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Mapping Data Acquisition and Processing Summary Report

EX-22-05: Voyage to the Ridge 2 (ROV and Mapping)

Mid-Atlantic Ridge & Azores Plateau

Norfolk, Virginia to Horta, Faial, Azores

July 9 - 30, 2022

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October 20, 2022

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Introduction

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

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

Report Purpose

The purpose of this report is to briefly describe the acoustic seafloor, water column, and subseafloor mapping data collection and processing methods used by NOAA Ocean Exploration on NOAA Ship *Okeanos Explorer* during Voyage to the Ridge 2 (EX-22-05) and to present a summary of mapping results and mapping-related expedition activities. A separate report detailing the remotely operated vehicle activities of the expedition will be available through the NOAA Central Library.

Detailed descriptions of *Okeanos Explorer's* mapping equipment and capabilities is available in the "NOAA Ship *Okeanos Explorer* Mapping Systems Readiness Report 2022," which is archived in the NOAA Central Library.[1] Supplemental documents are added to the Readiness Report throughout the year if changes to, or recalibrations of, the equipment are made.

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]

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[1] https://doi.org/10.25923/g2ep-ae34

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

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

Expedition Overview

From July 9 - 30, 2022, NOAA Ship *Okeanos Explorer* sailed for NOAA Ocean Exploration's Voyage to the Ridge 2 expedition (EX-22-05). Expedition operations involved transiting northeast from Norfolk, Virginia to the Mid-Atlantic Ridge (MAR). Due to an emergency drydock prior to this expedition, a multibeam geometric calibration ('patch test') was performed near Hudson Canyon to account for any changes in alignment. Once at the MAR, the focus turned to daily remotely operated vehicle (ROV) exploration and nightly mapping. The last portion of the expedition consisted of mapping and ROV exploration in the vicinity of the Azores Plateau while transiting to the final destination of Horta, Ilha do Faial, Azores.

The focus of this work was in the deep waters of the North Atlantic (greater than 200 m for mapping operations and greater than 250 m for ROV operations). This expedition contributed to critical baseline information to support priority NOAA science, partner, and management needs.

Atlantic U.S. deep-sea exploration contributes to NOAA's Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE), a major multi-year, multi-national, collaborative ocean exploration campaign focused on raising our collective knowledge and understanding of the North Atlantic Ocean. Building on previous work in the North Atlantic, including the 2011-2014 Atlantic Canyons Undersea Mapping Expeditions (ACUMEN), NOAA's ASPIRE campaign provides data to inform research planning and management decisions in the region, by broadening both the geographic focus to include more of the U.S. Atlantic and Canada, and the scope of partnerships to include U.S. federal agencies, such as U.S. Geological Survey (USGS) and Bureau of Ocean Energy Management (BOEM), as well as international partners from Canada and Europe. ASPIRE also supports the National Strategy for Mapping, Exploring, and Characterizing the United States Economic Zone[4] and Seabed 2030.

The complete objectives for this expedition are detailed in "Project Instructions: EX-22-05 Voyage to the Ridge 2 (ROV and Mapping)," which is archived in the NOAA Central Library.[5]

Operational Personnel

EX-22-05 onboard operational personnel, inclusive of the ship's force and mission team, who participated in operational execution are detailed in **Table 1**.

[4] https://oeab.noaa.gov/wp-content/uploads/2021/01/2020-national-strategy.pdf (last accessed 10/17/2022)
[5] https://doi.org/10.25923/64dm-6g04

Table 1. EX-22-05 Onboard personnel.

Name	Role	Affiliation	Dates Aboard
Derek Sowers	Expedition Coordinator	NOAA Ocean Exploration	07/05 – 07/30
Shannon Hoy	Mapping Lead	NOAA Ocean Exploration	07/05 – 07/30
Kimberly Galvez	Mapping Watch Lead	NOAA Ocean Exploration (FW)[1]	07/05 – 07/30
Marcel Peliks	Mapping Watch Lead	UCAR[2]	07/05 – 07/30
CST Charlie Wilkins	Chief Survey Technician	OMAO[3]	07/05 – 07/30
LT Hunter Brendel	Operations Officer	OMAO[3]	07/05 – 07/30
Ashton Flinders	Science Lead	UCAR[2]	07/05 – 07/30
Scott France	Science Lead	UCAR[2]	07/05 – 07/30
Arvind Shantharam	Sample Data Manger	NCEI[4]	07/05 – 07/30
Chris Ritter	GFOE Team Lead	GFOE[5]	07/05 – 07/30
Levi Unema	Ocean Engineer	GFOE[5]	07/05 – 07/30
Chris Wright	Data Engineer	GFOE[5]	07/05 – 07/30
Andrew O'Brien	Data Engineer	GFOE[5]	07/05 – 07/30
Jonathan Laning	Ocean Engineer	GFOE[5]	07/05 – 07/30
Lars Murphy	Ocean Engineer	GFOE[5]	07/05 – 07/30
Jon Mefford	Ocean Engineer	GFOE[5]	07/05 – 07/30
Caitlin Bailey	Video Engineer	GFOE[5]	07/05 – 07/30
Anna Sagatov	Video Engineer	GFOE[5]	07/05 – 07/30
Roland Brian	Video Engineer	GFOE[5]	07/05 – 07/30
Brian Doros	Video Engineer	GFOE[5]	07/05 – 07/30
Fernando Aragon	Data Engineer	GFOE[5]	07/05 – 07/30
Jon Simmons	Technician	DSPL[6]	07/05 – 07/30

