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Mapping Data Acquisition and Processing Summary Report

EX-21-01: 2021 EM 304 Sea Acceptance Testing and Mapping Shakedown (Mapping)

Key West, Florida to Cape Canaveral, Florida

April 16 - May 10, 2021

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June 07, 2021

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Table of Contents

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 subseafloor mapping data collection and processing methods used by NOAA Ocean Exploration on NOAA Ship *Okeanos Explorer* during the EM 304 Sea Acceptance Testing and Mapping Shakedown, EX-21-01, and to present a summary of mapping results and mapping-related expedition activities.

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.[1]

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[2] and also available from the website.[3]

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

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

[3] https://oceanexplorer.noaa.gov/data/publications/mapping-procedures.html *(last accessed 06/07/2021)*

Expedition Objectives

The objectives of EX-21-01 were to perform the sea acceptance testing of the newly installed Kongsberg EM 304 MKII transmit array, perform mission readiness of the mapping systems through annual testing and calibration, and to map unexplored areas on the Blake Plateau. Sea acceptance testing and readiness operations for the EM 304 multibeam sonar included a GNSS Azimuth Measurement Subsystem (GAMS) test, Patch Test, speed-noise test, coverage extinction data collection, backscatter normalization data collection, and four accuracy reference surveys conducted at 250 m, 1,100 m, 3,400 m, and 5,200 m (**Figure 1**). Results of the EM 304 Sea Acceptance Testing are provided in the "NOAA Ship *Okeanos Explorer* EX-21-01 EM 304 MKII Sea Acceptance Testing" report, which is archived in the NOAA Central Library.[4]

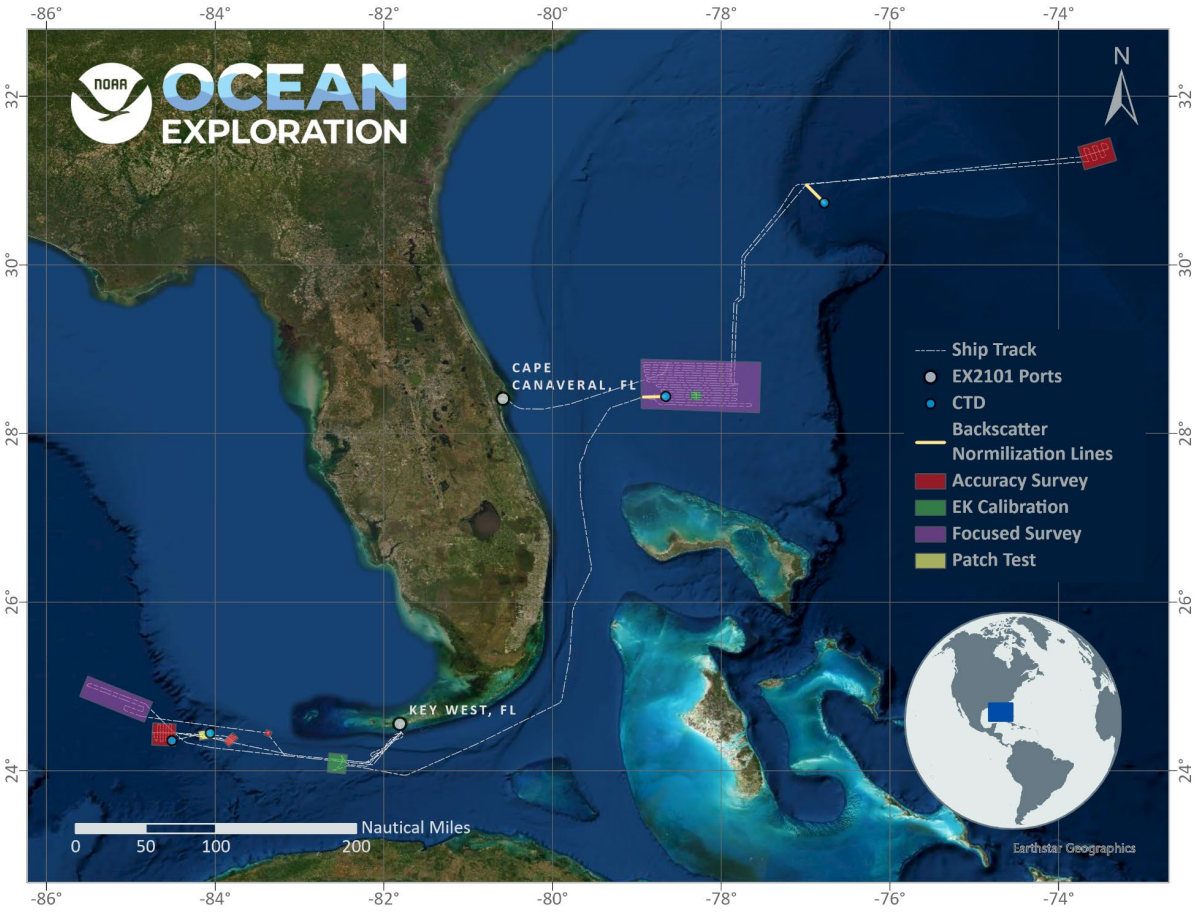

Figure 1. Overview of site locations during 2021 EM 304 Sea Acceptance Testing and Mapping Shakedown (EX-21-01).

[4] https://doi.org/10.25923/5fm9-0f17

In addition to the EM 304 multibeam sonar objectives, EK60/80 split-beam echosounder objectives included acceptance of the newly installed EK80 38 kHz transducer and calibration of each frequency (18, 38, 70, 120, 200 kHz). For calibration results refer to the "2021 EK60/EK80 Calibration Report," which is available in the NOAA Central Library.[5] Other mission readiness objectives included ensuring functionality of all ancillary equipment, including sound speed profiling equipment, updating and refining procedural documents, and defining new procedures for supporting shore-based processing using the Cloud. The complete objectives for this expedition are detailed in "Project Instructions: EX-21-01, 2021 EM 304 Sea Acceptance Testing and Mapping Shakedown (Mapping)," which is archived in the NOAA Central Library.[6]

Southeastern 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 program 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

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

[6] https://doi.org/10.25923/v34d-wj36

Operational Personnel

EX-21-03 included onboard operational personnel, inclusive of ship's force and mission team, who participated in operational execution (see **Tables 1**), and shore-based personnel (who participated remotely via telepresence) (see **Tables 1** and **2**).

