

# **MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT:**

## **EX-18-11, Océano Profundo 2018: Exploring Deep-Sea Habitats off Puerto Rico and the U.S. Virgin Islands (ROV & Mapping)**

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**January 2, 2020**

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## 1. Introduction

The NOAA Office of Ocean Exploration and Research is the only federal program dedicated to exploring our deep ocean, closing the prominent gap in our basic understanding of U.S. deep waters and seafloor and delivering the ocean information needed to strengthen the economy, health, and security of our nation.

Using the latest tools and technology, OER **explores** previously unknown areas of our deep ocean, making discoveries of scientific, economic, and cultural value. Through live video streams, online coverage, training opportunities, and real-time events, OER allows scientists, resource managers, students, members of the general public, and others to actively **experience** ocean exploration, expanding available expertise, cultivating the next generation of ocean explorers, and engaging the public in exploration activities. From this exploration, OER makes the collected data needed to **understand** our ocean publicly available, so we can maintain the health of our ocean, sustainably manage our marine resources, accelerate our national economy, and build a better appreciation of the value and importance of the ocean in our everyday lives.



## Contents

1. Introduction .....	2
2. Report Purpose .....	4
3. Cruise Objectives.....	4
4. Summary of Mapping Results .....	6
5. Mapping Statistics.....	9
6. Mapping Sonar Setup.....	9
7. Data Acquisition Summary.....	10
8. Multibeam Sonar Data Quality Assessment and Data Processing.....	13
9. Data Archival Procedures.....	16
10. Cruise Calendar .....	18
11. Daily Cruise Log Entries.....	18
12. References .....	24



## 2. Report Purpose

The purpose of this report is to briefly describe the acoustic seafloor and water column mapping data collection and processing methods used during exploration expedition EX-18-11, and to present a summary of the overall mapping results and mapping related cruise activities. A detailed description of the *Okeanos Explorer's* mapping capabilities is available in the 2019 NOAA Ship *Okeanos Explorer* Survey Readiness Report, available in the NOAA Central Library, doi:10.25923/kkwz-5t70. A full description of Remotely Operated Vehicle (ROV) operations and sample collections completed during the cruise is available in a separate Expedition Report available in the NOAA Central Library with the title “EX-18-11 Expedition Report, *Océano Profundo 2018: Exploring Deep-Sea Habitats off Puerto Rico and the U.S. Virgin Islands*,” doi: 10.25923/wc2n-qg29.

## 3. Cruise Objectives

EX-18-11 was one of several NOAA Ship *Okeanos Explorer* expeditions from 2018 to 2021 planned to contribute to NOAA’s Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE), a major multi-year, multi-national, collaborative ocean exploration program focused on raising our collective knowledge and understanding of the North Atlantic Ocean. The North Atlantic Ocean plays a pivotal role to humankind, providing biological and geological resources, ecosystem services such as seafood production and climate regulation, and a route for trade and travel between Europe and the Americas. However, we have only begun to understand the North Atlantic Ocean’s ecosystems, resources and oceanography, as much about the seabed bathymetry, geology, mineralogy, and trans-Atlantic connectivity of biological communities remains unknown. With the signing of the Galway Statement on Atlantic Ocean Cooperation by the European Union, Canada and the U.S., and the Atlantic Ocean Research Alliance’s deep-sea science and exploration efforts, there is significant momentum within the international community to cooperate on integrated exploration and research of the North Atlantic Ocean.

Building on previous work in the North Atlantic, including the 2011-2014 Atlantic Canyons Undersea Mapping Expeditions (ACUMEN), NOAA’s ASPIRE campaign will provide data to inform research planning and management decisions in the region, by broadening both the geographic focus to include more of the U.S. Atlantic and Canada, and the scope of partnerships to include U.S. federal agencies, such as U.S. Geological Survey (USGS) and Bureau of Ocean Energy Management (BOEM), as well as international partners from Canada and Europe.

The *Océano Profundo 2018* expedition was designed to address the science and management priorities put forward by NOAA, resource managers, and scientists from the region. In this regard, the geographic and exploration priority areas for the expedition were identified by the management and scientific community, in response to a call for input that was disseminated in July through August of 2018. NOAA priorities for the

expedition included a combination of science, education, outreach, and open-data objectives that aimed to provide a better understanding of this important, yet mostly unexplored, marine region. These objectives included:

- Acquire data on deep-water habitats to support science and management needs in Caribbean waters off Puerto Rico and the U.S. Virgin Islands, as well as in support of the ASPIRE campaign
- Explore deep-water areas relevant to resource managers, such as essential fish habitat (EFH), habitat areas of particular concern (HAPCs), marine protected areas (MPAs), and other priority management areas
- Map, survey, and characterize the diversity and distribution of deep-sea benthic communities, particularly those found within deep-sea coral and sponge habitats, deep-water snapper and grouper habitats, and other vulnerable marine habitats
- Investigate biogeographic patterns and connectivity of deep-sea organisms for use in broader comparisons of habitats across the Atlantic Basin
- Map, survey, and sample geologic features to better understand the geological context of the region, and improve knowledge of past and future geohazards
- Collect high-resolution bathymetry and backscatter data in areas with no (or low-resolution) sonar data, as well as to support ROV operations and identify potential maritime heritage sites
- Acquire a foundation of ROV, sonar, and oceanographic data to assist in better understanding the characteristics of the water column and the pelagic fauna
- Engage a broad spectrum of the scientific community and public in telepresence-based exploration and provide a foundation of publicly accessible data products to spur further exploration, research, and management activities

The *Océano Profundo 2018* expedition was a 22-day expedition that started in San Juan, Puerto Rico on October 30, 2018, and ended in San Juan, Puerto Rico on November 20, 2018. The expedition included 24-hour per day operations, with daytime ROV dives to depths ranging between 250-5,000 meters, and overnight mapping operations to depths of 6,000 meters, as well as continuous shore-side participation via telepresence technology. ROV dives focused on exploring deep-sea coral and fish habitats, midwater habitats, submarine canyons, seamounts, trenches, submarine landslides, and other poorly known deep-sea habitats. Mapping operations concentrated on seafloor and water column areas with little or no high-resolution sonar data, as well as to support ROV operations.

## 4. Summary of Mapping Results

Multibeam mapping operations covered an area of over 19,392 square kilometers of seafloor over a linear ship track distance of approximately 4,180 kilometers (2,257 nautical miles). Mapped seafloor areas included 18,434 square kilometers in the U.S. exclusive economic zone (EEZ) deeper than 200 m and 530 square kilometers in the EEZ of the Dominican Republic. Multibeam bathymetry data coverage is shown in Figure 1.

### Cruise Overview Map

Océano Profundo 2018: Exploring Deep-Sea Habitats off Puerto Rico and the U.S. Virgin Islands (ROV & Mapping)