[1]FedWriters
[2]University Corporation for Atmospheric Research
[3]NOAA Office of Marine and Aviation Operations
[4]National Centers for Environmental Information
[5]The Global Foundation for Ocean Exploration
[6]Deep Sea Power and Light

Summary of Mapping Operations

NOAA Ocean Exploration mapped 49,417 square kilometers (sq km) of seafloor during the 22 days at sea for EX-22-05. Of the 49,417 sq km mapped, 5,856 sq km were collected in waters deeper than 200 meters (m) and within the U.S. Exclusive Economic Zone and Territorial Sea. Multibeam bathymetry data coverage is shown in **Figure 1 and 2.**

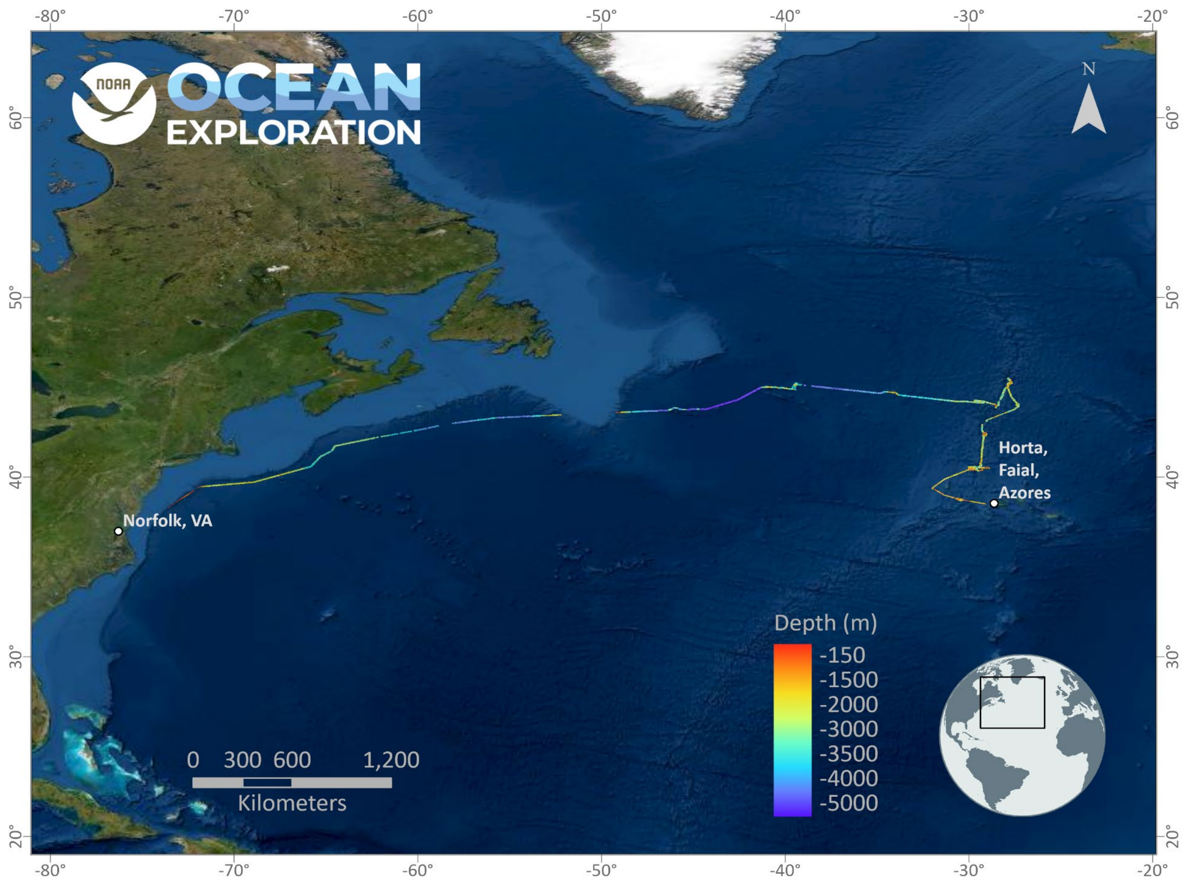

Figure 1. Overview of bathymetric mapping coverage collected during Voyage to the Ridge 2 (EX-22-05).

