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Mapping Data Acquisition and Processing Summary Report

EX-21-03: 2021 ROV Shakedown (ROV & Mapping)

U.S. East Coast (Mid Atlantic Canyons and Caryn Seamount)

Norfolk, Virginia to Newport, Rhode Island

June 13 - 27, 2021

Authors:

Shannon Hoy[1]

Other Contributors:

SST Charlie Wilkins[2]

Neah Baechler[3]

[1]Cherokee Federal, at NOAA Ocean Exploration

[2]NOAA Office of Marine and Aviation Operations

[3]University Corporation for Atmospheric Research

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NOAA Ocean Exploration

1315 East-West Highway

Silver Spring, MD 20910

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Introduction

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

Using the latest tools and technology, NOAA Ocean Exploration 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, NOAA Ocean Exploration 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, NOAA Ocean Exploration 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.

Report Purpose

The purpose of this report is to briefly describe the acoustic seafloor, water column, and sub-seafloor mapping data collection and processing methods used by NOAA Ocean Exploration on NOAA Ship *Okeanos Explorer* during the 2021 Remotely Operated Vehicle (ROV) Shakedown expedition (EX-21-03), and to present a summary of mapping results and mapping-related expedition activities. A separate report detailing the ROV activities of the expedition will be available through the NOAA Central Library.[1]

A detailed description of *Okeanos Explorer's* mapping equipment and capabilities is available in the "NOAA Ship *Okeanos Explorer* Mapping Systems Readiness Report 2021," which is archived in the NOAA Central Library.[2]

For further information about general equipment calibration procedures, data acquisition, processing, reporting, and archiving, see the "NOAA Ocean Exploration Deepwater Exploration Mapping Procedures Manual V1," which is archived in the NOAA Central Library[3] and also available from the website.[4]

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[1] https://doi.org/10.25923/6bg9-8417

[2] https://doi.org/10.25923/qbjz-m470

[3] https://doi.org/10.25923/jw71-ga98

[4] https://oceanexplorer.noaa.gov/data/publications/mapping-procedures.html

Expedition Objectives

The primary objective of EX-21-03 was to ensure the operational readiness of ROV operations onboard the *Okeanos Explorer.* In addition to engineering objectives related directly to the ROVs, objectives also included the preparedness of existing and new telepresence capabilities, and training of new personnel. Overnight operations focused on mapping using the ship's suite of sonars and mapping objectives included continuing readiness objectives from EX-21-01. While this expedition focused mainly on shakedown objectives, when possible, ROV and mapping operations occurred in priority areas for exploration and the wider science community.

Atlantic U.S. deep-sea exploration contributes to NOAA's Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE), a major multi-year, multi-national, collaborative ocean exploration campaign focused on raising our collective knowledge and understanding 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. ASPIRE will also support the National Strategy for Mapping, Exploring, and Characterizing the United States Economic Zone[5] and Seabed 2030.

The complete objectives for this expedition are detailed in "Project Instructions: EX-21-03, 2021 ROV Shakedown (ROV & Mapping)," which is archived in the NOAA Central Library.[6]

Operational Personnel

EX-21-03 included onboard personnel inclusive of the ship's force and the mission team who participated in operational execution (see **Table 1**).

[5] https://oeab.noaa.gov/wp-content/uploads/2021/01/2020-national-strategy.pdf *(last accessed 07/23/2021)*
[6] https://doi.org/10.25923/pqm9-7n61

Table 1. EX-21-03 onboard personnel.

Name	Role	Affiliation	Dates Aboard
Kasey Cantwell	Expedition Coordinator	NOAA Ocean Exploration	06/13 – 06/27
Shannon Hoy	Mapping Lead	NOAA Ocean Exploration (CNSP)[1]	06/13 – 06/27
Neah Baechler	Mapping Watch Lead	UCAR[2]	06/13 – 06/27
SST Charlie Wilkins	Senior Survey Tech	OMAO[3]	06/13 – 06/27
LT Bryan Pestone	Operations Officer	OMAO[3]	06/13 – 06/27
Matt Dornback	Expedition Coordinator (in training)	NOAA Ocean Exploration (CNSP)[1]	06/13 – 06/27
Karl McLetchie	ROV Lead	GFOE[4]	06/13 – 06/27
Fernando Aragon	Data Manager	GFOE[4]	06/13 – 06/27
Chris Wright	Data Engineer	GFOE[4]	06/13 – 06/27
Mark Durbin	Data Engineer	GFOE[4]	06/13 – 06/27
Andy Lister	Data Engineer	GFOE[4]	06/13 – 06/27
Jeff Lanning	ROV Engineer	GFOE[4]	06/13 – 06/27
Bobby Mohr	ROV Engineer	GFOE[4]	06/13 – 06/27
Anya Jenson	ROV Engineer	GFOE[4]	06/13 – 06/27
Sean Kennison	ROV Engineer	GFOE[4]	06/13 – 06/27
Lars Murphy	ROV Engineer	GFOE[4]	06/13 – 06/27
Jon Mefford	ROV Engineer	GFOE[4]	06/13 – 06/27
Brian Doros	Telepresence Engineer	GFOE[4]	06/13 – 06/27
Roland Brian	Video Engineer	GFOE[4]	06/13 – 06/27
Caitlin Bailey	Videographer	GFOE[4]	06/13 – 06/27

[1]Cherokee Federal
[2]University Corporation for Atmospheric Research
[3]NOAA Office of Marine and Aviation Operations
[4]The Global Foundation for Ocean Exploration

Summary of Mapping Operations

NOAA Ocean Exploration mapped 9,822 square kilometers (sq km) of seafloor during the 15 days at sea for EX-21-03. Of the 9,822 sq km mapped, 6,209 sq km were deeper than 200 meters (m) and within the U.S. Exclusive Economic Zone and Territorial Sea. Multibeam bathymetry data coverage is shown in **Figure 1.**

As the operational area for the majority of EX-21-03 was already well covered with bathymetric data, mapping objectives were not always primarily bathymetric focused and supported sub-bottom or water column objectives as time and weather allowed. These operations included focused sub-bottom transects of the Currituck Landslide, acoustic imaging of the upper water column while transiting the Gulf Stream, and an EK60/EK80 split beam survey at the head of Hudson Canyon. Additionally, operations conducting Underwater Cultural Heritage surveys to support the search for potential ROV dive targets and archaeological reconnaissance resulted in the discovery of the location of the scuttled Humaitá (ex-USS Muskallunge).

