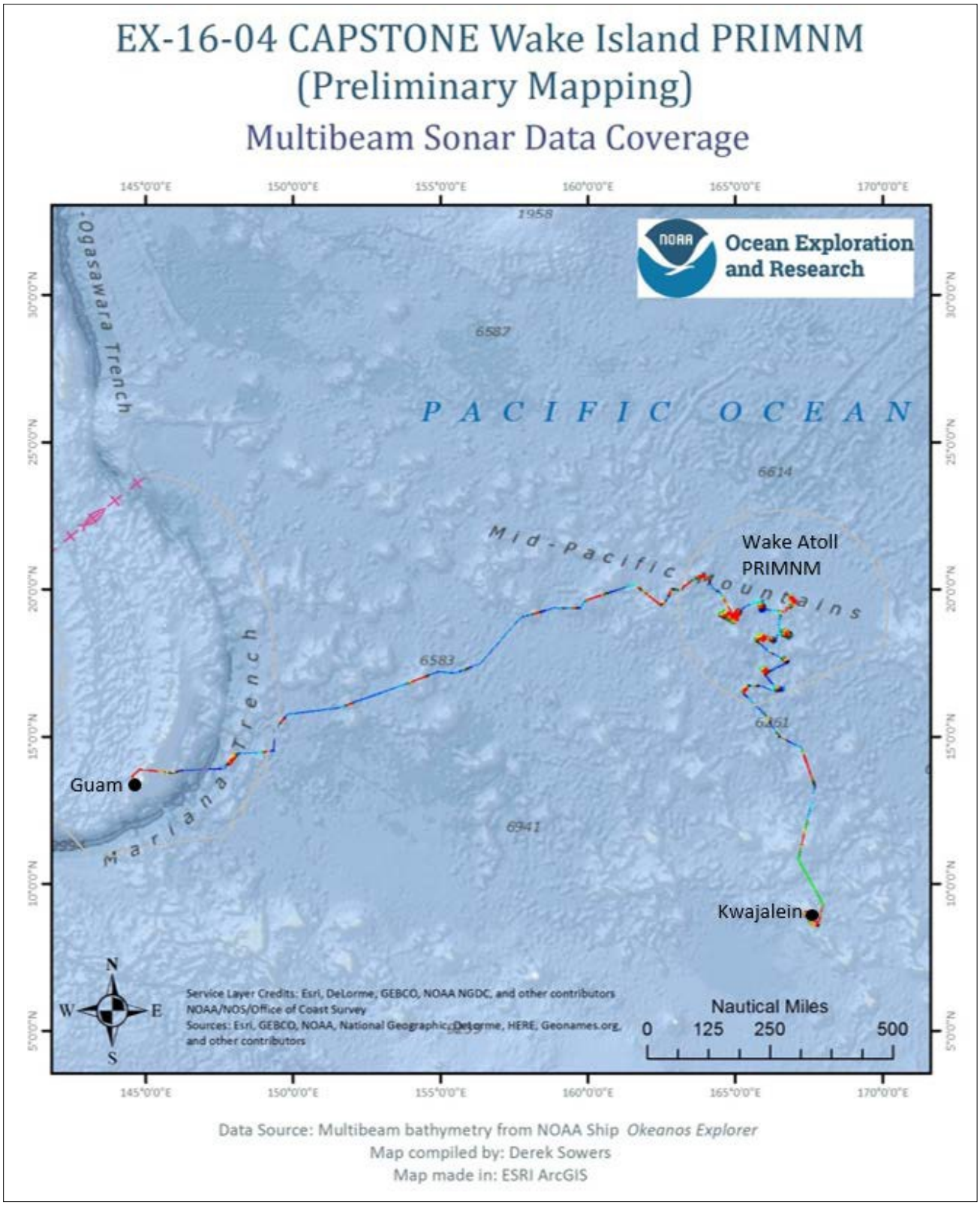


Figure 1. Map of multibeam sonar data coverage collected during EX-16-04. Bathymetry data coverage shown with color-coded bathymetry shading.

Table 1. Mapping Accomplishment Statistics from EX-16-04

Dates	March 23, 2016 - April 13, 2016
Days lost to weather	0 days
Total mapping days	22 days
Total non-mapping days	0 days
Unscheduled days alongside	0 days
Line kilometers of survey	7,517 km
Square kilometers of seafloor mapped	42,519 km^2
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files	700 files / 34.7 GB
Number / Data Volume of EM 302 water column multibeam files	700 files / 129 GB
Number / Data Volume of EK 60 water column singlebeam files	11,838 files / 50.3 GB
Number / Data Volume of subbottom sonar files	490 files / 8 GB
Number of XBT casts	85
Number of CTD casts (including test casts)	0
Beginning draft	FWD: 14' 9" AFT: 14' 3"
Ending draft	FWD: 15' 9" AFT: 14' 1.5"

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.

EM 302 Multibeam Bathymetry Data

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.

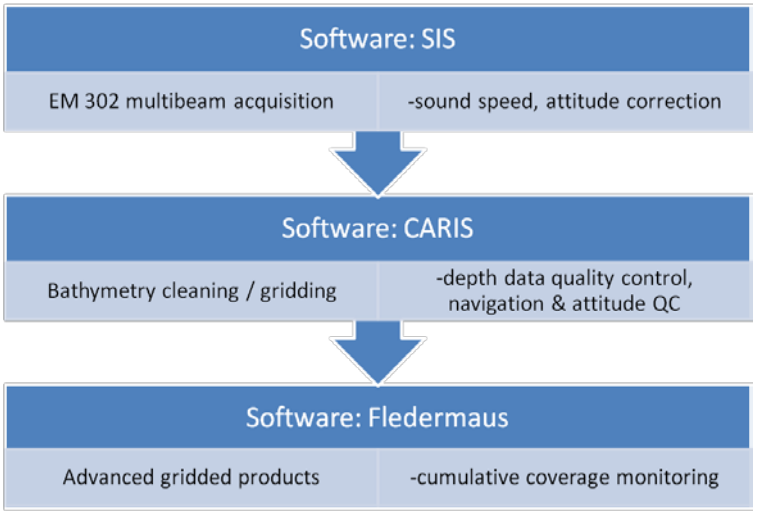


Figure 2. Shipboard multibeam data flow.

EM 302 Multibeam Water Column Backscatter Data Processing
Water column data was processed throughout the cruise to examine for the presence of seeps and other water column anomalies. Some water column curve distortion was noted in this processing, but no water column anomalies suspected of being gas seeps were discovered.

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.

B. Calendar of Events

March/April 2016						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			23 Cruise start. Departed Kwajalein and surveyed south of the atoll.	24 Part pickup in Kwajalein. Depart on northward transit towards Wake Atoll.	25 Transit mapping over seamounts heading north to Wake Atoll.	26 Transit mapping over seamounts heading north to Wake Atoll.
27 Transit mapping, then surveying inside Wake Atoll Unit of PRIMNM.	28 Surveying Seamounts within Wake Atoll Unit of PRIMNM.	29 Surveying Seamounts within Wake Atoll Unit of PRIMNM.	30 Surveying Seamounts within Wake Atoll Unit of PRIMNM.	31 Surveying Seamounts within Wake Atoll Unit of PRIMNM.	1 UCH survey operations. Seamount surveying overnight.	2 HARP mooring recovery and deployment. Seamount mapping resumes.
3 Surveying Seamounts within Wake Atoll Unit of PRIMNM.	4 Surveying Seamounts within Wake Atoll Unit of PRIMNM.	5 Surveying Seamounts within Wake Atoll Unit of PRIMNM.	6 Surveying Seamounts within Wake Atoll Unit of PRIMNM. Left Monument.	7 Transit mapping of seamounts on the way to Guam.	8 Transit mapping of seamounts on the way to Guam.	9 Transit mapping of seamounts on the way to Guam.

10 Transit mapping of seamounts on the way to Guam.	11 Transit mapping of seamounts on the way to Guam.	12 Transit mapping of seamounts on the way to Guam.	13 Last day of cruise. Ship reached pier in Apra Harbor, Guam.			