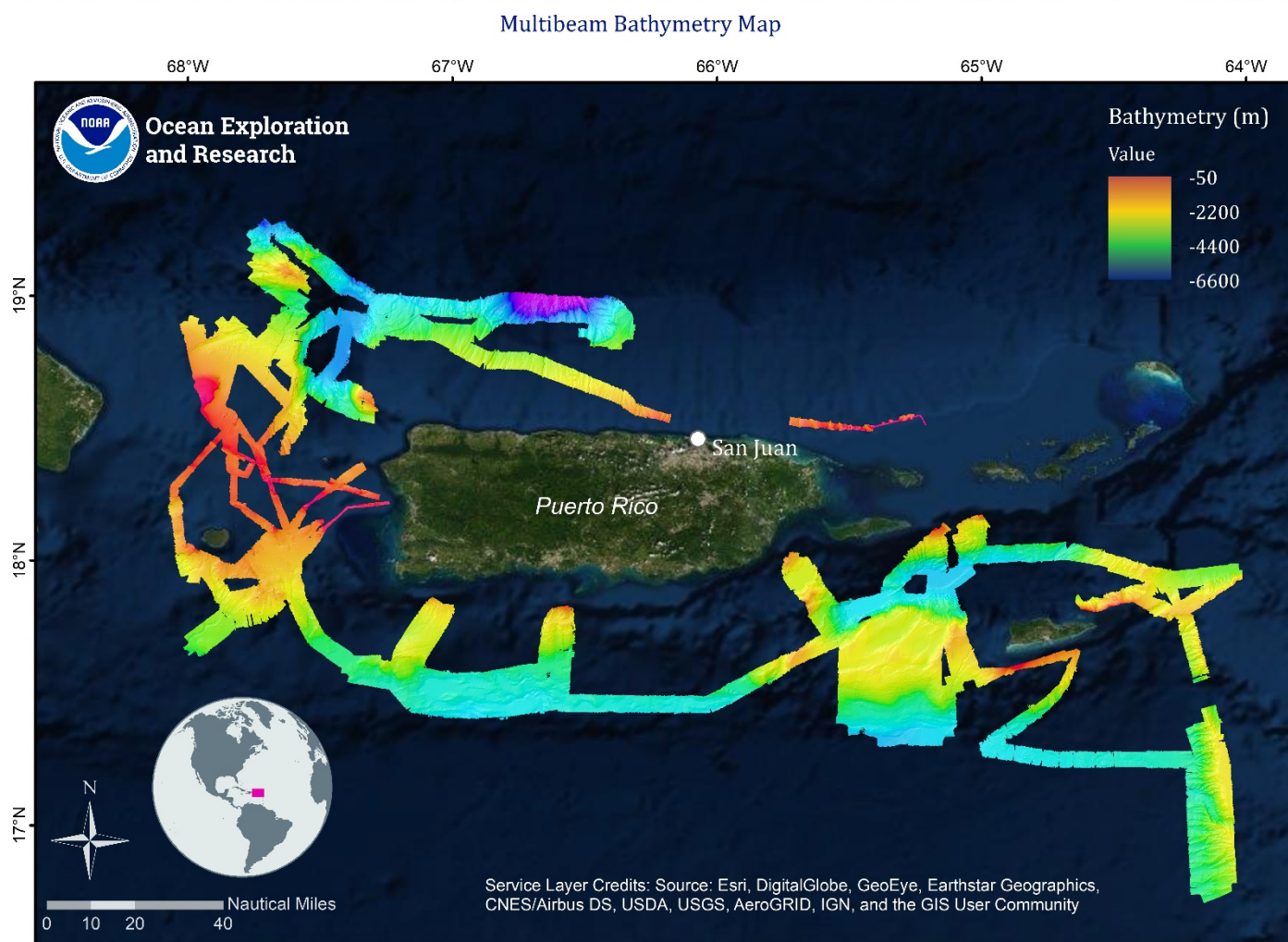


Figure 1. Cruise map showing overall EX-18-11 multibeam bathymetry coverage completed during the expedition to explore deep-sea habitats off Puerto Rico, the U.S. Virgin Islands, and the Dominican Republic. Depth units are in meters. The white dot indicates the location of San Juan, Puerto Rico, the starting and ending port for the cruise.

Mapping operations included several areas that had never before been mapped with high-resolution multibeam sonars, including deep-sea areas around Mona Island, Saba Valley (Figure 2), and Engaño Bank (Figure 3).

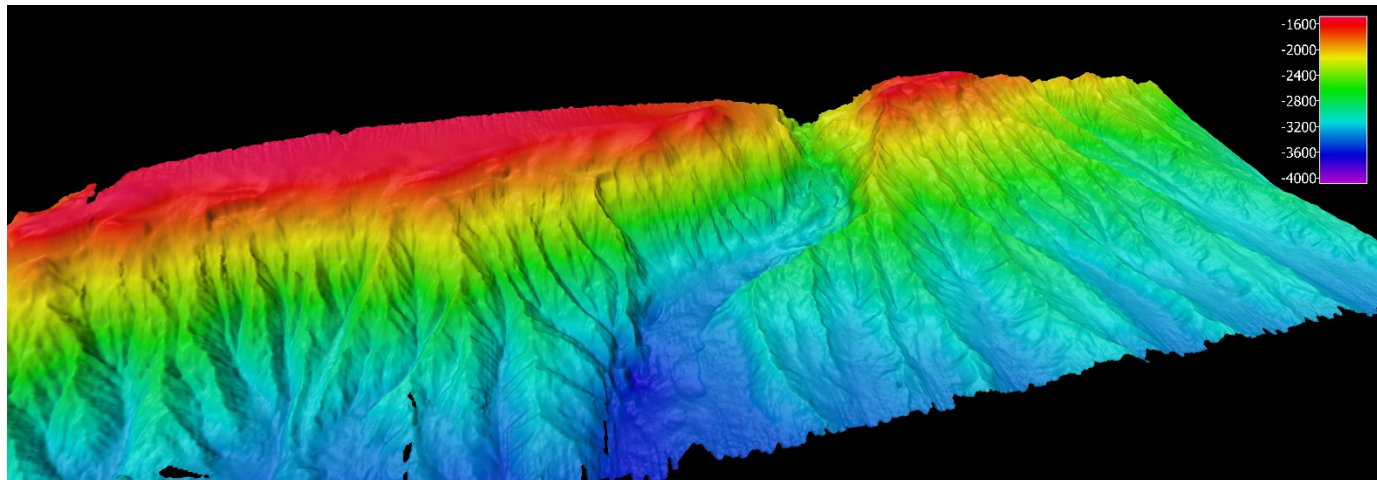


Figure 2. 3D Perspective view of multibeam bathymetry of canyons in the Saba Valley region within the Puerto Rico/U.S. EEZ, southeast of Puerto Rico. This large complex canyon area had never been previously mapped with multibeam surveys. The canyons to the north were previously mapped by the *Okeanos Explorer* in 2015. No deep submergence exploration work had ever been done here at the time of the cruise. EX-18-11 planned a dive in this region, but it was cancelled due to rough weather conditions. Figure produced in QPS Fledermaus software, with depth scale in meters, grid resolution of 50 meters, and vertical exaggeration 3x. Approximate location at the center bottom of the image is 64° 12.77' W, 17° 06.39' N.

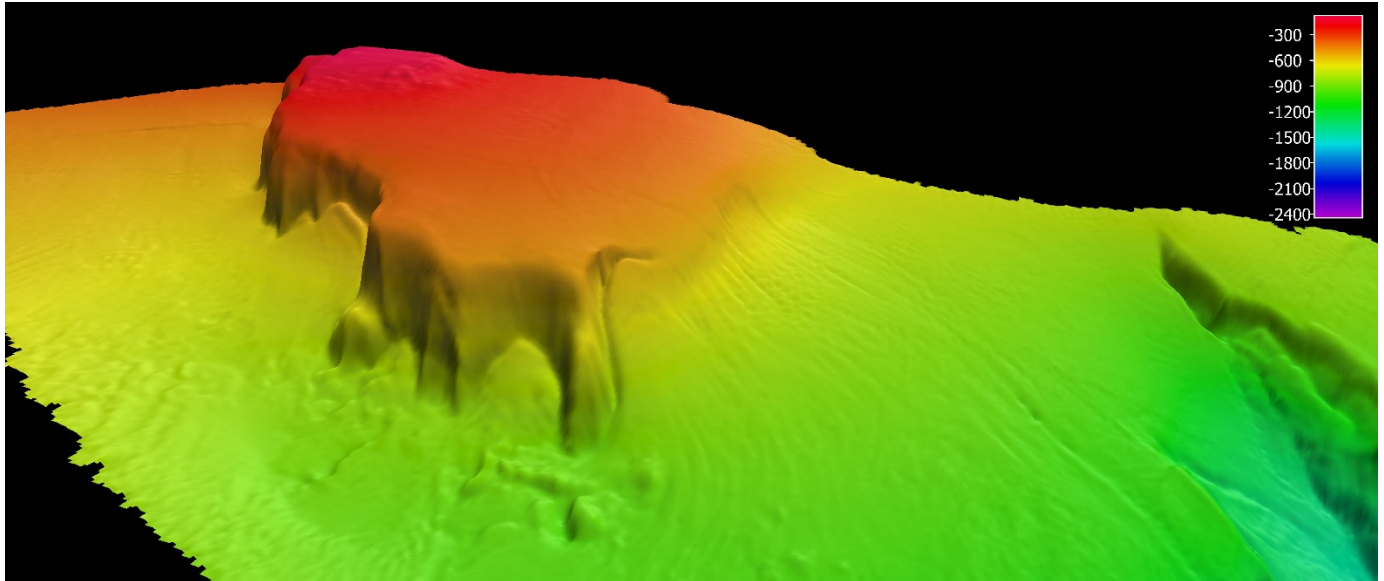


Figure 3. 3D perspective view of multibeam bathymetry of Engaño Canyon and Engaño Bank. This area within the Dominican Republic had never been previously mapped with multibeam surveys. The data reveals a plateau area with depths as shallow as 80 meters, distinct sand waves, and the head of a gently sloping canyon system with steep walls on the north side of the feature. Figure produced in QPS Fledermaus software, with depth scale in meters, grid resolution of 50 meters, and vertical exaggeration 6x. Approximate location at the center bottom of the image is 67° 51.76' W, 18° 43.06' N.

