doi:10.25923/sx56-q987

Mapping Data Acquisition and Processing Summary Report

EX-21-07, Windows to the Deep 2021: Southeast U.S. ROV and Mapping

U.S. East Coast

Charleston, South Carolina — Port Canaveral, Florida

October 26 - November 15, 2021

Authors: Derek Sowers[1], Sam Candio[1], Charlie Wilkins[2], and Treyson Gillespie[3]

[1] NOAA Ocean Exploration and Research

[2] NOAA Office of Marine and Aviation Operations

[3] University Corporation for Atmospheric Research

October 11, 2022

NOAA Ocean Exploration

1315 East-West Highway

Silver Spring, MD 20910

Table of Contents

Introduction

NOAA Ocean Exploration is dedicated to exploring the unknown ocean, unlocking its potential through scientific discovery, technological advancements, and data delivery. By working closely with partners across public, private, and academic sectors, we are filling gaps in our basic understanding of the marine environment. This allows us, collectively, to protect ocean health, sustainably manage our marine resources, accelerate our national economy, better understand our changing environment, and enhance appreciation of the importance of the ocean in our everyday lives.

With priority placed on exploration of deep waters and the waters of the U.S. Exclusive Economic Zone, NOAA Ocean Exploration applies the latest tools and technologies to explore previously unknown areas of the ocean, making discoveries of scientific, economic, and cultural value. By making collected data publicly available in increasingly innovative and accessible ways, we provide a unique and centralized national resource of critical ocean information. And, through live exploration video, online resources, training and educational opportunities, and public events, we share the excitement of ocean exploration with people around the world and inspire and engage the next generation of ocean scientists, engineers, and leaders.

Report Purpose

The purpose of this report is to briefly describe the acoustic seafloor, water column, and subseafloor mapping data collection and processing methods used by NOAA Ocean Exploration on NOAA Ship *Okeanos Explorer* during the Windows to the Deep 2021: Southeast U.S. ROV and Mapping expedition, EX-21-07, and to present a summary of mapping results and mapping-related expedition activities. A separate report, titled "Expedition Report: EX2107 Windows to the Deep 2021 (ROV and Mapping)[1]," detailing the remotely operated vehicle activities of the expedition is available through the NOAA Central Library.

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

[1] doi:10.25923/gap8-sp59

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

Mapping Procedures Manual V1," which is archived in the NOAA Central Library[3] and also available from the website.[4]

Expedition Objectives

The Windows to the Deep 2021: Southeast U.S. ROV and Mapping expedition was a combined mapping and remotely operated vehicle (ROV) telepresence-enabled expedition that departed from Charleston, South Carolina on October 26, 2021 and returned to Port Canaveral, Florida on November 15, 2021, for a total of 21 days at sea. The primary objective of this expedition was to collect critical information of deepwater areas in the Blake Plateau region within both the U.S. Exclusive Economic Zone (EEZ) and international waters. Additional mapping objectives were to test the newly installed Ocean Surveyor (OS)38 kilohertz (kHz) acoustic Doppler current profiler (ADCP), conduct a patch test of the EM 304 multibeam sonar to ensure no changes in the sonar suite geometry were introduced during the drydock, and to collect data to effectively plan ROV dives for both scientific objectives and safe navigation, and to map deepwater areas containing no or poor quality bathymetry data.

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-21-07, Windows to the Deep 2021: Southeast US ROV and Mapping (ROV and Mapping)" which is archived in the NOAA Central Library.[6]

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

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

[5] https://www.noaa.gov/nomec

[6] https://doi.org/10.25923/9hvv-we20

Operational Personnel

EX-21-07 included onboard operational personnel, inclusive of ship's force and mission team, who participated in operational execution (see **Table 1**).

Table 1. EX-21-07 Onboard personnel.

Name	Role	Affiliation	Dates Aboard
Matt Dornback	Expedition Coordinator	NOAA Ocean Exploration (CNSP)[1]	10/25 - 11/17
Derek Sowers	Mapping Lead	NOAA Ocean Exploration (CNSP)[1]	10/25 - 11/15
Allen Collins	Science Lead	NOAA Fisheries[2]	10/25 - 11/16
Stephanie Farrington	Science Lead	UCAR[3]	10/25 - 11/16
Sam Candio	Mapping Watch Lead	UCAR[3]	10/25 - 11/15
Treyson Gillespie	Mapping Watch Lead	UCAR[3]	10/25 - 11/15
SST Charlie Wilkins	Senior Survey Tech	OMAO[4]	10/25 - Staying on
LT Bryan Pestone	Operations Officer	OMAO[4]	10/25 - Staying on
Chris Ritter	ROV Team Lead	GFOE[5]	10/25 - 11/17
Fernando Aragon	Data Manager	GFOE[5]	10/25 - 11/17
Chris Wright	Data Engineer	GFOE[5]	10/25 - 11/17
Jim Meyers	ROV Engineer	GFOE[5]	10/25 - 11/17
Levi Unema	ROV Engineer	GFOE[5]	10/25 - 11/17
Jeff Laning	ROV Engineer	GFOE[5]	10/25 - 11/17
Sean Kennison	ROV Engineer	GFOE[5]	10/25 - 11/17
Andy O'Brien	Data Manager	GFOE[5]	10/25 - 11/17
Lars Murphy	ROV Engineer	GFOE[5]	10/25 - 11/17
Art Howard	Videographer	GFOE[5]	10/25 - 11/16
Caitlin Bailey	Videographer	GFOE[5]	10/25 - 11/16
Emily Narrow	Videographer	GFOE[5]	10/25 - 11/16
Roland Brian	Videographer	GFOE[5]	10/25 - 11/16

