



MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT

EX-18-10: Mapping Deepwater Areas off the Southeast U.S. in Support of the Extended Continental Shelf Project (Mapping)

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1. Introduction

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

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

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2. Report Purpose

The purpose of this report is to briefly describe the acoustic seafloor and water-column mapping data collection and processing methods used during the mapping expedition EX-18-10, 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 2018 NOAA Ship *Okeanos Explorer* Survey Readiness Report, available in the NOAA Central Library.

3. Cruise Objectives

EX-18-10, from October 3 to October 24, 2020 departed Davisville, Rhode Island and arrived San Juan, Puerto Rico. EX-18-10 began with 5 days of system acceptance trials (SAT) for a new EM 302 receive (RX) array and a new EK60 18 kHz transducer. Kongsberg engineers were onboard to conduct the SATs. An EM 302 RX Sea Acceptance Trials Report is planned to be archived in the NOAA Central Library or can be requesting by contacting oar.oer.exmappingteam@noaa.gov.

Exploratory mapping operations were focused in three adjacent priority areas east of the Blake Plateau (Figure 1), northeast of the Commonwealth of The Bahamas. These areas were designated as high priority areas by the U.S. Extended Continental Shelf (ECS) Project. These areas contained a limited amount of publicly available transect multibeam bathymetric data. However, more complete coverage was required to meet the U.S. ECS Project and boundary negotiation with The Bahamas objectives, and exploration mapping operations prioritized subsets of the priority areas that did not have any modern sonar data.

EX-18-10 was completed as part of the [Atlantic Seafloor Partnership for Integrated Research and Exploration \(ASPIRE\)](#) campaign. ASPIRE is a major multi-year, multi-national collaborative ocean exploration field program focused on raising collective knowledge and understanding of the North Atlantic Ocean.

Four Explorers-in-Training (Edit) were trained onboard in the acquisition and processing of exploratory mapping data.

The complete objectives for this cruise are detailed in the EX-18-10 Project Instructions, which are archived in the NOAA Central Library and can be accessed through the following link:

<https://doi.org/10.25923/kq5w-ry25>.

4. Summary of Mapping Results

EX-18-10 mapped 58,173 square kilometers of seafloor in an area approximately 415 nautical miles east of Cape Canaveral Florida, east of the Blake Escarpment during the 22 days-at-sea (Figure 1 and Table 1). 9,950 square kilometers of the total area mapped within the U.S. Exclusive Economic Zone in depths deeper than 200 meters.



