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MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT

CRUISE EX-20-00: Kongsberg EM 304 Sea Acceptance Trials *(OMAO-5921)*

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1. Introduction

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

Using the latest tools and technology, OER 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, OER 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, OER 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.

Contents

2. Report Purpose

The purpose of this report is to briefly describe the acoustic seafloor, water-column, and sub-seabed mapping data collection and processing methods used during the EM 304 Sea Acceptance Trials (SAT), EX-20-00, and to present a summary of the mapping related cruise activities. For detailed results from the sea acceptance trials, please refer to the NOAA Ship *Okeanos Explorer* EM 304 Sea Acceptance Testing Report.[1]

A detailed description of NOAA Ship *Okeanos Explorer's* mapping equipment and capabilities is available in the 2019 NOAA Ship *Okeanos Explorer* Survey Readiness Report, available in the NOAA Central Library.[2] This report does not include the EM 304 topside unit, and represents the status of the equipment pre EX-20-00. However, as the remainder of the cruises for the 2020 field season were canceled due to travel complications caused by SARS-CoV-2 / COVID-19, a 2020 Readiness Report was not created. The 2021 Readiness Report will include information about the EM 304 topside upgrade.

For further information about general equipment calibration procedures, data acquisition, processing, reporting, and archiving see the NOAA OER Deepwater Exploration Mapping Procedures Manual Version 1.0, available in the NOAA Central Library,[3] and from the OER website.[4]

3. Cruise Objectives

EX-20-00 departed from Pascagoula, Mississippi on March 3 and arrived in Key West, Florida on March 8, 2020. The primary purpose of this cruise was to perform the sea acceptance trials of the newly installed EM 304 topside unit. The multibeam receive array was replaced in 2018, and the transmit array is the original from the 2007 install. Visiting Kongsberg technicians performed and observed required tests to ensure acceptable functionality of the unit. These tests included a geometric calibration (patch test), speed-noise testing, and accuracy testing with both a shallow and deep reference survey.

The complete objectives for this cruise are detailed in the EX-20-00 Project Instructions, which are archived in the NOAA Central Library.[5]

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[1] http://mac.unols.org/sites/mac.unols.org/files/EX2000_EM304_SAT_FINAL_v3_20200325_Redacted.pdf (last accessed: 11/24/2020)

[2] https://doi.org/10.25923/kkwz-5t70 (last accessed: 11/24/2020)

[3] https://doi.org/10.25923/jw71-ga98 (last accessed: 11/24/2020)

[4] https://oceanexplorer.noaa.gov/ (last accessed: 11/24/2020)

[5] https://doi.org/10.25923/srya-9r44 (last accessed: 11/24/2020)

4. Summary of Mapping Results

In addition to the tests performed for the sea acceptance trials, EX-20-00 mapped 4,658 square kilometers of seafloor in the Gulf of Mexico during the 6 days at sea (**Figure 1** and **Table 1**). 4,575 square kilometers of this area was mapped within U.S. Waters including the Exclusive Economic Zone and the Territorial Sea and in depths deeper than 200 meters (m). Multibeam bathymetry data coverage is shown in **Figure 1**. Gaps in the data were a result of troubleshooting the new system or poor weather conditions. For detailed information regarding the location of each test site, refer to the EM 304 Sea Acceptance Testing Report.[6]