[1] Cherokee Nation Strategic Programs
[2] NOAA National Marine Fisheries Service
[3] University Corporation for Atmospheric Research
[4] NOAA Office of Marine and Aviation Operations
[5] The Global Foundation for Ocean Exploration

Summary of Mapping Operations

NOAA Ocean Exploration mapped 15,800 square kilometers (sq km) of seafloor during the 21 days at sea for EX-21-07. Of the 15,800 sq km mapped, 13,600 sq km were deeper than 200 m within the U.S. Exclusive Economic Zone and Territorial Sea. Multibeam bathymetry data coverage is shown in **Figure 1.**

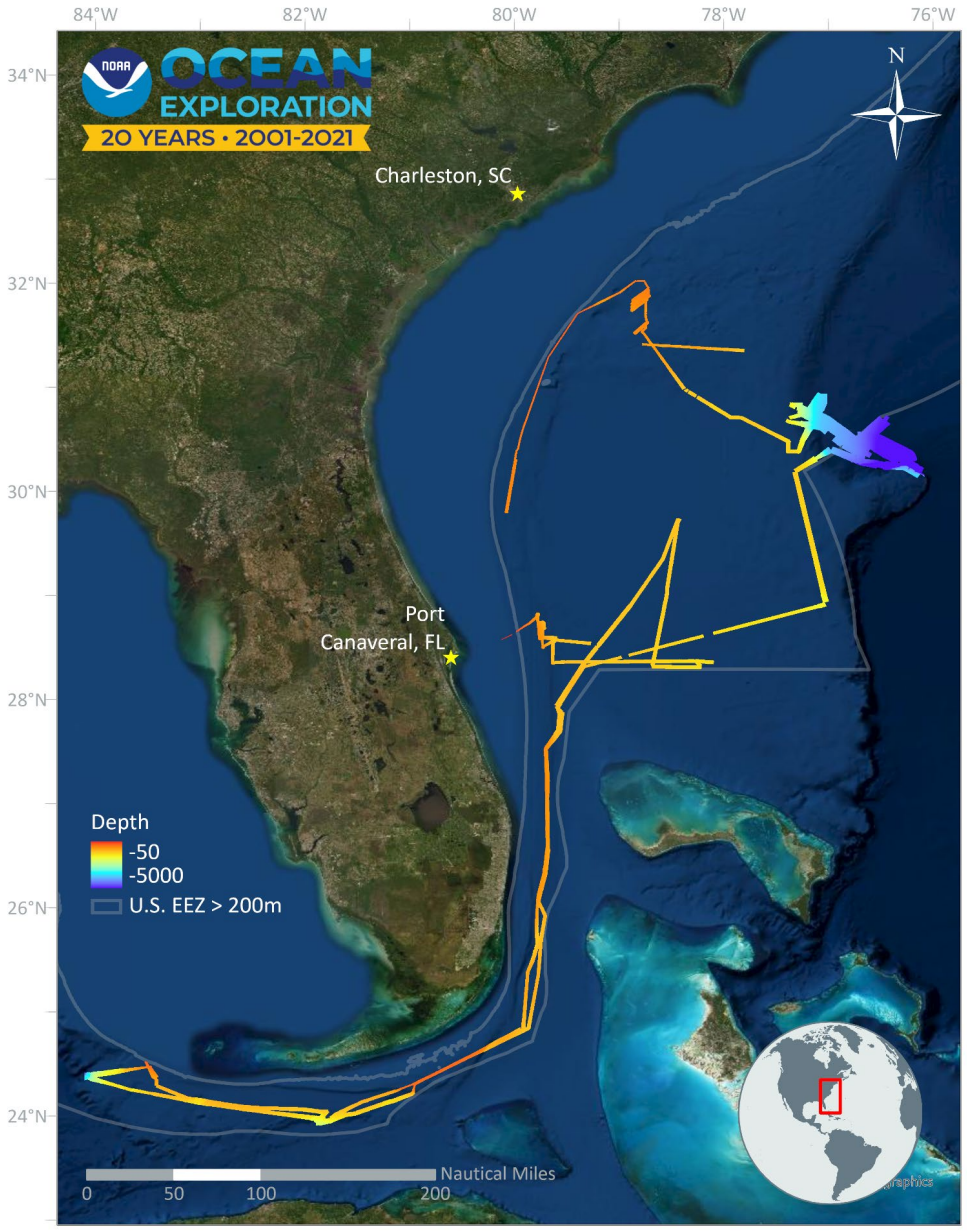

Figure 1. Overview of bathymetric mapping coverage completed during Windows to the Deep 2021: Southeast U.S. ROV and Mapping (EX-21-07).

Mapping Statistics

Table 2 provides summary statistics of ocean mapping work during EX-21-07 from October 26 - November 15, 2021 (UTC).

Table 2. Summary statistics of ocean mapping work during EX-21-07.

Statistic	Value
Ship's draft*: Start of expedition (10/26/2021) End of expedition (11/15/2021)	Fore: 16' 5.5''; Aft STBD: 15' 8.5"; Aft Port: 15' 7 Fore: 15' 8.5"; Aft STBD: 15' 10"; Aft Port: 15' 10.5
Linear kilometers of survey with EM 304	2,001
Square kilometers mapped with EM 304	15,800
Square kilometers mapped with EM 304 within U.S. waters deeper than 200 m	13,600
Number/data volume of EM 304 raw multibeam files (.kmall)	452 files/83.5 GB
Number/data volume of EM 304 water column multibeam files (.kmwcd)	451 files/247 GB
Number/data volume of EK60/EK80 water column split-beam files (.raw)	1,277/158 GB
Number/data volume of sub-bottom sonar files (.segy, .kea, .keb)	740/158 GB
Number of expendable bathythermograph (XBT) casts	127
Number of conductivity, temperature, depth profiler (CTD) casts (including test casts)	1

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

Mapping Sonar Setup

Kongsberg EM 304 Multibeam Sonar

NOAA Ship *Okeanos Explorer* is equipped with a 26 kHz Kongsberg EM 304 MKII multibeam sonar, capable of detecting the seafloor in up to 10,000 mof 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-21-07 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] An emergency dry dock occurred just prior to EX-21-07, and there was not time to do new EK sonar calibrations following the dry dock period. This potentially renders the calibration values used during EX-21-07 as incorrect, and users may therefore opt to consider these data as uncalibrated.