Cruise Overview Map

2018 Mapping Deepwater Areas off the Southeast U.S. in Support of the Extended Continental Shelf Project

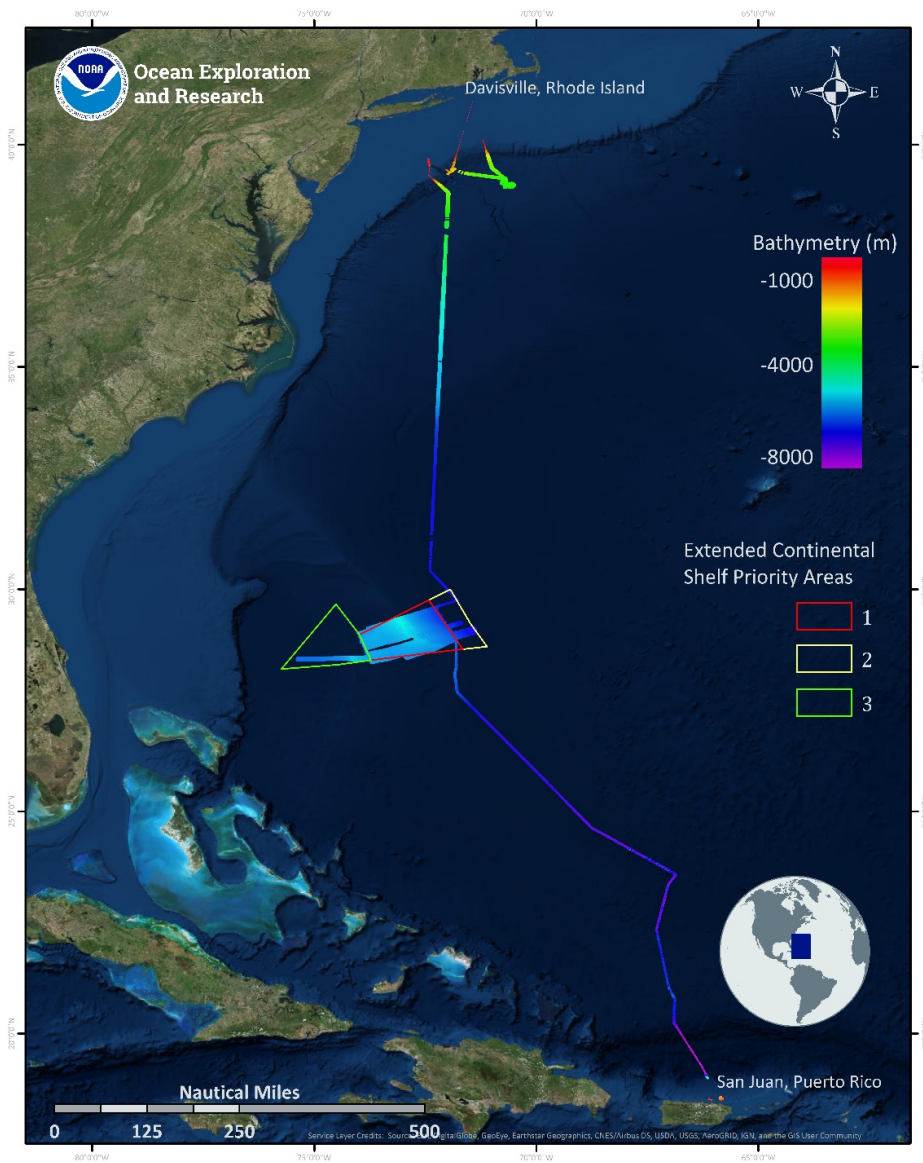


Figure 1. Overview of bathymetric mapping coverage completed during *2018 Mapping Deepwater Areas off the Southeast U.S. in support of the Extended Continental Shelf Project* expedition (EX-18-10). Red, yellow and green polygons indicated priority areas as identified by the ECS program partners.

5. Mapping Statistics

Table 1. Summary statistics of ocean mapping work completed during EX-18-10.

Dates of data collection	October 03– October 24, 2019
Linear kilometers of survey with EM 302	8,375
Square kilometers mapped with EM 302	58,173
Square kilometers mapped with EM 302 within U.S. EEZ deeper than 200m	9,950
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files (.all)	559 files/ 35.1 GB
Number / Data Volume of EM 302 water column multibeam files	559 files / 120 GB
Number / Data Volume of EK60 water column split-beam files (.raw/.idx)	202 files/ 11.2 GB
Number / Data Volume of sub-bottom sonar files (.segy, .kea, .keb)	375 / 3.96 GB
Number of XBT casts	85
Number of CTD casts (including test casts)	2

6. Mapping Sonar Setup

Kongsberg EM 302 Multibeam Sonar

NOAA Ship *Okeanos Explorer* is equipped with a 30 kilohertz (kHz) Kongsberg EM 302 multibeam sonar capable of detecting the seafloor in up to 10,000 meters of water and conducting productive mapping operations in 8,000 meters of water. The system generates a 150° beam fan containing up to 432 soundings per ping in waters deeper than 3300 meters. In waters shallower than 3300 meters the system is operated in dual swath mode, and obtains up to 864 soundings per ping by generating two swaths per ping cycle. The multibeam sonar is used to collect seafloor bathymetry, seafloor backscatter, and water column backscatter data. Backscatter represents the strength of the acoustic signal reflected from a target, such as the seafloor or bubbles in the water column. The system is patch tested annually and the results are reported in the annual readiness report. The 2018 NOAA Ship *Okeanos Explorer* Mapping Systems Readiness Report is available in the NOAA Central Library here:

<https://doi.org/10.25923/4hs3-bq40>.

Simrad EK60 Split-beam Sonars

The ship operated four Simrad EK60 split-beam fisheries sonars: 18 kHz (EK60), 70 kHz (EK60), 120 kHz (EK60), and 200 kHz (EK60). 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-18-10. The 2018 EK60 & EK Calibration Report (<https://doi.org/10.25923/6nb5-f816>) is available in the NOAA Central Library. The ship also has a 38 kHz EK60 transducer that is not operated during normal mapping operations due to interference with the EM 302 multibeam, in addition to being later deemed in need of replacement.

Knudsen 3260 Sub-bottom Profiler

The ship is equipped with a Knudsen 3260 sub-bottom profiler that produces a frequency-modulated chirp signal with a central frequency of 3.5 kHz. This sonar is used to provide echogram images of shallow geological layers underneath the seafloor to a maximum depth of approximately 80 meters below the seafloor. The sub-bottom profiler is normally operated to

provide information about sub-seafloor stratigraphy and features. The data generated by this sonar are fundamental to helping geologists interpret the shallow geology of the seafloor.

Teledyne ADCPs

The ship utilizes a 38 kHz Teledyne RDI Ocean Surveyor Acoustic Doppler Current Profiler (ADCP), with a ~1000 meter range; and a 300 kHz Teledyne RDI Workhorse Mariner ADCP, with a ~70 meter range. The ADCPs gather data prior to ROV deployments in order to assess currents at the dive site in support of safe operations. They are kept running throughout the ROV dives. The ADCPs are typically not run concurrently with the other sonars during mapping operations due to interference issues.

7. Data Acquisition Summary

Mapping operations included data collection via the EM 302 multibeam sonar, EK60 split-beam (18, 70, 120, and 200 kHz) sonars, and Knudsen 3260 sub-bottom profiler. Data were collected by each sonar concurrently during the transits.

Survey lines were planned to either maximize edge matching of existing bathymetric data, or to fill data gaps in areas with existing bathymetric coverage. In regions with no existing data, lines were planned to optimize potential exploration discoveries. Focused mapping operations occurred about 415 nautical east of Cape Canaveral, Florida near and on the Blake-Bahama Outer Ridge. A close-up of focused survey operations can be found in Figure 2. Figure 2 also displays east/west survey lines that were extended due to real-time feedback from scientists onshore in order to obtain sub-bottom data to identify sediment thickness. Figure 3 highlights a few interesting potentially soft sediment deformation and erosional/depositional features.