Table 1. EX-21-01 Onboard personnel

Name	Role	Affiliation	Dates Aboard
Shannon Hoy	Expedition Coordinator	NOAA Ocean Exploration (CNSP)[1]	04/16 – 05/11
Sam Candio	Expedition Coordinator (Training)	NOAA Ocean Exploration (CNSP)[1]	04/16 – 05/11
SST Charlie Wilkins	Senior Survey Tech	OMAO[2]	04/16 – 05/11
LT Bryan Pestone	Operations Officer	OMAO[2]	04/16 – 05/11
Adam Hughes-Wooton	Kongsberg Technician	Kongsberg	04/16 – 04/23
Kevin Jerram	Mapping Watch Lead	UCAR[3]	04/16 – 05/11
Erin Heffron	Mapping Watch Lead	UCAR[3]	04/16 – 05/11
Jim Meyers	Data Engineer	GFOE[4]	04/16 – 05/11
Andy Lister	Data Engineer	GFOE[4]	04/16 – 05/11
Chris Wright	Data Engineer	GFOE[4]	04/16 – 05/11
Mark Durbin	Network Engineer	GFOE[4]	04/16 – 04/23
Bob Knott	Video Engineer	GFOE[4]	04/16 – 05/11
Adrienne Copeland	EK Lead	NOAA Ocean Exploration	04/23 – 05/11
Lu Wang	Knauss Fellow	NOAA Ocean Exploration	04/23 – 05/11

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

Table 2. EX-21-01 Shore-based personnel

Name	Role	Affiliation
Meme Lobecker	Cloud Coordinator	NOAA Ocean Exploration (CNSP)
Colleen Peters	Cloud Mapping Data Processor	UCAR
Marcel Peliks	Cloud Intern	UCAR
Anna Takagi-Berry	Cloud Intern	UCAR

Summary of Mapping Results

NOAA Ocean Exploration mapped 22,187 sq km of seafloor during the 25 days at sea for EX-21-01. Of the 22,187 sq km mapped, 18,773 sq km was deeper than 200 m and within the U.S. Exclusive Economic Zone and Territorial Sea. Multibeam bathymetry data coverage is shown in **Figure 2.**

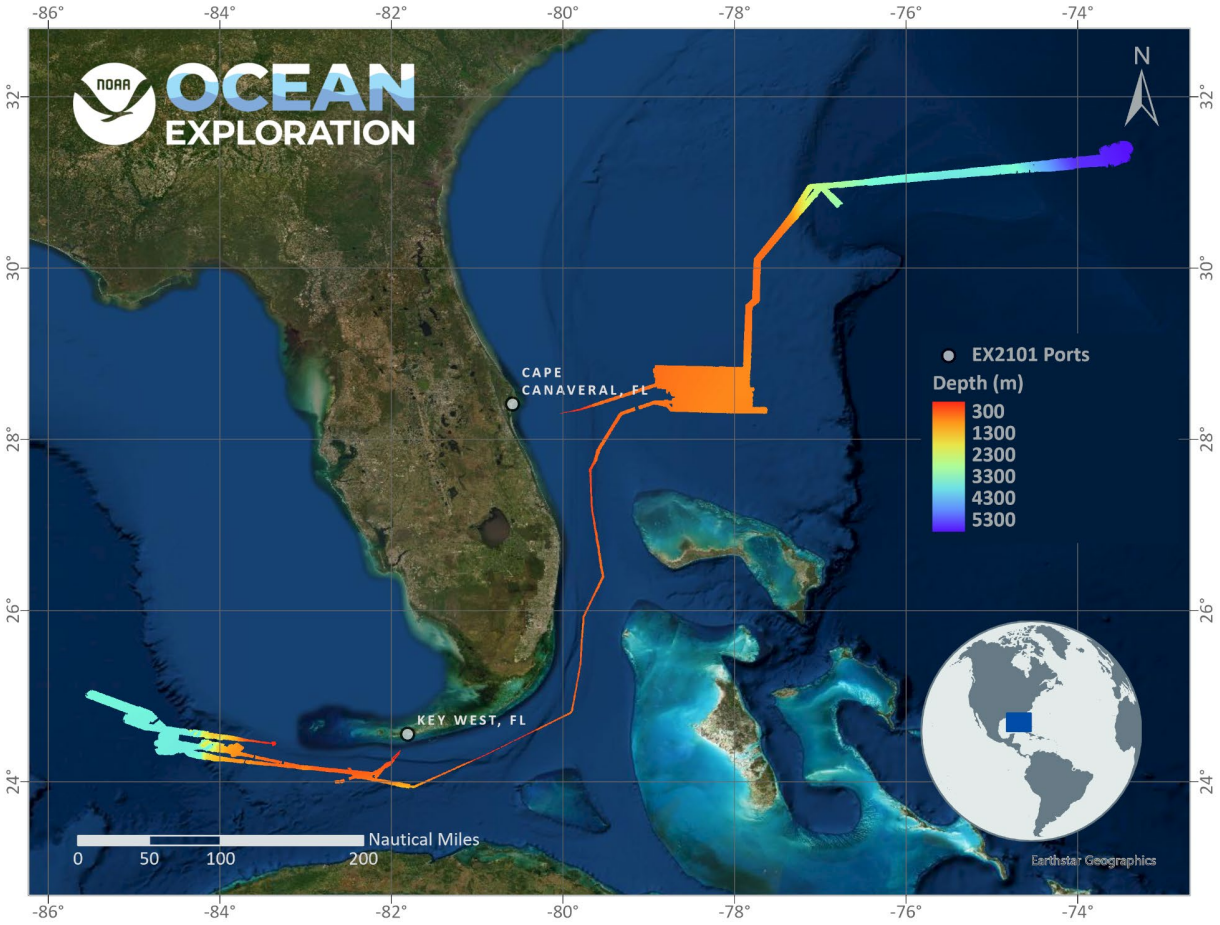

Figure 2. Overview of bathymetric mapping coverage completed during 2021 EM 304 Sea Acceptance Testing and Mapping Shakedown (EX-21-01).