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

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

Teledyne Acoustic Doppler Current Profilers

Two 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.

Data Acquisition Summary

Following port departure, data are typically collected with the ADCPs until the sea buoy is reached, at which point the ADCPs are secured. Then, data acquisition begins 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 CTD and ROV operations, the EM 304 multibeam and Knudsen sub-bottom profiler are secured to allow for the ADCPs and the entire suite of EK split-beam sonars to acquire data.

Multibeam survey lines are planned to maximize either edge-matching of existing bathymetric data or data gap filling in areas with existing bathymetric coverage. In regions with no existing data, lines are optimized for potential discoveries and to complete relatively large contiguous areas to support interpretation of features from bathymetry and backscatter. Most of the mapping time available during the expedition was during overnight transits between widely spaced ROV dive locations. However, dive cancellations due to poor conditions provided time to complete some larger surveys to fill gaps in existing multibeam sonar data coverage. Apart from a very small remaining gap, this expedition was successful at filling the small gaps left in multibeam coverage over the Blake Plateau. The vast majority of multibeam coverage on the Blake Plateau was completed by NOAA Ocean Exploration using NOAA Ship *Okeanos Explorer* over a series of missions beginning in 2012.

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 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 SV-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.

Just prior to the start of this expedition, the ship had completed a drydock repair period to address issues with the bow thruster and to repair the OS38 ADCP. Since this was the first expedition following the drydock, a multibeam calibration patch test was deemed necessary to account for any significant changes in the multibeam sonar angular offset values. A CTD cast was completed by the Senior Survey Technician and applied to the multibeam. An XBT cast was also completed, and the two datasets agreed closely, confirming good measurements by both systems as well as a stable sound speed environment for the multibeam patch test calibration (**Figure 2**).

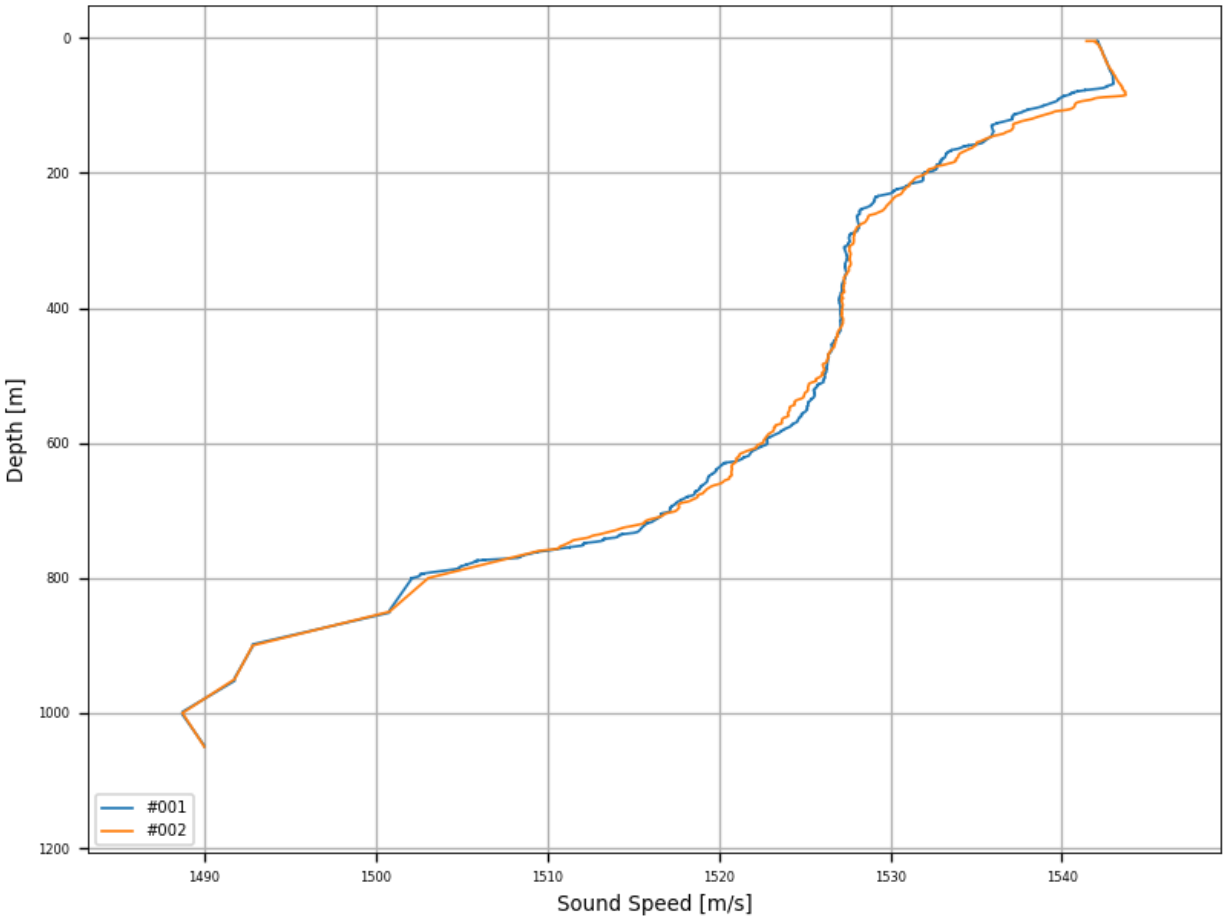

Figure 2. Plot of CTD cast derived sound speed profile (blue) versus XBT-derived sound speed profile (yellow).