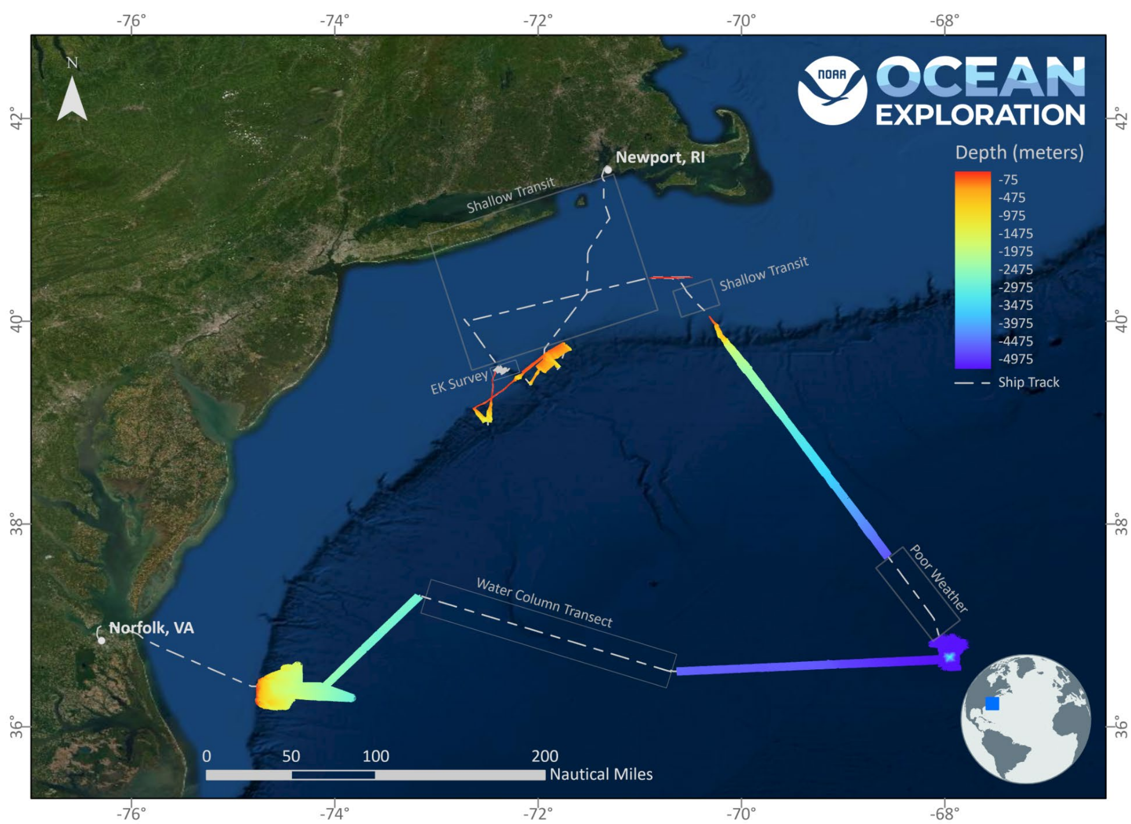

Figure 1. Overview of bathymetric mapping coverage completed during the 2021 ROV Shakedown (EX-21-03).

Mapping Statistics

Table 2 provides summary statistics of ocean mapping work during EX-21-03 June 13 - 27, 2021 (UTC).

Table 2. Summary statistics of ocean mapping work during EX-21-03.

Statistic	Value
Ship's draft*: Start of expedition (06/13/2021) End of expedition (06/27/2021)	 Fore: 16' 9.5''; Aft STBD: 15' 9"; Aft Port: 15' 7" Fore: 16' 1.5"; Aft STBD: 15' 8"; Aft Port: 15' 8"
Linear kilometers of survey with EM 304	2,403
Square kilometers mapped with EM 304	9,822
Square kilometers mapped with EM 304 within U.S. waters deeper than 200 m	6,209
Number/data volume of EM 304 raw multibeam files (.kmall)	270 files / 47.8 GB
Number/data volume of EM 304 water column multibeam files (.kmwcd)	270 files /125 GB
Number/data volume of EK60/EK80 water column split-beam files (.raw)	3,791 / 137 GB
Number/data volume of sub-bottom sonar files (.segy, .kea, .keb)	557 / 2.1 GB
Number of expendable bathythermograph (XBT) casts	76
Number of conductivity, temperature, depth profiler (CTD) casts (including test casts)	0

*Prior to EX-21-01, and as a result of the full marine survey completed during the 2020/2021 drydock, it was discovered that the draft markers on the bow are referenced to the bottom of the original hull, not the sonar blister, which is 16.5" lower than the hull bottom, requiring that a +16.5" offset be applied to the draft measurements. The measurements listed in Table 2 include the +16.5" offset.

Mapping Sonar Setup

Kongsberg EM 304 Multibeam Sonar

NOAA Ship *Okeanos Explorer* is equipped with a 26 kilohertz (kHz) Kongsberg EM 304 MKII multibeam sonar, capable of detecting the seafloor in up to 10,000 m of water and conducting productive mapping operations in up to 8,000 m of water. The nominal transmit (TX) alongtrack beamwidth is 0.5°, and the nominal receive (RX) acrosstrack beamwidth is 1.0°. The system generates a 140° beam fan (70° port/70° starboard maximum angles), containing 512 beams with up to 800 soundings per ping cycle when in high-density mode. In waters shallower than approximately 3,300 m the system is able to operate in dual-swath mode, where one nominal ping cycle includes two swaths, resulting in up to 1,600 soundings. The multibeam sonar is used to collect seafloor bathymetry, seafloor backscatter, and water column backscatter.

Simrad EK60/EK80 Split-Beam Sonars

The ship is equipped with a suite of Simrad EK60/EK80 split-beam fisheries sonars: 18 kHz (EK60), 38 kHz (EK80), 70 kHz (EK80), 120 kHz (EK60), and 200 kHz (EK60). These systems 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. In 2019, the 38 and 70 kHz transceivers were replaced with broadband units (WBTs). WBTs use frequency modulation to acquire higher resolution water column data allowing for the detection of finer features, improved depth capability without loss of range resolution, and support of broadband frequency response of targets.