C. Expedition Daily Log

All times listed are local ship time, which was equivalent to UTC time plus twelve hours (UTC+12)

March 23, 2016
Today was the scheduled start day for the cruise. The departure time was delayed until 1300 to give the ship time to gather information and figure out a delivery problem with parts/mail that had not yet been received in Kwajalein. The ship left at 1300, but must return tomorrow morning to pick up the supplies. The ship will then begin the actual transit to the primary cruise working grounds near Wake Island. We are surveying a deep water area off the southwest side of Kwajalein to gather exploration data until the supplies are ready to be picked up.

The ship will meet a pilot boat at the lagoon entrance and transit back to the pier at the base for a 1000 arrival time, pick up the needed supplies, and depart for the transit to Wake at approximately 1100 tomorrow.

March 24, 2016
The ship completed the survey to the SW side of Kwajalein and picked up the needed supplies/mail during a brief stop at Echo Pier in Kwajalein. The ship exited the lagoon via Gea Pass and began the transit to the primary working grounds in Wake Island PRIMNM. The ship is currently transit mapping as we move north towards Wake, surveying the high points of as many seamounts as we can without too much deviation from a straight line. Seas were favorable for surveying today, picking up somewhat on the NE side of Kwajalein. Data quality on the sonars is mostly good, with some issues keeping the multibeam tracking bottom in some areas of soft sediments and with transient loss of the “ext. date”, “ext. time”, and “PU-ZDA” inputs to SIS. These warnings are resulting from our issues with the POSMV antennas today. Periodically and without explanation the POS primary and secondary antennas will lose tracking of a majority of satellites in their constellations. Then they quickly regain them. There appears to be a sporadic source of interference in the GPS signals reaching the antennas.

March 25, 2016
The ship is currently transit mapping as we move north towards Wake, surveying the high points of as many seamounts as we can without too much deviation from a straight line. Weather was mild today and data quality was very good. Fire and abandon ship drills were completed. The problems we had yesterday with losing satellites on the POSMV, and associated warnings in SIS, were completely absent today. This lends support to the theory we speculated that something on the Kwajalein army base may have been interrupting our normal reception of GPS signals on the POS antennas, but the cause is still unknown. ADCPs are being kept off for now to avoid interference.

March 26, 2016
The ship continued transiting northward towards Wake Atoll. Weather was mild today and data quality was very good. Man overboard drills were completed today using a buoy as a retrieval target. In the middle of the night, the EM302 stopped pinging and SIS flashed red. The EC isolated the problem to a single TX36 board that was failing. With assistance from CET Blessing we re-seated the board in the TRU, tested it, and made sure all BIST tests passed before resuming multibeam surveying. Data quality on the multibeam for the rest of the day was very good. The POSMV is performing normally and no satellite losses or warnings were observed on the POSMV or in SIS.

March 27, 2016
We mapped portions of two seamounts, and the majority of a third seamount today. We officially entered into the Wake Atoll Unit of PRIMNM, which is the primary working grounds for the expedition. Given the size of the area to cover, we are mapping the tops and upper flanks of seamounts and not spending additional time on the full extent of the lower reaches of the features. This will enable us to map numerous potential ROV dive sites spread throughout the western half of the Monument. We intend to survey for UCH targets near Wake Atoll on March 30th (EDT). Weather continued to be calm and mapping data quality was excellent.

March 28, 2016
An unnamed seamount was mapped overnight, we transited northwest, then mapped another seamount for the rest of the day. The second seamount looked like it reached sea level based on the satellite altimetry data, so we mapped it with some caution ensuring at first the ship ran new lines within the edge of the outer multibeam swath. The guyot top turned out to average around 1300m, with the shallowest depth being 1249m. The guyot is an interesting feature with distinct ridges extending out in numerous directions, a prominent channel feature, and a very low backscatter region at the center of its top. Data quality was very good. Sea state is picking up some and will be 6-9' tomorrow.

March 29, 2016
Sea state picked up today to 6-9' and somewhat confused seas. Multibeam data quality was correspondingly reduced to fair. We adjusted heading orientation and survey lines to optimize data quality as much as possible. This evening we are running lines with roughly 100% overlap to ensure good coverage over the seamount we are mapping. The seamount features we are mapping are rugged and interesting. This weather is expected to continue all day tomorrow and into the next day, then may calm down somewhat. Given this forecast, we are now planning to survey for Underwater Cultural Heritage (UCH) targets on March 31th EDT (April 1st Wake Atoll time).

March 30, 2016
Sea state remained at 6-9' today, but with slightly better conditions than last night. Multibeam data quality was good. We have found a good heading orientation for running survey lines to optimize data quality. Seamount mapping continued all day, and is planned for tomorrow. The HARP buoy is planned for deployment on April 1 EDT. In the afternoon we conducted another practice cast with the UCTD. We did a cast with the dummy probe, not the actual SV or CTD probes. The dummy probe is just a solid metal probe that attaches to the winch line. There was a failure in the UCTD line during the recovery of the probe, and the probe was lost at sea.

March 31, 2016
Sea state was a mild 3-5' feet today and provided excellent conditions for surveying. Data quality was very good. Seamount mapping continued all day, and will occur through the night. We have mapped the better part of 10 seamounts so far this cruise, and the terrain is very interesting.

April 1, 2016
Sea state was very calm today (3-5' long period swell with no chop) and provided optimal conditions for surveying. Most of the daylight hours were spent surveying for non-public UCH targets. Data quality was excellent. Work finished late in the afternoon and we began transiting to a large seamount northeast of Wake Atoll for overnight seamount mapping work. The High-frequency Acoustic Recording Packing (HARP) mooring recovery and deployment operation is planned for first thing tomorrow morning near Wake Atoll. This survey of opportunity project should take about 4-6 hours to complete.

April 2, 2016
We finished mapping a seamount to the northeast of Wake Atoll overnight, then transited to near the south side of the island. Sea state was mild again today and we took advantage of the good weather to recover and deploy High-frequency Acoustic Recording Package (HARP) buoys near Wake Atoll. This was a project of opportunity we took on to assist the PIFSC Cetacean Research Program in monitoring cetacean occurrence in this remote area.

We hung a transducer overboard and pinged a coded signal to activate the acoustic release on the mooring, which was anchored to the seafloor at about 610 m. The mooring array surfaced about 200 m from the ship after 17 minutes of rising through the water column. This HARP was brought onboard, then the new HARP (which had been placed on the ship in Honolulu before EX1603) was deployed in the same location. The new one has been programmed to activate on 4/12. If the EX had not helped with this project, it would not have been done until 2017 when the Hi'ialakai is scheduled to transit to Guam. The whole operation was done before lunch and went very smoothly. After the HARP deployment we transited west and began mapping a new seamount. All sonars are working well and data quality was high today.

April 3, 2016

The morning was spent mapping a seamount 35 nm west of Wake Atoll. We then transited 50 nm further west to what appears to be the largest seamount within the Monument, and are in the process of mapping it. Seas were good for surveying today but conditions are building, and we will likely be in 6-9'+ seas tomorrow. The following day will be worse. Data quality was high on all sonars today. With the calm weather, the noise has disappeared from the 120 and 200 kHz EK60 sonars. During rough seas, these relatively high frequency sonars do not fare well. The largest seamount we are working on mapping now has a very interesting circular guyot feature on its SW side. Most of the top of the feature has very low backscatter.

April 4, 2016

Mapping of the largest seamount in the monument continued all day today. Weather gradually deteriorated into 30 knot winds and 8-10' seas with 4-6' wind waves. The forecast is worse for tomorrow with seas 9-12'. This weather has greatly slowed the progress we can make with mapping the feature. We considered moving to other areas but there is nothing nearby with weather any different and the highest priority mapping targets are north and northwest of here, against the wind/wave direction. In the morning we stuck with a line plan taking large rolls in order to avoid unacceptable pitch and bubble sweep down. This ride became very unpleasant and the resulting data was not great. We had to resort to 100% coverage line spacing to compensate for poor data quality, and crabbing angles were high due to the wind. We changed the line scheme to head northeast against the swell – knowing the data would be very poor on north lines, but very good (comparatively) on south lines with a following sea. This strategy is providing good results given the conditions, and we are sticking with it for now. EK60 data was very poor at all of the frequencies above 18 kHz, so we stopped pinging/logging those frequencies and just kept the 18 going. Knudsen subbottom data was impacted but acceptable.