EX-18-10 began with limited calibration and shakedown operations south of Rhode Island. These operations included acceptance tests for a new 18 kHz EK60 transducer and new EM 302 receive array. EX-18-10 also included two long transits, one from south of Long Island, New York to the Blake-Bahama Outer Ridge area and one from the Blake-Bahama Outer Ridge area to San Juan, Puerto Rico.

Throughout the cruise multibeam data quality was monitored in real time by acquisition watchstanders. Ship speed was adjusted to maintain data quality as necessary, and line spacing was planned to ensure at least $\frac{1}{4}$ swath width overlap between lines. Cutoff angles in the multibeam acquisition software Seafloor Information System (SIS) were generally left wide open for maximum exploration data collection and routinely adjusted on both the port and starboard side to ensure the best data quality and coverage.

Multibeam data received real time surface sound velocity corrections via the Reson SVP-70 probe at the sonar head, as well as through profiles generated from Expendable Bathythermographs (XBTs) conducted at intervals no greater than 6 hours, as dictated by local oceanographic conditions. Reson sound velocity values were constantly compared against secondarily derived sound speed values from the ship's onboard thermosalinograph flow-through system as a quality assurance measure.

Simrad EK60 split-beam water column sonar data were collected throughout the majority of the cruise, (Figure 4). Data were monitored in real time for quality but were not post-processed. Figure 2 shows the EK60 / EK80 data collected during EX-18-10.

Knudsen 3260 sub-bottom profiler data were also collected during the majority of the cruise. Figure 5 shows where sub-bottom data were collected during EX-18-10.

2018 Mapping Deepwater Areas off the Southeast U.S. in Support of the Extended Continental Shelf Project

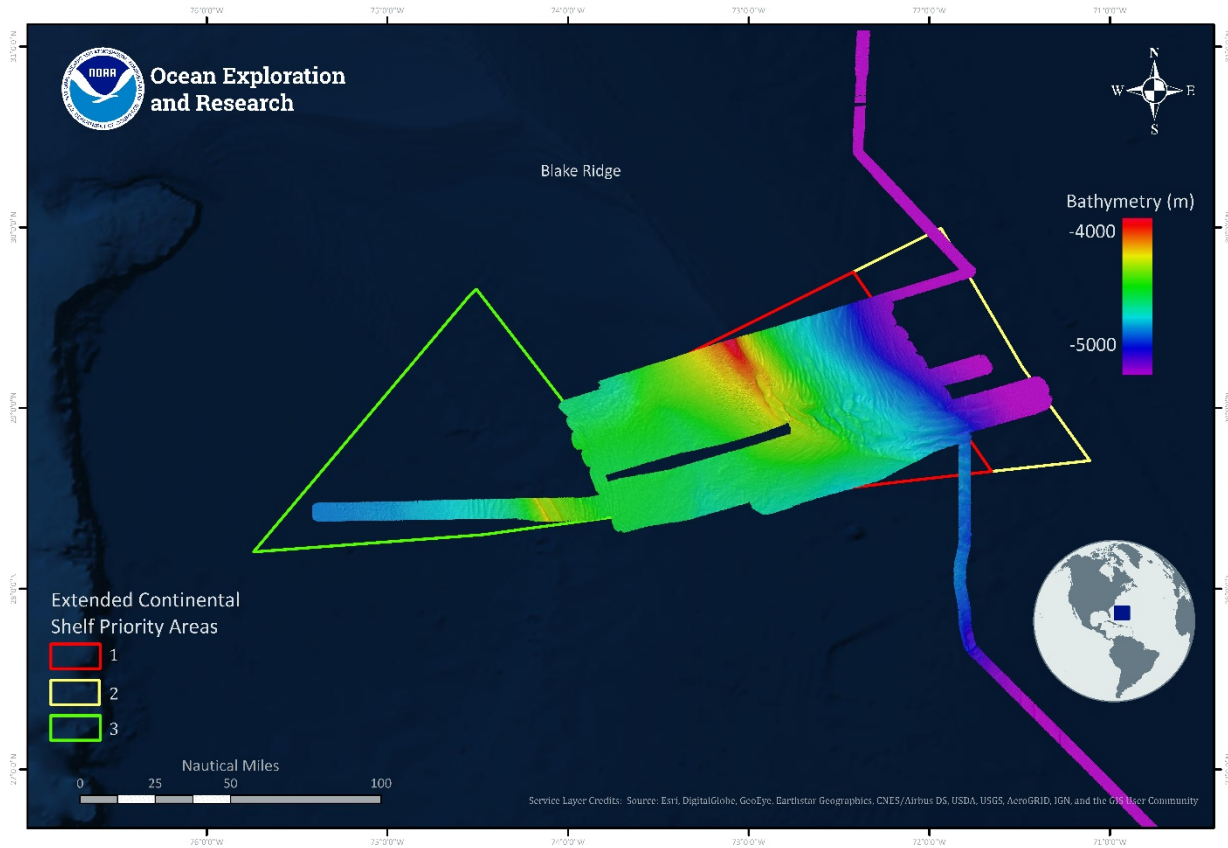


Figure 2: EX-18-10 focused survey area. Red, yellow and green polygons are priority areas defined by the ECS Project. Note the gap in coverage in the EX-18-10 data in Priority Area 1 where there was existing NOAA Ship *Ron Brown* Data (R1202).