The multibeam patch test was completed during the evening of October 27 in the vicinity of the first ROV dive (31.209 N, 77.854 W). See **Figure 3.** for an overview of the patch test site bathymetry and testing line orientation.

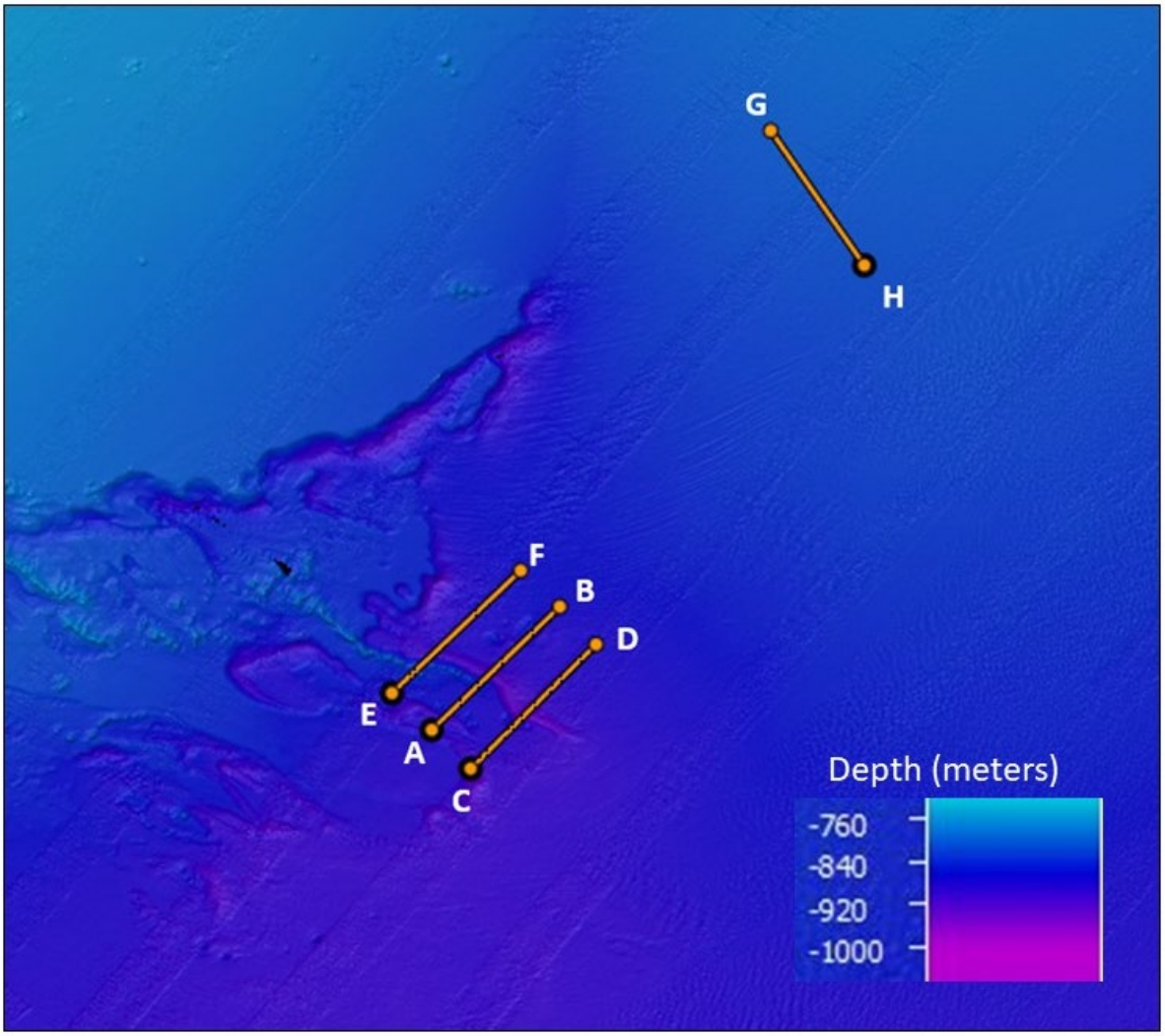

Figure 3. Multibeam sonar patch test calibration site and data logging lines. The site was selected for the distinct linear cold water coral mound features and adjacent depressions that provided slopes suitable for pitch and heading tests (lines A-B, C-D, and E-F). A nearby flat area was utilized for roll calibration lines (G-H).

The patch test consisted of 6 lines. The pitch line (A to B) and roll line (G to H) were completed two times total in reciprocal directions. The heading lines (C to D and E to F) were completed once each and in the same direction as each other. **Table 3** below specifies each line and the order in which they were logged for the patch test. Each line was about 4500 m in length.

Table 3. Multibeam sonar survey lines for patch test calibration.

Line #	Directions	Purpose	Speed	MB Line Name (fill in when logging data)
1	A to B	Pitch	6.5 knots	0000_20211027_224240_EX2107_MB.kmall
2	B to A	Pitch	6.5 knots	0001_20211027_232302_EX2107_MB.kmall
3	C to D	Heading	6.5 knots	0002_20211027_235928_EX2107_MB.kmall
4	E to F	Heading	6.5 knots	0003_20211028_004812_EX2107_MB.kmall
5	G to H	Roll	6.5 knots	0004_20211028_020005_EX2107_MB.kmall
6	H to G	Roll	6.5 knots	0005_20211028_023001_EX2107_MB.kmall

Very minor possible adjustments to angular offsets were calculated as a result of the patch test analysis: -0.03 for pitch, -0.05 for heading, and -0.04 for roll. The offshore mapping team decided to hold off on applying these very minor changes to see if there would be an opportunity to conduct a deep water patch test later in the cruise near the Blake Spur to provide more confidence in the results. However, rough sea conditions ultimately made the deep water patch test infeasible. Therefore, the initial patch test results were not applied to the data collected during the cruise. A new thorough patch test will be conducted during the shakedown expedition in 2022.