April 5, 2016
Mapping of the largest seamount in the monument continued again all day today. Weather was a bit worse today with 9-13' swell, 5-7' wind waves, and 30 knot winds. The weather made it only possible to get decent data in an orientation with a following sea – as soon as we turned at all into the waves, quality decreased rapidly. We made slow steady progress as possible. The seamount is a fascinating feature and it is hard to have to leave it only half mapped. However, tonight we begin transiting to the northwest to get some data over a whole new set of seamounts with no multibeam data. We will be departing the Monument boundary in the early hours of April 7th in order to get to Guam on time. The guyot we have been mapping is not only massive (50-60 nm wide at the base), but very tall – standing about 3800 meters (12,500 feet) proud of the surrounding seafloor.

April 6, 2016
Today we transited to the northwest corner of the Monument and transit mapped over three different seamounts. On the seamount farthest to the north we also did three survey lines to map about 1/3rd of the seamount. That used up the remainder of our mapping time within the Monument. The weather gradually subsided somewhat today to 8-10' seas. Data quality was fair to good on most of the line orientations we ran today. Tonight we cross out of the Monument boundary and begin the 6 day transit to Guam. That transit will have us gathering single lines of data over 13 different seamounts.

April 7, 2016
The weather subsided further today to 6-9', and with the following sea data quality was very good. We transit mapped over four different seamounts as we continue the journey to Guam. The ship did a time change today, setting the clocks back one hour. We are now UTC+11 hours. We are on schedule to arrive in port in Guam the morning of April 13.

April 8, 2016
The weather again subsided further today to 4-6' – sonar quality was very good. We transit mapped over three different seamounts today as we continued the journey to Guam. We are currently transiting over a long stretch of very flat abyssal plain. Drills were conducted in the afternoon. We tested the 300 kHz ADCP today and confirmed that it is still interfering with the multibeam.

April 9, 2016
Seas were 4-7', and should be mild for the next few days – sonar quality was very good. We transit mapped over one small seamount and one very large seamount today.

April 10, 2016
Seas were 3-5', and should remain so for the rest of the cruise. We transit mapped over one seamount and a lot of flat seafloor today, reaching depths of up to 6000m. Derek

participated in a live interaction with the OER teacher workshop at the Smithsonian, and the connection worked well. We are making good time and are scheduled to arrive on time in Guam the morning of the 13th. About 8 hours of contingency time built into the schedule should allow us to map the southern portion of Victoria Guyot. This guyot is about 20 hours away from Guam and may make a good ROV dive site when the ship transits back towards Wake Atoll later in the season. The ship is setting the clocks back another hour tonight. This puts the ship on the same time zone as Guam.

April 11, 2016
Seas were 4-7' today and mapping data was very good for most of the day. We transit mapped over two seamounts and began survey lines over Victoria Guyot which is about a 20-24 hour steam from port in Guam. The ship is now on the same time zone as Guam. Derek met with ship Department Heads, CO, and OPS for a post-cruise meeting. All objectives listed in the Project Instructions for the cruise were successful except for getting the UCTD fully operational due to the line breaking on the dummy probe testing work.

April 12, 2016
Seas were 4-6' today and mapping data was very good for most of the day. We finished our survey of the south end of Victoria Guyot and headed west over the Mariana Trench. The multibeam held bottom all the way over the trench, reaching a maximum depth of 9633 meters (~6 miles). The sub-bottom also recorded a full transect across the trench. The EK60 18 kHz was timing out and would not track bottom. We made a slight modification to our planned track line to survey directly over a volcano feature of interest to Patty Fryer – Chris Kelley relayed the coordinates to us. We sent them images of the interesting backscatter over this site. The ship is now on the same time zone as Guam. The DP system was briefly tested and worked normally. The ship will be re-fueling tomorrow immediately after we tie up at the pier.

April 13, 2016
Today was the final day of EX-16-04. We mapped all night until reaching the sea buoy outside of Apra Harbor at 0730. All sonars were secured at that point. The ship was escorted into the Naval Base with a pilot boat. Shortly after the ship was safely tied to the pier and the gangway was down, the ship began re-fueling.

5. Summary of Findings

A. Mapping Accomplishments

During the expedition approximately 42,519 square kilometers of seafloor area were mapped using the multibeam sonar, covering a linear track line distance of 7,517 km. The vast majority of this work was completed in areas un-mapped with multibeam sonars. Ten

days at sea were spent inside the boundaries of the Wake Atoll Unit of the Pacific Remote Islands Marine National Monument (PRIMNM), providing new high resolution bathymetry and backscatter data for over 19,176 square kilometers of seafloor inside the Monument. Ten of the seamounts within the Monument were mapped in their entirety, with an additional six seamounts partially mapped. Including transit mapping to/from the Monument, portions of 37 individual seamounts were mapped during the cruise. 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.

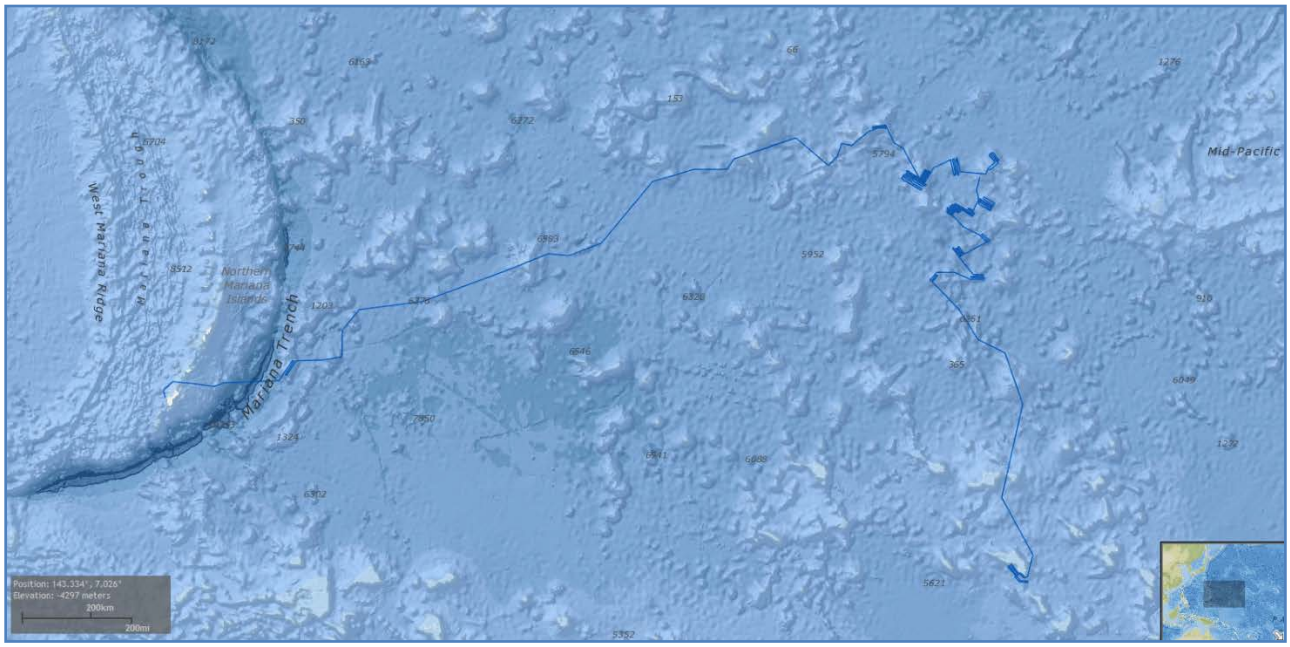


Figure 3. Shiptrack of the Okeanos Explorer during EX-16-04 (dark blue trackline). Map generated by the Water Column Sonar Data online mapping service maintained by the National Center for Environmental Information (NCEI).