Mapping operations were completed in seven different marine managed areas, including mapping areas in the deeper extensions of Buck Island Reef National Monument, Mona Island Nature Reserve, La Parguera Nature Reserve, Inés María Mendoza Nature Reserve, Cabezas de San Juan Nature Reserve, Río Espíritu Santo Nature Reserve, and Bosque Natural de Boquerón Nature Reserve. Deep-water portions of many of these areas had not been previously mapped with high-resolution sonars.

High-resolution multibeam data were collected over all 19 ROV dive locations and used to refine dive plans and safely conduct all dive operations. While no maritime heritage sites were identified in the field during seafloor mapping operations, the expedition included mapping in large areas around Mona Island that were identified as priorities by several maritime archaeologists.

When gathering bathymetric data in unmapped or poorly mapped areas was not possible, some areas with existing high-resolution data were remapped to enable time-series analysis of potential seafloor changes and to obtain improved datasets on seafloor and water column backscatter. Seafloor mapping operations covered a range of geomorphic features, including shallow banks, steep canyons, seamounts, ridges, abyssal hills, deep-sea troughs, and extensive submerged channels.



## 5. Mapping Statistics

Table 1. Summary statistics of ocean mapping work completed during EX-18-11.

Dates of cruise	October 30 – November 20, 2018
Linear kilometers of survey with EM 302	4,180
Square kilometers mapped with EM 302	19,392
Square kilometers mapped with EM 302 within U.S. EEZ deeper than 200 meters	18,434
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files (.all)	521 files/ 23.9 GB
Number / Data Volume of EM 302 water column multibeam files	521 files / 77.8 GB
Number / Data Volume of EK 60 water column split beam files (.raw)	266 files / 16.9 GB
Number / Data Volume of sub-bottom sonar files (.segy, .kea, .keb)	928 files / 4.91 GB
Number of XBT casts	42
Number of CTD casts (including test casts)	0

## 6. Mapping Sonar Setup

The following sonars were operated during the cruise:

### *Kongsberg EM 302 Multibeam Sonar*

The NOAA Ship *Okeanos Explorer* is equipped with a 30 kHz Kongsberg EM 302 multibeam sonar capable of detecting the seafloor in up to 10,000 meters of water and conducting productive mapping operations in 8,000 meters of water. The system generates a 150° beam fan containing up to 432 soundings per ping in waters deeper than 3300 meters. In waters less than 3300 meters, the system is operated in multi-ping, or dual swath mode, and obtains up to 864 soundings per ping, by detecting two swaths per ping cycle. The multibeam sonar is used to collect seafloor bathymetry, seafloor backscatter, and water column backscatter. Backscatter represents the strength of the acoustic signal reflected from a target, such as the seafloor or bubbles in the water column. The system is patch tested annually and the results are reported in the annual readiness report. The 2019 NOAA Ship *Okeanos Explorer* Mapping Systems Readiness Report is available in the NOAA Central Library with the following DOI: <https://doi.org/10.25923/kkwz-5t70>.



### *Simrad EK 60 Split-beam Sonars*

NOAA Ship *Okeanos Explorer* is equipped with five EK 60 split-beam sonar transducers operated at frequencies of 18, 38, 70, 120 and 200 kHz. These sonars were used continuously (aside from the 38 kHz which interfered with the multibeam during mapping operations) throughout the cruise during both overnight mapping operations and daytime ROV operations. These sonars are quantitative scientific echosounders calibrated to identify the target strength of water column acoustic reflectors - typically biological scattering layers, fish, or gas bubbles – providing additional information about water column characteristics and anomalies. These sonars were calibrated on the EX-18-02 cruise, and calibration values from that cruise were applied to the EK sonars for EX-18-11. The 2018 EK Calibration Report (<https://doi.org/10.25923/6nb5-f816>) is available in the NOAA Central Library.

### *Knudsen 3260 Sub-bottom Profiler*

The ship is equipped with a Knudsen 3260 sub-bottom profiler that produces a frequency-modulated chirp signal with a central frequency of 3.5 kHz. This sonar is used to provide echogram images of shallow geological layers underneath the seafloor to a maximum depth of approximately 80 meters below the seafloor. The sub-bottom profiler is operated to provide information about sub-seafloor stratigraphy and features. The data generated by this sonar is fundamental to helping geologists interpret the shallow geology of the seafloor.

### *Teledyne Acoustic Doppler Current Profiler (ADCP)*

The ship utilized a 300 kHz Teledyne RDI Workhorse Mariner ADCP, with a ~70 meter range. ADCP data were gathered data prior to ROV deployments in order to assess currents at the dive site in support of safe operations. The ADCP was kept running throughout the ROV dives. The ADCP is not typically run concurrently with the other sonars while transiting due to interference issues.

## **7. Data Acquisition Summary**

Mapping operations included EM 302 multibeam, EK 60 split-beam, and Knudsen sub-bottom profile data collection. Survey lines were planned to maximize either bathymetry edge matching of existing data or data gap filling in areas with existing bathymetry coverage. In regions with no existing data, lines were planned to optimize potential exploration discoveries.

Throughout the cruise, multibeam data quality was monitored in real-time by acquisition watch standers. Ship speed was adjusted to maintain data quality as necessary and line spacing was planned to ensure one-quarter to one-third swath width overlap between lines. Cutoff angles in SIS were generally left wide open for maximum exploration data collection, and were adjusted on both the port and starboard side during focused survey operations to ensure the best data quality and coverage. Data were corrected for sound velocity in real-time using the Reson SVP-70 data at the sonar head. Reson sound velocity values were constantly compared against secondary derived sound speed values from the ship's onboard thermosalinograph flow-through system as a quality assurance measure. Expendable Bathythermographs

(XBTs) were conducted every 2 to 4 hours to provide temperature profiles of the water column in order to calculate sound velocity profiles. These profiles are used while surveying with the multibeam sonar in order to properly account for sound speed changes and ensure the most accurate bathymetry data possible. In total there were 42 XBT casts taken as part of the mapping survey. EM 302 multibeam sonar tracklines and XBT locations are shown in Figure 4.