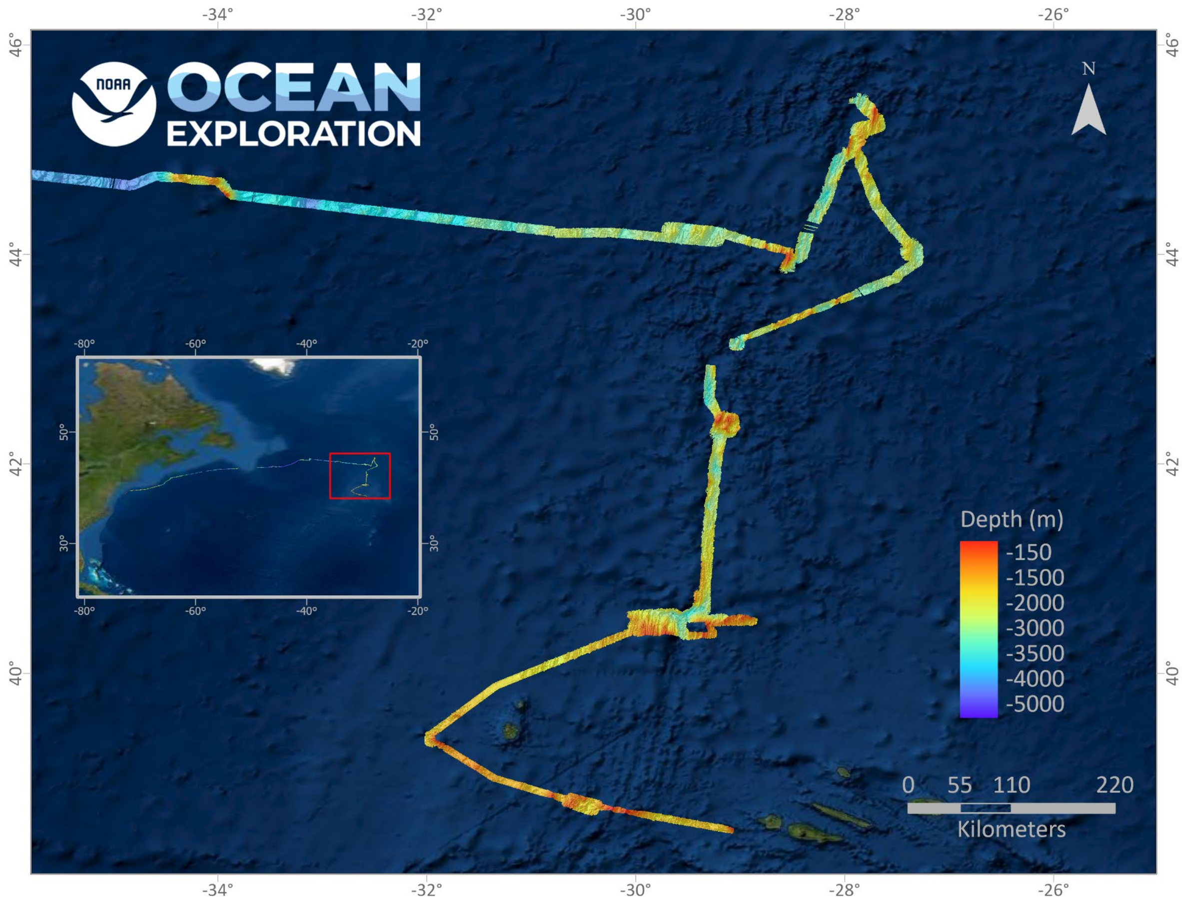

Figure 2. Bathymetric coverage along the Mid-Atlantic Ridge collected during Voyage to the Ridge 2 (EX-22-05).

Mapping Statistics

Table 2 provides summary statistics of ocean mapping work during EX-22-05, July 9 - 30, 2022 (UTC).

Table 2. Summary statistics of ocean mapping work during EX-22-05.

Statistic	Value
Ship's draft*: Start of expedition (07/09/2022) End of expedition (07/30/2022)	Fore: 15' 6.5''; Aft STBD: 16' 3.5"; Aft Port: 16' 4" Fore: 16' 4"; Aft STBD: 16' 0.5"; Aft Port: 16' 0.5"
Linear kilometers of survey with EM 304	5351.1
Square kilometers mapped with EM 304	49,417.30
Square kilometers mapped with EM 304 within U.S. waters deeper than 200 m	5,856
Number/data volume of EM 304 raw multibeam files (.kmall)	652** files/50.6 GB
Number/data volume of EM 304 water column multibeam files (.kmwcd)	643** files/127 GB
Number/data volume of EK60/EK80 water column split-beam files (.raw)	688/119 GB
Number/data volume of sub-bottom sonar files (.segy, .kea, .keb)	731/2.78 GB
Number of expendable bathythermograph (XBT) casts	107
Number of conductivity, temperature, depth profiler (CTD) casts (including test casts)	0

*Prior to EX-21-01, and as a result of the full marine survey completed during the 2020/2021 drydock, it was 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.

**Note that the number of files is not comparable to previous expeditions as the line files were set to split at 30 min rather than 60 min intervals due to a bug with the software.

Mapping Sonar Setup

Kongsberg EM 304 Multibeam Sonar

NOAA Ship *Okeanos Explorer* is equipped with a 26 kilohertz (kHz) Kongsberg EM 304 MKII multibeam sonar, capable of detecting the seafloor in up to 10,000 m of water and conducting productive mapping operations in up to 8,000 m of water. The nominal transmit (TX) alongtrack beamwidth is 0.5°, and the nominal receive (RX) acrosstrack beamwidth is 1.0°. The system generates a 150° beam fan, 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.

During EX-22-05 a multibeam geometric calibration ('patch test') was performed due to an emergency dry dock prior to the start of the expedition. The offset values calculated during this patch test supersede those calculated during the EX-22-01 shakedown expedition. The results of the multibeam calibration are archived with the 2022 Readiness Report as a supplemental document.[6]

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.

Due to the emergency dry dock following EX-22-04, the June EK calibrations are no longer relevant to the EX-22-05 EK dataset. Calibrations were performed during the following expedition (EX-22-06) on the Azores Plateau and these calibration values are most appropriate for the EX-22-05 dataset. The calibration files are archived with the sonar data and an updated calibration report is available in the NOAA Central Library as a supplemental document to the 2022 Readiness Report.

[6] https://doi.org/10.25923/g2ep-ae34

Knudsen 3260 Sub-Bottom Profiler

The ship is equipped with a Knudsen 3260 sub-bottom profiler (SBP) that produces a frequency-modulated chirp signal with a central frequency of 3.5 kHz. This sonar is used to provide echogram images of shallow geological layers underneath the seafloor to a maximum depth of approximately 80 m below the seafloor. The sub-bottom profiler is operated to provide information about sub-seafloor stratigraphy and features.

