doi: 10.25923/edtg-dq62

Mapping Data Acquisition and Processing Summary Report

EX-21-02: 2021 Technology Demonstration (AUV and Mapping)

U.S. Southeast
Cape Canaveral, Florida to Norfolk, Virginia
May 14 to May 27, 2021

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September 2, 2021

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Introduction

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

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

Report Purpose

The purpose of this report is to briefly describe the acoustic seafloor, water column, and subseafloor mapping data collection and processing methods used by NOAA Ocean Exploration on NOAA Ship *Okeanos Explorer* during EX-21-02 and to present a summary of mapping results and mapping-related expedition activities. A separate report detailing the technology demonstration aspects of the expedition (environmental DNA sampling work and testing of the Woods Hole Oceanographic Institution's *Orpheus* and *Eurydice* autonomous underwater vehicles) will be 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.[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" 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

Expedition Objectives

This expedition addressed scientific and technology themes and priority areas put forward by the broad ocean science community. The primary objectives of the expedition were to test and develop the Woods Hole Oceanographic Institution's *Orpheus* autonomous underwater vehicle (AUV), develop water sampling procedures for environmental DNA (eDNA) analysis onboard the *Okeanos Explorer*, and map deep water areas offshore Florida, Georgia, South Carolina, North Carolina, and Virginia to provide baseline information to support science and management needs. Exploration work completed on this expedition provided a direct contribution to the Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE) campaign - a major multi-year, multi-national collaborative ocean exploration field program focused on raising collective knowledge and understanding of the North Atlantic Ocean. The campaign provides data to inform and support research planning and management decisions in the region. A full description of expedition objectives can be found in the "Project Instructions: EX-21-02 2021 Technology Demonstration (AUV & Mapping)" archived in the NOAA Central Library.[4]

As occurs on every *Okeanos Explorer* expedition, mapping operations were conducted whenever operationally possible using the ship's suite of hull mounted sonars. Mapping priorities included completing new survey coverage of areas that had never been surveyed with multibeam sonars or that lacked high quality data. AUV vehicle testing and CTD work was completed during the day, with most night-time operations dedicated to mapping work. When vehicle mechanical issues or rough weather impacted AUV testing, exploration mapping work was conducted 24 hours per day.

Operational Personnel

EX-21-02 included onboard operational personnel, inclusive of ship's force and mission team, who participated in operational execution of mapping and AUV objectives (see **Table 1**).