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Multibeam Sonar Trackline and XBT Map

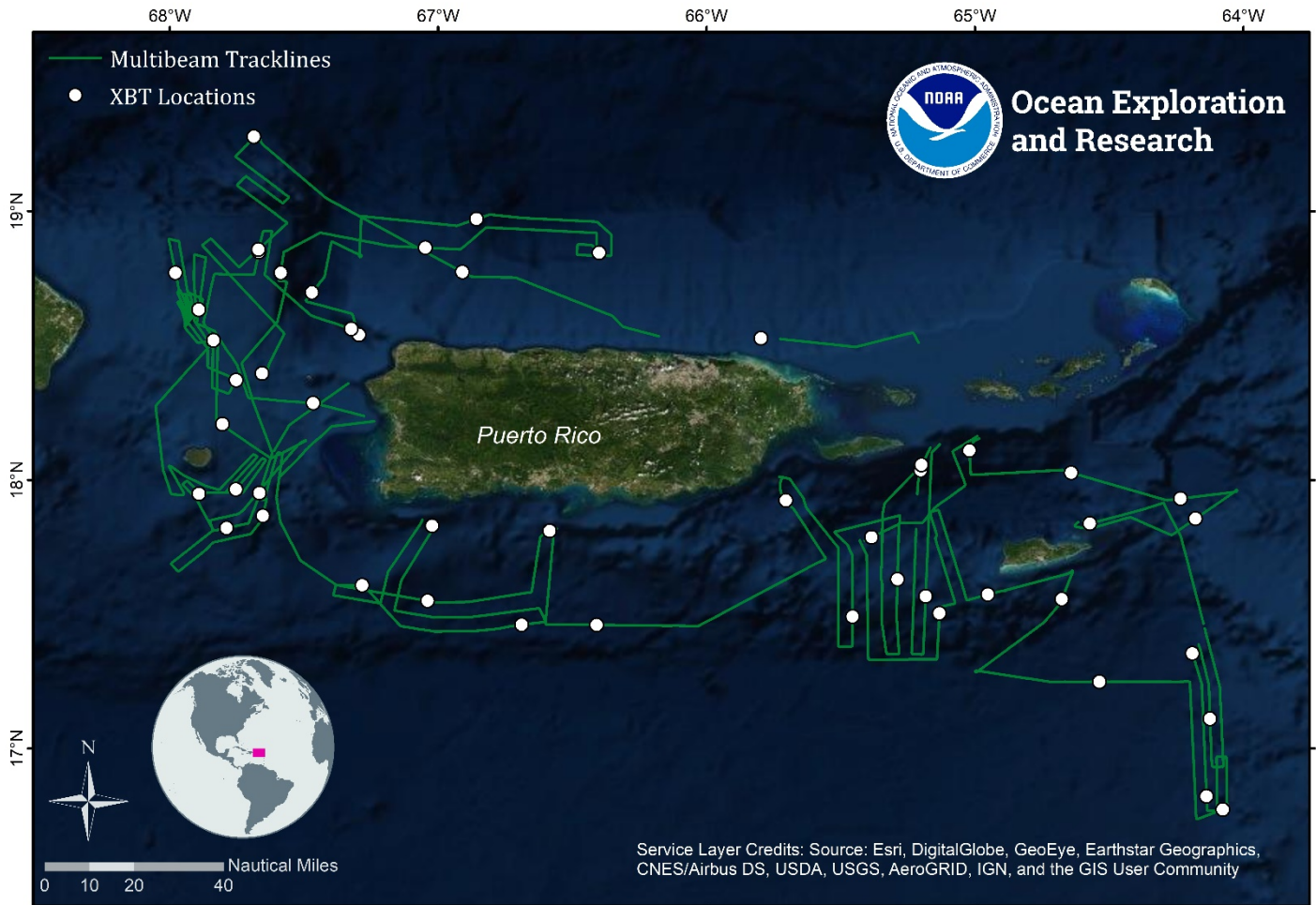


Figure 4. Cruise map showing XBT cast locations (white) and EM 302 multibeam sonar acquisition tracklines (green) completed during EX-18-11.

Simrad EK 60 split-beam water column sonar data were collected continuously during the cruise, while transit mapping and during ROV dive operations. Data were monitored in real time for quality but were not post-processed. Figure 5 shows the EK 60 data tracklines collected during EX-18-11.

Océano Profundo 2018: Exploring Deep-Sea Habitats off Puerto Rico and the U.S. Virgin Islands (ROV & Mapping)

EK 60 Sonar Trackline Map

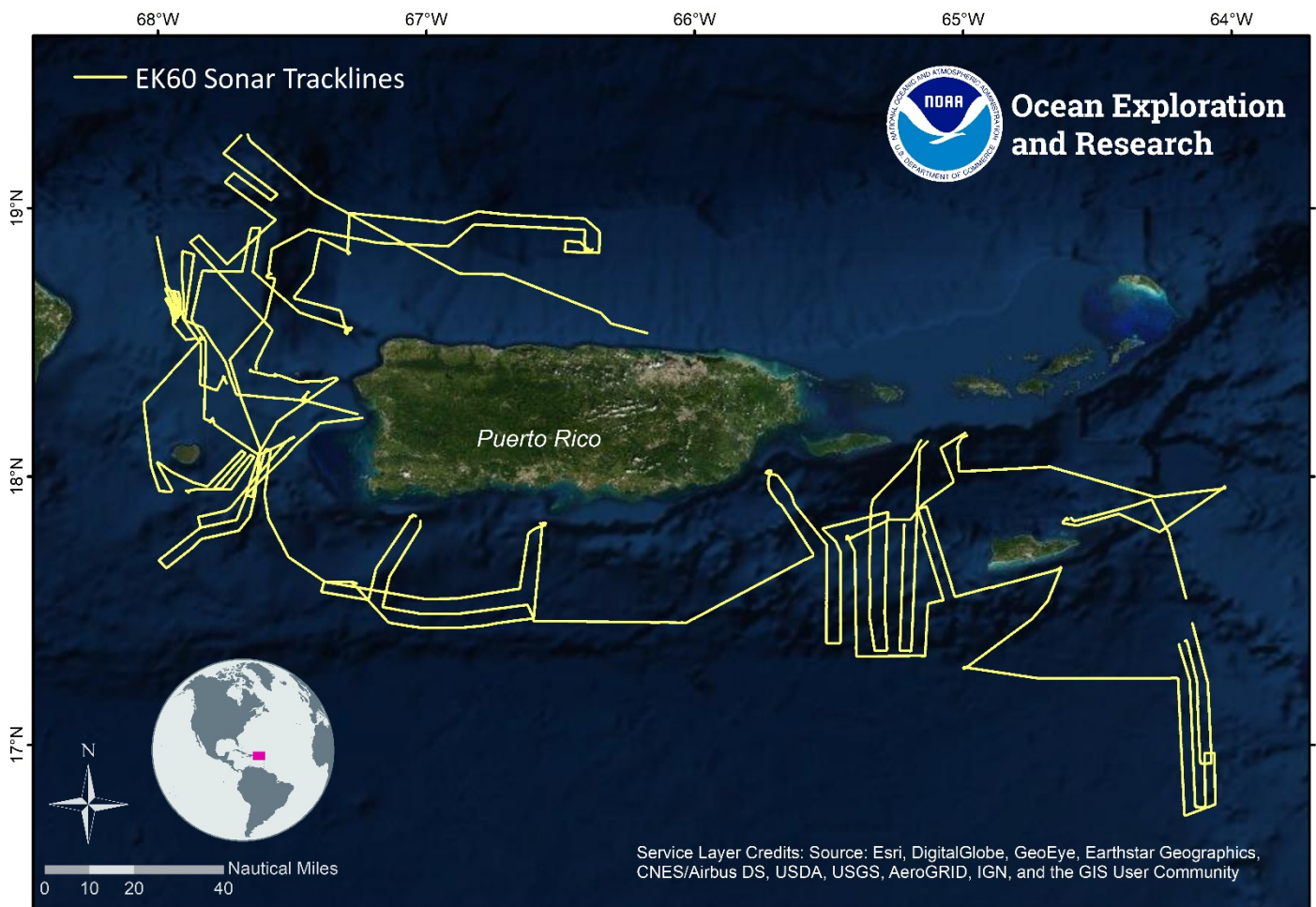


Figure 5. Map showing EK 60 split-beam sonar data tracklines (in yellow) collected during EX-18-11.

Knudsen 3260 sub-bottom profiler data were collected constantly throughout the cruise, except in certain areas with water depths less than approximately 50-300m or when conducting tests of other sonars. Figure 6 shows the Knudsen sub-bottom profiler data tracklines collected during EX-18-11.