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.

Data Acquisition Summary

Following port departure, calibration data was collected with the ADCP WH300 and secured once appropriate water depths (200 m) were reached. A patch test for the EM 304 multibeam sonar was performed with the POS MV set as the primary positioning and motion unit. A second patch test was not performed with the Seapath set as the primary positioning and motion unit, though offset values for the Seapath were calculated using the POS MV patch test surface. The offset values were updated in Kongsberg's Seafloor Information System (SIS) software, and the results are archived in a supplemental patch test document added to the 2022 Readiness Report.[7]

Standard mapping operations included the EM 304, EK60/EK80 (18, 38, 70, 120, and 200 kHz), and the Knudsen 3260 sub-bottom profiler, with these sonars operated concurrently using a Kongsberg Synchronization Unit (K-Sync). During ROV operations, the EM 304 multibeam and Knudsen sub-bottom profiler were secured to allow for the ADCPs and the entire suite of EK split-beam sonars to acquire data.

[7] https://doi.org/10.25923/g2ep-ae34

Multibeam survey lines 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 are optimized for 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 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 the continuous application of surface sound speed obtained with a hull-mounted Reson SV-70 probe, and application of water column sound speed profiles obtained with Sippican Deep Blue Expendable Bathythermographs (XBTs) and/or Seabird CTD 9/11. 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 in more dynamic areas). 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.

The POS MV 320 version 5 was set as the primary positioning and inertial motion unit at the beginning of the expedition until a GNSS antenna failure occurred, at which point the primary system was set to the Seapath. Inspection of the data collected with the POS MV showed poor quality heading data, therefore these data were set to use the Seapath position and motion data in post-processing. More details can be found in the Daily Log Entries in Appendix A and the associated acquisition and processing logs.

Simrad EK60/EK80 split-beam water column sonar data were collected throughout the majority of the expedition, including during ROV dives. Data were monitored in real time for quality but were not post-processed. Knudsen 3260 sub-bottom profiler data were also collected during the majority of the expedition.

Multibeam Sonar Bathymetric Data Processing and Quality Assessment

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

The full-resolution multibeam .kmall files (Level-00 data) were imported into QPS Qimera, and then processed and cleaned of noise and artifacts. Outlier soundings were removed using multiple methods including automatic filtering and/or manual cleaning with the swath and subset editing tools. The default sound speed scheduling method used was "Nearest-in-Time; SVP Crossfade 60 sec" If another method was implemented, it will be noted in the associated log. All files were set to have the Seapath as the primary positioning and motion data source due to the failing POS MV GNSS antenna. 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 3** shows the onboard multibeam data processing workflow.

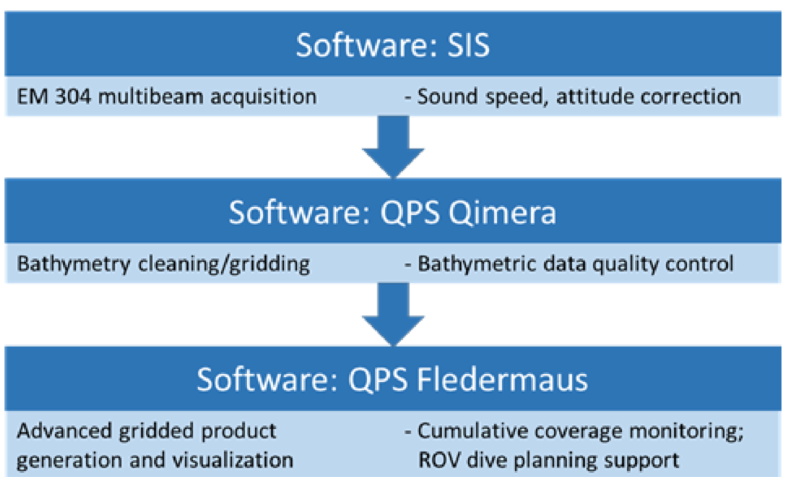

Figure 3. Shipboard multibeam data processing workflow.

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 July 23, 2022, as shown in **Figure 3**, and the results are presented in **Table 4**.