Simrad EK60/EK80 split-beam water column sonar data were collected throughout the majority of the expedition, including during ROV dives. Data were monitored in real time for quality but were not post-processed. **Figure 4** shows the EK60/EK80 data collected during EX-21-07.

Figure 4. Simrad EK60/EK80 split-beam sonar data collection tracklines (in white) collected during EX-21-07.

Knudsen 3260 sub-bottom profiler data were also collected during the majority of the expedition. **Figure 5** shows where sub-bottom data were collected during EX-21-07.

Figure 5. Sub-bottom profiler data collection tracklines (in green) collected during EX-21-07.

Multibeam Sonar Bathymetric Data Processing and Quality Assessment

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 will be 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. Daily bathymetric surfaces were created and sent to shore. **Figure 6** shows the onboard multibeam data processing workflow.

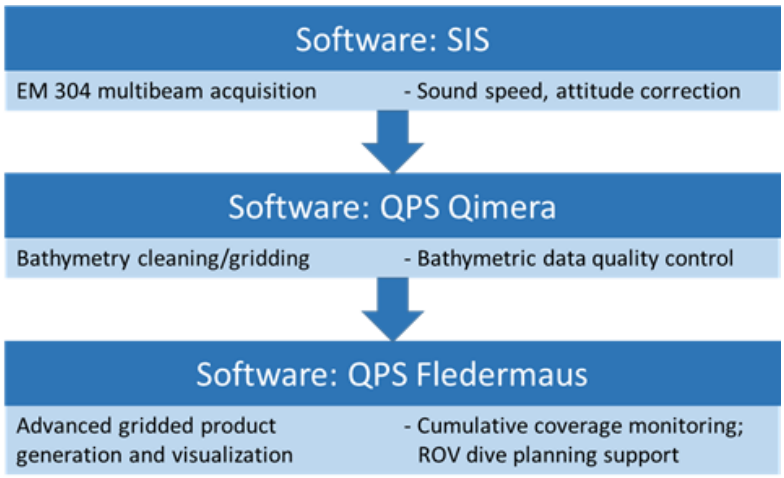

Figure 6. Shipboard multibeam data processing workflow.

On shore, the Mapping Team 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 November 1, 2021, as shown in **Figure 7**, and the results are presented in **Table 4**.

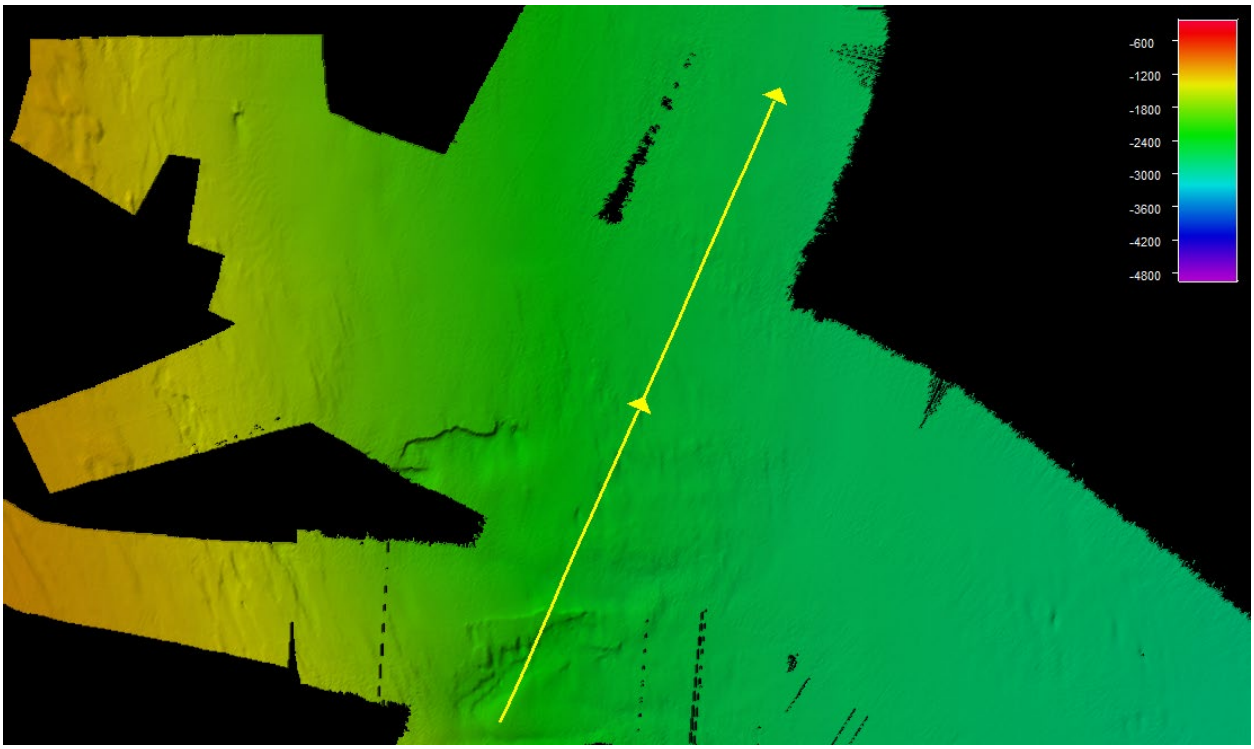

Figure 7. EX-21-07 crossline (shown in yellow) used for comparison against the bathymetric grid generated via orthogonal multibeam survey lines. Depth units are in meters.