Sub-bottom Sonar Trackline Map

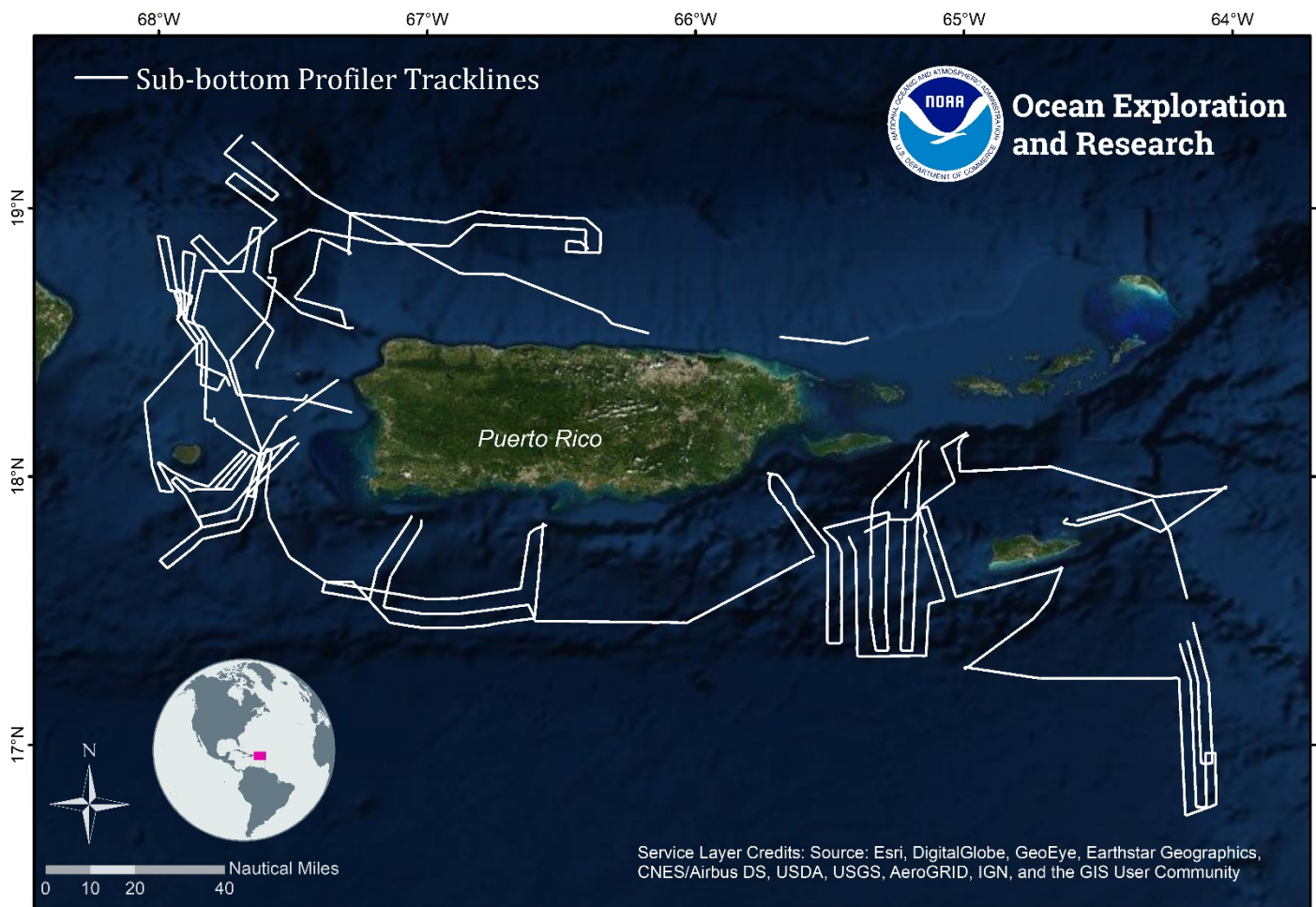
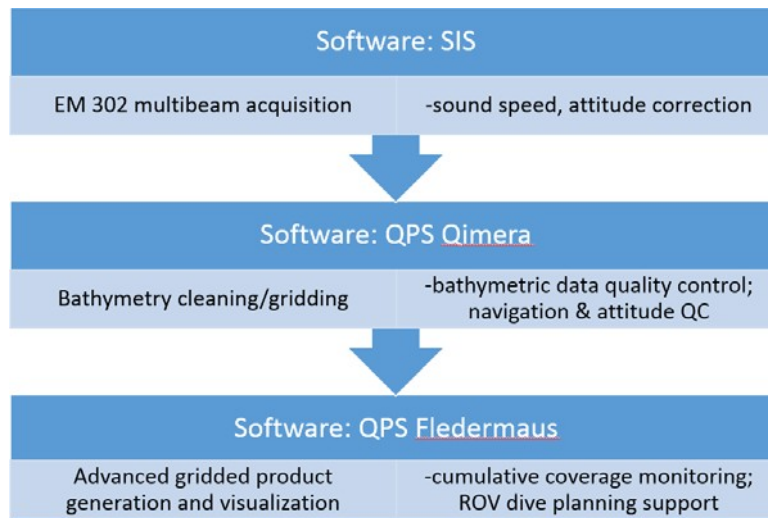


Figure 6. Map showing Knudsen sub-bottom profiler sonar data tracklines (in white) collected during EX-18-11.

## 8. Multibeam Sonar Data Quality Assessment and Data Processing

Figure 7 shows the multibeam data processing workflow for this cruise. EM 302 Built-in Self Tests (BISTs) were run at the beginning and ending of the cruise to monitor multibeam sonar system status and are available as ancillary files in the sonar data archives. Raw multibeam bathymetry data files were acquired by SIS, then imported into QPS Qimera multibeam sonar processing data. Erroneous soundings were removed using 2-D, 3-D, and spline filtering editing tools in Qimera. Gridded digital terrain models were exported utilizing QPS Fledermaus software and posted to the ship's ftp site for daily transfer to shore. Final bathymetry QC was completed post-cruise onshore at the Center for Coastal and Ocean Mapping at the University of New Hampshire. With the vast majority of surveying completed in deep water, depth

measurements were not adjusted for tides, as they are an essentially insignificant percent of the overall water depth. Data cleaning projects were in UTM zone projections for the operations area. Final data products were exported and archived as field geographic WGS84 coordinate reference frame (i.e., un-projected).



**Figure 7. Shipboard multibeam data processing workflow.**

### *Crosslines*

Comparing depth values from orthogonal survey lines is a standard hydrographic quality control measure to evaluate the consistency of the multibeam sonar data collected during a cruise. A crossline was run on November 2, 2018 as shown in Figure 8. Crossline analysis was completed using the Crosscheck Tool in QPS Qimera software to evaluate if the survey meets the requirements for an International Hydrographic Order 1 survey. The results are shown below.

#### Crossline file:

0065\_20181102\_233834\_EX1811\_MB.all

#### Main scheme line file:

0053\_20181102\_065137\_EX1811\_MB.all



The results showed data quality sufficient for an International Hydrographic Organization Order 1 survey. Depths listed ("Z") are in meters.

<u>Statistic</u>	<u>Value</u>
Number of points of comparison	165,179
Grid Cell Size	50
Difference Mean	0.157
Difference Median	0.550
Difference Std. Dev	5.598
Difference Range	[-73.55 37.02]
Mean + 2*Stddev	11.353
Median + 2*Stddev	11.747
Data Mean	-1238.87
Reference Mean	-1239.03
Data Z-Range	[-1481.68 -1067.14]
Reference Z-Range	[-1465.17 -1072.51]
Order 1 Error Limit	16.115099
Order 1 # Rejected	2229
Order 1 P-Statistic	0.013494
<b>Order 1 Survey</b>	<b>ACCEPTED</b>