These sonars were calibrated during EX-21-01, and calibration values from that expedition were applied to the EK sonars for EX-21-03 and will continue to be applied until the next calibration scheduled for early in 2022. The "2021 EK60/EK80 Calibration Report" is available in the NOAA Central Library and the calibration files are included with the dataset of each expedition to which they are relevant.[7]

Knudsen 3260 Sub-Bottom Profiler

The ship is equipped with a Knudsen 3260 sub-bottom profiler (SBP) 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

[7] https://doi.org/10.25923/v5kz-ge28

approximately 80 m below the seafloor. The sub-bottom profiler is operated to provide information about sub-seafloor stratigraphy and features.

Teledyne Acoustic Doppler Current Profilers

Two acoustic Doppler current profilers (ADCPs), a Teledyne Workhorse Mariner (300 kHz) and a Teledyne Ocean Surveyor (38 kHz), are installed on the ship. Depending on environmental conditions, the 300 kHz system provides ocean current data to approximately 70 m deep, and the 38 kHz system provides data to approximately 1,200 m deep. The 38 kHz system is capable of collecting data in narrowband and broadband frequency ranges. The ADCPs gather data prior to remotely operated vehicle (ROV) and conductivity, temperature, depth profiler (CTD) deployments in order to assess currents in support of safe operations. The ADCPs are typically not run concurrently with the other sonars during mapping operations due to issues of interference.

During EX-21-01 the 38 kHz transducer experienced temperature spikes, and at the beginning of EX-21-03, the 38 kHz ADCP permanently failed and was not operational for the duration of the expedition. The 38 kHz will not be operational until the transducer is replaced.

Data Acquisition Summary

Following departure, and once the ship reached suitable depths, data acquisition began with the EM 304, EK60/EK80 (18, 38, 70, 120, and 200 kHz), and the Knudsen 3260 sub-bottom profiler, with these sonars running concurrently using a Kongsberg Synchronization Unit (K-Sync). During ROV operations, the EM 304 multibeam and Knudsen sub-bottom profiler were secured to allow for the 300 kHz ADCP and the entire suite of EK split-beam sonars to acquire data (generally in CW mode).

Multibeam survey lines were planned to maximize edge-matching of existing bathymetric data, data gap filling in areas with existing bathymetric coverage, or to meet scientific objectives. In regions with no existing data, lines were planned to optimize potential discoveries and to complete relatively large contiguous areas to support interpretation of features from bathymetry and backscatter. As much of the operational area was already well mapped, acoustic operations were at times tailored to meet scientific and partner objectives.

Throughout the expedition, multibeam data quality was monitored in real time by acquisition watchstanders. Ship speed was adjusted to maintain data quality and sounding density as necessary, and line spacing was planned to ensure one-quarter to one-third swath-width overlap between lines, depending on the environmental conditions and impact on the quality of the outer swath regions. Angles in the SIS were generally left open (70°/70°) during transits to maximize data collection and were adjusted on both the port and starboard sides to ensure the best data quality and coverage. If outer beams were returning obviously spurious soundings (e.g., due to attenuation or low grazing angle), beam angles were gradually reduced and monitored closely until a high-quality swath was obtained.

Real-time corrections to the data upon acquisition included: continuous application of surface sound speed obtained with a hull-mounted Reson SVP-70 probe, application of water column sound speed profiles obtained with Sippican Deep Blue Expendable Bathythermographs (XBTs) and/or Seabird CTD 9/11, and application of roll, pitch, and heave motion corrections obtained with POS MV 320 version 5 inertial motion unit. No tidal corrections were applied to the raw or processed data. Sound speed profiles were conducted every four hours or more frequently as dictated by local oceanographic conditions (typically every two hours when operating near currents). Reson sound speed 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/EK80 split-beam water column sonar data were collected throughout the majority of the expedition, including during ROV dives. Any deviations from standard acquisition settings are noted in the associated Watch Log. Data were monitored in real time for quality but were not post-processed. **Figure 2** shows the EK60/EK80 data collected during EX-21-03.

Knudsen 3260 sub-bottom profiler data were also collected during the majority of the expedition. Any deviations from standard acquisition settings are noted in the associated Watch Log. **Figure 3** shows where sub-bottom data were collected during EX-21-03.