2018 Mapping Deepwater Areas off the Southeast U.S. in Support of the Extended Continental Shelf Project

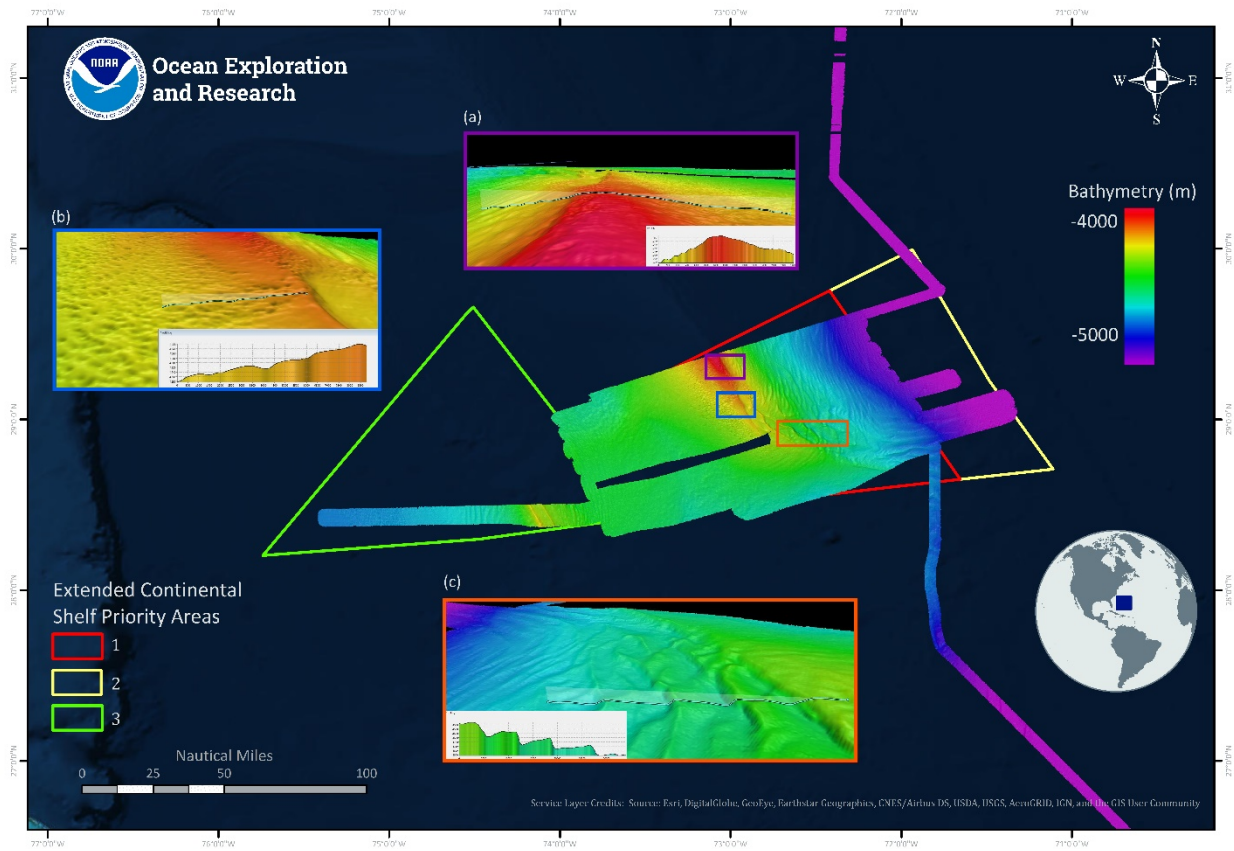


Figure 3: Examples of interesting sedimentary features from the ECS survey area. Blue, purple and orange bordered insets highlight 3D images of features; vertical exaggeration 3x, 50 meter cell size, depth in meters.