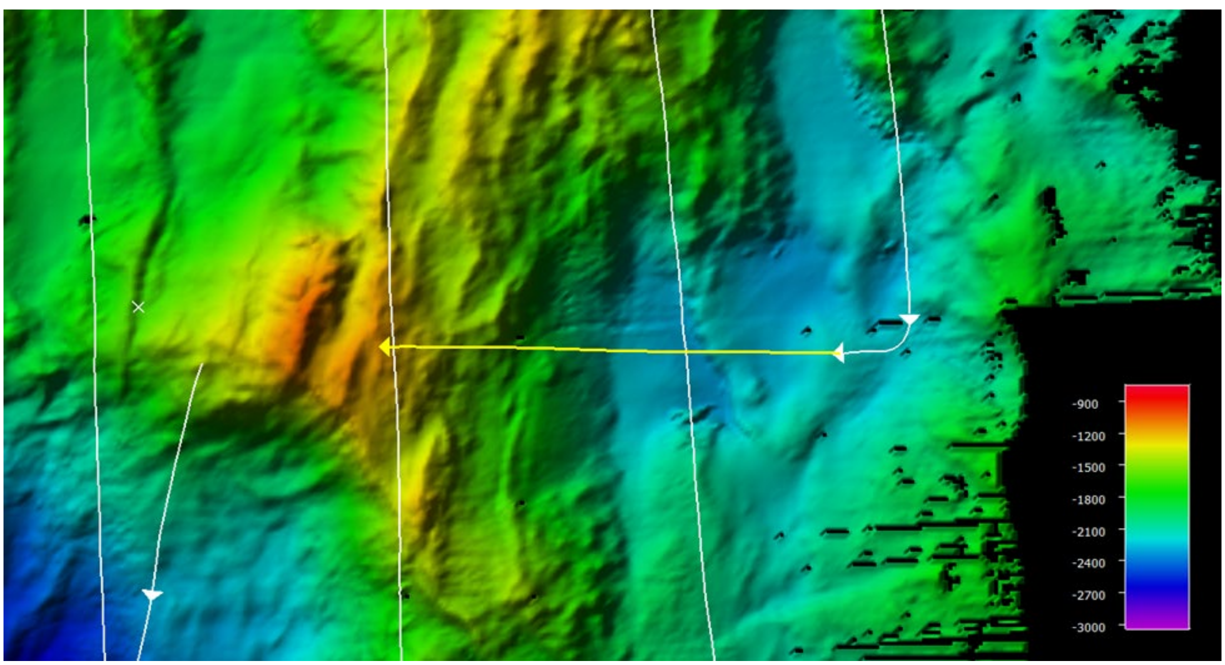

Figure 4. EX-22-05 crossline (shown in yellow) used for comparison against the bathymetric grid generated via orthogonal multibeam survey lines.

Crossline file: 0525_20220724_071152_EX2205_MB.kmall

Mainscheme line files:

- 0505_20220724_015257_EX2205_MB.kmall
- 0509_20220724_024942_EX2205_MB.kmall
- 0519_20220724_052731_EX2205_MB.kmall
- 0523_20220724_063400_EX2205_MB.kmall

Table 3. Crosscheck results.

Statistic	Value
Number of points of comparison	202,349
Grid cell size (m)	50.000
Difference mean (m)	-1.229465
Difference median (m)	-0.514728
Difference standard deviation (m)	7.623862
Difference range (m)	[-59.43, 93.09]
Mean + 2* standard deviation (m)	16.477190
Median + 2* standard deviation (m)	15.762453
Data mean (m)	-1697.404218
Reference mean (m)	-1696.174753
Data z-range (m)	[-2253.41, -1106.92]
Reference z-range (m)	[-2222.18, -1111.66]
Order 1 error limit (m)	22.055941
Order 1 # rejected	4022
Order 1 p-statistic	.0000415
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-22-05.

Table 4. Versions of acquisition and processing software used during EX-22-05.

Software	Purpose	Version
SIS	EM 304	5.10.1
EK80	EK suite	21.15
EchoControl	Knudsen	4.09
UHDAS	ADCPs	14.04
AMVERSEAS	Autolaunch XBT	9.3
WinMK21	XBT	3.0.2
K-Sync	Synchronization	1.9.0
Fledermaus 7	Visualization/Data Analysis	7.8.11
Qimera	Bathymetry	2.4.9
FMGT	Backscatter	7.10.1
FMMidwater	Water Column	7.9.4
Sound Speed Manager	Sound Speed Profiles	2022.1.0
NRCan (SegJp2)	Sub-bottom	1.0

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-22-05, Voyage to the Ridge 2 (ROV and Mapping)," which is archived in the NOAA Central Library. For each data type, raw data (Level 00), processed data (Level 01), derived products (Level 02), and ancillary files may be available, depending on the dataset and the level of staffing for the expedition. **Tables 5-9** describe the data archived for each dataset. For further information about proprietary software and freeware that can handle the varying data types, refer to the "NOAA OER Deepwater Exploration Mapping Procedures Manual."

Table 5. EM 304 bathymetry and seabed backscatter dataset.

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

Table 6. EM 304 water column backscatter dataset.

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

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

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

Table 8. Knudsen 3260 sub-bottom profiler dataset.

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

Table 9. Sound speed profiles dataset.

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

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

Table 10. Locations of data collected during EX-22-05 (at the time of writing this report).

Data Type	Description	Location
EM 304 bathymetry and backscatter data	EM 304 bathymetric and backscatter data, supporting informational logs, and ancillary files are available through the NCEI Bathymetry Data Viewer	https://www.ncei.noaa.gov/maps/bathymetry/ Request raw sonar data (*.kmalls) from ncei.info@noaa.gov with oer.info.mgmt@noaa.gov cc'd. POSPac and BS correction files can be requested from oar.oer.exmappingteam@noaa.gov
Water column data (EM 304 and EK60/EK80)	EM 304 and EK60/EK80 water column data, supporting data, and informational logs are available through the NCEI Water Column Sonar Data Viewer	https://www.ncei.noaa.gov/maps/water-column-sonar/
Knudsen 3260 sub-bottom profiler data	Sub-bottom data, supporting data, and informational logs are available in the NCEI data archives	https://www.ncei.noaa.gov/maps/trackline-geophysics/

8 https://www.ngdc.noaa.gov/

9 https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm

10 ncei.info@noaa.gov

11 oar.oer.exmappingteam@noaa.gov

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://www.ncei.noaa.gov/maps/bathymetry/ or through the oceanographic archives at: https://www.ncei.noaa.gov/
Reports	Reports are archived in the NOAA Central Library's Ocean Exploration Program (OEP) institutional repository	NOAA Central Library home: https://library.noaa.gov/ OEP institutional repository: https://repository.library.noaa.gov/cbrowse?pid=noaa%3A4&parentId=noaa%3A4

Expedition Schedule

Table 11. EX-22-05 schedule.