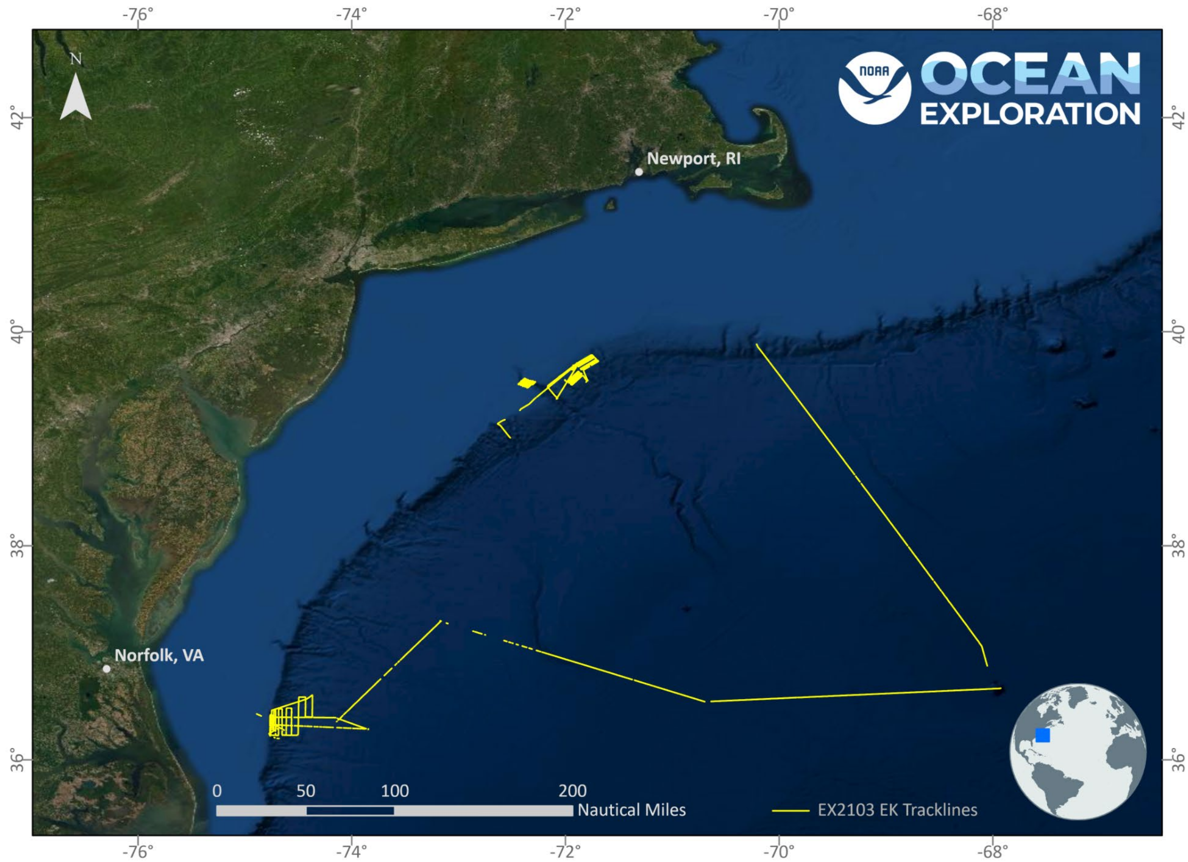

Figure 2. Simrad EK60/EK80 split-beam sonar data collection tracklines (in yellow) collected during EX-21-03.

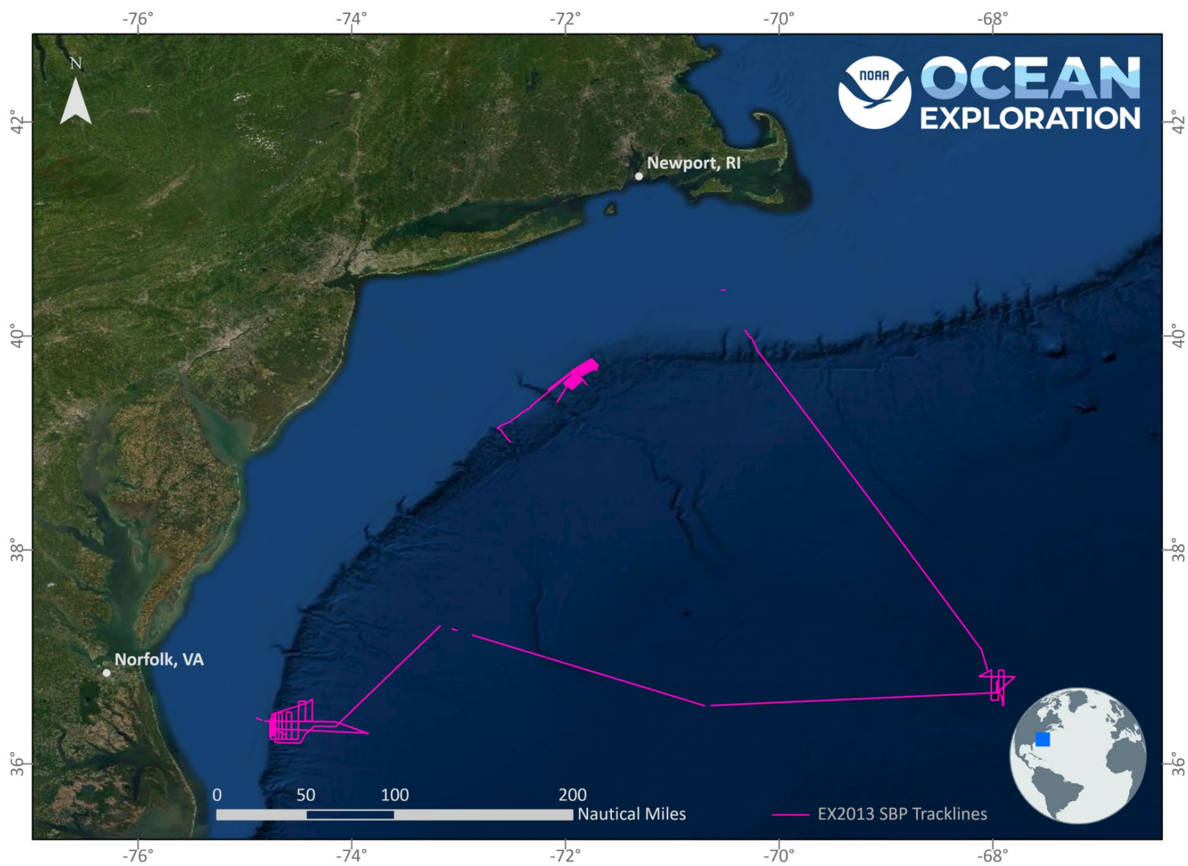

Figure 3. Sub-bottom profiler data collection tracklines (in pink) collected during EX-21-03.

Multibeam Sonar Data Quality Assessment and Data Processing

The bathymetry data were generated using a Kongsberg EM 304 MKII multibeam system, and recorded using Kongsberg's Seafloor Information System (SIS) software as *.kmall files. Collocated to the bathymetric data, bottom backscatter data were collected and stored within the *.kmall files, both as beam averaged backscatter values, and as full time series values (snippets) within each beam. Water column backscatter data were recorded separately within *.kmwcd files.

The full-resolution multibeam .kmall files (Level-00 data) were imported into QPS Qimera, and then processed and cleaned of noise and artifacts. Outlier soundings were removed using multiple methods including automatic filtering and/or manual cleaning with the swath and subset editing tools. The default sound speed scheduling method used was “Nearest-in-Time.”

If another method was implemented, it was noted in the associated log. Gridded digital terrain models were created using the weighted moving average algorithm and were exported in multiple formats using QPS Fledermaus software. **Figure 4** shows the onboard multibeam data processing workflow.

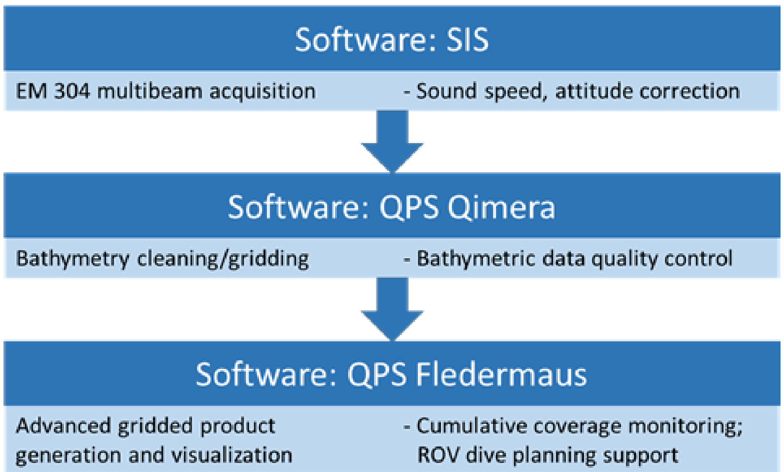

Figure 4. Shipboard multibeam data processing workflow.