EX-18-10 Simrad EK60 Tracklines

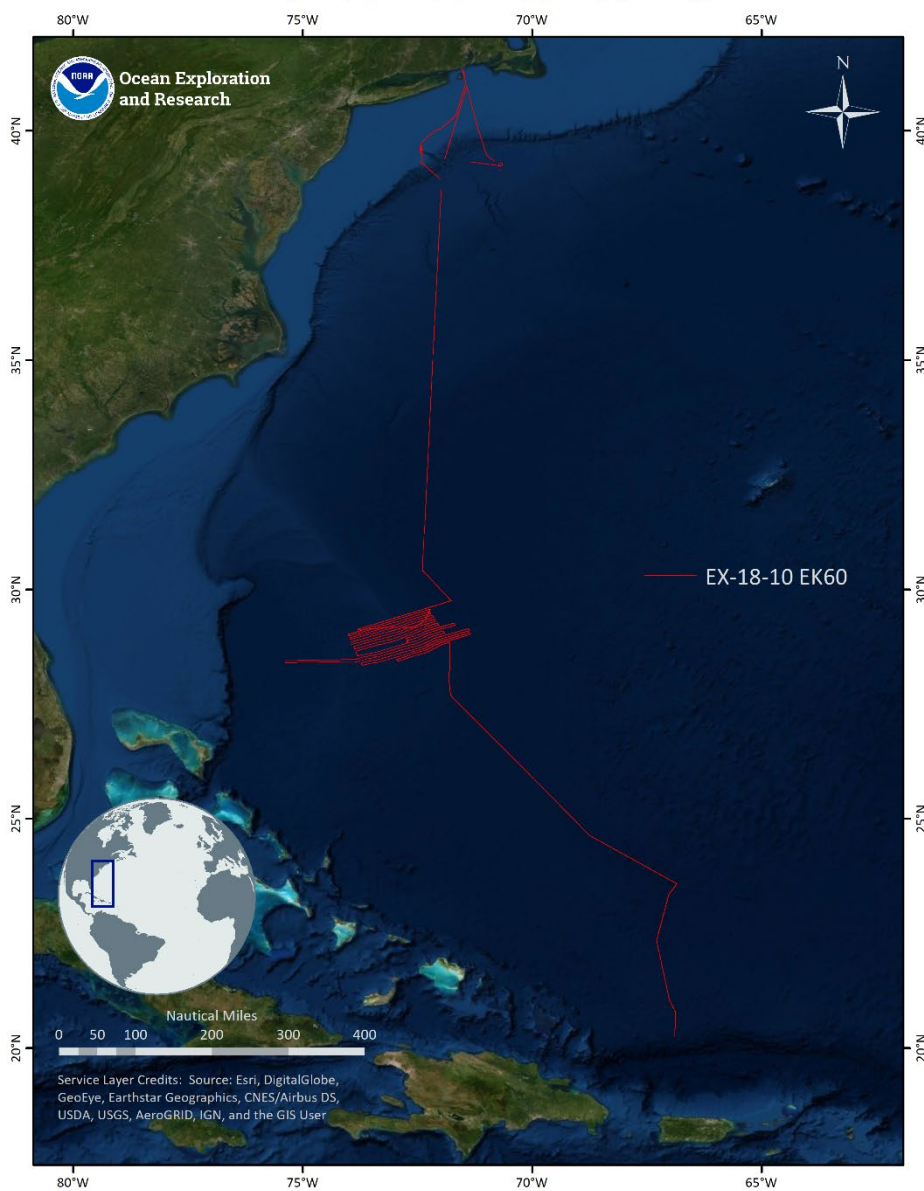


Figure 4. Simrad EK60 split-beam sonar data tracklines (in white) collected during EX-18-10.