Crossline files:

0098_20211101_030825_EX2107_3_MB.kmall

0099_20211101_040825_EX2107_3_MB.kmall

Mainscheme line files:

0112_20211101_231039_EX2107_3_MB.kmall

0129_20211102_064121_EX2107_3_MB.kmall

0139_20211102_233536_EX2107_3_MB.kmall

Table 4. Crosscheck results.

Statistic	Value
Number of points of comparison	848816
Grid cell size (m)	50
Difference mean (m)	0.091303
Difference median (m)	0.253361
Difference standard deviation (m)	3.457232
Difference range (m)	[-33.81, 51.88]
Mean + 2* standard deviation (m)	7.005768
Median + 2* standard deviation (m)	7.167825
Data mean (m)	-2373.287346
Reference mean (m)	-2373.378649
Data z-range (m)	[-2665.01, -1852.41]
Reference z-range (m)	[-2658.22, -1849.06]
Order 1 error limit (m)	30.85
Order 1 # rejected	38
Order 1 p-statistic	0.000045
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 5 provides a list of the acquisition and processing software versions that were used during EX-21-07.

Table 5. Versions of acquisition and processing software used during EX-21-07.

Software	Purpose	Version
SIS	EM 304	5.7.0
EK80	EK suite	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	2.4.0
FMGT	Backscatter	7.9.7
FMMidwater	Water Column	7.9.3
Sound Speed Manager	Sound Velocity Profiles	2021.2.0
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-21-07, Windows to the Deep 2021: Southeast US ROV and Mapping (ROV and 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 6-10** 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 6. 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 7. 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 8. 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 9. 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 10. 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	.xlsm, .xlsx, .shp, .kml, .cal, .xml, .pdf

	and in Google Earth format, any associated calibration files	

All sonar data is 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 11**. For any challenges accessing data, send an inquiry to NCEI,[10] or contact the Ocean Exploration Mapping Team.[11]

Table 11. Locations of data collected during EX-21-07 (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://www.ncei.noaa.gov/maps/bathymetry/ Request raw sonar data (Kmalls) from ncei.info@noaa.gov with oer.info.mgmt@noaa.gov cc'd POSPac and BS correction files can be requested from oar.oer.exmappingteam@noaa.gov
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.ncei.noaa.gov/maps/water-column-sonar/
Knudsen 3260 sub-bottom profiler data	Sub-bottom data, supporting data, and informational logs	https://www.ncei.noaa.gov/maps/trackline-geophysics/

[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

	are available in the NCEI data archives	
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://www.ncei.noaa.gov/maps/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 12. EX-21-07 schedule.

Date (UTC)	Activity
10/25	All personnel moved aboard.
10/26	The ship got underway at 1100. ADCPs were run by themselves to test functionality of the newly repaired OS38 system.
10/27	Conducted reciprocal line tests with the OS38 ADCP. Dive 01: "Reef Tracts". Successful CTD cast was taken and applied to multibeam patch test data. Transit mapping to next day's dive site.
10/28	Transit mapping. Dive 02: "Bloody Marsh". Following the dive, all sonars were secured due to poor weather.
10/29	Dive cancelled due to weather. 24 hour mapping operations focused on the western edge of a coral mound region in about 400 m of water.
10/30	Dive cancelled due to currents. 24 hour mapping operations focused on a priority mapping area on the northern Blake Plateau.
10/31	Dive cancelled due to weather. Transit mapping to the next dive site focused on filling small bathymetry gaps in the region.

11/1	Transit mapping to the dive site. Overnight mapping focused on gaps in international waters. Dive 03: “Mid-water North”.
11/2	Overnight mapping operations outside of the US EEZ. Transit mapping following the dive. Dive 04/05: “Deep Mound”.
11/3	Transit mapping. Remapped the steep wall of the Blake Escarpment to provide higher resolution data to the ROV team. “Dive 06: Blake Spur Escarpment”.
11/4	Overnight mapping operations focused on a gap between the US EEZ and the Extended Continental Shelf. Dive 07: “Blake Spur Canyon”.
11/5	Transit mapping. Dive 08: “Sinkhole”.
11/6	24 hour transit mapping towards the Florida Keys region to avoid poor weather.
11/7	24 hour transit mapping towards the Florida Keys region to avoid poor weather.
11/8	Transit mapping. Dive 09: “Tortugas Scarp”.
11/9	Transit mapping. Dive 10: “Shark Fin Ridge”.
11/10	Transit mapping. Dive 11: “Key West Scarp”.
11/11	24 hour transit mapping operations.
11/12	Transit mapping. Dive 12:” Knolls North”.
11/13	Transit mapping. Dive 13: “Mid-water South”.
11/14	Transit mapping. Dive 14: “Million Mounds South”.
11/15	Arrive in Port Canaveral, FL.

References

Candio, S., Hoy, S., Jerram, K., Wilkins, C., Copeland, A., Lobecker, M., and Sowers, D. 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

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.

Dornback, M., 2021. Project Instructions: EX-21-07, Windows to the Deep 2021: Southeast US ROV and Mapping (ROV and Mapping). Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://doi.org/10.25923/9hvv-we20

Dornback, M.; Collins, A.G.; Farrington, S.F.; Sowers, D.; Candio, S. (2022). Expedition Report: EX-21-07, Windows to the Deep 2021 (ROV and Mapping). NOAA Ocean Exploration, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. NOAA Ocean Exploration Expedition Rep. 21-07. https://doi.org/10.25923/gap8-sp59

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

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). https://iho.int/uploads/user/pubs/standards/s-44/S-44_5E.pdf

Jerram, K., Hoy, S., and Wilkins, C. (2020). NOAA Ship *Okeanos Explorer* EM 304 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).