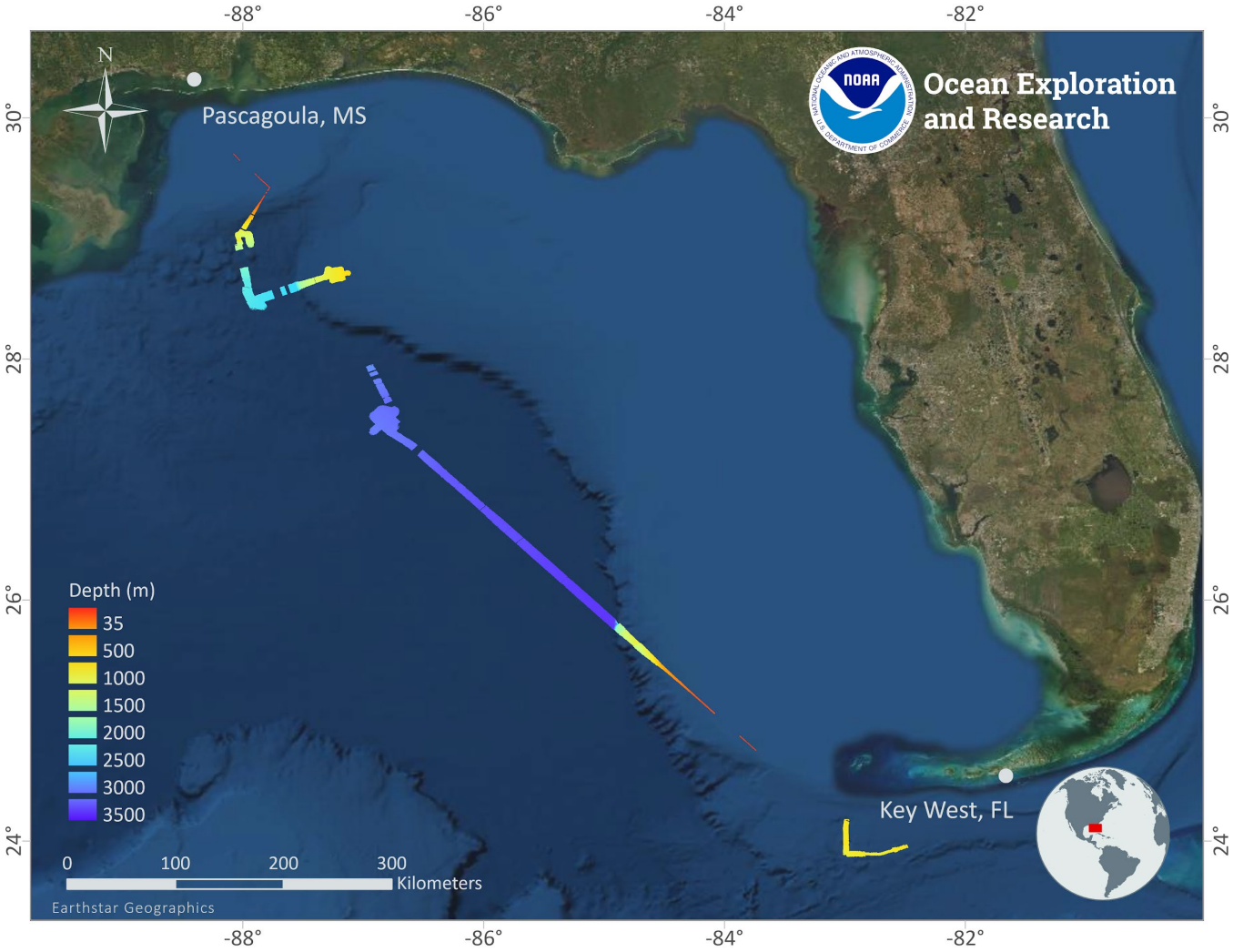

Figure 1. Overview of bathymetric mapping coverage completed during the EM 304 Sea Acceptance Trials (EX-20-20). Map generated in ArcPRO.

[6] http://mac.unols.org/sites/mac.unols.org/files/EX2000_EM304_SAT_FINAL_v3_20200325_Redacted.pdf (last accessed: 11/24/2020)

5. Mapping Statistics

Table 1. Summary statistics of ocean mapping work completed during EX-20-00.

Dates of cruise (UTC -6)	March 3 – March 8, 2020
Ship's draft: Start of cruise (03/03/2020) End of cruise (03/08/2020)	 Fore: 15' 7''; Aft STBD: 14' 1"; Aft Port: 13' 8.5" Fore: 14' 9"; Aft STBD: 14' 4.5"; Aft Port: 13' 9.5"
Linear kilometers of survey with EM 304	1,160
Square kilometers mapped with EM 304	4,658
Square kilometers mapped with EM 304 within U.S. Waters deeper than 200 m	4,575
Number / data volume of EM 304 raw multibeam files (.kmall)	157 files / 28.8 GB
Number / data volume of EM 304 water column multibeam files (.kmwcd)	103 files / 26.70 GB
Number / data volume of EK60/EK80 water column split-beam files (.raw)	6 / 1.23 GB
Number / data volume of sub-bottom sonar files (.segy, .kea, .keb)	14 / 0.24 GB
Number of XBT casts	17
Number of CTD casts (including test casts)	0