EX-18-10 Knudsen Sub-bottom Tracklines

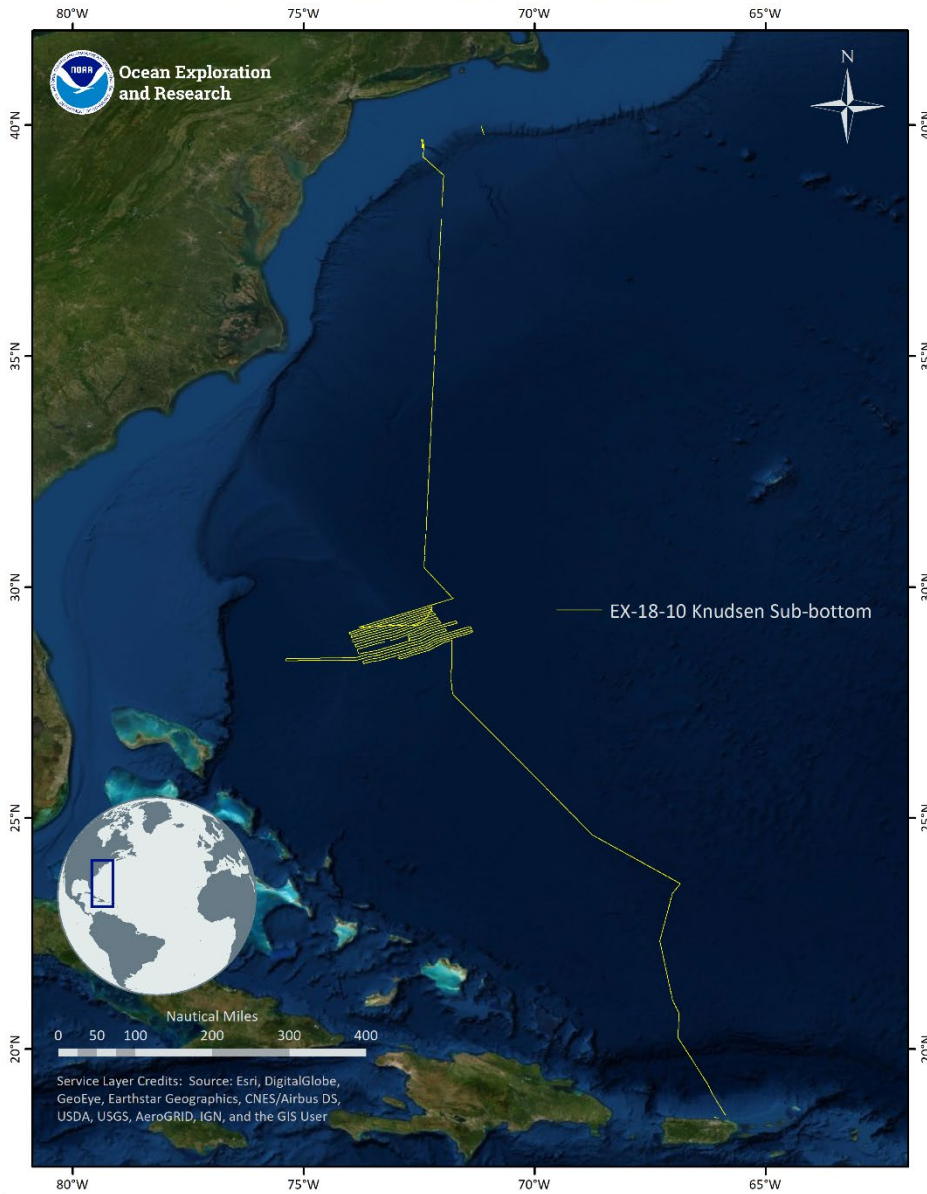


Figure 5. Sub-bottom profiler data tracklines (in yellow) collected during EX-18-10.

8. Multibeam Sonar Data Quality Assessment and Data Processing

Figure 6 shows the multibeam data processing workflow for this cruise. EM 302 Built-in Self Tests (BISTs) were run throughout the cruise to monitor multibeam sonar system status and are available as ancillary files in the sonar data archives. Raw multibeam bathymetry data files were acquired in SIS, then imported into QPS Qimera for processing. In Qimera, the attitude and navigation data stored in each file were checked, and erroneous soundings were removed using 2-D and 3-D editors. 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., unprojected).

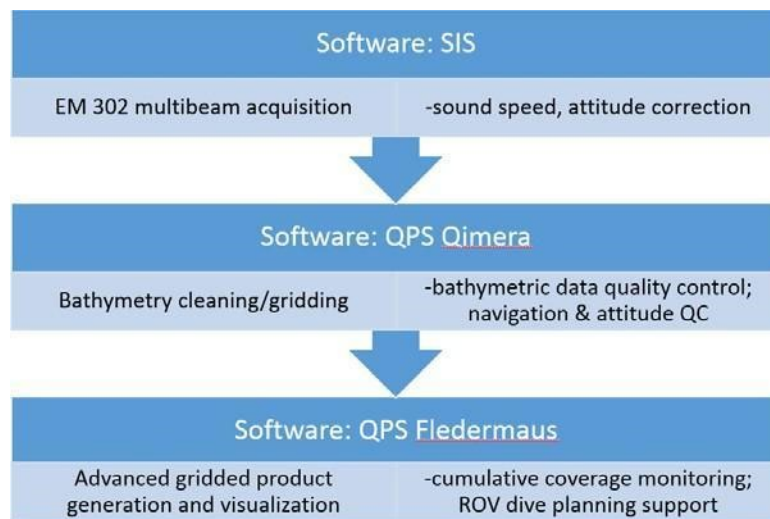


Figure 6. Shipboard multibeam data processing workflow.

Crosslines

A full transducer array sea acceptance test including patch testing and reference surface data collection was run at the beginning of this cruise, and therefore traditional crossline was not run during this expedition

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-18-10 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
- Text files of telnet sessions on the EM 302 transceiver unit (TRU)

Simrad EK 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
- Text files of telnet sessions on the EM 302 transceiver unit (TRU)
- Multibeam water column data review log if data were reviewed for presence of seeps in Fledermaus MidWater

All sonar data is permanently discoverable at <https://www.ngdc.noaa.gov/>

At the time of writing this report,

EM 302 and EK60 / 80 water column data, supporting data, and informational logs were/will be available in the NCEI Water Column Sonar Archives:

https://www.ngdc.noaa.gov/maps/water_column_sonar/index.html (last accessed 31/03/2020).

Sub-bottom data, supporting data, and informational logs will be available in the NCEI Data Archives accessible at <https://www.ngdc.noaa.gov/>. For any challenges accessing SBP data, send an inquiry to ncei.info@noaa.gov requesting access to EX-18-10 Knudsen 3260 sub-bottom raw and processed data.

EM 302 bathymetry data, supporting informational logs, and ancillary files were/will be available in the NCEI Data Archives accessible at <https://maps.ngdc.noaa.gov/viewers/bathymetry/>(last accessed 31/01/2020).