October 26

Restored positioning feeds to the acoustic Doppler current profilers (ADCPs). Ran ADCPs and logged data to test initial functionality of 300 kHz and the repaired 38 kHz system. Updated multibeam processing unit (PU) with new files from Kongsberg that should make improvements to the system's performance and swath widths. Made products for ROV Team and science leads for Dive 01 - Reef Tracts. Completed drills.

Upon departure from port, ran ADCPs by themselves to provide verification of proper functioning of the repaired OS38. Collected bottom tracking data for OS38 transiting over the shelf and into deeper waters to enable heading calibration of the sonar. All other sonars kept off for this to avoid interference and because the transit area is already mapped.

Attempted to run multibeam at time 2000. The new files loaded onto the PU appear to have temporarily made the EM 304 inoperable. It would not ping in SIS and there were errors in the Telnet session not normally observed. Troubleshooting this issue and submitted help ticket to Kongsberg.

October 27

Overnight mapping completed reciprocal line tests with the OS38 ADCP. University of Hawaii Data Acquisition System (UHDAS) partners reviewed the data from the ADCP today and confirmed that no further calibration was needed and that the ADCP data were looking good. ADCP and EK data were collected throughout today's ROV dive.

The new files from Kongsberg for the multibeam PU were removed since they were not working, and the old files were put back on the PU. Following recovery of the ROVs, we tested the multibeam and confirmed that it was working normally again.

A conductivity/temperature/depth (CTD) cast was completed by the Senior Survey Tech (SST) and applied to the multibeam. An expendable bathythermograph (XBT) cast was also completed, and the data collected agreed closely with the CTD data, confirming good measurements by both systems as well as a stable sound speed environment for the multibeam patch test calibration.

Patch test data gathering was completed in the evening, followed by a high-speed transit to tomorrow's dive site.

October 28

The multibeam patch test was completed last night in the vicinity of the first ROV dive. Very minor possible adjustments to angular offsets (in degrees) were calculated as a result: -0.03 for pitch, -0.05 for heading, and -0.04 for roll. The offshore mapping team decided to hold off on applying these very minor changes until a deep water patch test could be done later in the cruise near the Blake Spur.

Normal survey operations were completed in transit to the underwater cultural heritage (UCH) site. Only EK and ADCP data were collected within the UCH restricted radius since the region was just mapped on the last cruise.

The Seafloor Information System (SIS) software is not appending the cruise name to the kmall files like it should. The processing unit and SIS were rebooted to see if this would help. Upon reboot, the telnet session indicated the same errors we had last night using the Kongsberg PU files – even though the system was working normally during the patch test.

October 29

The weather and seas were too rough for mapping data collection all night and into the morning. Mapping data collection resumed after breakfast when the seas and wind became less severe. The night was spent transiting roughly against the wind and Gulf Stream to a survey area on the western edge of a coral mound region in about 400 m of water. Two new swaths of about 35 km were collected to add to this multibeam coverage.

There were some raw file naming issues with .kmall files that we had to fix. SIS was not appending the cruise name to the data files like it should.

The evening hours involved transit mapping to the north on the way to the new Dive 03 site that was selected to avoid the worst of weather and currents forecasted for 10/30. The ship was able to reach a peak speed of 14.9 knots and still collect good multibeam data given the shallow water depths and mostly following sea in the Gulf Stream current.

October 30

Completed overnight transit mapping to the dive site. Data quality was good overall due to going with the Gulf Stream and with a following sea/wind. The first daily product was completed.

We had to resolve some file naming issues due to SIS not appending extensions correctly - this issue has been resolved.

The day was spent on a focused survey of the last remaining priority mapping area that was not finished on EX-21-06. Good progress was made on the priority mapping box, but part of it will remain unmapped for now. Dive plan and ROV navigation products were completed for the U.S. Geological Survey (USGS) test site dive as well as a backup dive option further to the south (dive option "Scarp Mound").

October 31

Completed overnight transit mapping to the USGS Exploration dive site. Following cancellation of the dive a transit map to the region of tomorrow's Midwater North dive site was planned, incorporating some filling of small bathymetry gaps in the region.

November 1

Overnight mapping filled some small gaps in multibeam coverage in the vicinity of the dive site. The EK and ADCP sonars were run throughout the midwater dive. Following ROV recovery, the ship transited just outside U.S. waters to map some gaps in international waters. The seas have calmed down and conditions are quite good for mapping operations.

November 2

Overnight mapping filled the southern end of a bathymetric data gap between U.S. waters and potential extended continental shelf data outside the exclusive economic zone (EEZ). Following ROV recovery, transit mapping out to the Blake Spur became the focus of mapping operations. Backscatter data of the mound we dove on was processed and shared with USGS partners interested in the unusual feature.

November 3

Overnight mapping was mostly a simple edge-matching transit to the next dive site. We re-mapped the dive site area since it was on the extremely steep wall of the Blake Escarpment and only a 100 m resolution bathymetry map was available from previous surveys. The improved 50 m resolution map was used to generate the final dive products for the ROV team.

The evening mapping watch began a transit to a gap in multibeam coverage between data within U.S. waters and the Extended Continental Shelf mapping survey further offshore beyond the U.S. EEZ.

November 4

Overnight mapping work focused on filling a prominent gap between the U.S. EEZ boundary and the Extended Continental Shelf survey. Post ROV recovery, a long transit mapping line was started around the Bahamas EEZ boundary and south to the Dive 08 location. This line was run at the current maximum ship speed of about 10 knots since it is a long transit and will already result in a 1.5 hour delay to tomorrow's dive.