The seafloor terrain on the seamounts within the Monument is complex and fascinating, with the many flat-topped seamounts (guyots) indicating that many of the features were above sea level at some point (figures 4, 5, and 6). A particularly extraordinary seafloor feature that was partially mapped was McDonnell Seamount, the largest seamount within Wake Island PRIMNM (figure 5). The flat top of this guyot spanned up to 42 km across, with the base diameter of the feature spanning at least 75 km. This guyot, along with many of the guyots in this region, had distinct areas of remarkably low sonar backscatter intensity on the summits of the features. There was not enough time to finish mapping the entire feature on the cruise, but it was finished later in the field season during EX-16-06.

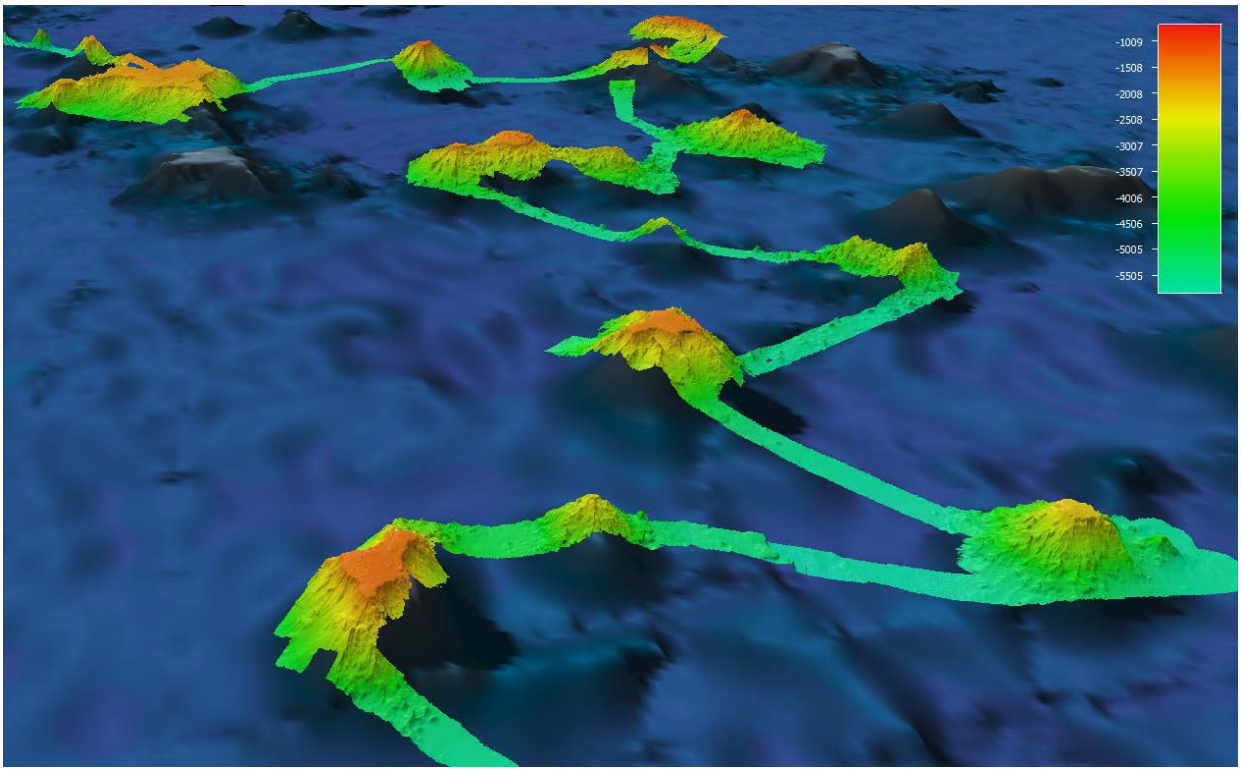


Figure 4. Multibeam bathymetry collected inside the Wake Atoll Unit of PRIMNM during the cruise (rainbow color ramp) overlaid on satellite-derived bathymetry (blue background), 3x vertical exaggeration. Note the mix of seamounts with flat summits (guyots) as well as conical shapes.

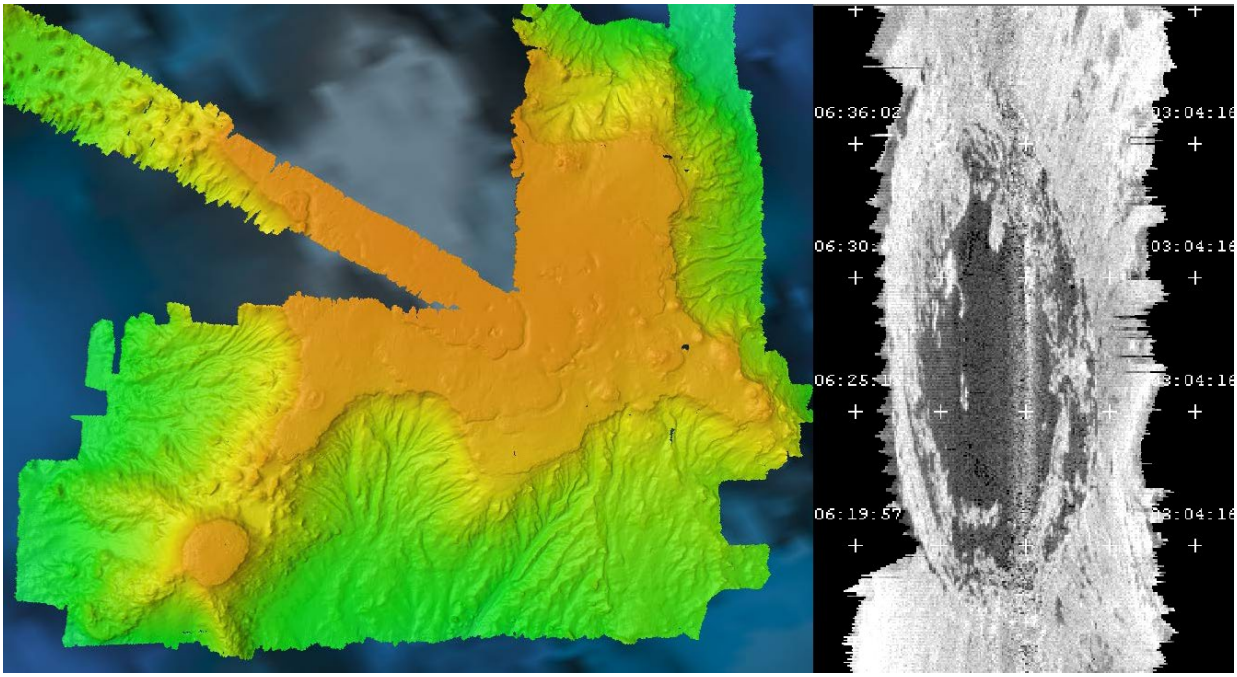


Figure 5. New multibeam bathymetry of McDonnell Seamount, the largest seamount within the Wake Island PRIMNM (left). Sonar backscatter intensity from the circular portion of the seamount, exhibiting extremely low reflectance (dark colors in right image).