Mapping Statistics

Table 3 provides summary statistics of ocean mapping work during EX-21-01 April 16 - May 10, 2021 (UTC).

Table 3. Summary statistics of ocean mapping work during EX-21-01

Statistic	Value
Ship's draft*: Start of expedition (04/16/2021)* End of expedition (05/20/2021)*	 Fore: 16' 4.5''; Aft STBD: 15' 9"; Aft Port: 15' 6" Fore: 15' 4.5"; Aft STBD: 15' 10"; Aft Port: 14' 11.5"
Linear kilometers of survey with EM 304	3,317
Square kilometers mapped with EM 304	22,187
Square kilometers mapped with EM 304 within U.S. waters deeper than 200 m	18,773
Number/data volume of EM 304 raw multibeam files (.kmall)	593 files / 100 GB
Number/data volume of EM 304 water column multibeam files (.kmwcd)	584 files / 287 GB
Number/data volume of EK60/EK80 water column split-beam files (.raw)	1,064 files / 108 GB
Number/data volume of sub-bottom sonar files (.segy, .kea, .keb)	307 / 3.76 GB
Number of expendable bathythermograph (XBT) casts	159
Number of conductivity, temperature, depth profiler (CTD) casts (including test casts)	4

*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 3 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 meters of water and conducting productive mapping operations in up to 8,000 meters 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-21-01 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.[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 meters 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.

The OS 38 transducer experienced temperature spikes during EX-21-01, and was therefore secured until further troubleshooting could occur.

Data Acquisition Summary

Throughout EX-21-01, data were acquired with the EM 304, the EK60/EK80 (18, 38, 70, 120, and 200 kHz), the Knudsen 3260 sub-bottom profiler, and the ADCPs. The ADCPs were only run while leaving port for annual calibration. Further testing with the ADCP OS 38 was planned, however due to a temperature spike suspected to be caused by water intrusion into the unit, the ADCP 38 was secured for the majority of the expedition.

Generally, during specific testing objectives all but the sonar being tested were secured. During focused surveying operations off of Key West and on the Blake Plateau the EM 304, EK60/EK80 (18, 38, 70, 120, and 200 kHz), and the Knudsen 3260 sub-bottom profiler were run concurrently using a Kongsberg Synchronization Unit (K-Sync). During CTD operations, the EM 304 multibeam sonar and the 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.

Multibeam survey lines for focused surveys or transits were 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 were planned to optimize potential discoveries and to complete relatively large contiguous areas to support interpretation of features from bathymetry and backscatter.

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 manually 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, 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 CTD casts. Data were monitored in real time for quality. **Figure 3** shows the EK60/EK80 data collected during EX-21-01.

Knudsen 3260 sub-bottom profiler data were also collected during the majority of the expedition. **Figure 4** shows where sub-bottom data were collected during EX-21-01.

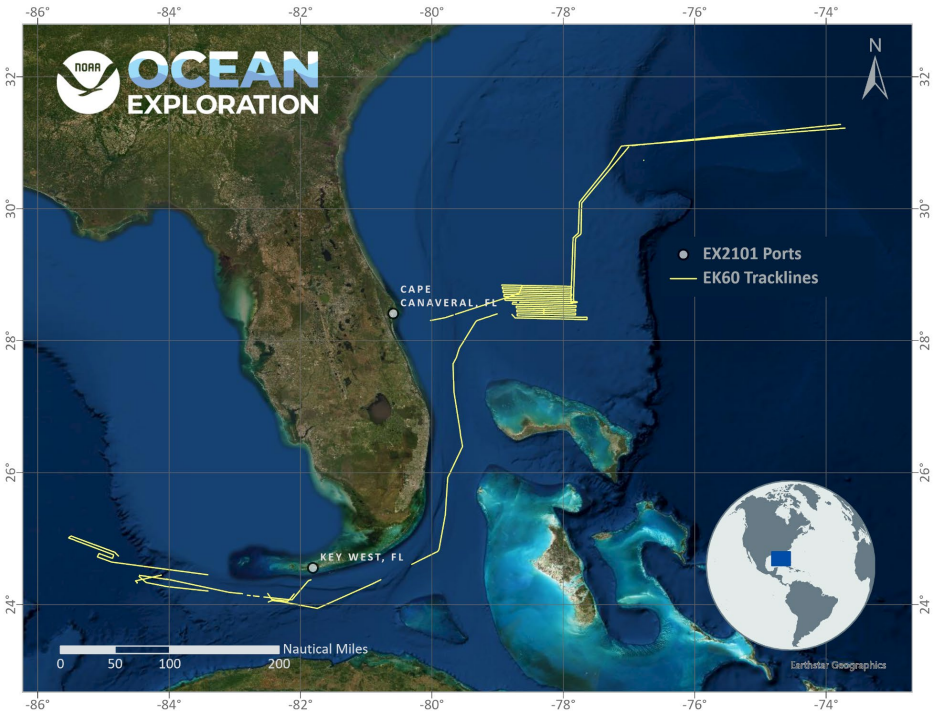

Figure 3. Simrad EK60/EK80 split-beam sonar data tracklines collected during EX-21-01.