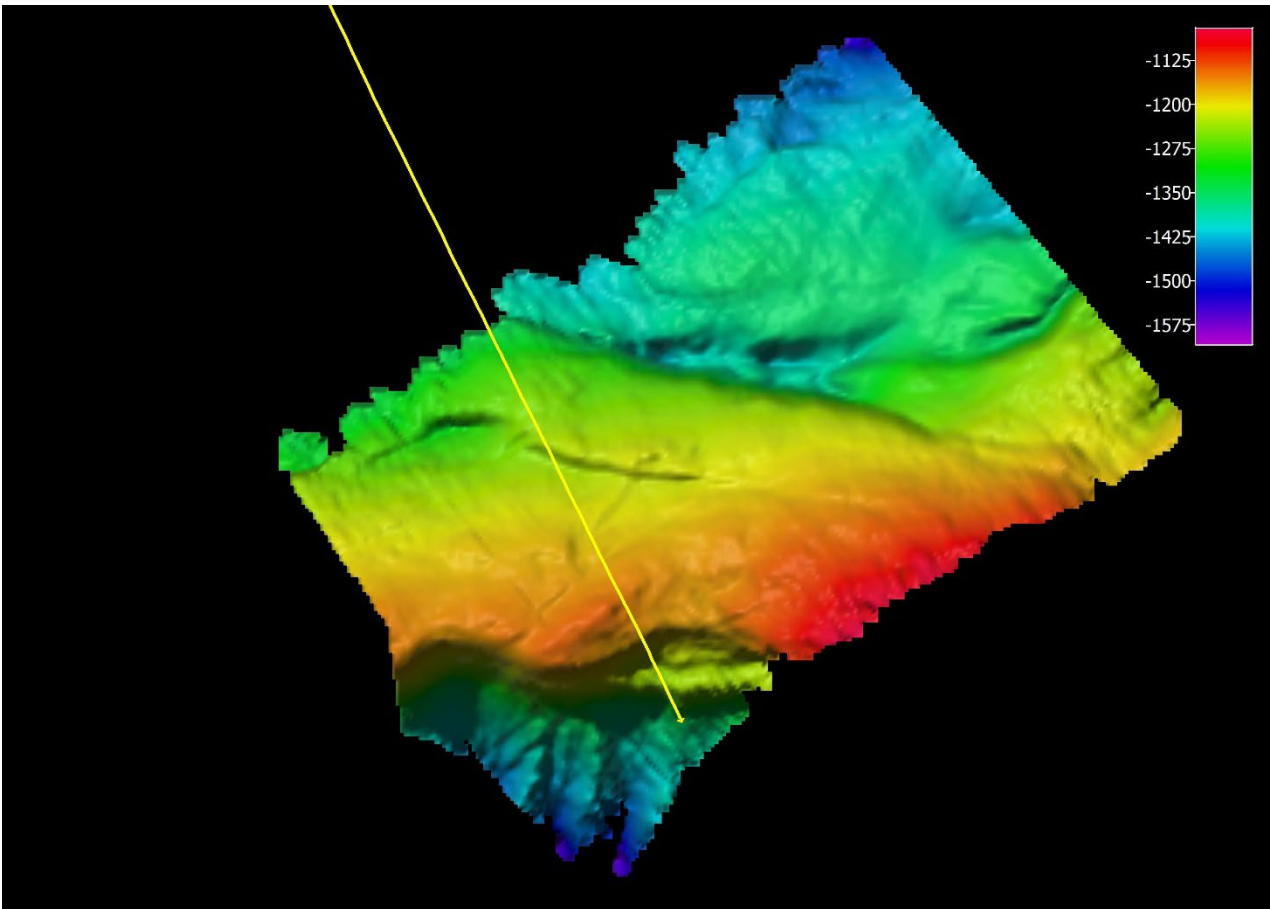


Figure 8. EX-18-11 crossline (shown in yellow) used for comparison against the bathymetric grid generated via orthogonal multibeam survey lines.

## 9. Data Archival Procedures

All mapping data collected by the NOAA Ship *Okeanos Explorer* are archived and publicly available within 90 days of the end of each cruise via the National Centers for Environmental Information (NCEI) online archives. The complete data management plan (which describes the raw and processed data formats produced for this cruise) is available as an appendix in the EX-18-11 project instructions available in the NOAA Central Library. Ancillary and supporting files are archived with the sonar datasets. These include:

*EM 302 Multibeam bathymetry and bottom backscatter dataset:*

- Mapping watch stander log
- Weather log
- Sound velocity profile log



- Multibeam acquisition and processing log
- Built-In-System-Tests (BISTs)
- Processor Unit Parameters

*Simrad EK 60 split-beam water column dataset:*

- Mapping watch stander log
- Weather log
- EK data log

*Knudsen 3260 Sub-bottom Profiler dataset:*

- Mapping watch stander log
- Weather log
- Sub-bottom data log

*EM 302 Multibeam water column dataset:*

- Mapping watch stander log
- Weather log
- Sound velocity profile log
- Multibeam acquisition and processing log
- Built-In-System-Tests (BISTs)
- Processor Unit Parameters
- Multibeam water column data review log identifying files with potential seeps

EM 302 and EK 60 water column data, supporting data, and informational logs are available in the NCEI Water Column Sonar Archives:

[https://www.ngdc.noaa.gov/maps/water\\_column\\_sonar/index.html](https://www.ngdc.noaa.gov/maps/water_column_sonar/index.html) (last accessed 1/17/2020).

Sub-bottom data, supporting data, and informational logs are available in the NCEI Data Archives accessible at <https://www.ngdc.noaa.gov/>. For assistance in accessing SBP data, send an inquiry to [ncei.info@noaa.gov](mailto:ncei.info@noaa.gov) requesting access to EX-18-11 Knudsen 3260 sub-bottom raw and processed data.

EM 302 bathymetry data, supporting informational logs, and ancillary files are available in the NCEI Data Archives accessible at <https://maps.ngdc.noaa.gov/viewers/bathymetry/> (last accessed 1/17/2020).

## 10. Cruise Calendar

*All times listed are local ship time, which was -4 hours from UTC*

### October/November 2018

Sun	Mon	Tues	Wed	Thur	Fri	Sat
28 Mobilization day. Most mission personnel arrive.	29 Mobilization day. Pre-cruise meetings and trainings.	30 First day of the cruise. Depart San Juan, Puerto Rico. All day mapping operations while in transit.	31 Ultra-short baseline (USBL) navigation system calibration, Dive 1, overnight mapping operations.	1 November Dive 2, overnight mapping operations	2 Dive 3, overnight mapping operations	3 Dive operations cancelled due to weather, all day mapping operations
4 Dive 4, overnight mapping operations	5 Dive 5, overnight mapping operations	6 Dive 6, overnight mapping operations	7 Dive 7, sun photometer measurements, overnight mapping operations	8 Dive 8, sun photometer measurements, overnight mapping operations	9 Dive 9, overnight mapping operations	10 Dive 10, overnight mapping operations
11 Dive 11, overnight mapping operations	12 Dive 12, overnight mapping operations	13 Dive 13, overnight mapping operations	14 Dive 14, overnight mapping operations	15 Dive 15, overnight mapping operations	16 Dive 16, overnight mapping operations	17 Dive 17, overnight mapping operations
18 Dive 18, overnight mapping operations	19 Dive 19, overnight mapping operations	20 Sonars were run until the sea buoy near San Juan. Arrived in San Juan, end of the cruise.	21	22	23	24

## 11. Daily Cruise Log Entries

*Generated from the daily expedition situation reports. All times listed are in local ship time which was Atlantic Standard Time (AST) (-4 hours from Coordinated Universal Time (UTC)).*



*October 30, 2018*

The EM 302 did not begin with clean Built-in Self Tests (BISTs) and was troubleshot until fixed. Both transmit and receive boards were reseated and Ethernet cables were moved until it worked. This is typical for the Transmit-Receive Unit (TRU) these days unfortunately. Once working, data quality was excellent and sea state was mild. EK 60 and Knudsen sonars worked normally. The ADCP was run leaving San Juan and through the shallow waters of the Virgin Passage with bottom tracking on. Transmit (TX) errors on the multibeam were observed in the Telnet session and the bathymetry suffered some holes around time 1900. It was bad enough to stop the multibeam and restart the TRU. Reseating of TX boards was needed to fix this issue. Running telnet sessions during boot up and BIST tests is helpful in diagnosing the issue. Data quality returned to excellent following this work. The transit plan for tomorrow was modified since the original plan to map in the British Virgin Islands waters is not possible since the Marine Scientific Research (MSR) is not approved. The mapping watch schedule was established and coordination mechanisms between the Mapping Team, ROV Team, and Science Leads have been agreed upon for the cruise.

*October 31, 2018*

The ADCP ran normally for a while this morning, then flashed some warnings and stopped acquiring data and making output plots. We started and stopped acquisition cruises in the UHDAS control software, restarted the software, computer, and deck unit and checked all the connections. Eventually it started working again, and ran normally the rest of the day. The multibeam worked normally without any issues today. We are edge matching last night's coverage south of Vieques and west of St. Croix. This area has been mapped previously, but the new coverage will be of higher quality and resolution. The latest version of Sound Speed Manager software provides a nice database and spreadsheet of sound velocity profile (SVP) casts including position data that can easily be exported at the end of the cruise as a spreadsheet or shapefile in ArcGIS. The XBT autolauncher had one failure last night but is otherwise working well.