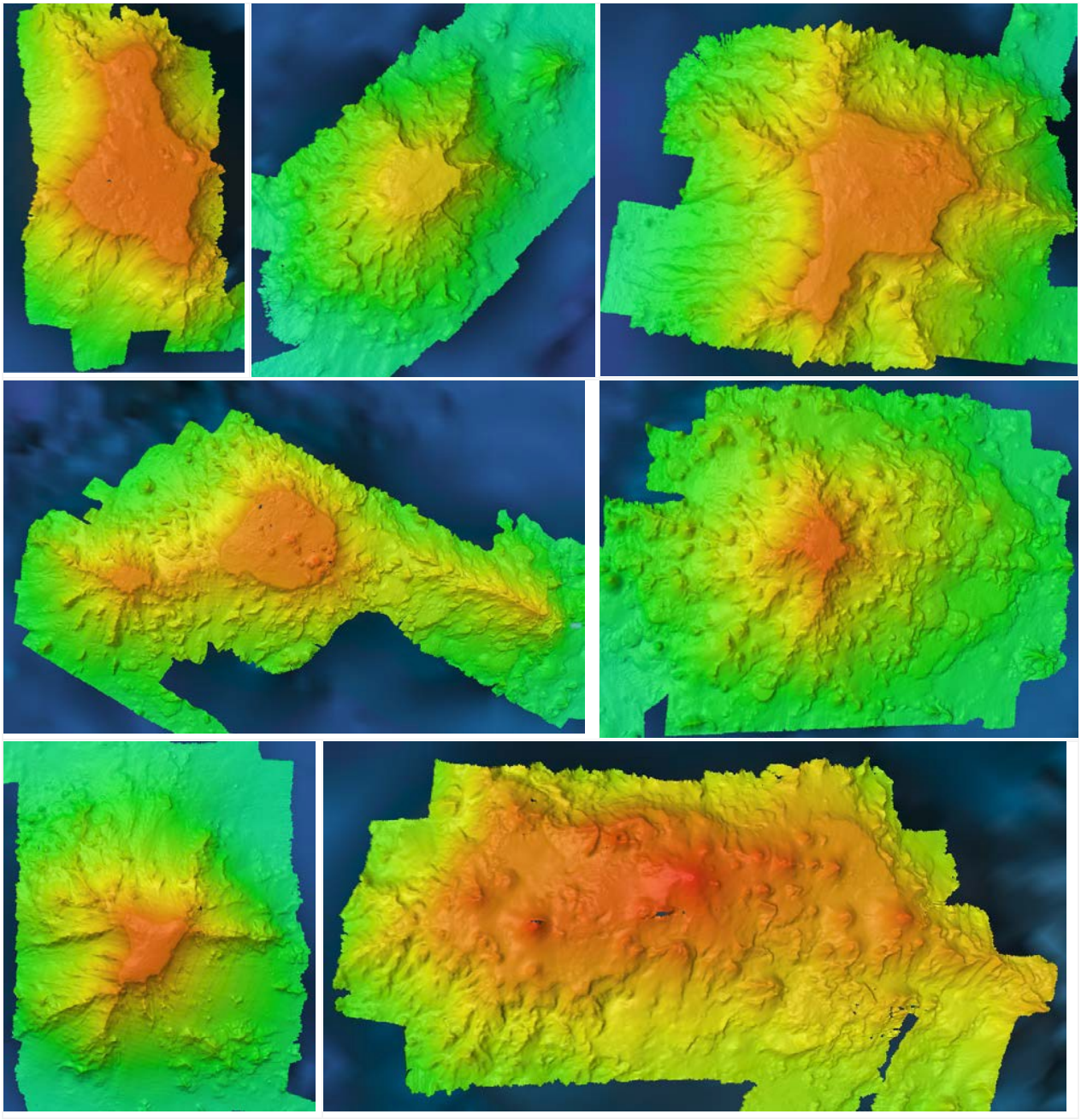


Figure 6. Overview map images of seven of the seamounts mapped in most of their entirety during the expedition. Since the priority was to map the tops, ridges, and slopes of the seamounts the deeper portions of some of them were not mapped. Mapping coverage for many of these features was substantially expanded during the EX-16-06 mapping and ROV cruise.

Ship-based measurements of seamount elevations using the EM302 multibeam sonar revealed differences of up to 1400 meters from satellite-derived bathymetry maps (Figure 7). Satellite-derived bathymetry maps were essential for planning higher resolution exploration surveys during the cruise. This demonstrates the importance of ship-based measurements of seamounts to gain higher resolution maps, as well as the importance of satellite-derived bathymetry datasets in guiding deep-sea exploration mapping work.

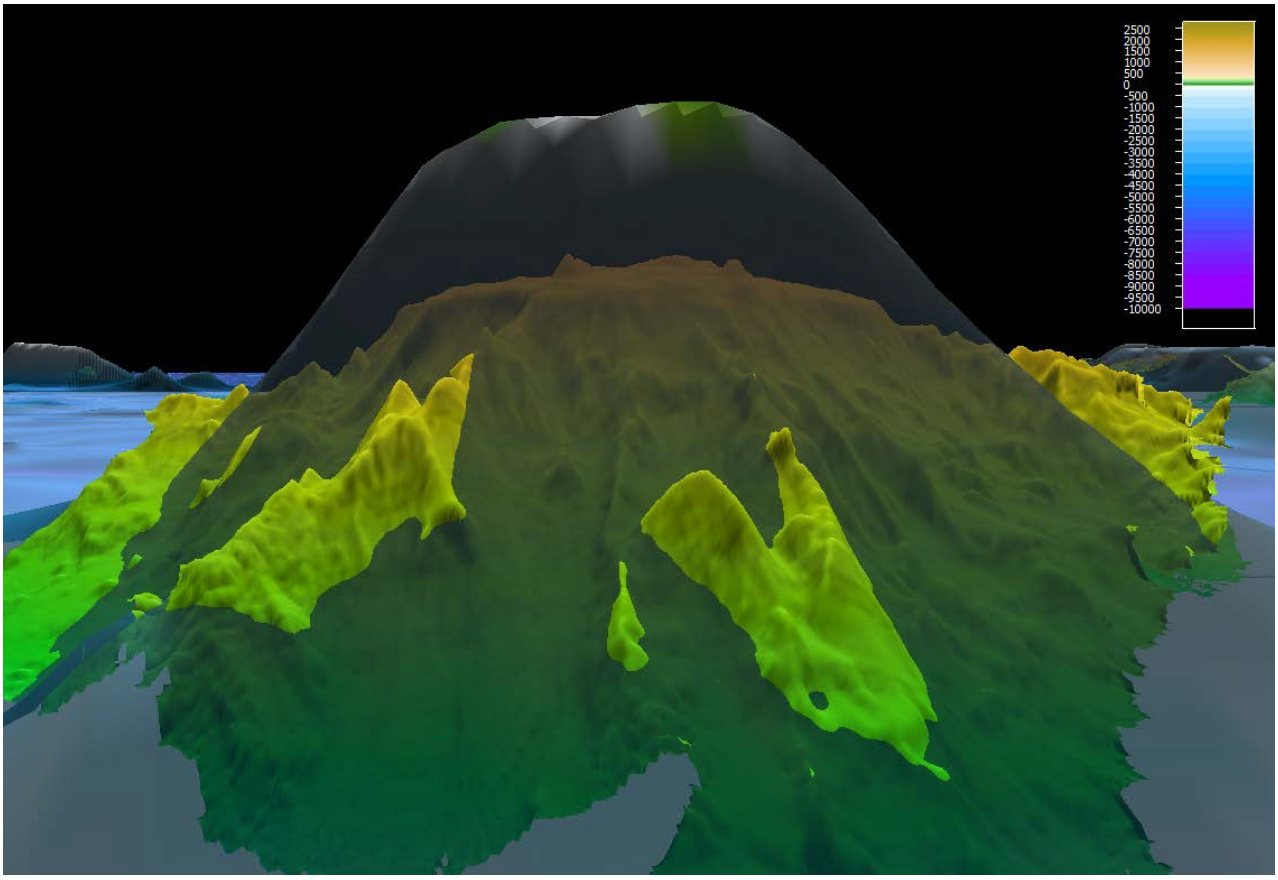


Figure 7. Image of an unnamed seamount inside PRIMNM highlighting the difference between the satellite-derived bathymetry map (SRTM30, shown as partially transparent) and the EM302 multibeam bathymetry. Note that the SRTM30 layer predicts the seamount to be roughly at sea level, while the actual summit of the seamount was found to be about 1400 m below sea level. The depth scale bar is for the SRTM30 data. Image made in QPS Fledermaus software, 3x vertical exaggeration.

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

B. Sonar Data Quality Assessment

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 0.2 m. This result indicates that in survey water depths ranging from 2100-4500 meters, the mainscheme and crossline multibeam tracks surveyed in orthogonal

directions at different times obtained seafloor depths that agreed with each otherwithin 0.2 meters (on average), with a standard deviation of 6.4 m. Figure 17 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.