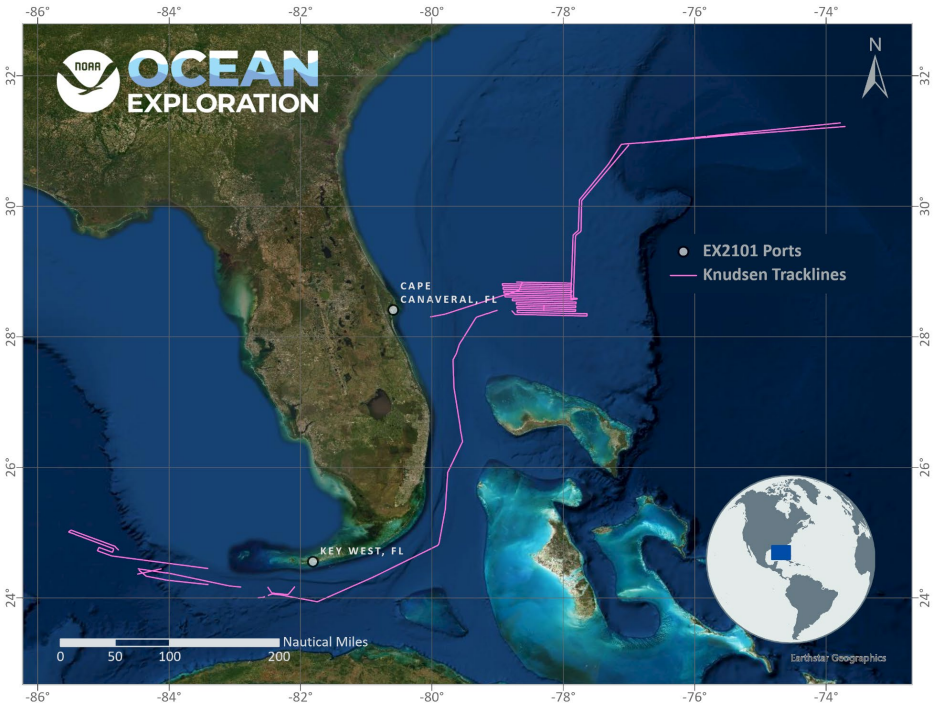

Figure 4. Sub-bottom profiler data tracklines collected during EX-21-01.

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. 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 5** shows the onboard multibeam data processing workflow.

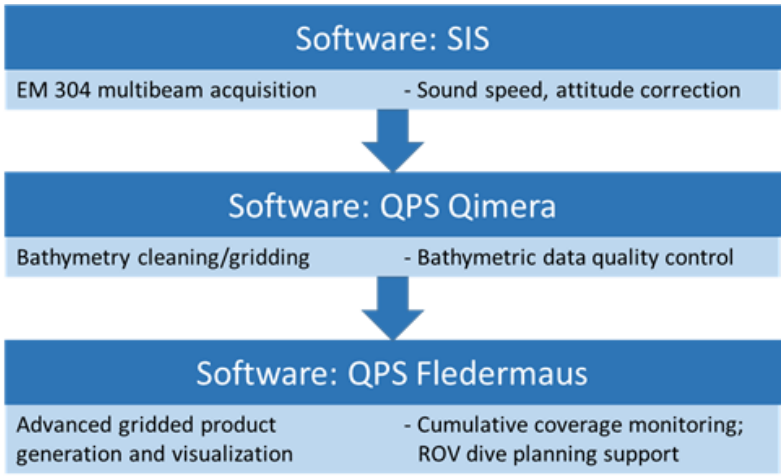

Figure 5. Shipboard multibeam data processing workflow.

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 May 05, 2021 during the 5,400 m accuracy reference survey, as shown in **Figure 6**, and the results are presented in **Table 4**.

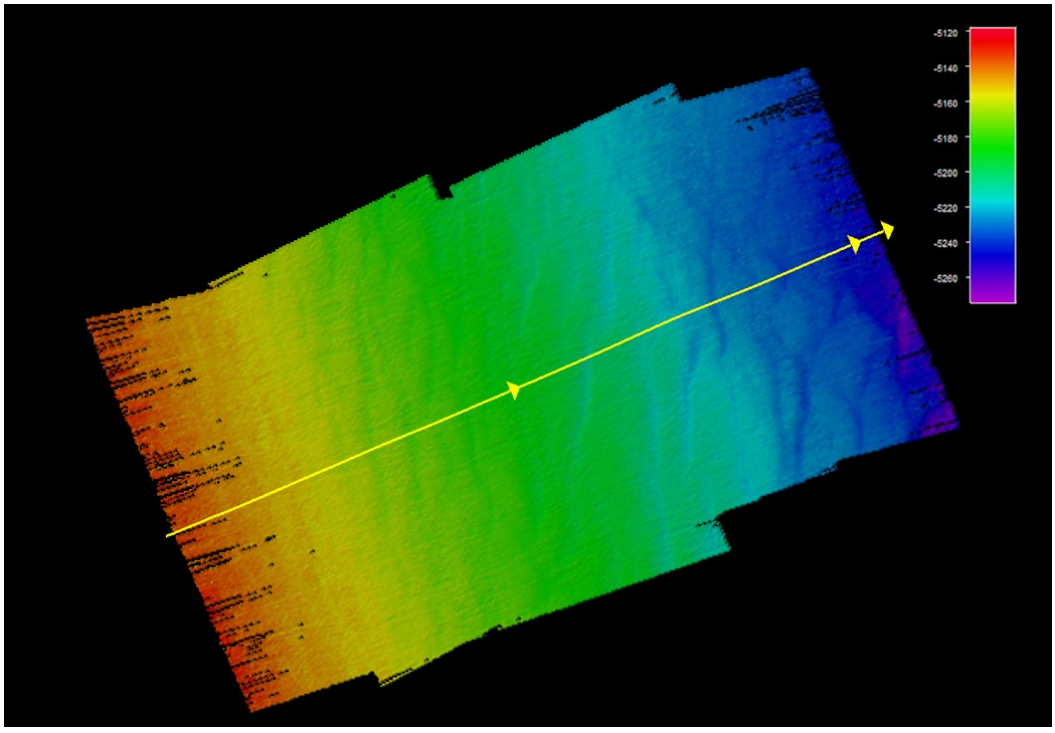

Figure 6. EX-21-01 crossline (shown in yellow) used for comparison against the bathymetric grid generated via orthogonal multibeam survey lines at the 5,400 m accuracy reference survey location.