Date (UTC)	Activity
07/03	Mission personnel began to arrive in Norfolk, Virginia.
07/04 - 07/08	Mobilization.
07/09	Departed Norfolk, VA after fueling. ADCP calibration data collected while leaving port.
07/10	Transit, GAMS test, and multibeam calibration completed.
07/11 - 07/13	Transit mapping.
07/14	ADCP OS 38 calibration data collected and ADCP survey while transiting over shallow shelf.
07/15 - 07/16	Transit mapping.
07/17	Dive 01 was attempted and then aborted due to high winds, sea state, and an electrical error with D2. Transit mapping resumed following the aborted dive.
07/18	Transit mapping and multibeam troubleshooting remotely with Kongsberg.
07/19	Transit mapping and ROV dunk test.
07/20	Map and Dive 01. Transit to Dive 02.

Date (UTC)	Activity
07/21	Map and Dive 02. Transit to Dive 03 and mapping of an unmapped seamount followed.
07/22	Map and Dive 03. Transit to Dive 04.
07/23	Map and Dive 04. Transit to Dive 05.
07/24	Map and Dive 05. Transit to Dive 06.
07/25	Map and Dive 06. Transit to Dive 07.
07/26	Map and Dive 07. Transit to Dive 08.
07/27	Map and Dive 08. Transit to Dive 09.
07/28	Map and Dive 09. Transit to Dive 10.
07/29	Map and Dive 10. Transit to port.
07/30	Arrive in Horta, Azores, Portugal.

References

Candio, S., Hoy, S., Morrow, T., Wilkins, C., and Copeland, A. 2022. 2022 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/g2ep-ae34

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

International Hydrographic Organization. (2008). IHO Standards for Hydrographic Surveys, 5th edition, February 2008. Monaco, International Hydrographic Bureau, 28pp. (International Hydrographic Organization Special Publication, S-44). https://iho.int/uploads/user/pubs/standards/s-44/S-44_5E.pdf

Sowers, D. 2022. Project Instructions: EX-22-05, Voyage to the Ridge 2 (ROV and Mapping). Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://doi.org/10.25923/64dm-6g04.

Wang, L. (2022). NOAA Ship *Okeanos Explorer* FY22 Field Season Instructions. Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://doi.org/10.25923/37xx-ed34

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 (-2 hours from UTC).

July 6

The mapping team performed a ping test of the EM 304 and the EK 60/80s. Systems booted up normally and functionality was confirmed. Updating SIS to the newest version is postponed until the ship gets underway and internet is available, as the last step of the software update is a check ensuring that all components are up-to-date.

Sonar closet and rack room training occurred for new personnel.

July 7

Mapping team was in standby mode.

July 8

The mapping team planned for the upcoming GAMS and patch test.

July 9

After leaving port, data were collected with the ADCP WH300 for calibration purposes. UHDAS confirmed optimal alignment of the ADCP WH300. Late in the evening, the ship reached waters deep enough to collect calibration data for the ADCP OS38; the team awaited to hear results from UHDAS. The Bridge confirmed functionality with the UHDAS browser during calibration. UHDAS noted issues with the time server and an investigation is ongoing by the CET. UHDAS relies on the OMAO timeserver - the GFOE timeserver used for other mission systems was synced correctly to GPS time.

The overnight transit occurred in waters less than approximately 60 m, so data were only collected with the suite of EKs following the ADCP calibration.

The EM 304 transmit and receive unit (TRU) and SIS were updated to the most recent versions (5.10.1). The installation went smoothly. Qimera was updated on all MBPROC computers to 2.4.9.

New personnel continued training while setting up expedition logs, new surveys for each sonar, and planning projects. Updates have been made to the SOPs and acquisition screenshots when needed.

July 10

Once appropriate depths were reached at the shelf break, data acquisition began with the EM 304 and Knudsen. The new SIS update has some minor bugs that are affecting the standard workflow: the line files were split at 30 minutes rather than 60 minutes, and the vessel name was unable to be appended to the raw file name. The latter issue required that the mapping watchstanders rename the raw files on the local machine so that the automatic script can accept them and move them to the network. Bulk Rename Utility was installed on the hydrographic workstation to make this additional step as streamlined as possible.

Both Seapath and POS feeds dropped out in SIS, causing a gap in data. These dropouts were seen frequently in port both pre and post-SIS update. No issues were observed in POS or Seapath software. This seemed isolated to the EM 304 and not the positioning systems. Others in the community have reported similar issues due to network/data overload on the PU. The mapping team monitored to see if it occurs again and was trying to determine the issue in the interim.

A GAMS test was performed that confirmed no changes to the GNSS antennas during drydock. The patch test was completed successfully in ideal conditions (minimal sea state and stable sound speed). The results of the patch test provided new offsets, minimizing offsets calculated during EX2201, most likely due to the improved conditions. An expert onshore reviewed the new values. Once confirmed, a Patch Test supporting document was produced to archive as a supporting document with the 2022 Readiness Report.

CET investigated issues with the OMAO time server.

July 11

Transit mapping continued with the EM 304, Knudsen, and EKs. Conditions were optimal. The frequency of positioning dropouts in SIS have increased, causing gaps in data. The mapping lead corresponded with Kongsberg and the Multibeam Advisory Committee to troubleshoot.