The crossline used:
0233_20160329_160607_EX1604_MB (heading 38°)

The mainscheme lines used:
0215_20160329_064157_EX1604_MB (heading 122°)
0219_20160329_093459_EX1604_MB (heading 302°)
0221_20160329_101431_EX1604_MB (heading 121°)
0225_20160329_125106_EX1604_MB (heading 301°)
0227_20160329_132138_EX1604_MB (heading 122°)

	Points Compared	Max Value	Minimum Value	Mean Difference	Standard Deviation
Crossline	16,561	105.1 meters	-90.4 meters	0.2 meters	6.4 m

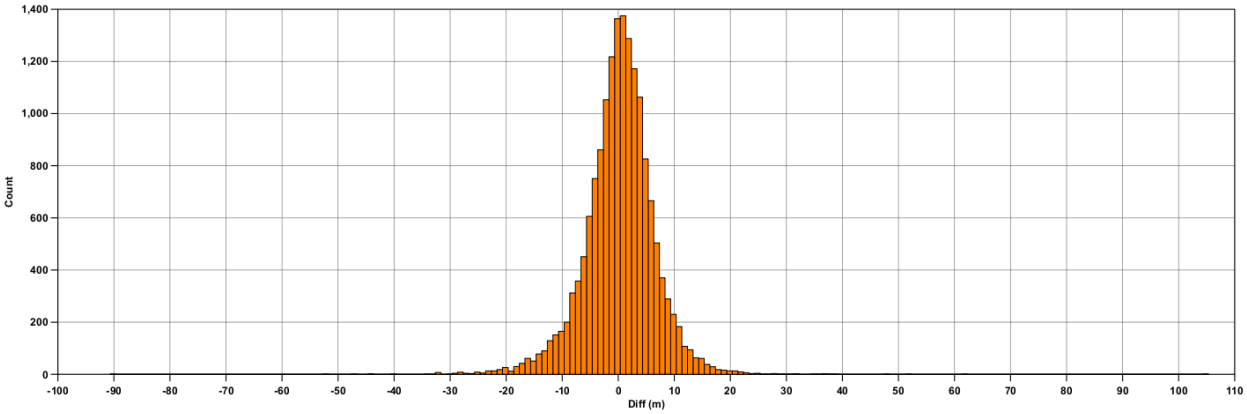


Figure 3. Summary statistics and a histogram plot of the differences between the mainscheme and crossline bathymetric surfaces.

6. Data Deposition and Archival

A. OER Data Discoverability Tools

All data collected by *Okeanos Explorer* are archived and publically available within 90 days of the end of each cruise via the National Center for Environmental Intelligence (NCEI, formerly NGDC) online archives. 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

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. The 2016 Survey Readiness Report can be obtained by contacting NOAA Ship Okeanos Explorer at oar.oer.exmappingteam@noaa.gov. The complete 2016 Field Season Okeanos Explorer Data Management Plan can be found in the Data Management Report, accessible through http://service.ncddc.noaa.gov/rdn/oer-waf/media/docs/EX_FY16_DMP.pdf.

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/
- National Centers for Environmental Information at http://www.nodc.noaa.gov/cgi-bin/OAS/prd/accession/
- NGDC Interactive Water Column Data Viewer at http://maps.ngdc.noaa.gov/viewers/water_column_sonar/

7. Additional Information

This cruise was the first in a series of three 2016 *Okeanos Explorer* cruises to the Wake Island PRIMNM. *Okeanos Explorer* cruises EX-16-06 was an exploratory mapping and ROV cruise focusing in the region. EX-16-07 was a mapping cruise that gathered additional mapping data of the region. Please refer to the cruise reports and archived datasets for these additional cruises for additional information.

Daily Situation Reports, internal operational records, are also on file with OER. For questions, please contact OER.

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.

9. Appendix: Explorer-in-Training Products

The Explorer-in-training program provides the opportunity for graduate and undergraduate students to gain experience using an advanced multibeam bathymetric sonar mapping system, while contributing in a significant way to the *Okeanos Explorer* ocean exploration mission. Each trainee also completes an onboard project of their own interest, with approval and support from experienced mapping team personnel. Five Explorers-in-training participated in EX-16-04. Several of them completed posters featured in this appendix section.

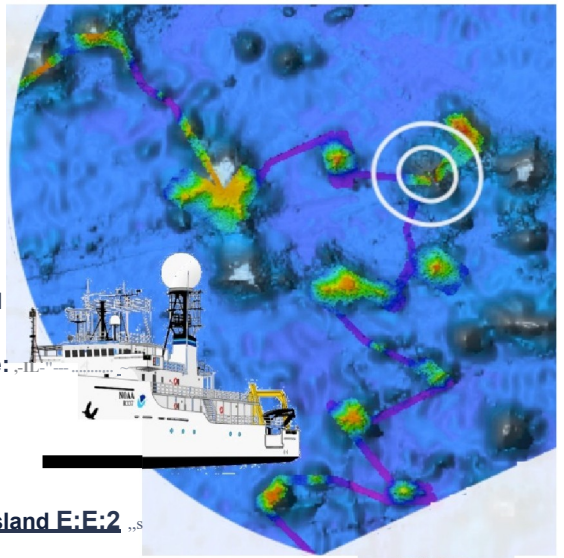
CAPSt a N E WAKE ISLAND ATOLL

PaciRc Remote Islands Marine National Monument

Location: I .2132 "N l66.6+ o·c ı

The no rthe rnmos t atoll in the Marshall Islands geological ridge, Wake Island is estimated to be the oldest living atoll in the world. The atoll lays 3,700 kilometer s west of Honolul u, Hawaii . It is composed of a reef-enc losed lagoon, and three coral islets; Peale, Wake, and Wilkes. The landmass of Wake is 7 km2, with the highest elevation being 21 feet. Wake's EEZ covers 407,241 km².

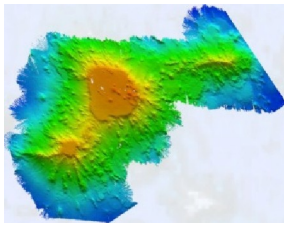
NOAA ship okeanos Explorer
E:XJ6o+ Mapping Wake Island PRIMNM
Mardi 2?-April I? , 2016
Wake Island Exclusive Economic Zone:
Traveled: ?,758 km
charted: *19,176* km2.
Mapped: 16 seamounts



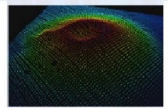
Histo of Wake Island ,,.

The first visito rs to En en Kio (Wake Island) were the early Marshallese navigators
1568- Sighted by Spanish expl orer Alvaro de Mendana
1796- Visited by Britis h Captain William Wake, the atoll's namesake
1941 - Charted by Lt. Charles Wilkes and naturalist Titian Pea le on U.S. expedition
1899- U.S. claimed Wake during the Spanish American War for the site of a cable station
1935- Pan American Airways established seaplane refueling base and ho tel on Peale Island
1939· U.S. Navy began construction of an air and subma ri ne base
1941- The Battle of Wake Island began with an attack by the Japanese on December 11' h
1943- October 5th ,98 U.S. civilian POW's were executed, 98 Rock marks their mass grave
1945 • WWII ends, Japan surrenders Wake, U.S. p ersonnel ret urned to the atoll
1985- Wake Island becomes Nationa l Historic Landmark for role in WWII
2009- President George W. Bush establishes PRIMNM
2014- The Obama Admin istration expands PRI MNM, creating largest marine reserve in world

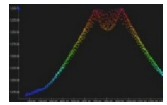
Expedition Highlights within the Wake Island E:E:2 ,,s

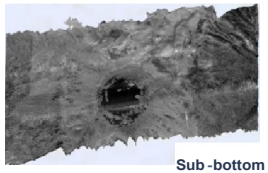


Seamounts are und erwa ter mountains predominantl y formed by abrupt volcanic activ ity. Their st ru ctur e cr eate s areas of upwelling, providing a sour ce of nutrients and habit at that supports a biodiversity hot spo t.



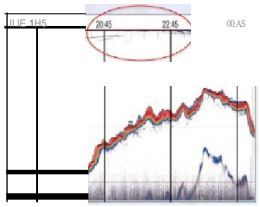
Multibeam sonars are sound t ransmitting and receiving system. 'Pings' are sent out at different frequen cies, and depth is calculated by measur ing the retu rn signal. Volcanic features were identifie d with multibeam bathymetry, a pr ime specimen of an underwater volcano (right) was discovered on top of EX1604-15 seamount (left).