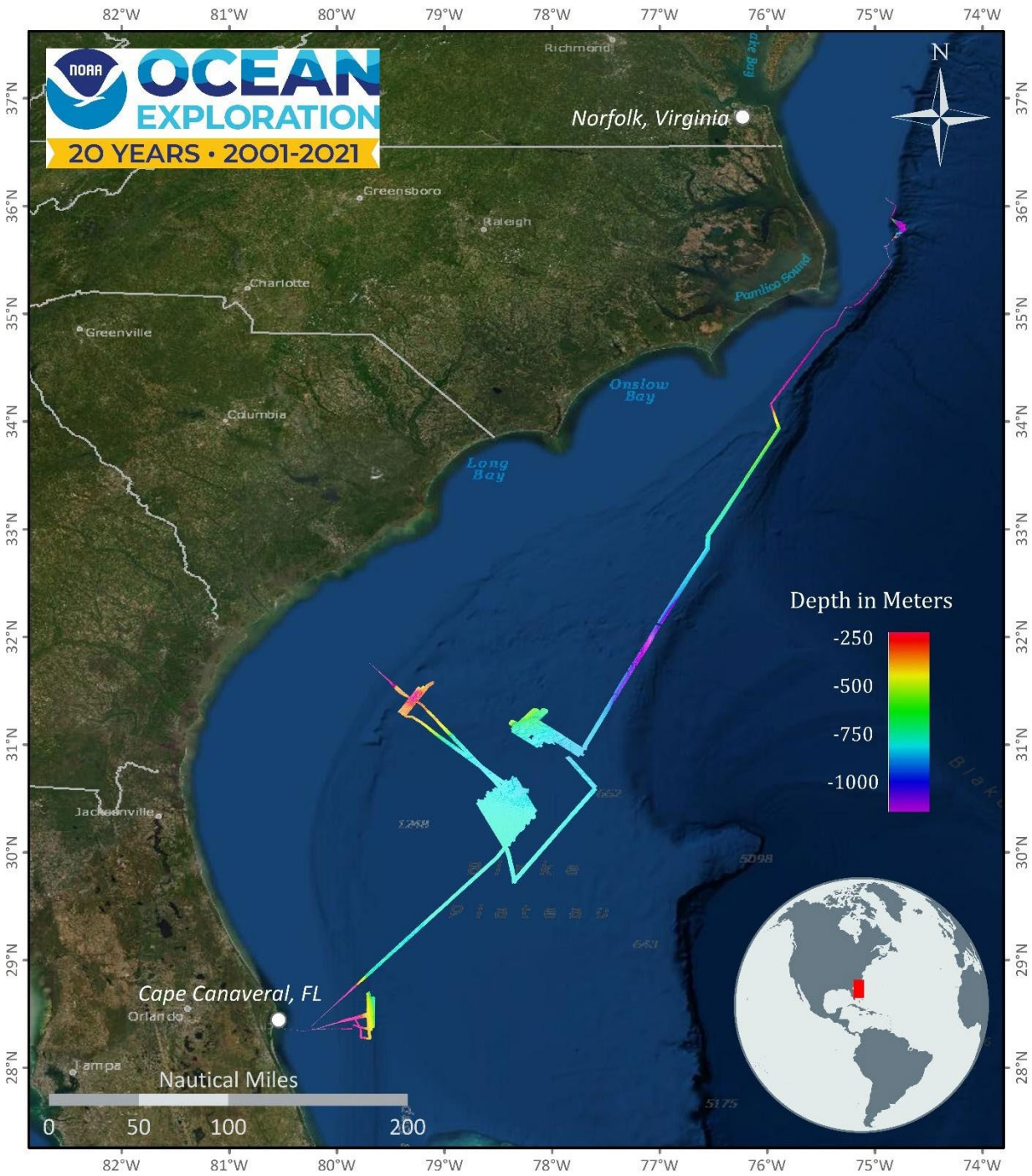
[4] https://doi.org/10.25923/ksks-3e94

Table 1. EX-21-02 Onboard personnel.

Name	Role	Affiliation
Michael White	Expedition Coordinator	NOAA Ocean Exploration/Cherokee Federal
Kim Galvez	Expedition Coordinator (training)	NOAA Ocean Exploration/Cherokee Federal
Derek Sowers	Mapping Lead	NOAA Ocean Exploration/Cherokee Federal
Daniel Freitas	Mapping Watch Lead	University Corporation for Atmospheric Research
Jason Meyer	Mapping Watch Lead	University Corporation for Atmospheric Research
Katharine Egan	eDNA Lead	NOAA Ocean Exploration
Meredith Everett	eDNA Subject Matter Expert	NOAA Northwest Fisheries Science Center
Rachel Gulbraa	Engagement Specialist	NOAA Ocean Exploration/ University Corporation for Atmospheric Research (UCAR)
Tim Shank	*Orpheus* Science Lead	Woods Hole Oceanographic Institution
Casey Machado	*Orpheus* Engineer Lead	Woods Hole Oceanographic Institution
Andy Klesh	*Orpheus* Engineer	NASA Jet Propulsion Laboratory
Russell Smith	*Orpheus* Engineer	NASA Jet Propulsion Laboratory
Jessica Kaelblein	Videographer	Inner Space Center/University of Rhode Island
Jim Meyers	Computer Administrator	Global Foundation for Ocean Exploration
Chris Wright	Computer Administrator	Global Foundation for Ocean Exploration
Brian Doros	Video Engineer	Global Foundation for Ocean Exploration
Art Howard	Videographer	Global Foundation for Ocean Exploration

Summary of Mapping Results

NOAA Ocean Exploration mapped 9,669 sq km of seafloor during the 14 days at sea for EX-21-02. Of the 9,669 sq km mapped, 9,655 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 1.**



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Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 1. Overview of bathymetric mapping coverage completed during the 2021 Technology Demonstration (EX-21-02).

Mapping Statistics

Table 2 provides summary statistics of ocean mapping work during EX-21-02 May 14-27, 2021 (UTC).

Table 2. Summary statistics of ocean mapping work during EX-21-02.

Statistic	Value
Ship's draft*: Start of expedition (05/14/2021) End of expedition (05/27/2021)	 Fore: 16'7.5"; Aft STBD: 15'6.5"; Aft Port: 15'10.5" Fore: 15'10.5"; Aft STBD: 16'0.5"; Aft Port: 16'5"
Linear kilometers of survey with EM 304	3,345
Square kilometers mapped with EM 304	9,669
Square kilometers mapped with EM 304 within U.S. waters deeper than 200 m	9,655
Number/data volume of EM 304 raw multibeam files (.kmall)	352 files/94.2 GB
Number/data volume of EM 304 water column multibeam files (.kmwcd)	352files/216 GB
Number/data volume of EK60/EK80 water column split-beam files (.raw)	1,112/68.6 GB
Number/data volume of sub-bottom sonar files (.segy, .kea, .keb)	538/2.52 GB
Number of expendable bathythermograph (XBT) casts	83
Number of conductivity, temperature, depth profiler (CTD) casts (including test casts)	12

*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 3 reflect 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-21-02 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.[5]

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

[5] 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.

During EX-21-01 the 38 kHz transducer experienced temperature spikes indicating possible water intrusion and imminent failure. The ADCP was used during EX-21-02 to help assess currents at AUV dive sites, with the data appearing reasonable. However, the data from this expedition for the 38 kHz ADCP is of unknown quality given the expected degradation of the transducer from water intrusion.