Crossline files:

0060_20210505_000658_EX2101_MB.kmall
0061_20210505_010658_EX2101_MB.kmall
0062_20210505_020658_EX2101_MB.kmall

Mainscheme line files:

0071_20210505_082046_EX2101_MB.kmall
0072_20210505_092046_EX2101_MB.kmall
0074_20210505_100546_EX2101_MB.kmall
0075_20210505_110546_EX2101_MB.kmall
0077_20210505_115641_EX2101_MB.kmall
0078_20210505_125641_EX2101_MB.kmall
0080_20210505_134145_EX2101_MB.kmall
0081_20210505_144145_EX2101_MB.kmall
0083_20210505_152745_EX2101_MB.kmall
0084_20210505_162745_EX2101_MB.kmall

Table 4. Crosscheck results

Statistic	Value
Number of points of comparison	529,084
Grid cell size (m)	75
Difference mean (m)	0.208933
Difference median (m)	0.415280
Difference standard deviation (m)	4.402076
Difference range (m)	[-32.64, 33.50]
Mean + 2* standard deviation (m)	9.013085
Median + 2* standard deviation (m)	9.219432
Data mean (m)	-5191.675635
Reference mean (m)	-5191.884568
Data z-range (m)	[-5290.03, -5107.83]
Reference z-range (m)	[-5286.94, -5112.19]
Order 1 error limit (m)	67.496353
Order 1 # rejected	0
Order 1 p-statistic	0.000000
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-21-01.

Table 5. Versions of acquisition and processing software used during EX-21-01

Software	Purpose	Version
SIS	EM 304	5.6 1.5.2
EK80	EK suite	2.0.0
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	2.3.4
FMGT	Backscatter	7.9.5
FMMidwater	Water Column	7.9.3
Sound Speed Manager	Sound Velocity Profiles	2021.1.6
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-21-01, 2021 EM 304 Sea Acceptance Testing and Mapping Shakedown (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 Ocean Exploration 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, .edf, .rdf, .csv
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 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 NOAA Ocean Exploration Mapping Team.[11]

Table 11. Locations of data collected during EX-21-01 (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 12. EX-21-01 schedule

Date (UTC)	Activity
04/14	Mission personnel joined the vessel in Key West, FL. Mobilization began.
04/15	Mobilization continued, including a ping test of the EM 304.
04/16	The ship departed Key West, FL. and transited to the Patch Test location. A GAMS test was performed.
04/17	The EM 304 Patch Test was completed. Two 1,000 m CTD casts were conducted. The 3,400 m accuracy reference survey began.
04/18	The 3,400 m accuracy reference survey and the speed-noise test were completed, and the 1,100 m accuracy reference survey began.
04/19	The 1,100 m accuracy reference survey was completed. The very deep crosslines at the 3,400 m accuracy reference survey were repeated, however the weather deteriorated and the data quality was poor. The ship transited to Key West for personnel transfer due to medical reasons.
04/20	The ship transited back to the 3,400 m accuracy reference survey after the personnel transfer and collected coverage extinction data along the way.
04/21	The third attempt to collect data for the very deep crosslines was successful. An opportunistic survey occurred following the crosslines.

Date (UTC)	Activity
04/22	The 250 m accuracy reference survey was completed. The ship transited to Key West for a personnel transfer.
04/23	Personnel transfer occurred. Calibration of the ship's dynamic positioning system began.
04/24	Calibration of the ship's dynamic positioning system continued.
04/25	Calibration of the ship's dynamic positioning system was completed and the final personnel transfer occurred. Due to an engineering issue, the ship held location outside of Key West overnight.
04/26	Calibration of the EK60/80 38, 70, 120, and 200 kHz occured
04/27	The ship transited to the Blake Plateau.
04/28	The ship continued its transit to the Blake Plateau.
04/29	The shallow backscatter normalization lines were collected, followed by a 1,000 m CTD cast. A focused survey on the Blake Plateau began.
04/30	The focused survey on the Blake Plateau continued.
05/01	The focused survey on the Blake Plateau continued, as well as successful calibration of the EK60 18 kHz sonar.
05/02	The focused survey on the Blake Plateau continued, followed by a transit to the deep backscatter normalization location.
05/03	The collection of the deep backscatter normalization data was completed, as well as a 3,000 m CTD cast. Following the backscatter normalization data collection the ship transited to the 5,200 m accuracy reference survey.
05/04	The 5,200 m accuracy reference survey began.
05/05	The 5,200 m accuracy reference survey was completed and the ship began its transit to the southern survey area, collecting data for coverage extinction along the way.
05/06	The ship continued transiting to the southern Blake Plateau survey location.
05/07	Focused surveying of the Blake Plateau occurred.
05/08	Focused surveying of the Blake Plateau continued.
05/09	Focused surveying of the Blake Plateau continued, followed by the transit to Cape Canaveral, Florida.
05/10	Arrival in Cape Canaveral, Florida. Demobilization efforts began.
05/11	The mission team departed the vessel.

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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 cruise. All times are in local ship time (-4 hours from UTC).

April 14

The ship was alongside. The mapping team inspected the new vessel surveys and updated all of the offsets in the acquisition software to the newest values. A waterline was established by measuring the distance to the sea surface from the newly established benchmarks. The waterline was determined to be 1.80 m. Historically, the waterline has been approximately 2.2 m. The mapping team determined that this discrepancy was caused by the draft markers referencing the original keel rather than the sonar blister. The new methodology for determining the waterline has been documented.