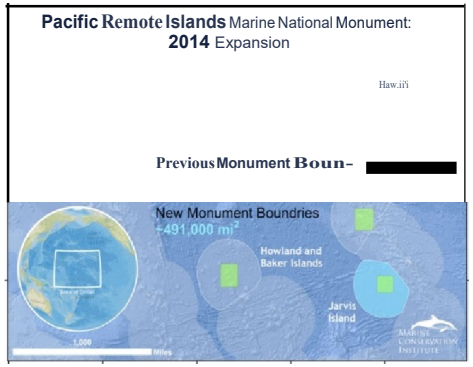


Backscatter is the amount of acoustic energy being received by the sona r after interacting with the seafloor. This information can be used to dep ict bottom type, whether it be har d (rock) or soft (mud). This combined with the bathymetric information can help confirm the seafloor composition and/or geological featu res, such as the flat surface top of a seamount seen in the backscatter (left).

Sub-bottom profilers extend into the sea floor bed to look at the buried sediments and rock layers as well as composition. This is also used to investigate geological processes. A SBP taken from our cru ise (left) shows detai led layering with fine-grained sed iments on top of the seabed .



Water column sonar uses acoustic scatteri ng information from t he near surface to the seafloo r. This data is used to examine both biological and physical anoma lies within the water co lumn, such as methan e seeps, oil plumes, and mar in e organisms. An example of docum enting the diurna l vertical mig ration of plankton is seen in the EK60 sonar image (left).



Marine National Monument ,,.4

Wake Islan d atoll offers an ideal ecosystem to conduct cli mate change re search in a remote equatorial location. The area is home to a high diversity of species, in cludin g many endangered and also tho se not found anywhere else in the world. There is estimated over 100 species of coral, 323 species of fish, and several migrato ry and land birds. The waters surrounding the islan d at oll are also home to sea turtles, many species of sharks, whales, and dolphins. The coral skeletons found within the PRIMNM are amongst the oldest in the world and have recor ded Earth's climatic history for a mill ennia. Monument status ensures these unique areas are conserved, protecting t hese natural reso ur ces and geo lo gical " hist ory books".

5reez_y Grenier, Explorer in Training

E:X.16o+ March 2y-d_ April I?th

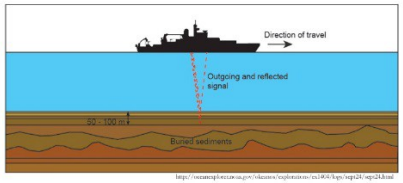
0 C E A N E XPL <&RAT I ON 8: RESEARCH

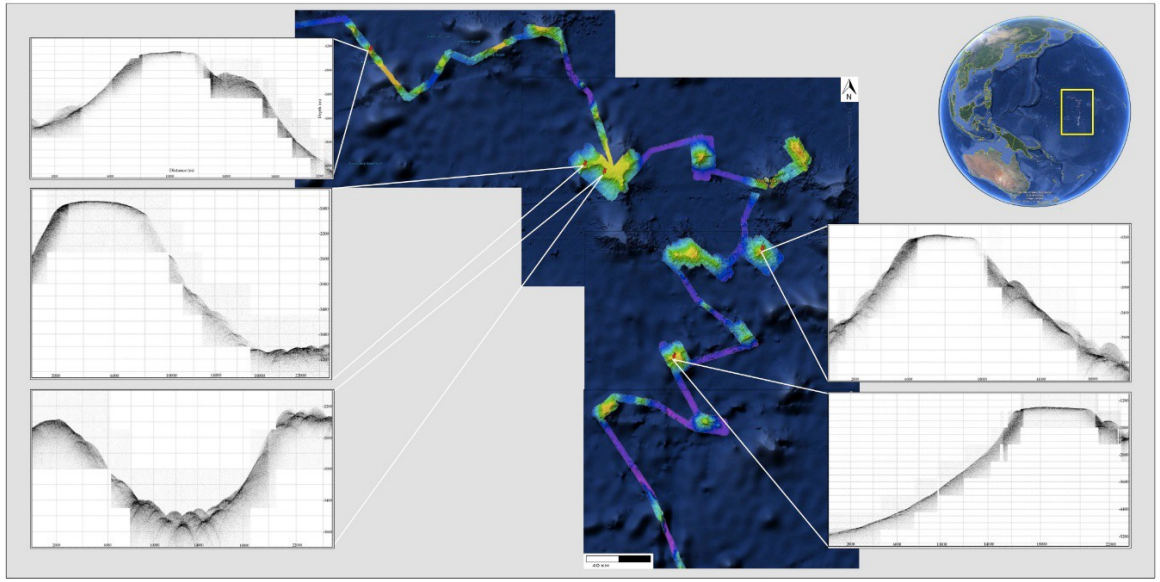
References 1. NOAA Office of Ocean hploration and Research [www.explore.noaa.gov], 2. Marine Conservation Institute [www.Marine-Conservation .org], 3, NOAA Pacific Island fi sheri es [www.fpir.noaa.gov], 4, U.S. Fish and Wildlife Services [www.fw s.gov], S. NOAA National Ocean Service (www.oceanservice.noaa.gov)

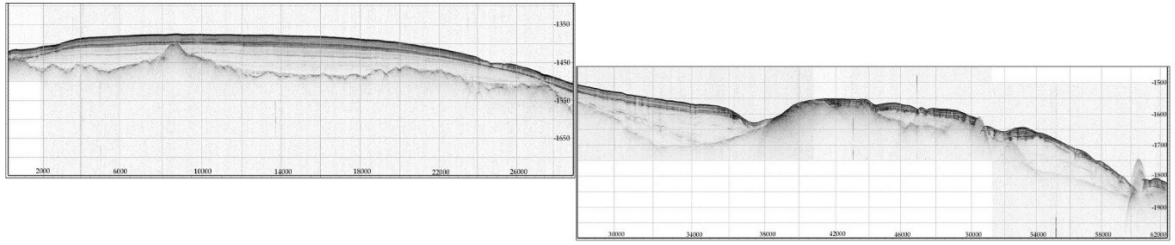
Sub-Bottom Profiling on *Okeanos Explorer*

About the Project

March 23 to April 13 2016 on *Okeanos Explorer* served as an exploratory mapping expedition as part of the multi-year Campaign to Address Pacific monument Science, Technology, and Ocean NEeds (CAPSTONE). The goal of the project was to map seamounts between Kwajalein, Wake Island, and Guam – with an emphasis on exploration within the Wake Atoll Unit of the Pacific Remote Islands Marine National Monument. Ocean mapping datasets collected during the cruise included EM302 multibeam sonar (bathymetry, bottom backscatter, water column backscatter), split-beam EK60 sonar, and Knudsen sub-bottom profiles. This poster focuses on sub-bottom profiling and how it works and highlights various profiles recorded during the project.







How Sub-Bottom Profiling Works

Sub-bottom profilers are acoustic systems used to image sediment and rock layers beneath the seabed, providing scientists with insights into the underlying stratigraphy. The profiler uses a hull-mounted transducer array to generate low frequency sound pulses, which effectively travel long distances through water and reflect off boundaries between materials with differing acoustic properties (see image at left). Some of the sound wave energy is lost through spherical spreading and attenuation in the water column, some can be absorbed by sediments, and some is scattered off the layers in the shallow subsurface geology of the seafloor. The energy reflected back to the sonar transducer provides a time series of echo amplitudes, effectively building a profile of sediment layers to a depth of about 80 meters below the seafloor. Better resolution of profiles requires higher frequencies, but reaching deeper layers requires lower frequencies. Chirp systems produce a sound pulse through a range of frequencies which enables a higher signal-to-noise ratio than is possible with a single-frequency pulse. On *Okeanos Explorer*, a 3.5 kHz Knudsen Chirp 3260 sub-bottom profiler is used to record high-resolution profiles. This system is useful for imaging layers of fine-grained sediments (silts and clays), as well as boundaries between different hard rock types.