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 AUV 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. During EX-21-02, focused mapping surveys of four areas lacking multibeam sonar data were completed (see **Figure 1** for specific locations). Most of the other mapping data were collected during transits between ports and AUV dive locations.

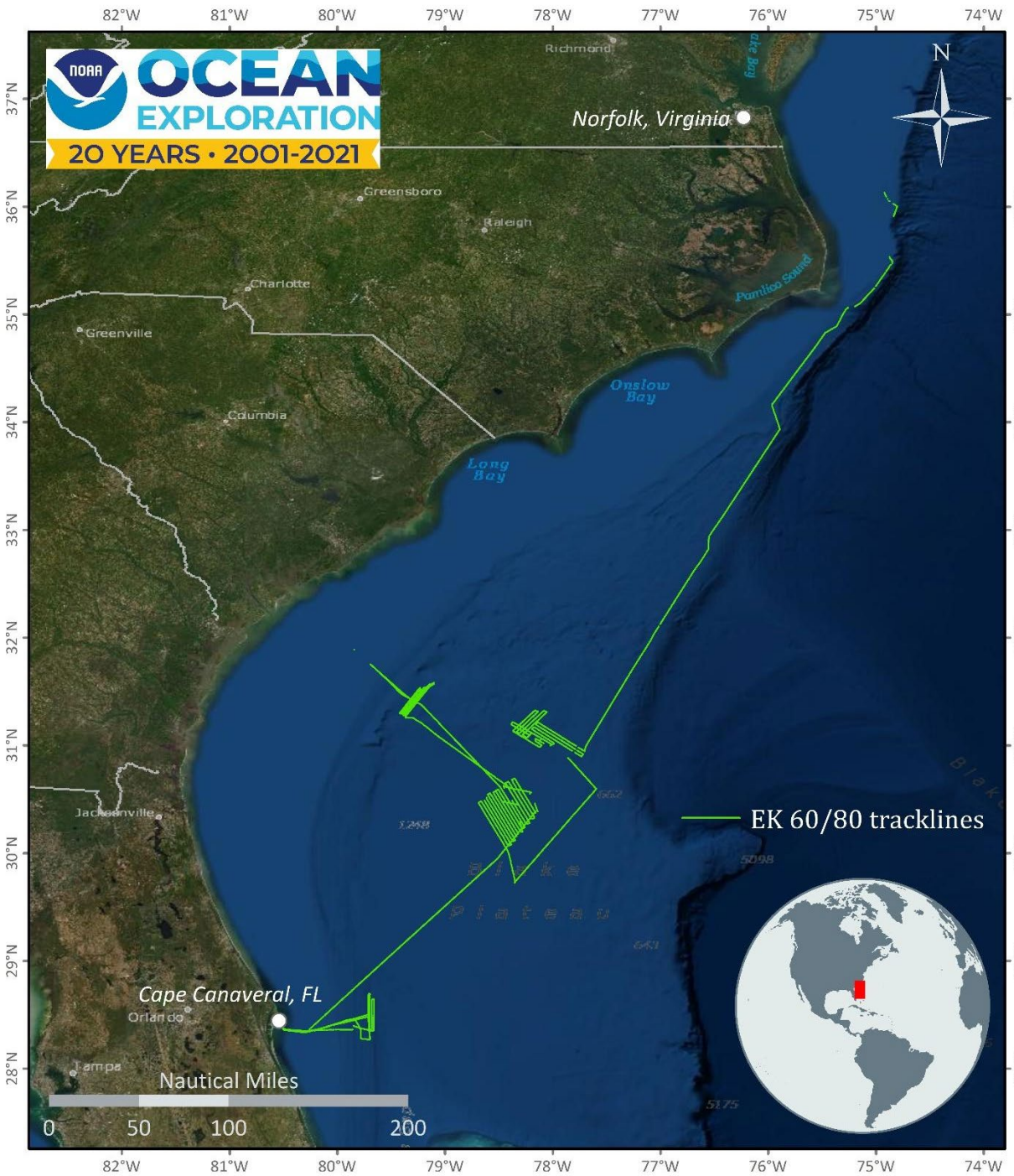
Throughout the expedition, multibeam data quality was monitored in real time by acquisition watchstanders. Ship speed was adjusted to maintain data quality and sounding density as

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

Real-time corrections to the data upon acquisition included: continuous application of surface sound speed obtained with a hull-mounted Reson 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 AUV dives. Data were monitored in real time for quality but were not post-processed. **Figure 2** shows the EK60/EK80 data collected during EX-21-02.

Knudsen 3260 sub-bottom profiler data were also collected during the majority of the expedition. **Figure 3** shows where sub-bottom data were collected during EX-21-02.



Service Layer Credits: Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 2. Simrad EK60/EK80 split-beam sonar data collection tracklines (in green) collected during EX-21-02.