CET successfully set up the backup OMAO time server and was able to confirm synchronization lock. The time now matches the GFOE timeserver. UHDAS contacts will help to verify that the ADCP data is now correctly time synced.

July 12

In an attempt to troubleshoot the multibeam dropouts, Kongsberg requested that the back up serial connection to the POS MV (Position 3) be disconnected from the processing unit (PU) - with no success. Due to a storm affecting the shoreside satellite link, the mapping and data teams were able to reliably correlate the multibeam dropouts to internet outages, particularly when changing state (disconnecting/connecting). The teams worked tirelessly trying to figure out the cause. Troubleshooting revealed that dropouts continued even when the PU was only connected to the POS MV via serial, and set to internally trigger (removing the network connection to the positioning units or the K-sync). Troubleshooting continued the next day.

New SIS update accepted angles up to 75/75 degrees. Standard language was amended to 150 degree swath.

UHDAS contact verified that the ADCP data is now correctly time synced.

July 13

SIS stopped gridding overnight (most likely due to the large area covered in the current survey) and a new survey was created. Prior to starting the new survey, the mapping lead amended a program file to allow appending of vessel name to the raw file following steps outlined by Kongsberg. Gridding returned and the vessel name is now successfully appended to the raw files.

The mapping and data teams continued to troubleshoot the EM 304 during the transit. Kongsberg requested that the EM 304 EM switches be updated to the latest firmware version. After disconnecting the cables to the PU, it was discovered that the switch version was already up-to-date.

After the firmware check, the EM 304 exhibited unexpected and concerning behavior prior to starting up. It took multiple attempts before the multibeam regained functionality. The issues are detailed below.

- When starting pinging the swath was shown in SIS as alongtrack instead of acrosstrack, then a repeated doppler attitude velocity message showed in the Telnet until SIS was closed.
- When trying to load PU parameters in K-Controller multiple red warnings indicated data packets/tokens could not be loaded and the datagrams didn't match sensor types (though sensor configuration was confirmed by the team).
- When external triggering was toggled the EM 304 would not internally trigger and required K-Sync to trigger.

The source(s) of the issues were still unknown as well as what order of operations brought the EM 304 back to life. The mapping team continued to work with Kongsberg to investigate underlying issues.

After troubleshooting the EM 304, UHDAS alerted the team that the USB serial hub had become disconnected and ancillary feeds were not available. The SST and CET will further investigate tomorrow.

July 14

All systems are functioning today. The ancillary feeds to the UHDAS computer were restored. Data was collected to calibrate the OS 38 while transiting upslope to the shelf. Analysis shows a slight alignment offset, though nothing that will affect upcoming operations. ADCP data were collected with the WH 300 while transiting the shallow shelf.

July 15

The overnight transit line was designed to maximize coverage over unexplored seamounts. The sound speed is extremely variable, requiring a high frequency of XBT casts.

The multibeam dropout occurred again while transiting over the peak of one of the seamounts. The mapping lead will continue investigating with Kongsberg.

July 16

Mapping operations consisted of transit surveying to the dive site and a targeted survey over the dive site. Significant mistracking down slope was consistently apparent when mapping seamounts. The mapping team tried multiple settings in an attempt to fix this issue with no success. The mapping lead will reach out to Kongsberg in the morning for further troubleshooting.

July 17

The two-day mapping transit began following the attempted dive. During the early evening, numerous multibeam dropouts occurred coinciding with a storm at the ground station. The GFOE data team continued to help troubleshoot alongside the mapping team what appears to have been an issue with communication between the PU and the transmit units during these events, and secured satellite tracking during the worst of the storm so that mapping data could be preserved. Reports of similar issues on other platforms continue to support the mapping team's understanding that this is related to an issue with the multibeam processing unit (PU). The mapping lead was able to contact Kongsberg customer support to set up a remote session tomorrow. Many thanks to the GFOE team for all of their continual help in troubleshooting this!

July 18

Transit mapping continued throughout the day. Conditions were favorable. Lines were designed to maximize coverage of the unmapped seamounts in the Altair Seamount High Seas marine protected area.

The mapping lead and GFOE team worked with Kongsberg through a remote session for 5 hours to try to determine the cause of the multibeam dropouts. The cause remains unknown. Kongsberg did amend a program file to change the logging interval from 30 minutes to 60 minutes. They also suggested that when mapping down slopes to use a “Large” range gate. This was set when transiting down the seamounts but it is hard to tell if it mitigated the mistracking issue. Investigation continues for the multibeam dropouts.

July 19

Transit mapping continued. The seas have increased but the sound speed is more stable. Coverage was added to the west of the Mid Atlantic Ridge prior to arriving at the dive site.

July 20

Morning operations consisted of a targeted survey over the dive site and a quick turnaround for the “map and dive.” The mapping lead trained two new watch leads on this workflow.

Around 0500 the position lamp on the POS MV went red, and the accuracy began to steadily degrade reaching about 1000m accuracy. After about 6 minutes with the position lamp out, the velocity lamp also turned red. Fortunately, this issue was not experienced by the Seapath, and the mapping team was able to choose the Seapath position in post-processing. This is an exemplary practical scenario justifying having two positioning units aboard and connected to the scientific equipment. The onboard theory for the outage was that it was due to the solar storm. Questions remain about why the Seapath didn’t also experience the outage. This could be due to the different model GNSS antennas or their placement on the ship in comparison to the POS MV antennas.