*November 1, 2018*

Overnight data quality was excellent. There was a mistake in the daily products that was fixed. The corrected files should be pushed to shore tonight. The Mapping Lead simplified the daily products Standard Operating Procedure (SOP) and fully tested the revised workflow to make sure it worked right. The SOP will be independently tested tonight. Sound Speed Manager software was updated to the latest version. This was in response to a help request we submitted and code improvements made by University of New Hampshire Center for Coastal and Ocean Mapping (CCOM). The improved code enables us to successfully import just the upcast of the ROV CTD data into SSM (to be used to generate a sound velocity profile without doing an XBT). However, the software did not apply the transducer sound speed and profile extension properly and we will be requesting addition de-bugging. Overnight surveying is focused on gaps east and south of St. Thomas and St. Croix, and data quality is excellent.

*November 2, 2018*

Overnight operations filled in some mapping gaps south and east of the dive site. We added coverage to the shallower part of the slope within the Buck Island Reef National Monument. Data quality was very good. Weather conditions deteriorated rapidly during ROV recovery. We had some issues with bottom tracking while pitching into 5-9' seas this evening. Running south in the trough helped greatly. We completed a series of six different tests with the EM 302 multibeam TX array and logged files (.all and .wcd) to send to CCOM. These tests were requested on behalf of the research team leading the acoustic tests

within the U.S. Navy Atlantic Undersea Test and Evaluation Center (AUTEK) range on EX-18-12. These preliminary tests will ensure the team is ready when they get to AUTEK. All of the testing was done while transiting an area already well mapped by EX in 2015. In case the dive tomorrow is cancelled, a contingency mapping plan was developed and delivered to the bridge. Overnight mapping will provide new coverage of the area on the south side of Saba Valley, with some very interesting canyon and ridge topography.

#### *November 3, 2018*

Despite fairly rough conditions, the mapping data quality was good overnight. Our survey heading was mostly in the trough and we kept the system in very deep mode for a narrower but higher quality swath. We are mapping completely unexplored areas in the southern part of the Saba Valley and building on coverage from the 2015 EX cruise here. The terrain is dramatic with steep canyons and ridges. All sonars are working normally. Several ROV team members helped monitor the sonars today, since we were mapping all day and night. Results of the previous night's EM 302 TX tests were put on the FTP site for CCOM.

#### *November 4, 2018*

Surveying last night was all transit data, half of which was edge matching previous EX data near Saba Valley. Data quality was decent with a following sea, and was moderate the rest of the night while transiting against the wind and waves. All sonars are working well, with the multibeam having clean BISTs consistently since the second day of the cruise. We ran the ADCP and EK 60s throughout the dive today. Overnight mapping is filling an area with no previous ship-based multibeam coverage, and thereby improving the quality of previously collected data en route to tomorrow's dive site. SST Wilkins completed an inventory of onboard XBTs and completed deck testing of the CTD to ensure it is ready for a post-dive cast tomorrow. The updated daily product SOP is working great and is quicker and easier to complete now that Fledermaus upgrades have addressed previous issues impacting our workflow. We provided images for a web daily update on the mapping work completed yesterday with a full day committed to mapping.

#### *November 5, 2018*

Overnight mapping operations filled a significant gap to the west of St. Croix, and then edge-matched the previous night's data in an area of older multibeam data. Data quality was very good. Tonight's mapping will fill some holidays in our nearby coverage, then edge match a large contiguous area we have been mapping to the southwest of St. Croix. Mapping plans are being carefully developed to ensure adequate distances from land for sewage waste disposal and safe water making. The auto XBT launcher (AXBT) continues to work well and has been a great asset with the frequent squalls and lightning storms we have been experiencing.

#### *November 6, 2018*

Overnight data quality was excellent with good surveying conditions. We updated the Knudsen SOP to ensure that data file formats are SEG-Y filtered, as opposed to raw format, which has proven problematic to some of our partners. We upgraded to the latest version of Sound Speed Manager (1.48) which includes a bug fix that will enable the use of ROV CTD data upcasts for sound velocity profiles for the multibeam. This appears to work quite well. We will further test this capability and compare against results from XBTs. A new Hypack project was set up for UTM19N, which we are moving into tonight and will remain in for

most of the rest of the cruise. We are also starting a new Qimera project for UTM19N zone to keep the processing times nimble. As advised by a geologist partner, we are looking closely for seeps tonight, as it is possible there may be some mud volcano geology present in the area. If a strong seep is found it will become our dive target tomorrow. Barring a surprise seep discovery we are planning a shallow (350-550 m) dive south of Ponce targeted at exploring seafloor habitats for benthic communities.

#### *November 7, 2018*

Overnight transit mapping went smoothly with good data quality. We did not find any seeps, despite careful review using FM midwater software. Tonight's mapping plan will again go outside 20 nm from mainland Puerto Rico for water making. We will build on coverage of Jaguey Spur tonight, which is our planned dive site for the day after tomorrow. Today was sunny and sun photometer measurements were taken. We are running the ADCP with bottom tracking off at all times. University of Hawaii partners have reiterated they do not need any more data to confirm heading offset numbers and having bottom track on degrades the quality of the water profiling data. The ship is planning to get back the spare newly calibrated Reson SVP probe back by the end of the year, in time to swap in for next field season.

#### *November 8, 2018*

Overnight mapping went outside 20 nm for water making, then mapped over the dive 9 site, prior to heading in close to the south side of the island for dive 8. Data quality was very good. Tonight's mapping will edge match the previous night's work, then head to Jaguey Spur for tomorrow's dive. Sun photometer measurements continued today.

#### *November 9, 2018*

Overnight mapping quality was excellent and improved the resolution of bathymetry southeast of Jaguey Spur. Tonight's mapping is mostly transit to Mona Canyon, plus a small focused survey to fill a multibeam gap southeast of Mona Island. The EM 302 has had clean BISTs on the first try every day since the second day of the cruise. We have been leaving the TRU on during dives. We are doing some midwater data processing to look for evidence of seeps as time allows. It was sunny again today so we collected sun photometer measurements. We have relied on U.S. Geological Survey (USGS) input to plan a very steep dive tomorrow on the upper portion of Mona Canyon. Mapping Lead Sowers participated in a live interaction today with a telepresence workshop group as part of the National Ocean Exploration Forum.

#### *November 10, 2018*

Last night we mapped a small gap near Mona Island that lacked any multibeam en route to Mona Canyon, as well as some nearby holes in previous EX survey coverage. Data quality was excellent. We had good success using the weak spline filter tool in Qimera to help with data cleaning, particularly in shallower low relief data with high-ping rates and dense data. It was brought to our attention that the sub-bottom profiler files now have "FLT" in their names instead of "RAW" as has been the naming convention. We had changed the recording format on these files a few days ago based on recommendations from end users and Knudsen. The data scripts are being fixed to enable the new file name convention to get copied to shore successfully. SST Wilkins has developed an SOP for importing ROV CTD data into Sound Speed Manager and using it in lieu of an XBT to get a sound velocity profile for the multibeam. This process works well, but does require a thinning filter to be applied to the profile in the software and does require a few quick spike edits prior to use. Our direct comparisons with XBT casts showed very close agreement except

at the very surface (which gets edited out anyway). The procedure will be used tomorrow after the ROV dive. Tonight we are edge matching EX data on the way to a canyon north of San Juan. We are mapping over old multibeam data. We will re-map our proposed dive site before sending the vehicles down as the older data looks a bit coarse. The preferred dive site from USGS ended up being directly on a submarine cable route as plotted on NOAA charts. We therefore moved the dive site to a safe distance from these charted potential hazards.