While updating the vessel offsets in POS Config, the mapping team noticed that the AUX 1 GNSS sensor within POS Config did not have a comparable antenna in the Westlake report. It was determined that this sensor was the historical CNAV antenna, and was thus removed from ancillary sensors in POS Config.

The EK 80 software was updated to the latest version: V 2.0.

The Autolauncher was set up and functionality was confirmed.

The Qimera standard operating procedure (SOP) was updated to reflect the new file format (.kmalls) and the new software version. This SOP will be reviewed and tested out by the shore team.

A summary of notable items that happened during the alongside period prior to shelter-in-place (April 01 - 06):

- All mission processing software were updated to the latest version using the recently set up remote computer access.
- The EK 80 WBT Licenses were updated remotely.
- A keyboard-video-mouse (KVM) station was set up in the stateroom: 228.
- The mapping watch standing laptop screen was slightly damaged since its last use in November 2019, it is slightly dull on the right side of the screen. It is still usable and GFOE has a new screen arriving in Port Canaveral.
- The GFOE hydrographic workstation was set up and all ancillary feeds were confirmed.

- The Reson SVP-70 probe was replaced.

April 15

The ship was alongside. The POS MV V5 was updated to the latest version (10.5). This version supports KM Binary which will allow attitude information to be sent over ethernet to the EM 304 processing unit. The mapping team will further investigate during this cruise. The positioning message being sent to the EM 304 was increased from baud rate 9600 to 36400 to reflect optimal historical settings.

The K-Sync application was installed on the MBPROC-3 computer and configured for the installed sonars. The issue with sending the EM 304 depth to the K-Sync (which supports using 'calculated' synchronization mode used for the Knudsen) is still unresolved.

The EM 304 was powered up and all built-in-systems-test (BISTs) tests passed. A pierside ping test showed functionality of the sonar. This completed the harbor acceptance test (HAT) for the system.

The Senior Survey Technician (SST) confirmed functionality of the conductivity, temperature, and depth (CTD) sensor and a successful 'deck test' was completed.

April 16

After leaving the pier the ADCPs were brought up to calibrate while transiting to deeper water. University of Hawaii Data Acquisition System (UHDAS) team indicates the bottom track calibration looks good, they may make a slight adjustment following the cruise.

A GAMS test was performed on the transit to the patch test, and confirmed the surveyed baseline, as a result no values were changed.

The Kongsberg engineer updated SIS to a new version supplied by Kongsberg headquarters in Norway, V5.6 1.5.2. New surveys were set up in all sonar acquisition software. All sonars were able to be externally triggered with K-Sync, and are operating normally on the transit.

A wet deck test of the CTD confirmed functionality.

The mission team is investigating a request from EX-20-00 to change some of the file naming conventions.

April 17

The patch test for the new EM 304 MKII array was completed. Results showed very minimal deviation from the recently surveyed values, and confirmed functionality of the system. The

patch test showed exemplary integration of offsets and is a testament to Westlake's services, as well as the effort and coordination of the NOAA Ocean Exploration and OMAO teams involved.

Following the patch test, two CTD casts were performed to a depth of 1,000 m (one at the patch test location and one at the 3,400 m reference survey location). These casts were successful, including the ability to fire the Niskin bottles. Readiness continues to ensure integrity of the bottles themselves for the following cruise objectives.

During the first CTD cast we also conducted an AXBT cast and a Castaway CTD cast. The Castaway was only able to go down to 16 m due to the strong currents, even with the weights added. Where data were available, all three profiles showed consistency when compared. The new Reson SVP-70 probe and the TSG also show good agreement.

Sound Speed Manager is still unable to receive data from the EM 304, investigation will continue.

Following the second CTD casts, we began the 3,400 m reference survey. Weather conditions are good.

A daily bathymetry product was created to test the ship-shore downstream functionality.

April 18

The 3,400 m reference survey was completed. Upon finishing the mainscheme lines, the mapping team realized that the EM 304 had not been able to utilize frequency modulated (FM) pulses. This was found to be due to not setting up FM corrections in Installation Parameters. "Active Attitude System" has to be set to "Attitude FM corr." Following changing this setting, the EM 304 was able to employ FM pulses as expected.

Following the 3,400 m reference survey and on the way to the 1,100 m reference survey, a speed-noise test was performed. Weather conditions were good. Results of the speed-noise test show lower susceptibility to increased speeds.

If the "Restart SIS 5.6 GUI" application is used - it causes multiple windows to no longer display data (e.g., Beam Intensity, Waterfall, and Time Series). The processing unit has to be restarted to get the functionality of these windows to return. It is advised to not use this tool at this time.

With the help of the GFOE data team, the Kongsberg engineer was able to get the Hydrographic Workstation and K-Sync to talk, allowing the K-Sync application to receive the "DPT" and "DBS" data packet.

Sound Speed Manager and the Hydrographic Workstation are able to talk; however Sound Speed Manger is only able to receive one of the three data packets (SPO). It is believed that the issue lies with the application at this time.

April 19

The 1,100 m reference survey was completed, and FM pulses remained functional. Following the survey, a noise spectrum test was performed to meet the SAT requirements.

The ship transited back to the site of the 3,400 m reference survey to redo the crosslines in Very Deep mode with FM operational. Unfortunately, the weather degraded and the data quality was very poor.

Following the crosslines, the ship transited to Key West.

During the transit, the K-Sync firmware was updated to troubleshoot an issue where the EKs continue pinging even with the K-Sync paused and the EKs set to externally trigger. There were issues getting the K-Sync operational following the update, and files were needed from Norway to fix the issue. Following the receipt of the files, the K-Sync is now operational. Tests will be performed tomorrow to see if this fixes the triggering issue with the EKs.

The team continues to work on updating and organizing all SOPs and logs.