The mapping lead performed a final quality check of the data using QPS Qimera and Fledermaus software. This involved additional fine cleaning of soundings and minimization of residual artifacts from sound speed biases and field-cleaning errors. Depth values were compared from orthogonal lines (crosslines) to evaluate the consistency of the multibeam sonar data collected during the expedition.

A crossline analysis was completed using the Crosscheck Tool in QPS Qimera software to evaluate the data against the Order 1 S-44 standards set by the International Hydrographic Organization (IHO, 2008).

Each line of cleaned full resolution data was exported to a *.gsf file (Level-01 data). The processed and cleaned files were used to create a static surface in QPS Qimera. This final surface was re-projected into the field geographic WGS84 reference frame in QPS Fledermaus software and saved as a *.sd file for archiving. Using QPS Fledermaus, this *.sd bathymetric grid file was then exported into ASCII XYZ text file (*.xyz), color *.tif, floating point *.tif, and Google Earth *.kmz file formats. The *.gsf files were used to create daily backscatter mosaics using QPS FMGT. All products maintain horizontal referencing to WGS84 (G1762) and vertical referencing to the assumed mean waterline. There is a complete accounting of each individually archived multibeam data file and of each bathymetric surface product in the multibeam data acquisition and processing logs archived with the dataset.

Crossline Analysis

A crossline was run on June 20, 2021, as shown in **Figure 5**, and the results are presented in **Table 3**.

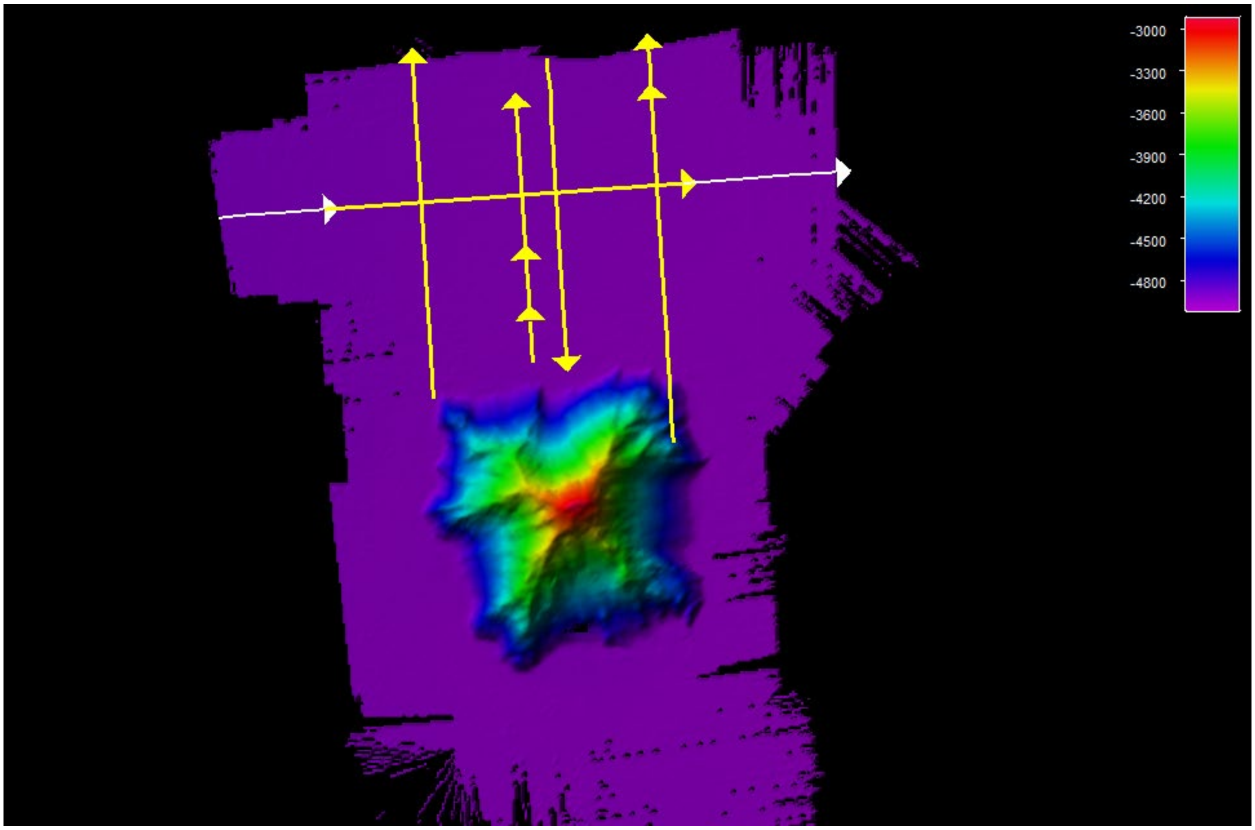

Figure 5. EX-21-03 crossline (shown in yellow) used for comparison against the bathymetric grid generated via orthogonal multibeam survey lines.

Crossline file:

0145_20210620_065037_EX2103_MB.kmall

Mainscheme line files:

0131_20210619_232940_EX2103_MB.kmall

0132_20210620_002940_EX2103_MB.kmall

0136_20210620_010249_EX2103_MB.kmall

0141_20210620_043145_EX2103_MB.kmall

0152_20210620_104824_EX2103_MB.kmall

0153_20210620_105656_EX2103_MB.kmall

0154_20210620_110934_EX2103_MB.kmall

Table 3. Crosscheck results.

Statistic	Value
Number of points of comparison	1,057,869
Grid cell size (m)	100
Difference mean (m)	0.158
Difference median (m)	0.367
Difference standard deviation (m)	4.459
Difference range (m)	[-55.23, 109.61]
Mean + 2* standard deviation (m)	9.075
Median + 2* standard deviation (m)	9.284
Data mean (m)	-4926.641
Reference mean (m)	-4926.799
Data z-range (m)	[-4989.55, -3558.98]
Reference z-range (m)	[-4963.78, -3572.23]
Order 1 error limit (m)	64.0503
Order 1 # rejected	4
Order 1 p-statistic	0.000004
Order 1 survey	ACCEPTED

These results confirm that the data collected meet International Hydrographic Organization Order 1 specifications for data quality.