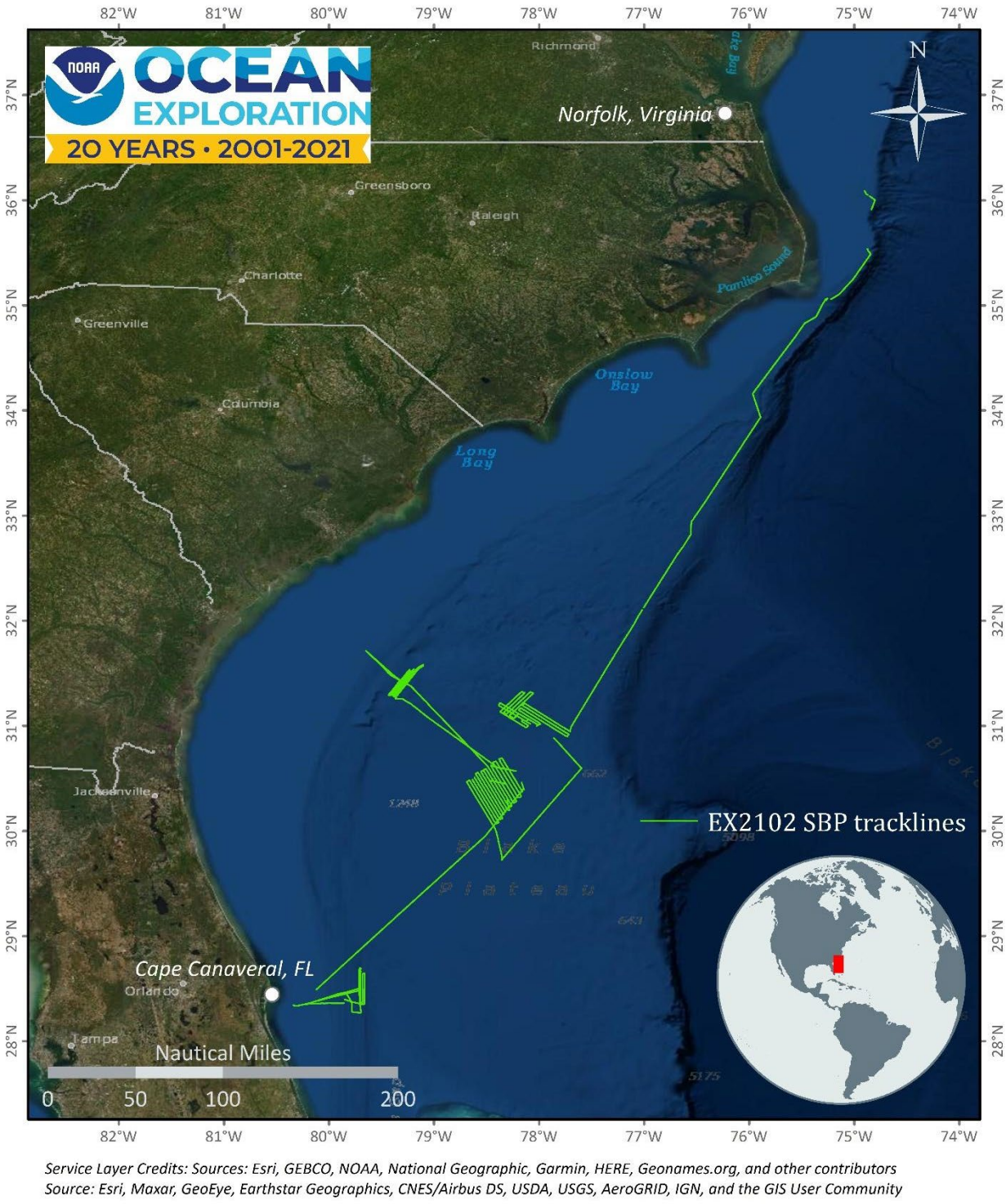


Figure 3. Sub-bottom profiler data collection tracklines (in green) collected during EX-21-02.

Multibeam Sonar Bathymetry Data Quality Assessment and Data Processing

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

The full-resolution multibeam .kmall files (Level-00 data) were imported into QPS Qimera, and then processed and cleaned of noise and artifacts. Outlier soundings were removed using multiple methods including automatic filtering and/or manual cleaning with the swath and subset editing tools. The default sound speed scheduling method used was "Nearest-in-Time." If another method was implemented, it 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 4** shows the onboard multibeam data processing workflow.

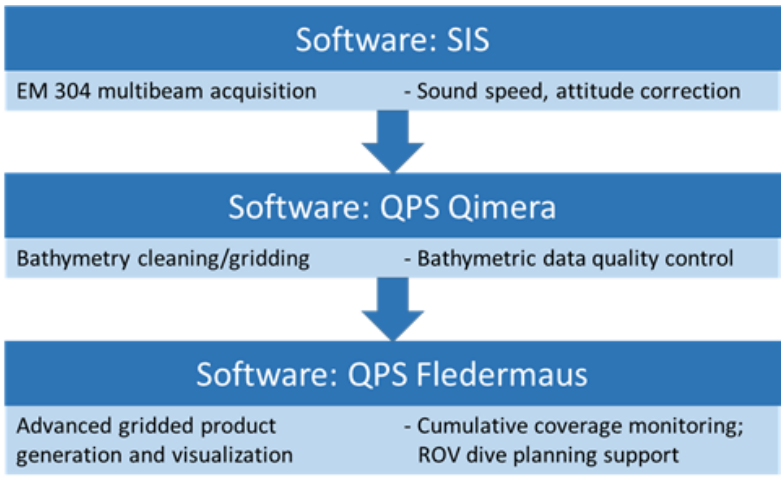


Figure 4. Shipboard multibeam data processing workflow.