10. Cruise Calendar

All times listed are local ship time, -5 hours from UTC

October 2018

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	1 Mobilization began, mission personnel arrived	2 Depart Davisville, RI. Transit to patch test site. Begin first round of patch test	3 Patch testing continues	4 EM 302 Verification lines complete. EK60 18kHz calibrations. 2 CTD casts	5 Small boat transfer of personnel near Point Judith, RI	6 Transit south to ECS priority area
7 Transit south to ECS priority area	8 Transit to ECS priority area	9 Elevated weather, ship held weather patterns for safe ride	10 Weather cleared and normal survey operations resumed	11 ECS survey lines	12 ECS survey lines	13 ECS survey
14 ECS survey	15 ECS survey, line plans being adjusted based on onshore input	16 ECS survey	17 ECS survey	18 ECS survey	19 ECS survey	20 Depart ECS survey, begin transit mapping to San Juan
21 Transit mapping to San Juan	22 Transit mapping to San Juan	23 Transit mapping to San Juan. Overnight Sound/speed noise testing	24 Arrive San Juan, demobilization. Secured mapping systems	25	26	27 Finished demobilization.

11. Daily Cruise Log Entries

Generated from the daily expedition situation reports. All times listed are in local ship time (-5 hours from UTC)

October 01

Mobilization for EX-18-10 is ongoing. Originally scheduled to leave Monday, October 1, the cruise has been delayed by a day in order for ship's personnel to complete additional training and drills. The follow-up fleet inspection is scheduled for 0800 Tuesday October 2. Upon completion of a successful inspection, sailing time have been scheduled for 1200 on October 2. The cruise will begin with approximately 5 DAS completing system acceptance tests (SATs), calibrations and shakedown operations.

Upon arrival of Kongsberg Engineer, EM 302 TRU was powered on. Startup was clean, followed by a fully passed BIST. Offsets from the recent vessel survey, following the installation of the EM 302 receive array, have been applied in SIS. Some of these numbers show discrepancies with the original Westlake survey from 2007, in the XYZ and EM 302 transmitter orientation. The API roll sign convention is opposite from the Kongsberg convention.

October 02

Overnight transit to EM 302 patch test area included speed noise testing. First round of patch test lines have been completed (pitch, roll, heading) and will complete a verification run through tonight.

Patch test results are being evaluated in Qimera and SIS by onboard team. After consensus, offsets are being applied in SIS. There are some roll artifacts present in the outer beams that require additional attention.

October 03

Patch testing continues.

October 04

EM 302 verification lines were completed for pitch, roll and heading. After verification lines were run the onboard team agreed that additional offsets were not required.

EK60 18kHz was calibrated in all sectors at 1.024, 4.096, and 8.192 milliseconds during a drifting calibration off of the shelf in deep water.

Two CTDs were successfully completed today: a shallow cast (<100 m) for the EK60 18kHz calibration and one full cast down to 2601 m in order to obtain a full sound speed profile for EM 302 deep roll verification testing. During the deep cast, the Deck department took the opportunity to grease the CTD wire for long term preservation from sea air exposure, and the Senior Survey Technician test-fired the Niskij bottles at full depth to ensure water sampling functionality.

October 05

A small boat transfer of the Kongsberg technician to shore was completed near Point Judith, Rhode Island. Begin transit to ECS priority area.

Calibrations of the EM 302 continued with deep roll lines over an RV Sikuliaq EM 302 reference grid ([Johnson, Flinders and Greenaway, 2014](#)). It seems the wobbles in the outer beams are consistent, although they are less than 1% of water depth in amplitude and the Kongsberg engineer has stated that is within operating parameters of the systems. It may be the survey completed at Colonna's dry dock may be of poor quality; it has a heading change of the EM 302 transmit array which seems unlikely. Recommend a higher quality survey be completed this winter dry dock repair period.

October 06

Transit south to ECS priority area.

POS/MV COM ports setting troubleshooting continues. This morning it was discovered by Bridge watch standers that the Dynamic Positioning system (DP) does indeed need the feed from COM 1. Chief Electronics Engineer related that the DP feed is sensitive to the number of National Marine Electronics Association (NMEA) characters, and this is why it has a dedicated COM port. Onboard team spent the day brainstorming on how to distribute all POS feeds (attitude and position) to all devices, while still ensure the EM 302 feed does not go through any buffer boxes. Note, all devices include not only all mapping sonars. Also included are Global Foundation for Ocean Exploration (GFOE) and Office of Marine and Aviation Operations (OMAO) Scientific Computer System (SCS), Ultra Short Baseline (USBL), CTD, XBT launcher, ADCPs etc. There are only five COM ports. Long term we are reaching out to Kongsberg DP

support to see if any other configuration will work for the DP. At this time all OER/GFOE devices are no longer downstream of the OMAO buffer boxes.

October 07

Transit to ECS survey area continues. SOPs are being updated with post SATs screenshots and notes. Systems continue to function normally.

October 08

Transit to ECS priority area.

The POS/MV re-configuration has been completed and we are updating diagrams and SOPs. Several advantages are: 1) No OER/GFOE systems are downstream of OMAO buffer boxes that are known to cause issues. 2) The EM 302 and USBL Tracklink positioning and attitude feeds do not flow through any buffer boxes. Current PU ZDA is 0 and current PU POS is 5. The onboard team is curious to see if eliminating the buffer boxes will mitigate some of the issues with the USBL (teleportation). 3) Current systems that can share a POS/MV COM port now share ports. There is one caveat and that is the USBL and EM 302 cannot be run at the same time. Since we do not run the EM 302 during ROV dives this should not be an issue. Also note, switching between ROV and mapping operations will require a total of 3 clicks to configure the correct POS feed.