Acquisition and Processing Software

Table 4 provides a list of the acquisition and processing software versions that were used during EX-21-03.

Table 4. Versions of acquisition and processing software used during EX-21-03.

Software	Purpose	Version
SIS	EM 304	5.6.0 1.5.3
EK80	EK suite	*06/13 -06/22:* 2.0.0 *06/22 -06/27:* 2.0.1
EchoControl	Knudsen	4.09
UHDAS	ADCPs	14.04
AMVERSEAS	Autolaunch XBT	9.3
WinMK21	XBT	3.0.2
K-Sync	Synchronization	1.9.0
Qimera	Bathymetry	2.3.5
FMGT	Backscatter	7.9.6
FMMidwater	Water Column	7.9.3
Sound Speed Manager	Sound Velocity Profiles	2021.1.7
NRCan (SegJp2)	Sub-bottom	1.0
Fledermaus 7	Visualization/Data Analysis	7.8.11

Data Archiving Procedures

All mapping data collected by NOAA Ocean Exploration on *Okeanos Explorer* are archived and publicly available within 90 days of the end of each expedition 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 expedition) is available as an appendix in the "Project Instructions: EX-21-03, 2021 ROV Shakedown (ROV & Mapping)," which is archived in the NOAA Central Library. For each data type, raw data (Level 00), processed data (Level 01), derived products (Level 02), and ancillary files may be available, depending on the dataset and the level of staffing for the expedition. **Tables 5-9** describe the data archived for each dataset. For further information about proprietary software and freeware that can handle the varying data types, refer to the "NOAA OER Deepwater Exploration Mapping Procedures Manual."

Table 5. EM 304 bathymetry and seabed backscatter dataset.

Level	Description	File Type
Level 00	Raw multibeam files (in native sonar format) that include both raw bathymetry and backscatter (horizontal referencing = WGS84)	.kmall
Level 01	Processed multibeam files in generic sensor format that include bathymetry and backscatter (horizontal referencing = WGS84)	.gsf
Level 02	Gridded multibeam data and backscatter mosaics (horizontal referencing = WGS84)	.xyz, .tif, .tif (floating point GeoTIFF, .kmz, .sd, .scene
Ancillary files	Mapping watchstander log, weather log, sound speed profile log, multibeam acquisition and processing log, backscatter correction file, built-in self test logs, processing unit parameters, telnet session records	.xlsm, .xlsx, .txt

Table 6. EM 304 water column backscatter dataset.

Level	Description	File Type
Level 00	Raw multibeam files (in native sonar format) that include water column backscatter (horizontal referencing = WGS84)	.kmwcd
Level 01	n/a	n/a
Level 02	QPS Fledermaus objects such as beam fan, beam line, volume and/or track line; produced if time and staffing allows (horizontal referencing = WGS84)	.sd, .scene
Ancillary files	Mapping watchstander log, weather log, sound speed profile log, multibeam acquisition and processing log, water column data log, built-in self test logs, processing unit parameters, recorded telnet sessions	.xlsm, .xlsx, .txt

Table 7. EK60/EK80 split-beam echosounder dataset.

Level	Description	File Type
Level 00	Raw water column files provided in native sensor format (horizontal referencing = WGS84)	.raw, .idx
Level 01	n/a	n/a
Level 02	n/a	n/a
Ancillary files	Mapping watchstander log, weather log, EK data log, EK calibration report, calibration files and the raw files used for calibration	.xlsm, .xlsx, .txt, .pdf, .xml, .raw, .idx

Table 8. Knudsen 3260 sub-bottom profiler dataset.

Level	Description	File Type
Level 00	Raw sub-bottom files provided in native sonar format (horizontal referencing = WGS84)	.sgy, .kea, .keb
Level 01	Raw sub-bottom files converted to images and shapefiles of the tracklines; produced as time and staffing levels allow	.jpg, .shp
Level 02	n/a	n/a
Ancillary files	Mapping watchstander log, weather log, sub-bottom profiler data log	.xlsm, .xlsx

Table 9. Sound speed profiles dataset.

Level	Description	File Type
Level 00	Raw profile data for any XBT or CTD cast	.txt, .hex, .cnv
Level 01	Processed sound speed profiles created for multibeam data acquisition	.asvp
Level 02	n/a	n/a
Ancillary Files	Mapping watchstander log, sound speed profile log, profile locations as a shapefile and in Google Earth format, any associated calibration files	.xlsm, .xlsx, .shp, .kml, .cal, .xml, .pdf

All sonar data are permanently discoverable within the NCEI archives[8] and searchable through the Ocean Exploration Digital Atlas,[9] which provides access to all of the data collected during an expedition. The locations for specific data types (at the time of writing this report) are detailed in **Table 10**. For any challenges accessing data, send an inquiry to NCEI,[10] or contact the Ocean Exploration Mapping Team.[11]

Table 10. Locations of data collected during EX-21-03 (at the time of writing this report).

Data Type	Description	Location
EM 304 bathymetry and backscatter data	EM 304 bathymetric and backscatter data, supporting informational logs, and ancillary files are available through the NCEI Bathymetry Data Viewer	https://maps.ngdc.noaa.gov/viewers/bathymetry/
Water column data (EM 304 and EK60/EK80)	EM 304 and EK60/EK80 water column data, supporting data, and informational logs are available through the NCEI Water Column Sonar Data Viewer	https://www.ngdc.noaa.gov/maps/water_column_sonar/index.html
Knudsen 3260 sub-bottom profiler data	Sub-bottom data, supporting data, and informational logs are available in the NCEI data archives	May be requested directly from NCEI: https://www.ncei.noaa.gov/ National Centers for Environmental Information (NCEI) E/NE42 325 Broadway Boulder, Colorado USA 80305 ncei.info@noaa.gov (828) 271-4800

8 https://www.ngdc.noaa.gov/
9 https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm
10 ncei.info@noaa.gov
11 oar.oer.exmappingteam@noaa.gov

Data Type	Description	Location
Sound speed profiles	Ancillary sound speed profiles are available along with all mapping data per expedition in the NCEI data archives, or within the oceanographic archive for the expedition.	https://maps.ngdc.noaa.gov/viewers/bathymetry/ or through the oceanographic archives at: https://www.ncei.noaa.gov/
Reports	Reports are archived in the NOAA Central Library's Ocean Exploration Program (OEP) institutional repository	NOAA Central Library home: https://library.noaa.gov/ OEP institutional repository: https://repository.library.noaa.gov/cbrowse?pid=noaa%3A4&parentId=noaa%3A4

Expedition Schedule

Table 11. EX-21-03 schedule.