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.

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 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). A crossline was run on May 23, 2021 as shown in **Figure 5**, and the results are presented in **Table 3**.

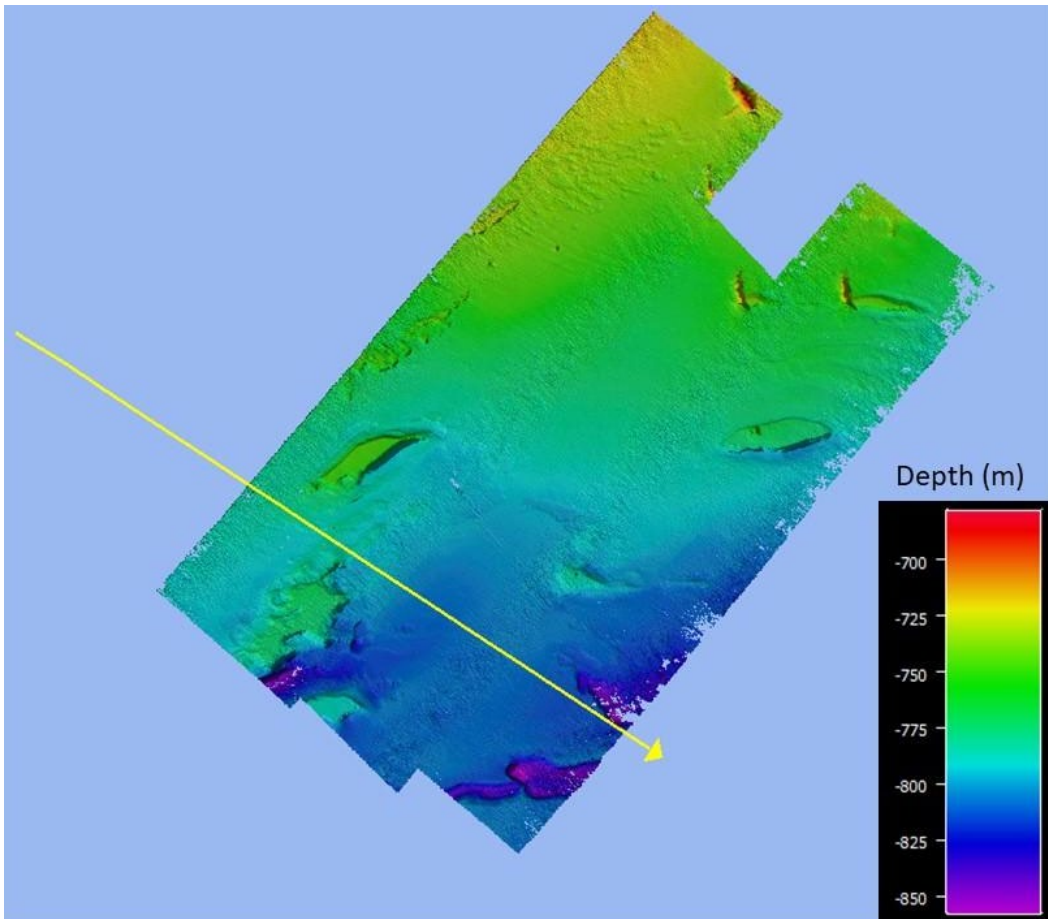


Figure 5. EX-21-02 crossline (shown in yellow) used for comparison against the bathymetric grid generated via orthogonal multibeam survey lines.

Crossline file: 0004_20210523_234557_EX2102_MB.kmall

Mainscheme line files:

- 0228_20210524_030955_EX2102_MB.kmall
- 0232_20210524_061806_EX2102_MB.kmall
- 0236_20210524_071932_EX2102_MB.kmall
- 0241_20210524_101148_EX2102_MB.kmall

Table 3. Crosscheck results

Statistic	Value
Number of points of comparison	892,181
Grid cell size (m)	20.00
Difference mean (m)	-0.059810
Difference median (m)	-0.213355
Difference standard deviation (m)	2.183756
Difference range (m)	[-44.55, 31.21]
Mean + 2* standard deviation (m)	4.427321
Median + 2* standard deviation (m)	4.580866
Data mean (m)	-781.710733
Reference mean (m)	-781.650923
Data z-range (m)	[-833.89, -736.64]
Reference z-range (m)	[-827.30, -737.82]
Order 1 error limit (m)	10.173756
Order 1 # rejected	1,869
Order 1 p-statistic	0.002095
Order 1 survey	ACCEPTED

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

Acquisition and Processing Software

Table 4 provides a list of the acquisition and processing software versions that were used during EX-21-02.