The mapping team worked with the GFOE data team on troubleshooting the EM 304 outages. Thanks is owed to the GFOE data team that continued to help us try to get to the bottom of these dropouts of the multibeam processing unit.

July 21

Overnight mapping consisted of edge-matching existing data while transiting to the next dive site. Sea state has increased and data quality is fair. Sound speed conditions have remained stable.

July 22

While mapping the dive site for that day's dive, the POS MV experienced another significant position dropout. Fortunately, the Seapath position was able to be applied in post-processing allowing us to recover the data critical for dive site selection and operations. The mapping team reiterated that this is a perfect example of why having a redundant positioning system and motion unit onboard is essential, especially when operating in remote locations. The team has reached out to Applanix for diagnostics and troubleshooting.

The ADCP surface currents seemed to be jumping around (in magnitude and direction) within a very short time frame (e.g. within 10 consecutive pings the surface current (WH 300) goes from -.7 to + .7 kts). Nothing about the operational set up has changed and this seems like a new behavior. The mapping lead checked with UHDAS that all settings were correct and the ADCPs appear to be working correctly, which UHDAS confirmed. UHDAS noted that there are numerous internal waves near the surface that are likely causing the observed behavior.

July 23

Overnight mapping included a transit to the following dive site, adding coverage when possible, and a small survey over the dive site.

During the dive, the mapping team received diagnostic information from Applanix indicating that the L2 band signal on the primary antenna for the POS MV was very weak, and that replacing the antenna would likely fix the position drop outs. Fortunately, a spare GA830 antenna was aboard, and the CET and CST replaced the antenna following the dive. A GAMS calibration was attempted following replacement, though the heading value never dropped below the pre-defined threshold of 0.5 degrees. The GAMS calibration baseline values indicated no change in distance between the primary and secondary antenna's L1 phase centers, however a future GAMS test should be performed to confirm. The slow GAMS calibration was likelay due to a slow start-up after powering down the POS MV.

The watchstanders are reviewing previous data to determine any degradation in data quality due to the failing POS MV antenna.

Seemingly unrelated to the failing antenna, the Seapath and the POS MV are experiencing heading outages at the same time, likely due to environmental conditions. The mapping team will continue to monitor and investigate.

The Seapath has been set as the primary position and attitude sensor for the EM 304 (and will likely stay as primary until the end of the cruise until the reliability of the POS MV can be established). Angular offsets were calculated for the Seapath using the patch test data collected at the beginning of the cruise and applied in SIS.

The ancillary feeds dropped out of the UHDAS machine. This was found to be caused by accidentally turned off breakers in the rack room and was remedied.

July 24

Overnight mapping included a transit along the MAR axis and a focused survey over the dive site to improve the resolution of the pre-existing data. Sea-state is ideal. A small crossline was performed on the way to the dive site.

The mapping lead decided to use the Seapath position, motion, and heading for all of the data for this expedition, since the data collected with the POS MV prior to learning about the antenna failure were likely of poorer quality (due to less accurate position and heading). The watchstanders will post-process all of the previous data overnight and investigate changes in resulting bathymetry. It is very easy to switch to the Seapath in Qimera in post-processing, and having the secondary positioning source readily available ensured that all the data collected during this expedition are of high quality regardless of the failing antenna.

The POS MV has been stable since the antenna swap, except for the heading dropouts which are experienced by both the POS MV and Seapath and are likely unrelated to the antenna issue and caused by environmental conditions.

July 25

Overnight mapping included a straight transit along the MAR axis and a quick survey over the dive site. The new data is shallower and steeper at peaks in comparison with the GMRT grid, as has been the trend for all of the dives in this area. Conditions are optimal.

The investigation into the effects of the poor-quality heading measurements by the POS MV on the previous data continues. One problematic area with significant disagreement between two overlapping lines has been completely mitigated after setting all data to Seapath for positioning, motion, and heading.

Heading dropouts are still being observed in both the POS MV and Seapath consistently around 4 - 5 am. The cause is thought to likely be environmental as both systems are experiencing these dropouts. The heading dropouts are processed and interpolated in Qimera by the watchstanders.

No multibeam dropouts have been observed for a while, but the internet has been stable. The mapping lead will confirm that behavior still exists before the end of the expedition.

The ROV team reported a 50 m offset between the bathymetric map and the depths experienced by the ROV. The mapping lead investigated and believes this to be due to the distortion near the UTM border. The mapping lead has made a custom projection for the next dive (Transverse Mercator, with central meridian set to -29 degrees (the longitude for the dive site) in an attempt to rectify this offset.

The mapping lead continues to train new team members; this evening's training is on setting up and using Hypack.

July 26

A focused survey was conducted west of the MAR following the dive site. Conditions are optimal. Slope mistracking continues to significantly affect the data at nadir.

July 27

Coverage was added overnight to the previous night's data. Conditions are optimal.

July 28

The ADCP Serial bus failed again and was replaced. Transit mapping to the final dive site occurred.

A new colormap was designed in Qimera to highlight bad bottom detection points from the surrounding seafloor when the multibeam mis-tracks on steep downslopes.

July 29

Survey coordinated with UHDAS, CST, CET, and GFOE to establish a positioning feed from the Seapath to the ADCPs. This improvement enables the ADCP to get positioning feeds from two separate devices (SeaPath and POSMV) and will enable UHDAS to also monitor and report lost data or drifts in accuracy that occur with these systems. The team worked on final wrap up tasks during the last night of transit back to port. Systems secured prior to entering with 12 nm of Faial.

July 30

Mapping operations ended just prior to entering 12 nm from the island.