Features of Interest

When combined with multibeam bathymetry, seafloor backscatter, and water column data, sub-bottom profiling allows scientists to more thoroughly understand the marine geological processes taking place in this section of the Pacific. More specifically, the data acquired during this cruise will enable future explorations employing remotely-operated vehicles (ROVs) to select the best locations for dives to retrieve rock samples from these recently mapped seamounts. Taking rock samples may shed light on the age of the seamounts and provide insights into the origin and evolution of these geologic features. Guyots are seamounts that once reached above the surface of the ocean, were eroded by wave action, and later subsided back below the ocean surface. Seamounts, which are not flat topped, were likely never above sea level, or after subsiding, had secondary volcanism that built mounds or cones at some point later in geological time. A selection of seamounts and guyots are shown in the accompanying callouts to the left.

A Fascinating Find

The image on the left represents a transect profile about 62,000m across the top of a flat-topped seamount (called a "guyot") at a depth of 1400m. A number of hard rock features can easily be seen covered in some areas by almost one hundred meters of sediment. The sedimentation in this profile is fairly uniform across and is mostly horizontal, regardless of the underlying morphology. Without sub-bottom profiling data in this area, the ocean floor would appear smooth and we would not have seen these hidden features.

Created by Melissa Price, *Okeanos Explorer* Mapping Intern, 2016

Mapping the seafloor: A journey to explore the ocean

NOAA Ship *Okeanos Explorer*

CAPSTONE EX1604

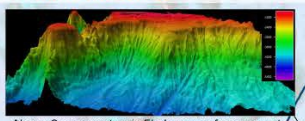
OCEAN EXPLORATION & RESEARCH

WHY IS OCEAN EXPLORATION IMPORTANT?

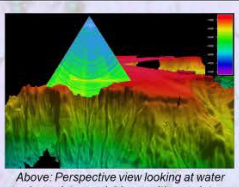
We rely on the oceans for food, energy, transportation, recreation, climate moderation, and innumerable other tangible and intangible benefits. 50% of the Earth's surface is covered in ocean waters deeper than 3200 meters (GEBCO, 2014). We know very little about deep-sea habitats, the organisms living there, and the ecosystem processes in these harder-to-study areas. Ocean exploration is a critical undertaking in order to further our knowledge, bridge information gaps and minimize the unknowns. It is devoted to making discoveries, gathering new data, and searching for the unexpected. It consists of observations and documentation of biological, chemical, geological, physical, and archaeological aspects of the ocean. This will provide us a better understanding of the impact of human activity and how to protect marine areas. Findings can help us understand climate, tsunamis, earthquakes, and even develop new medicines, resources, or products.

"The ocean plays an essential role in our lives and yet remains full of mysteries"

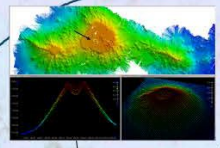
Above: Screen capture in Seafloor Mosaic Display of the seafloor acoustic backscatter.

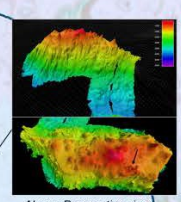


Above: Screen capture in Fledermaus of a seamount estimated to be 3,600 m high.



Above: Perspective view looking at water column data overlaid on multbeam data.

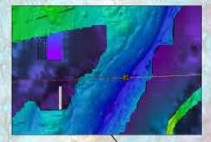




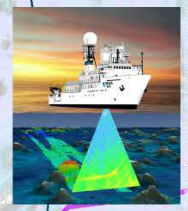
Above: Perspective view looking at seamount with a potential volcano. Above left: Screen capture in Caris of a seamount with a volcano.

Cruise Statistics

Distance Mapped (km) =
Area Mapped (sq km) =
XBT Casts = 85
Seamounts = 34



HOW MAPPING WORKS?



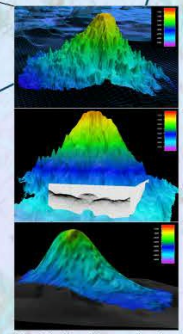
Presently, sonar systems are widely used for mapping the seafloor, because sound waves travel farther in water than do radar and light waves. Sonar systems provide accurate information about the ocean bathymetry that is used to develop nautical charts, search for specific objects, and reveal unprecedented details about marine habitats and geological features. Learning about the ocean floor will help us understand the composition and the type of sediment found on the seafloor and the types of habitats associated with that area. There are two broad categories of sonar: active and passive.

MARIANNA TRENCH

Wake Island

CAPSTONE

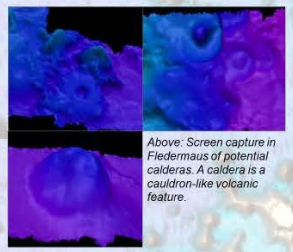
The **Campaign to Address Pacific monument Science, Technology, and Ocean NEeds** (CAPSTONE) is a major multi-year foundational science effort focused on providing public data and information about the poorly studied deep-water areas of U.S. marine protected areas in the central and western Pacific. The exploration is providing critical information relevant to emerging regional issues like understanding deep-sea ecosystems that could be threatened by activities such as deep-sea mining in un-protected areas.



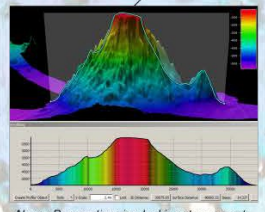
Top to bottom: Perspective view looking at seamount discovered during survey. Sub-bottom profiler data merged with bathymetry. Multibeam data draped on top of satellite-altimetry data.

EXPLORING THE PACIFIC REMOTE ISLANDS MARINE NATIONAL MONUMENT (PRIMNM)

Cruise EX1604 is part of the mission to explore the PRIMNM. PRIMNM boundaries include Wake, Baker, Howland, and Jarvis Islands, Johnston Atoll, Kingman Reef, and Palmyra Atoll which lie to the south and west of Hawaii. It is one of the largest marine conservation areas in the world and sustains an important unique biodiversity. This cruise was focused on mapping Wake Island Atoll surroundings for the first time. Our journey began departing from Kwajalein Atoll of Marshall Islands (3/232016) and ended in Guam (4/13/2016).



Above: Screen capture in Fledermaus of potential calderas. A caldera is a cauldron-like volcanic feature.



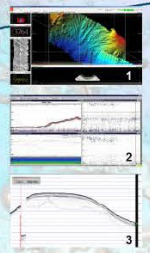
Above: Perspective view looking at seamount discovered during survey. Profile drawn from left to right.

Guam

Kwajalein

Kwajalein Lagoon

SYSTEMS ONBOARD NOAA SHIP OKEANOS EXPLORER



1. **Kongsberg EM302 multibeam echosounder**: gathers broad swaths of seafloor soundings (up to 864/ping) to effectively create 3D models of seafloor bathymetry, creates image mosaics of seafloor backscatter intensity, and identifies strong scatterers in the water column (e.g. gas plumes)
2. **Kongsberg EK60 split-beam echosounder**: sonars typically used to identify and quantitatively measure the target strength of biology in the water column (e.g. schools of fish, biological scattering layers, zooplankton aggregations)
3. **Knudsen Sub-bottom profiler**: sonar used to characterize the rock and sediment layers up to 80 meters below the surface of the seafloor to provide a cross sectional picture of seafloor sediments, underlying rock outcrops, and faults.
4. **Teledyne Acoustic Doppler Current Profilers (ADCPs)**: sonars used to estimate averaged ocean current velocity and direction profiles of the water column.

SEAMOUNTS ARE AN ESSENTIAL HABITAT

One of the most common features found around the world's ocean basins are seamounts. Seamounts have been conventionally defined as stand-alone underwater mountains that rise over 3,280 feet (1,000M) above the seafloor, are volcanic in origin, and not part of a continental shelf. Scientists often describe them as "oases of life" and in some cases endemic species (species found only in a single location on the planet) are associated with them. Ocean exploration is just fascinating!

Want to learn more?
oceanexplorer.noaa.gov
oceanservice.noaa.gov

148°E 152°E 156°E 160°E 164°E 168°E

22°N 18°N 14°N 10°N

0 25 50 100 150 200 Miles

N

Stephanie Martínez-Rivera[1] and Derek Sowers[2]
[1]NOAA EPP Intern and [2]NOAA Office of Ocean Exploration and Research