October 09

Arrived ECS priority area. Seas were 13+ feet and winds were gusting over 40 knots. Data looked okay in the morning as we rode following seas. The ship proceeded with holding headings and speed in a favorable directions for safety of ship and crew. Data quality was poor throughout the day.

October 10

Weather cleared in the morning. Ship resumed transit lines around 0930. Data quality is excellent, and survey is adjusting for coverage. EM 302 processing is up to date.

October 11

Mapping data quality remains high and mission team is in regular communications with ECS personnel onshore.

October 12

No updates, EM 302 coverage is being shifted as needed.

October 13

Data quality is excellent. Based on input from ECS folks onshore there is minimal overlap in the outer beams between lines. This increases the potential for a holiday, but this area of seafloor is not very dynamic.

October 14

Data quality continues to be excellent. Lines are continuously being shifted based on coverage. Systems continue to operate normally. Summary products are being sent to shore for evaluation by ECS team.

October 15

During the late afternoon and evening, real-time communication with ECS personnel onshore resulted in altering the planned survey in order to acquire targeted priority data. As the EM 302 and Knudsen sub-bottom screens were being monitored onshore, line plans were adjusted until all were able to identify the change from continental slope to abyssal plain.

Survey lines were adjusted as not to re-run pre-existing EM122 multibeam data. Overall data quality is high. Data layers processed by EITs are being sent onshore for additional analysis.

October 16

Ship to shore communications continue with ECS personnel. They have requested the ship run about 100nm west of our current survey, across Priority Area 3 and then back across matching existing coverage. Products, processed by EITs, continue to be sent onshore for further planning. Systems continue to function normally.

October 17

Data quality remains high and systems continue to function normally.

Update on SIS: While completing updates to SIS SOP, one of the watch leads needed a screenshot of the Start-up Timer box with a value in it for documentation purposes. The Start-Up Timer is designed to set a specified time for the EM 302 to ramp up to full power and is located in the Runtime Parameters/Mammal Protection Mode GUI. A value was entered and while the TX strength did no update in the SIS acquisition screen (remained at 0, indicating full

power) bottom tracking was lost for several pings. SST Wilkins related this feature was tested feature a while back and could not determine if was actually changing any settings.

The upshot of all of this is updating a value within the Timer box does seem to change TX Pulse power, although this is not reflected in the acquisition screen. Mission team still would advise changing the TX Pulse power manually at time intervals instead of relying on the timer.

October 18

Data quality remains high and systems continue to operate normally.

October 19

Ship remained on ECS working grounds throughout the night and day. Data quality was poor in the morning but improved throughout the day. Ship will stay on the ECS survey area throughout the evening and overnight and break lines tomorrow.

October 20

Ship broke survey lines at 1400 and began transit to San Juan. Since mission team was able to work through the weather there will not be much time to map within PR waters. EiTs are producing summary products and maps.

October 21

Continued transit to San Juan, Puerto Rico. During transit mapping took the opportunity to target the 'Vema Knoll' features. Identified EM 302 calibration lines that can be run near San Juan. EiTs are producing summary products.

Sun photometer measurements downloaded and sent to NASA.

October 22

Transit mapping to San Juan.

October 23

A successful live interaction was completed between the EX, Atlantis and Oceans 18 MTS conference in Charleston hosted by RDML Gallaudet.

Late in the day the EM 302 just stopped pinging, Depth display in SIS went red and we could not get it back. SIS was restarted. With help from Kongsberg survey team spent the next hours

swapping boards and cycling power. Net result: swapped out 12v power supply, TX board in slot 17 (18th board) was showing Low Voltage repeatedly and followed the board to different slots during swaps –the board from slot 0 was put into slot 17 (removed the board from slot 17 altogether) and put a brand new spare TX board in slot 0. This fixed the TX Channel BIST failures. At some point in the troubleshooting External Triggering was turned on and after it was turned off, pinging resumed with a full clean BIST.

October 24

Overnight shallow calibration lines as well as continued speed/noise testing.

Arrived San Juan, Puerto Rico. Demobilization and mapping systems secured.

12. References

The 2018 NOAA Ship *Okeanos Explorer* Survey Readiness Report can be obtained at the NOAA Central Library.

The EX-18-10 Project Instructions can be obtained from the NOAA Central Library here:

<https://doi.org/10.25923/kq5w-ry25>. The EX-18-10 Data Management Plan is an appendix of the project instructions.

The EX-18-02 EK60 Calibration Report can be obtained in the NOAA Central Library here:

<https://doi.org/10.25923/6nb5-f816>

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NOAA Nautical Charts; <https://www.charts.noaa.gov/InteractiveCatalog/nrnc.shtml>, last accessed March 2020

Various datasets downloaded from the NCEI archives via NOAA Autogrid;
<https://www.ngdc.noaa.gov/maps/autogrid/>, last accessed March 2020