Date (UTC)	Activity
06/11	Mission personnel joined the ship in Norfolk, VA. Mapping mobilization began.
06/12	Mobilization continued.
06/13	Departed Norfolk, VA. Overnight mapping included sub-bottom transect of Currituck Landslide.
06/14	USBL Calibration. Overnight mapping of Currituck Landslide.
06/15	Dive 1. Overnight mapping of Currituck Landslide.
06/16	Dive 2 and 3. Overnight mapping of Currituck Landslide.
06/17	Dive 4. Overnight transit mapping.
06/18	Dive 5. Acoustic water column imaging of Gulf Stream.
06/19	Dive 6. Overnight transit mapping.
06/20	Overnight mapping of Caryn Seamount and crossline. Following the mapping of Caryn Seamount, the seas deteriorated and phase data was collected for diagnostic objectives. We then transited to sheltered waters.
06/21	Shallow mapping (~ 80 m) while sheltering from weather and transiting.

Date (UTC)	Activity
06/22	Dive 7. Overnight transit mapping.
06/23	Dive 8. Overnight EK mapping of Hudson Canyon.
06/24	Dive 9. Overnight mapping.
06/25	Dive 10. Overnight mapping.
06/26	Dive 11. Overnight mapping.
06/27	Arrived in Newport, RI.

References

Copeland, A. 2021. 2021 EK60/80 Calibration Report. Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://doi.org/10.25923/v5kz-ge28

Lobecker, M., Hoy, S., Sowers, D., Copeland, A., Jerram, K., Wilkins, C., Heffron, E., and Candio, S. 2021. 2021 NOAA Ship Okeanos Explorer Mapping Systems Readiness Report. Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://doi.org/10.25923/qbjz-m470

Hoy, S., Lobecker, E., Candio, S., Sowers, D., Froelich, G., Jerram, K., Medley, R., Malik, M., Copeland, A., Cantwell, K., Wilkins, C., and Maxon, A. 2020. Deepwater Exploration Mapping Procedures Manual. Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://doi.org/10.25923/jw71-ga98

Cantwell, K., and Dornback, M. 2021. Project Instructions: EX-21-03, 2021 ROV Shakedown (ROV and Mapping). NOAA Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://doi.org/10.25923/pqm9-7n61

Dornback, M., Cantwell, K., Hoy, S., and Bowman, A. 2021. Project Instructions: EX-21-03, 2021 ROV Shakedown (ROV and Mapping). NOAA Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://doi.org/10.25923/pqm9-7n61

International Hydrographic Organization. 2008. IHO Standards for Hydrographic Surveys, 5th edition, February 2008. Monaco, International Hydrographic Bureau, 28pp. (International Hydrographic Organization Special Publication, S-44). http://hdl.handle.net/11329/388

Jerram, K., Hoy, S., and Candio, S. 2021. NOAA Ship Okeanos Explorer EX-21-01 EM 304 MKII Sea Acceptance Testing. Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://doi.org/10.25923/5fm9-0f17

Sowers, D. 2021. NOAA Ship *Okeanos Explorer* FY21 Field Season Instructions. Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://doi.org/10.25923/83ze-r686

Appendix A: Daily Log Entries

The following entries were excerpted from each of the daily expedition situation reports provided by the onboard team to the onshore support team, and therefore are somewhat informal in language. These are included to provide situational awareness for future users of the data collected during this expedition. All times are in local ship time (-4 hours from UTC).

June 11

Mission personnel joined the vessel in Norfolk, VA and mapping mobilization began.

SIS was updated to the newest version, a new calibration file provided by Kongsberg was added to the processing unit (PU), and the TX firmware was updated. Following the update a complete series of built-in-systems-tests (BISTs) were run, and all completed successfully.

The Hypack project was created for the first dives in WGS84 UTM18N.

June 12

Mobilization continued today. The mapping lead prepared for upcoming operations by setting up ArcPro, Hypack, and Fledermaus projects. The first set of navigation products were produced for the USBL Calibration. The first line plan was also created and provided to the bridge.

New acquisition projects were set up for each sonar. A complete series of BISTs were run for the EM 304 and all tests passed. A successful ping test was conducted for the EM 304 and EKs.

The Sun Photometer was tested to ensure that data could be acquired and downloaded successfully.

The “Mapping Lead Roles and Responsibilities on ROV Expeditions” and “Sun Photometer” standard operating procedures (SOPs) were updated.

June 13

Once we reached deeper waters (~ 50 m), all sonar systems were powered up. Initially, Sound Speed Manager was unable to receive data from SIS, and this was found to be caused by Data Distribution not carrying over port information post update. Entering the correct parameters for Data Distribution within SIS fixed the connection.

Sound Speed Manager, Qimera, Fledermaus, and FMGT were updated to the latest versions.

Mapping lines were designed to collect sub-bottom data on the Currituck landslide. All mapping systems are performing as expected.

June 14

Overnight we performed a sub-bottom transect over the Currituck landslide. The sound speed environment is highly dynamic (changing 15 - 17 m/s over 20 minutes), significantly impacting multibeam data quality. XBT casts were at times deployed at one hour intervals, which was still not frequent enough to adequately capture the conditions. Watchstanders are working on processing efforts to mitigate the impacts to data quality.

We again witnessed the sustained POS outage during overnight mapping. We are in communication with Applanix, Kongsberg and other vessels within the NOAA fleet that are experiencing concurrent outages. In addition to the sustained outage, we are observing missed pings at irregular intervals, seemingly associated with the following heading error in the Telnet log:

decodeATT: Input error: Att sensor: roll = -341, pitch = 72, heave = 87, heading = 36000

While frustrating, one ping every now and again does not significantly impact the quality of data.

This behavior was witnessed during both EX2101 and EX2102.

During turns, SIS sometimes displays a “MWC lost” warning. We are unsure of what this is in reference to (and cannot find mention of it in the manual). We have contacted Kongsberg for more information.