Table 4. Versions of acquisition and processing software used during EX-21-02.

Software	Purpose	Version
SIS	EM 304	5.6 1.5.2
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	2.3.4
FMGT	Backscatter	7.9.5
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-21-02, 2021 Technology Demonstration (AUV & Mapping)" document which is archived in the NOAA Central Library. For each data type, raw data (Level 00), processed data (Level 01), derived products (Level 02), and ancillary files may be available, depending on the dataset and the level of staffing for the expedition. **Tables 5-9** describe the data archived for each dataset. For further information about proprietary software and freeware that can handle the varying data types, refer to the "NOAA OER Deepwater Exploration Mapping Procedures Manual."

Table 5. EM 304 bathymetry and seabed backscatter dataset.

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

Table 6. EM 304 water column backscatter dataset.

Level	Description	File Type
Level 00	Raw multibeam files (in native sonar format) that include water column backscatter (horizontal referencing = WGS84)	.kmwcd
Level 01	n/a	n/a
Level 02	QPS Fledermaus objects such as beam	.sd, .scene

	fan, beam line, volume and/or track line; produced if time and staffing allows (horizontal referencing = WGS84)	
Ancillary files	Mapping watchstander log, weather log, sound speed profile log, multibeam acquisition and processing log, water column data log, built-in self test logs, processing unit parameters, recorded telnet sessions	.xlsm, .xlsx, .txt

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

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

Table 8. Knudsen 3260 sub-bottom profiler dataset.

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

Table 9. Sound speed profiles dataset.

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

All sonar data is permanently discoverable within the NCEI archives[6] and searchable through the Ocean Exploration Digital Atlas,[7] which provides access to all of the data collected during an expedition. The locations for specific data types (at the time of writing this report) are detailed in **Table 10**. For any challenges accessing data, send an inquiry to NCEI,[8] or contact the Ocean Exploration Mapping Team.[9]

[6] https://www.ngdc.noaa.gov/

[7] https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm

[8] ncei.info@noaa.gov

[9] oar.oer.exmappingteam@noaa.gov

Table 10. Locations of data collected during EX-21-02 (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
Sound speed profiles	Ancillary sound speed profiles are available along with all mapping data per expedition in the NCEI data archives, or within the oceanographic archive for the expedition.	https://maps.ngdc.noaa.gov/viewers/bathymetry/ or through the oceanographic archives at: https://www.ncei.noaa.gov/

Reports	Reports are archived in the NOAA Central Library's Ocean Exploration Program (OEP) institutional repository	NOAA Central Library home: https://library.noaa.gov/ OEP institutional repository: https://repository.library.noaa.gov/cbrowse?pid=noaa%3A4&parentId=noaa%3A4

Expedition Schedule

Table 11. EX-21-02 schedule.

Date (UTC)	Activity
5/11	Mobilization Port Canaveral, Florida. AUV 20' container staged next to ship. Mission team moved onboard.
5/12	Mobilization Port Canaveral, Florida.
5/13	Mobilization Port Canaveral, Florida. Walkthrough of *Orpheus* launch and recovery.
5/14	1000 Depart Port Canaveral, Florida. Tethered launch and recovery of *Orpheus* for engineering testing (vehicle deployments 001, 002, and 003). Overnight mapping.
5/15	*Orpheus* dive 004, shallow dive, 'Port Canaveral East'. Small boat calibration operations. CTD rosette cast 001. Overnight mapping.
5/16	*Orpheus* dive 005 and CTD cast 002, both shallow about 4 nautical miles from Port Canaveral. Overnight transit mapping operations.
5/17	*Orpheus* dive 006, first deep dive (860 m). CTD cast 003 completed with *Orpheus* in the water. Overnight Blake Plateau mapping.
5/18	*Orpheus* dive 007. CTD cast 004. Overnight mapping operations on the Blake Plateau.
5/19	*Orpheus* dive cancelled due to weather. CTD cast 005 in the main axis of the Gulf Stream. 24-hour mapping operations on the eastern Blake Plateau.
5/20	Inaugural dive with AUV *Eurydice* in shallow water (30 m). CTD cast 006. Overnight mapping operations.
5/21	*Orpheus* dive 008. CTD cast 007. Overnight mapping operations.
5/22	*Orpheus* dive cancelled, engineering and maintenance day. CTD Cast 008. 24 hour mapping operations on the Blake Plateau.

5/23	*Orpheus* dive 009. CTD cast 009. Overnight mapping operations on the Blake Plateau.
5/24	*Orpheus* dive 010. Final AUV dive. Overnight mapping operations on the Blake Plateau.
5/25	CTD cast 011. Begin northward transit, overnight transit mapping operations.
5/26	Attempted handheld ROV deployment. CTD cast 012. Mapping operations in support of Monitor National Marine Sanctuary (MNMS).
5/27	Arrival in Norfolk, Virginia. Demobilization. Unloading of 20’ container from 02 Deck.