#### *November 11, 2018*

We mapped the Dive site 11 overnight, and provided an updated map and dive track to the ROV team this morning. It was slightly different than the older mapping data collected by NOAA Ship *Ronald Brown*. We have been creating maps of ROV dive tracks as actually dove to include in the dive summary forms. EC Wagner has been creating shapefiles of the smoothed ROV navigation data to facilitate making these maps. The maps provide a nice way to see what was actually explored during each dive, and is therefore a more accurate representation of the dive within the dive summaries. SST Wilkins and Watch Lead Baechler have been doing an excellent job managing overnight survey operations and keeping up with data cleaning. The AXBT continues to perform reliably. Tonight we will be edge matching the previous night's data and filling gaps en route to the dive site on the east side of Mona Canyon while staying 20 nm from Puerto Rico for water making purposes.

#### *November 12, 2018*

All sonars are performing normally. We tried to use the ROV CTD for a sound velocity profile today, but the salinity sensor on the *Deep Discoverer* ROV is not recording reliable data right now so we reverted to an XBT cast. One release pin on the AXBT unit appears to be jammed - it will be troubleshot when the whole launcher is empty and we can do a complete pin check. Cable crossings in the area have been challenging to plan ROV dives around, as they seem to be placed in many of the prime areas that are identified as dive targets. Plans for this morning's dive and tomorrow's dive needed to be moved away from cable routes to ensure we are minimizing risk of entanglements. Overnight mapping plans for the next few days will be moving to the southwest side of the island to stay in calmer weather.

#### *November 13, 2018*

We filled a mapping data gap on a plateau west of Mona Canyon during overnight mapping operations. Tonight's mapping plan had to be diverted for about an hour to deal with water in the chain locker. The issue was resolved quickly and is now fixed. Mapping operations for the next few days will be very constrained by rough seas (mostly to the north) and complying with the required distances from land for sewage disposal and water making. SST Wilkins caught an issue this evening with pings being dropped on a TX board when monitoring the Telnet session. The problem was fixed by re-seating the Ethernet connection on the TX board. This can be done while pinging and logging. These cords have been fairly regularly shaking loose with ship movement lately and should continue to be closely monitored.

#### *November 14, 2018*

Survey operations were tightly constrained by the required distances from land for discharges and water making. We were able to map in some previously unmapped areas south of Mona Island outside 12 nm, but the rest of the night was spent mapping previously mapped areas. Sea state both south and north of the Mona Passage are getting rougher with the storm system affecting most of Puerto Rican waters, and

this will get worse over the weekend. Tonight will focus on getting new mapping coverage in waters of the Dominican Republic to the north of Mona Passage. All sonars are functioning normally.

#### *November 15, 2018*

Overnight mapping filled a gap in multibeam coverage within the Dominican Republic as this was the only area within reach without coverage. We will be building on this coverage tonight, including a shallow bank (Engaño Bank). Sea state is moderate, but data quality has been good. The tablet used for logging sonar watch notations would not start up today. We were finally able to get it to open a troubleshooting menu and opted for a refresh. This kept all the files on the tablet, but removed Microsoft Office. Until this is re-installed, we are running the log on the EK 60 computer. A replacement laptop for the tablet has already been ordered by the Mapping Team, so the timing is good.

#### *November 16, 2018*

Last night we surveyed an interesting gently sloping Engaño Canyon and a shallow portion of the Engaño Bank in the Dominican Republic. Data quality remained good. The second Qimera project of the cruise became very slow today, presumably because of the large geographic area we have covered and the high data density from some of the shallow-water surveys. We are starting a third Qimera project for the last four days of the cruise to keep data processing fast. The 300 kHz ADCP is having some problems with occasional failures to acquire data. Yesterday it came back on its own - today we power cycled the whole system and it came back. Tonight we will be mapping a high priority survey around the southern side of Mona Island. This area lacks any previously collected multibeam and should be quite interesting terrain. This survey work is made possible through close coordination with the ship Engineering Department, as they are securing black water discharges all night and all day tomorrow in order to enable accomplishment of this key science objective of the cruise.

#### *November 17, 2018*

Last night's surveying of the gap south of Mona Island went smoothly, and the survey area was completed at the beginning of today's mapping watch after the dive. Tonight's work is improving the resolution of areas further south, then transiting to the site for Dive 18 east of Desecheo Island. Sea state is moderate and data quality is still mostly good. Video team members have been incorporating mapping scenes into their long form videos. We have planned the last two dives of the cruise, and have good existing bathymetry for both sites. ROV CTD data is being used to generate SVP casts for the multibeam, saving XBTs upon the beginning of mapping operations. SST Wilkins has a solid SOP written for this process and it is pretty straightforward thanks to the tools in Sound Speed Manager software.

#### *November 18, 2018*

Last night we finished mapping all of the remaining gap in coverage south of Mona Island, and then moved further offshore to the south to complete a small survey before transiting to the Dive 18 site. Several new dive scenes were needed this morning since it took us three different attempts to find an area with suitable dive conditions. Tonight's mapping will fill some gaps en route to Dive 19, while maintaining headings that avoid excessive pitching/rolling. Data quality remains high. The multibeam regularly loses bottom tracking in depth ranges where a switch from "Deep" to "Very Deep" mode should take place without a hitch. This now needs to be anticipated and manually switched into "Very Deep" to avoid gaps in coverage, and appears to be another symptom of an aging system. The ADCP worked normally at first, then

stopped logging data as it did the previous two days. We started a new cruise with it and restarted data logging, which did not solve the issue. The next step was to stop logging, close UHDAS software and power cycle the deck unit. After that, we waited 5 minutes, started UHDAS, started logging data, and that finally worked. The ADCP worked normally for the rest of the day. However, tomorrow we will run the ADCP by itself (EK 60s secured) to see if that makes any difference. University of Hawaii partners are aware of the issue. This issue should be tracked on EX-18-12 and if it continues or gets worse we need to get this assessed at the next drydock.

*November 19, 2018*

We filled some multibeam gaps last night and got excellent data over the top half of Mona Seamount. Tonight's survey will be mostly a fairly direct transit to San Juan, with a few deviations to strategically fill holes. Sonars will be run until the pilot area outside of the entrance to San Juan. We operated the ADCP without the EK 60s on today, and there were no problems with the ADCP. This may be coincidence, but it would be a good idea to only run the EK 60s if really needed at the same time as the ADCP until proven otherwise. We shared some Fledermaus highlight slides and a fly through video at the final science presentation for the cruise. Overall, the mapping systems have been stable this cruise and a lot of useful mapping was completed despite the constraints imposed by our proximity to land and significant pre-existing data coverage. We mapped an area over 1.5 times the land area of Puerto Rico. All sonars will be fully secured for the in port period, given its length and the potential of a hull check dive occurring.

*November 20, 2018*

Last day of the cruise. Multibeam mapping concluded near the sea buoy. Arrived dockside in San Juan in the morning as planned.

## 12. References

The 2019 NOAA Ship *Okeanos Explorer* Survey Readiness Report can be obtained in the NOAA Central Library or by contacting the NOAA OER mapping team at [oar.oer.exmappingteam@noaa.gov](mailto:oar.oer.exmappingteam@noaa.gov).

The 2018 EK Calibration Report is available at the NOAA Central Library at <https://doi.org/10.25923/6nb5-f816>.

The EX-18-11 Project Instructions can be obtained from the NOAA Central Library at <https://doi.org/10.25923/rz5x-k707>. The EX-18-11 Data Management Plan is an appendix of the project instructions.





The full cruise report for EX-18-11 can be cited as follows:

Wagner D, Sowers D, Williams SM, Auscavitch S, Blaney D & Cromwell M (2018). EX-18-11 Expedition Report - Océano Profundo 2018: Exploring Deep-Sea Habitats off Puerto Rico and the U.S. Virgin Islands. Office of Ocean Exploration and Research, Office of Oceanic & Atmospheric Research, NOAA, Silver Spring, MD 20910. OER Expedition Report EX-18-11, 171 pp. doi: 10.25923/wc2n-qg29

The following data were used as background data throughout the expedition:

- Sandwell, D.T., and W.H.F Smith, Global marine gravity from retracked Geosat and ERS-1 altimetry: Ridge Segmentation versus spreading rate, *J, Geophys. Res.*, 114, B01411, doi:10.1029/2008JB006008, 2009.
- NOAA Nautical Charts
- Various datasets downloaded from the NCEI archives via NOAA AutoChart.