Both the WH300 and the OS38 ADCPs are functioning at this time to support ROV operations.

June 15

Overnight mapping focused on the Currituck landslide. Both KMALLs and KMWCDs are being sent to shore (not typically done during ROV expeditions). As of now, it seems like this will be achievable during ROV expeditions going forward, though we will continue monitoring throughout the shakedown expedition.

Following the ROV dive we were unable to get SIS and SSM to communicate, even after restarting the software, computers, and the EM304 processing unit. We will power down the PU during tomorrow ROV’s dive to see if a connection can be made once mapping operations resume.

Ethernet logging of POS data seems to stop logging randomly and with no apparent cause. Watchstanders are diligently monitoring the logging status to ensure minimal data is lost.

Investigation continues of missed pings in the EM304.

The OS 38 ADCP has permanently failed and will not be available until replaced during the next drydock.

June 16

Overnight mapping continued adding coverage on the previously mapped Currituck landslide. Due to the nature of the dynamic sound speed environment, the 'nearest in distance' sound speed scheduling method has been most effective for mitigating the impacts on data quality.

Iterative testing was performed with the EKs, EM 304, and K-Sync, to isolate and identify the cause of the apparent 'missed pings.' Testing showed that these are caused by an irregular and random long ping of the EKs, causing the EM 304 to also have an abnormally long ping as they are synchronized. These long pings seem to occur regardless of depth, though more frequent when shallow, and occurred regardless of EK ping mode. We also tested if this was caused by the newly installed 38 kHz by putting the 38 kHz in passive mode, and no change was observed. It seems most plausible that this is caused by the newly installed (as of EX2101) EK80 software (v 2.0.0). The mapping lead will reach out to Kongsberg for a new software update and/or further guidance.

June 17

Overnight we transited to Dive 04. Numerous spurious outlier soundings in the outer swath were observed in the deep transit data, similar to the data collected during EX2000. As this behavior was absent on the deep transit during EX2101, we expect this to be caused by the new SIS update or the new calibration file added to the processing unit. The mapping lead contacted Kongsberg and will monitor as we transit deeper.

The EKs crashed during the night and took multiple reboots for all transceivers to successfully connect to the software.

June 18

Overnight mapping focused on acoustic imaging of the upper water column while transecting the Gulf Stream. The EM 304 collected data in "Sonar Mode," and no bathymetry was collected, and the EKs were collected in wideband mode (38 and 70 kHz). In support of a science request, we attempted to collect "Complex Samples" of the EK data, however the software would immediately crash. All of the issues with the EKs point to an issue with the new software version, and the Mapping Lead is requesting an update from Kongsberg.

After switching from ROV to mapping operations, high frequency interference was apparent in the EK 38 and 70 kHz data. This turned out to be the Bridge's speed log, which was powered off but not secured at the breaker. We have added to our checks to ensure that the speed log is secured at the breaker before starting mapping operations.

June 19

Overnight we transit mapped on the way to Caryn Seamount. Watch leads focused on catching up on daily products.

Prior to the dive, we attempted to get the Live Vehicle tracking set up. We could connect to the data streams, but could only see data populating for the Ship's location. The GFOE data team is investigating further.

June 20

The overnight survey was planned to increase the resolution of data of Caryn Seamount and improve on the 2015 survey. Unfortunately, the weather deteriorated and data quality was affected. The mapping team has observed that bringing the angles in by 1 degree less than what the sonar is achieving, improves sonar performance. The summit of the seamount is about 3300 m, right at the Very Deep / Deeper transition. The sonar struggled switching between the two automatically and was forced into Very Deep mode.

The EKs were secured throughout overnight mapping to ensure that the irregular and random long ping issue with the EKs did not affect the planned survey.

When beginning the survey, the PU - ZDA and PU - POS times were approximately 1000 milliseconds (ms) off, indicating that the internal PU clock drifted during the day's dive. After restarting the PU the difference was approximately 1 ms. The mapping team will monitor throughout the rest of the expedition.

Following the survey, we had two extra hours to map before heading to shore. We used this time to collect EM 304 Phase data with and against the seas for Kongsberg. They are interested in this data to improve sonar performance in poor conditions.

June 21

The weather deteriorated as we transited to shore. The EM 304 was secured during the worst conditions.

Less intense POS dropouts were observed early in the morning by the watchstanders. Data was lost for a second and quickly returned. The event ended after a few minutes.

Multibeam data was collected in a shallow priority area (~80 m) to support an opportunistic USGS objective while sheltering from the storm.

June 22

Overnight transit occurred in less than 50 m water depth and no acoustic data was collected.

During Dive 07, the EK80 software was updated to the newest version (2.0.1). Hopefully this improves the issues previously seen during this expedition.

June 23

An EK survey was conducted over Hudson Canyon to acoustically image the deep scattering layer and diurnal migration. The updated software (2.0.1) is operational when collecting Complex Samples - an improvement from 2.0.0.

Following the survey we mapped while transiting to Dive 08.

June 24

Overnight the mapping team searched for the USS Snowden. No target was identified. No missed pings were witnessed in the shallow survey, indicating that the new EK80 software update fixed the previously seen issue.

When switching from ROV to mapping operations, the EK ping interval was longer than the multibeam echosounder's. No operation on the EKs was able to change the ping interval. After restarting the EK80 software everything was fully functional. Following the dive, EK data was collected in WBT mode for an hour to support a partner objective.

June 25

The overnight survey was designed to locate a potential shipwreck target, the Humaitá (ex-USS Muskallunge). A potential target was identified in the bathymetry, approximately 1000 m from the location provided by Naval History and Heritage Command, and further supported by corresponding high backscatter returns and consistent dimensions.

The mapping lead facilitated shore side scientists' participation in the midwater portion of the dive.

June 26

Another POS thrashing event occurred. This event occurred concurrently with other vessels across the NOAA fleet. The ship performed dynamic maneuvers, as suggested by Applanix, and the thrashing event ended. This could be coincidental and should continue to be tested. Data was provided to the University of Hawaii ADCP team (UHDAS) who has been tracking the issue across the fleet, and to Applanix for further troubleshooting.

The EKs have been randomly freezing, needing a restart of the EK80 software. A consistent ping interval that is not able to be changed typically precursors a crash.

The Qimera project has been crashing. A new version was released and will be updated prior to EX-21-04.

June 27

End of expedition, arrival in Newport, Rhode Island. The mapping team finalized the data package and the mapping data report.