April 20

A line planned for coverage extinction was collected during the transit back to the 3,400 m reference site. At this time, data for coverage extinction covers depths to approximately 3,500 m. During the second portion of this cruise, this will be expanded to approximately 5,000 m.

The GFOE data team worked to understand the issues with using ArcOnline layers in both ArcGIS Online (AGOL) maps and ArcPro (see below for specifics). At this time, users will be unable to access NCEI Bathymetry Viewer and will be unable to load non vector AGOL layers. Expedition Coordinators should be prepared to not have access to these resources while aboard. The ‘download map’ capability within ArcPro has been moderately functional, however not all online layers successfully downloaded.

April 21

The third attempt to collect the Very Deep crosslines in FM mode at the 3,400 m reference site was successful. Following these crosslines, the ship transited northwest to conduct a survey to

test out the standard operational mode. All systems are functional. This survey was planned to expand bathymetric coverage in the Gulf of Mexico.

Multiple casts from the autolauncher have either stopped recording data early in the profile, or record bad profiles with the characteristic saw tooth pattern. SST will inspect during the dynamic positioning calibration days.

During the transit to the survey, the Kongsberg engineer received a request from Kongsberg HQ in Norway to collect a few lines with phase detections enabled for their testing purposes. Our license was updated to include this feature and we will have the capability to collect phase detections in the future if desired. It is noted that the resulting files were very large compared to multibeam files containing bathymetry and bottom backscatter.

The mapping team received a warning from UHDAS that the OS 38 was transmitting a temperature error. This was the same temperature spike witnessed the last time the OS 38 failed, and experience predicts that the unit will fail within 0.5 - 3 months. The Chief Electronics Technician (CET) and SST are in communication with UHDAS and Teledyne RDI to discuss testing methods.

April 22

The 250 m reference survey was completed during optimal weather conditions. The ship handling from the Officers of the Deck (OODs) was very impressive, with extremely minimal cross-track-error on very tightly spaced lines.

Following the shallow reference survey, the ship transited to Key West for the personnel transfer. During the transit, the Kongsberg Engineer, CET, and SST, worked to get the OMAO backup sonar acquisition computers operational. Afterwards, the EM 304 was officially accepted and the SAT was completed.

Following the transition back to the primary NOAA Ocean Exploration managed systems, it was necessary to power cycle all of the EK general purpose transceivers (GPTs) in order for the systems to be recognized by the EK 80 software. The team will further look into this during the dynamic positioning calibration.

While updating the multibeam (MB) processing SOP and coordinating with shore, the mapping team is refining our standard methods for scheduling sound speed profiles when processing the bathymetry data. These changes will be reflected in the SOP.

A few *.kmall files were originally unable to be processed upon import into Qimera and have been crashing the software. This has been resolved by setting their sound speed scheduling method to “Realtime Acquisition.”

The mapping team worked with the GFOE data team to have the multibeam raw files automatically copy from the local machine to the mapping drive, to reduce the potential errors introduced with manual copying. The mapping team will be evaluating this method throughout the field season.

April 23

No acoustic objectives will be performed during the dynamic positioning (DP) calibration. The team is working on documentation and readiness objectives.

The Expedition Coordinator (EC) reached out to NCEI to further troubleshoot the issue with loading NCEI online layers on the ship. NCEI helped narrow down that the layers that are unable to load are all *.ngdc.noaa.gov servers, and not ArcGIS Online. GFOE will continue to troubleshoot remotely.

The EC reached out to UHDAS to understand whether the team should proceed with testing objectives given the state of the OS 38, and articulated that the highest priority is to not jeopardize the potential use of the OS 38 for upcoming cruises when it will be operationally critical/useful to have a functional OS 38. UHDAS advised to halt all non-operationally significant testing objectives.

The SST refurbished all of the Niskin bottles on the CTD rosette. Each o-ring and tension band were inspected and any showing wear were replaced. The bottles were filled with water on the deck to ensure integrity. All bottles showed no sign of leaks.

April 24

The mission team focused on setting up the EK calibration gear, including training of newer mission personnel (including the ECs, Watch Leads, and the SST) on gear set up.

Using the new ship cameras, residual copper wire was noticed around the XBT AutoLauncher. The SST removed the copper wire and performed maintenance to try to fix the previously seen issues with ‘sawtoothing’ and casts terminating early in the water column. The new cameras will be useful for ensuring that the AutoLauncher is clear of copper wire.

The mission team caught up on the backlog of multibeam daily products and continued to work on updating SOPs.

April 25

AC was lost while the engineers were addressing the Port Auxiliary Seawater intake valve. The mission team assisted with securing the mission systems to mitigate rising temperatures.

The mission team continued with set up for the EK calibrations and SOP updating.

2019 cruise data was copied to the mapping reference drive and removed from the mapping drive.

April 26

The 38, 70, 120, and 200 kHz EKs were successfully calibrated at multiple pulse lengths. The new EK 38 transducer can be considered accepted at this time. Thanks to the mission team, wardroom, and ship's crew for quickly operationalizing to take advantage of the good weather.

The Castaway CTD worked really well for the EK calibrations, especially since the schedule had to quickly change for impending weather.

The team was sent a new version of Sound Speed Manager that should fix issues with reading the "MRZ" data packet.

April 27

Due to deteriorating weather, EK calibrations were halted following the successful calibrations of the port side sonars. Conditions are not forecasted to improve within the next few days, so the ship began transiting to the backscatter normalization line in US Atlantic waters north of the Bahamian exclusive economic zone (EEZ) in lieu of attempting the calibration of the 18 kHz EK. If a favorable weather window occurs within the duration of this cruise, a calibration will be attempted. The ship's command, crew, and the mission team have been extremely flexible and supportive of changing conditions and evolving plans, which has allowed for the successes of this cruise thus far.

Transit mapping occurred en route to the shallow backscatter reference site. Data are relatively poor due to weather conditions and the short period swell. Seas are 4-6 ft with winds 15-20 kn.