The ADCP experts at the University of Hawaii provided some new suggestions on modifying the runtime settings of the OS38 ADCP in order to increase the potential range at which it can estimate currents and to increase the density of data and optimize the sonar for depths above or below 500 meters.

Mapping Lead Sowers participated in the live interaction event today with the Smithsonian and the White House Office of Science and Technology Policy.

November 5

High speed transit mapping was conducted overnight to get us to the Dive 08 site by 0730. After ROV recovery, high speed transit mapping resumed as we made our way towards the Straits of Florida to move south out of the rough weather heading our direction. Data quality is moderate given the high transit speeds and occasional bubble sweepdowns from heavy rolls. The multibeam maximum angles were reduced to improve data quality. Most of the data collection tonight is over areas already fully mapped by other surveys. We will be edge matching other multibeam coverage when we move into the Straits of Florida.

We are now putting the “dive-as-dove” post-dive images into the onshore engagement team folder along with the pre-dive images.

November 6

Last night’s transit mapping was quite rough with significant heavy rolls. However, data collection was over areas already well mapped. Today was a 24/hr mapping day since it is too rough to dive anywhere and this is the first day of a two day transit to the Florida Keys region where weather is conducive to dive operations. There are frequent bubble sweepdown impacts on the sonar data, but they are periodic.

We filled gaps in multibeam coverage as we moved down through the Florida Straits. SIS had two seemingly random complete lock ups last night and would not ping or collect data. Full PU restart was needed to get it back to normal. There is no warning for this and luckily it does not happen often and did not occur again during the day.

Mapping team compiled data layers and generated potential ROV dive options for the anticipated three days in the Florida Keys region.

The ADCP SOP was updated to fully incorporate setting changes and operational mode thresholds suggested by UHDAS.

Daily products and daily backscatter processing work is all up to date.

November 7

Transit mapping was conducted all night and all day through the Florida Straits. All sonars performed normally and data quality improved with milder seas near Key West. Mapping Lead Candio is fully familiarized with ROV cruise procedures and has taken over completing the daily ROV product generation for Science Leads and the ROV Team.

Mapping Lead Sowers is observing ROV drift tests, deployments, and recoveries and getting more familiar with the lab and sampling procedures.

SST Wilkins discovered a strange channel formation with distinct regular lobe patterns that we will seek to edge match on the way north to see if it continues in the channel.

November 8

Overnight transit mapping filled small gaps in multibeam coverage. Night time mapping focused on filling larger gaps in nearby multibeam coverage in water depths between 600-1200 m, then transiting over already mapped terrain to the Dive 10 site. The Dive 09 site was mapped as we left the site so that we could compare the new bathymetry data set to the one gathered in 2014 to see if the site had experienced slumping.

November 9

A substantial gap in multibeam coverage was filled with a focused survey en route to the Dive 10 site. The post dive mapping effort was mostly a high speed transit to the next dive site south of Key West. The preferred dive site was too near to submarine cables, so we opted for the backup option. All mapping systems working normally.

Sun photometer measurements were taken today and yesterday given the sunny conditions.

PS Sowers became familiarized with the ROV sample data processing procedures immediately following ROV recovery. PS Candio is now well versed in Mapping Lead responsibilities on ROV cruises.

November 10

High speed transit mapping was conducted overnight in order to get to the Dive 11 site in time. Following ROV recovery, mapping was conducted at the ship's top speed to begin a 36 hour stretch of mapping as we completed a rapid transit back to the Blake Plateau for the final three dives of the expedition.

November 11

Full day of transit mapping at 12+ knots through the Florida Straits, while edge-matching existing multibeam coverage (mostly from our transit south several days ago). Data quality is good despite the high transit speed. Having an additional mapper on this expedition has made the numerous weather days and additional mapping workload manageable.

PS Sowers made Fledermaus fly-through videos for the videographers to provide imagery for their long form videos. PS Candio calculated the area of the Blake Plateau mapped through NOAA Ocean Exploration efforts to provide statistics and content to the long form videos.

November 12

Completed the 36 hour mapping transit from Key West to the Dive 12 site "Knolls North." Overnight mapping conducted a transit south to the Dive 13 site while filling minor gaps in the EX2106 survey (due to periodic POSMV dropouts) and a substantial gap near the U.S. maritime boundary with The Bahamas. Restarted SIS and the EM 304 processing unit to re-enable shiptracking and measurement tools in SIS. The Mapping Data Report for the expedition was drafted.

November 13

Overnight mapping filled a long linear gap in multibeam coverage at the southern edge of the U.S. EEZ near The Bahamas. The ADCPs and EK sonars were run throughout the water column dive. Post ROV dive, mapping operations transited west to fill some small gaps in the "Million Mounds" region. All mapping systems are working normally.

November 14

Overnight mapping filled a gap and an area of poor quality data nearby. After the final ROV dive of the expedition, a small focused mapping survey was completed to fill the last remaining multibeam gap in the southern Blake Plateau deeper than 500 m, followed by a transit to Port Canaveral. The onboard mapping team is up to date with all processing of multibeam bathymetry, backscatter, and sub-bottom data. PS Candio produced the end-of-cruise map

template. PS Sowers downloaded the sun photometer data and sent it to NASA. The SOP for the sun photometer data download was also updated to use the Putty com port reader instead of Hercules. Mapping input was provided at the post-cruise meeting today. The sun photometer, Castaway CTD, and XBT autolauncher will be shipped out for calibrations and repairs by SST Wilkins after the expedition.

November 15

Arrived in Port Canaveral, FL and started the cruise wrapup and demobilization process. Copied data to hard drives.