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., Wang, L., Candio, S., and Hoy, S. (2021). 2021 EK60/EK80 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

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). http://hdl.handle.net/11329/388

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

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

White, M. (2021). Project Instructions: EX-21-02, 2021 Technology Demonstration (AUV & Mapping). Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://doi.org/10.25923/ksks-3e94

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).

May 11-13, 2021

Mission team successfully completed their shelter in place period (May 3-11) with negative COVID tests. The team moved aboard on May 11 and began mobilizing equipment. Mapping systems were set up for the expedition. The augmenting Senior Survey Technician (SST) was provided with a two-day pass-down from SST Wilkins in order to be ready for mission operations, including support of eDNA work via CTD casts. All mapping systems confirmed ready for the expedition.

May 14, 2021

The ship departed Port Canaveral at 1000 local time. The ship transited straight out into 6-8' seas. The ADCP 300 kHz was run leaving Cape Canaveral to assess nearshore currents in order to get a preview of conditions for the following morning of AUV testing. The ADCP showed a surface current of 4.5 knots running in the exact orientation of the ship, which was immediately suspect. The ship was transiting at full speed, and that speed did not seem to be fully accounted for in the ADCP measurements. Bottom tracking was off, which may have impacted the ability of the ADCP to assess currents correctly. The unit will be tested with bottom tracking on tomorrow. After leaving the nearshore area, the ADCP was secured and the EK, Knudsen, and multibeam were synced and collected data during the transit to the focused mapping priority area 5. Survey speeds were kept slower than normal to reduce the impact of the elevated sea state on the data. Data quality was moderate overall. Sonars and related equipment working as expected.

May 15, 2021

Several lines within mapping priority area 5 were completed following the collection of transit data. Data quality was moderate northbound and good southbound. The ADCP 300 kHz was tested again and seemed to work fine when the ship was stationary, but looked like erroneous data when the ship was transiting. Transit lines will be edge matched tonight and more data collected in priority area 5. The bottom detection depth maximum on the EK18 has to be kept pretty close to actual depth or it will delay the K-Sync and the EM304 data will show periodic gaps.

May 16, 2021

Overnight mapping completed about 75% of the area 5 priority box despite very rough seas. The EM304 would occasionally drop a series of pings in shallow water. This was not due to POSMV feed dropouts. This only happens with high ping rates in shallow water (<100 m), so may be a duty cycle issue of the EM304 or EKs. We will try a slight synchronization offset in the EK ping timing to see if we can mitigate. Night mapping will be a high speed transit to the deep AUV site in the central Blake Plateau. We installed Fledermaus on the NASA laptop and provided a 15 m grid of the dive site with contours.

May 17, 2021

Overnight mapping was a straight transit from the Cape Canaveral area to the central Blake Plateau AUV deployment area. Mapping data quality was good especially considering transit speeds up to 11 knots. Daily products were brought up to date. The augmenting SST has been doing an excellent job managing CTD casts, SCS, maintaining the XBT autolauncher, and cleaning multibeam data. Overnight mapping Watch Leads are also doing excellent work watchstanding for night mapping operations and keeping up with data processing. The OS38 was operated today to provide local current data at the AUV and CTD site. It seemed to provide good data down to about 700 m, and was consistent with the current speed/directions from the 300 kHz ADCP. The 38 kHz ADCP was secured after launch and will be used again tomorrow. EK data is being used by the eDNA team to guide bottle sample collection depths associated with the deep scattering layer.

May 18, 2021

The EK80 software abruptly stopped logging/pinging at 0430 this morning and lost connection to the 18 and 200 transceivers entirely. Power cycling of the EK breaker and the EK80 machine/software fixed the problem. Most mapping computers had to be powered off today for a repair to the ship's cooling water system. Getting all computers up and running and configured again properly took some time. All systems returned to normal and transit mapping towards the shallow AUV dive site commenced in the afternoon. Tonight we will focus on some lines of focused survey close to tomorrow's dive site.

May 19, 2021

Around-the-clock mapping operations were conducted today due to the postponement of the AUV dive. The sea was rough with 6-8' seas and challenging for data collection. Good data were obtained by running southward and terrible data going northward. At one point, SIS lost displays for crosstrack, seabed, intensity, and waterfall window views (but still logged data). This was fixed by power cycling the processing unit. When struggling with bottom tracking, the

EK sonars were secured since the K-Sync was making the multibeam wait for them. Slow but steady progress was completed on a priority mapping box in about 400-500 m of water. Late tonight we will transit to a shallow dive site on the shelf.