April 28

Transit mapping continued en route to the shallow backscatter reference site. Weather conditions improved throughout the day, leading to much better data quality. Thanks to a boost from the Gulf Stream, the ship was able to cruise at a blistering pace of 14 kn, reaching the backscatter reference line earlier than expected. The collection of backscatter lines continued throughout the night.

The mission team continued to test efficiencies in acquisition and processing throughout the transit. SOP generation and updating continued as well.

April 29

Acquisition of backscatter normalization lines continued through the morning. Crosslines were collected in each mode over the data to aid in interpretation. Data quality was negatively affected slightly by short period wind chop, especially while transiting from east to west.

A CTD cast was performed in the area to be applied to the normalization data, to test the firing of the Niskin bottles, and to run through the current iteration of the CTD Summary Form. Everything worked well, and the SST and mission team is providing input on how to better operationalize the CTD form.

Following the completion of the CTD and backscatter normalization acquisition, the ship began focused mapping operations in the southern extent of the Blake Plateau priority polygons. There is a storm forecasted to affect the northern areas where further deepwater testing is planned, therefore the mission team prioritized the collection of higher quality data in the south with the plan to head to deeper water once the weather conditions improve.

An overview of the Global Multi-resolution Topography (GMRT) Quality Control (QC) tools was presented by onboard mapping experts, for consideration of potential integration into the quality control workflow.

April 30

Focused mapping operations continued in the southern portion of the Blake Plateau priority polygon. Seas were 2-4ft with winds 10-15 kn, and data quality was relatively good. Oceanographic conditions have led to variable sound speed throughout the operational area; the mapping team has been working to take a network of XBT casts to aid in sound speed corrections in post processing.

In preparation for a potentially favorable weather window to conduct the final outstanding EK calibration, the mission team set up the calibration gear on deck. The command and crew continue to be flexible and accommodating to the evolving operational needs.

May 1

Focused mapping operations continued on the Blake Plateau through the morning, with improving weather/data quality throughout the day. Following a small morning squall the winds died off considerably, and the mapping line was halted in order to do a drift test to assess conditions for the calibration of the 18 kHz EK60. The calibration was given the green light, and thanks to assistance from all departments on the ship, the calibration of the 18 kHz system at

three pulse lengths was successful. The entire EK suite is now fully calibrated for the 2021 field season.

Following the calibrations, an opportunistic crossline was collected while transiting back to resume mapping operations. Focused mapping continued for the rest of the day and through the night, with a slight increase in wind/sea state.

Several crashes of the SIS computer led to data loss and the subsequent reacquisition of small areas. The mission team is investigating what seems to provoke the machine, as well as a few apparent bugs in the software relating to gridding and the projection of imported geotiffs. The crashes were few in number, and restarting the SIS computer seems to alleviate the issue. These crashes were determined unrelated to concurrent data/network failures.

May 2

Focused mapping operations continued until ~1600, when an assessment of the improving weather conditions deemed it was time to begin the 16 hour transit north to the deep backscatter reference line. The seas gradually subsided throughout the day, and data quality was relatively high.

SIS continued its temperamental behavior in the early morning. A new project was created in an effort to appease the software, and so far it appears a truce has been struck between the mission team and SIS 5.

May 3

The deep backscatter normalization line was reached in the morning and a CTD was successfully conducted to a depth of approximately 3,000 m. Backscatter normalization lines were then run for the remainder of the day. Multiple dropouts were observed in the POS/MV system on the second line run in Deep mode, however the dropouts were short in duration and likely had limited effects on the data. The POS data were logged via Ethernet logging, and are available if further investigation becomes necessary.

May 4

Collection of backscatter reference data was completed at ~0600, and the ship began the 16 hour transit to the deep accuracy testing location. Weather picked up slightly, but did not significantly affect the data, even at the increased transit speed. The EM 304 was set to automatically select the depth mode, and seems to take too long to transition from Deeper to Very Deep, leading to a decrease in data quality. This will continue to be monitored as the ship transits through these transitional depths.

The deep accuracy location was reached at ~2000 m. Acquisition of reference data and crosslines will continue through the night into early afternoon tomorrow. Data quality was relatively high despite the increased sea state. The sonar appears to be functioning well in these depths (~5,200 m).

May 5

Data acquisition on the deep accuracy survey continued through the morning. Data quality was relatively high, and the sonar continues to perform well in these depths. Following the completion of the survey, the ship began the transit back to the Blake Plateau to continue the focused mapping operations. During the transit, the depth modes were manually transitioned at the expected depths to get coverage extinction data as there seems to be an issue with the sonar doing this properly when left in Auto. Weather has deteriorated leading to a decrease in overall data quality. A manual XBT was successfully conducted to ensure a backup system is available in the event the autolauncher fails. Seas are a disorganized 4-6 ft, with winds 20-25 kn.

May 6

Transit mapping continued until reaching the Blake Plateau priority area ~2200, when focused mapping operations resumed. Weather conditions improved, and data quality was relatively high.

May 7

Focused mapping operations continued on the Blake Plateau. The seas picked up throughout the day, however data quality remained relatively high. All systems seemed to be functioning well. The mission team continued to update SOPs and generate reports.

May 8

Focused mapping operations continued on the Blake Plateau. Periodic POS dropouts at alternating intervals of 27 seconds and 2 minutes 2 seconds apart occurred for ~30 minutes, causing small data gaps. The POS also stopped logging data via Ethernet during this period. It is unclear at this point whether this issue is related to a hardware issue or satellite dropouts. All other data collection occurred as normal, and seas/weather conditions improved throughout the day.

Report writing continued as the mission team began to look towards the completion of this cruise.

May 9

Focused mapping operations continued on the Blake Plateau. The seas picked up throughout the day, however data quality remained relatively high. All systems seemed to be functioning well. The mission team continued to update SOPs and generate reports.

May 10

The ship arrived in Cape Canaveral, Florida. Demobilization began.