May 20, 2021

Mapping continued last night on priority area 3 in rough seas. North lines were done quickly and in some cases data were not logged because they were too poor to be usable. South lines were moderate quality, and were spaced to ensure full coverage mapping without processing of north lines. Despite challenging conditions, the resulting bathymetric surface is reasonably good. We then transited several hours to the shallow water AUV testing site on the shelf. The POSView computer abruptly shut down last night for no apparent reason. This did not affect the POS data itself, and the computer was quickly brought back online and has been normal ever since (appeared to be a windows issue). Mapping operations resumed in the afternoon after an early recovery of the AUV. Transiting tonight to the deep AUV test area and will continue to map unmapped areas to the south in priority area 2.

May 21, 2021

The night was spent mapping in priority mapping area 2 south of the planned AUV dive site. We mapped several very prominent elongated features that appear to be significant coral mounds, along with large flat areas. Data quality was good overall. The compromised OS38 ADCP still seems to be gathering valid data and is being used to inform the team of currents at the AUV dive sites for deployment and recovery. This has helped us plan our strategy to try to get the AUVs close to mound features even though they drift with the current on descent/ascent and we don't know their position during a dive. Mapping resumed at the priority mapping area immediately following AUV recovery and will continue overnight and all day and night tomorrow. The staffing level for the onboard mapping team has been effective at keeping up with the data flow. We have been managing sound velocity changes carefully and overall data quality is good. SIS is still exhibiting some display functionality issues while surveying – but nothing major that interrupts logging of data.

May 22, 2021

Today was an around-the-clock mapping day. We continued progress mapping in priority area 2. Our line orientation was optimal for data quality and sea state subsided during the day. The area is flat and mostly featureless thus far with very stable sound speed. Sound Speed Manager stopped getting SIS datagrams last night. The CTD1 computer was rebooted and this fixed the problem. SIS has continued to have issues with display windows randomly not working - including geographic display today. These issues have not affected data logging on the

multibeam and are fixed with a reboot of the processing unit. Overnight mapping will complete a transit northward to the next planned AUV dive and CTD site.

May 23, 2021

We conducted transit mapping while edge matching existing multibeam coverage to get to the AUV dive site to the north. After AUV recovery we began surveying in the adjacent high priority mapping area. We encountered a serious issue with SIS. It would not automatically or manually advance the line count number and thus the file would not write more data. So the software appeared to be logging like normal but was actually not collecting data into a new file. This issue cost us several hours of mapping data that we had to repeat. We fixed it by rebooting SIS, restarting the workstation and PU, and starting a new survey. We had to start the new survey to resolve the issue, so it appears that this problem can corrupt an entire survey project from gathering new data. We were able to start the new survey starting at the line count we left off on, which minimized duplicate multibeam survey file line names. These issues required substantial changes to our overnight line planning. Other than that, sea state was quite calm and survey data was very good.

May 24, 2021

Overnight mapping work focused on filling an odd shaped gap in multibeam coverage nearby. Some interesting mound and scarp features were revealed. Following AUV recovery, mapping work focused on a survey area just north of the dive site at priority area two. SIS continued randomly losing tool functionality such as ship tracking and the measurement tool. The gridding engine has been stable this expedition. The final transit north was planned today, including a visit to an unknown wreck of interest to the Monitor National Marine Sanctuary.

May 25, 2021

Overnight mapping worked on a focused survey in the central Blake Plateau, followed by beginning the northward transit towards Norfolk. Transit speeds today were up to 11-13 knots and still collecting good data. SIS had a major incident today (as also reported on the shakedown) with many errors flashing all at once. Data logging still looked fine, so we waited until crossing an area with coverage then restarted SIS and the processing unit to fix the issue. Our experience confirms lessons from the shakedown - restart SIS and the processing unit as much as possible proactively to avoid issues. We planned a focused survey near Monitor National Marine Sanctuary for tomorrow morning in collaboration with onshore managers and Office of National Marine Sanctuaries program. The expedition package data syncing to hard drive for transport to shore data storage was started today. We have completed focused surveys of substantial areas in four different priority mapping areas as time allowed on this

expedition. Bathymetry and completed AUV dive locations were merged into a Fledermaus scene file and delivered to the AUV team.

May 26, 2021

We transit mapped all night at high speed collecting edge-matching sonar data. Data quality was impacted slightly by the speed but we were just mapping gently sloping featureless seafloor most of the way. We conducted a shipwreck mapping survey starting at 0630 and were able to locate the wreck and map it with parallel and orthogonal lines. Bathymetry was quickly processed to generate a map of the wreck to guide the attempted ROV dive. The backscatter did not show the wreck well. All data collected this day is publicly available. After ROV recovery we transit mapped along the edge of the continental shelf and mapped another wreck based on coordinates given to us by MNMS. On the transit towards port in Norfolk we conducted a series of tests with the EM304, Knudsen, and EKs. These tests were requested by research partners at the University of New Hampshire Center for Coastal and Ocean Mapping (UNH/CCOM). We completed the tests and recorded the data files to share.

May 27, 2021

Sonars were secured overnight at 50 m water depth on the shelf on the way into Norfolk. Daily bathymetry products and daily and cumulative backscatter products were completed. The data package was copied to bring back to UNH/CCOM. All sonars were secured at the breakers.