6. Mapping Sonar Setup

Kongsberg EM 304 Multibeam Sonar

Okeanos Explorer is equipped with a 30 kilohertz (kHz) Kongsberg EM 304 multibeam sonar capable of detecting the seafloor in up to 10,000 m of water and conducting efficient mapping operations in up to 8,000 m of water. The topside unit was upgraded from the EM 302 to the EM 304 in March 2020. 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 hard set within the acquisition software) containing 512 beams with up to 800 soundings per ping cycle when in high-density mode. In waters less than 3,300 m deep, the system is able to operate in dual-swath mode, where one nominal ping cycle includes two swaths and, therefore, results in up to 1,600 soundings. The multibeam sonar is used to collect seafloor bathymetry, seafloor backscatter, and water column backscatter. Data are acquired using Kongsberg's Seafloor Information System (SIS) software package. To produce files of manageable size, bathymetric and seabed backscatter data are recorded in .kmall files and water column backscatter data are recorded separately in .kmwcd files.

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 calibrated scientific echosounders are used to identify the backscatter returns of water column and seafloor acoustics scatterers, typically biological scattering layers, fish, or gas bubbles, providing additional information about water column characteristics and anomalies. In 2019, the 38 and 70 kHz general purpose transceivers (GPTs) were replaced with wide band transceivers (WBTs). The 70 kHz system is fully functional with continuous wave (CW) operation at 70 kHz and frequency-modulated (FM) operation over 45-90 kHz. A new transducer for the 38 kHz system that supports FM operations is expected to be installed before the 2021 field season, and the 38 kHz was not operational during this cruise. To mitigate interference and maintain sounding density, the 70 kHz WBT is usually operated in FM mode in waters shallower than approximately 700 m and in CW mode in deeper waters.

These sonars were calibrated on the EX-19-02 cruise, and calibration values from that cruise were applied to the EK sonars for EX-20-00. The 2019 EK60/EK80 Calibration Report is available in the NOAA Central Library.[7]

[7] https://doi.org/10.25923/wzk7-6d52 (last accessed: 11/24/2020

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 meters below the seafloor. The sub-bottom profiler is operated to provide information about sub-seafloor stratigraphy and features. The data generated by this sonar are fundamental to helping geologists interpret the shallow geology of the seafloor.

Teledyne ADCPs

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 sensor (CTD) deployments in order to assess currents in support of safe operations. They are kept running throughout the ROV dives. The ADCPs are typically not run concurrently with the other sonars during mapping operations due to issues of interference.

7. Data Acquisition Summary

Mapping operations included data collection with the EM 304, EK60/EK80 (18, 70, 120, and 200 kHz), and the Knudsen 3260 sub-bottom profiler. Data was collected with the EM 304 during each sea acceptance test, as well as during transits. Data was only briefly collected with the Knudsen 3260 sub-bottom profiler and the EK60/EK80s, to test functionality with the EM 304 (**Figure 2** and **Figure 3**). Gaps in data coverage were caused by troubleshooting or poor weather. For more detailed information about data acquisition for the sea acceptance trials, refer to the EM 304 Sea Acceptance Testing Report.[8]

Throughout the cruise 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 is 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 Seafloor Information Systems (SIS) were generally left open (70°/70°) during transits to maximize data collection and were adjusted on both the port and starboard side 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 pulled in manually and monitored closely until a high-quality swath was obtained.

[8] http://mac.unols.org/sites/mac.unols.org/files/EX2000_EM304_SAT_FINAL_v3_20200325_Redacted.pdf (last accessed: 11/24/2020)

Multibeam data were corrected for surface sound speed in real time at the sonar head using the Reson probe data and throughout the water column using profiles from the expendable bathythermographs (XBTs) (or the CTDs or oceanographic archives, as appropriate). Sound speed profiles were conducted every six hours, or more frequently as dictated by local oceanographic conditions. 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.

Backscatter collected during this cruise will not have an associated correction file, as the most recent backscatter correction routine was conducted with the previous transceiver for the EM 302.

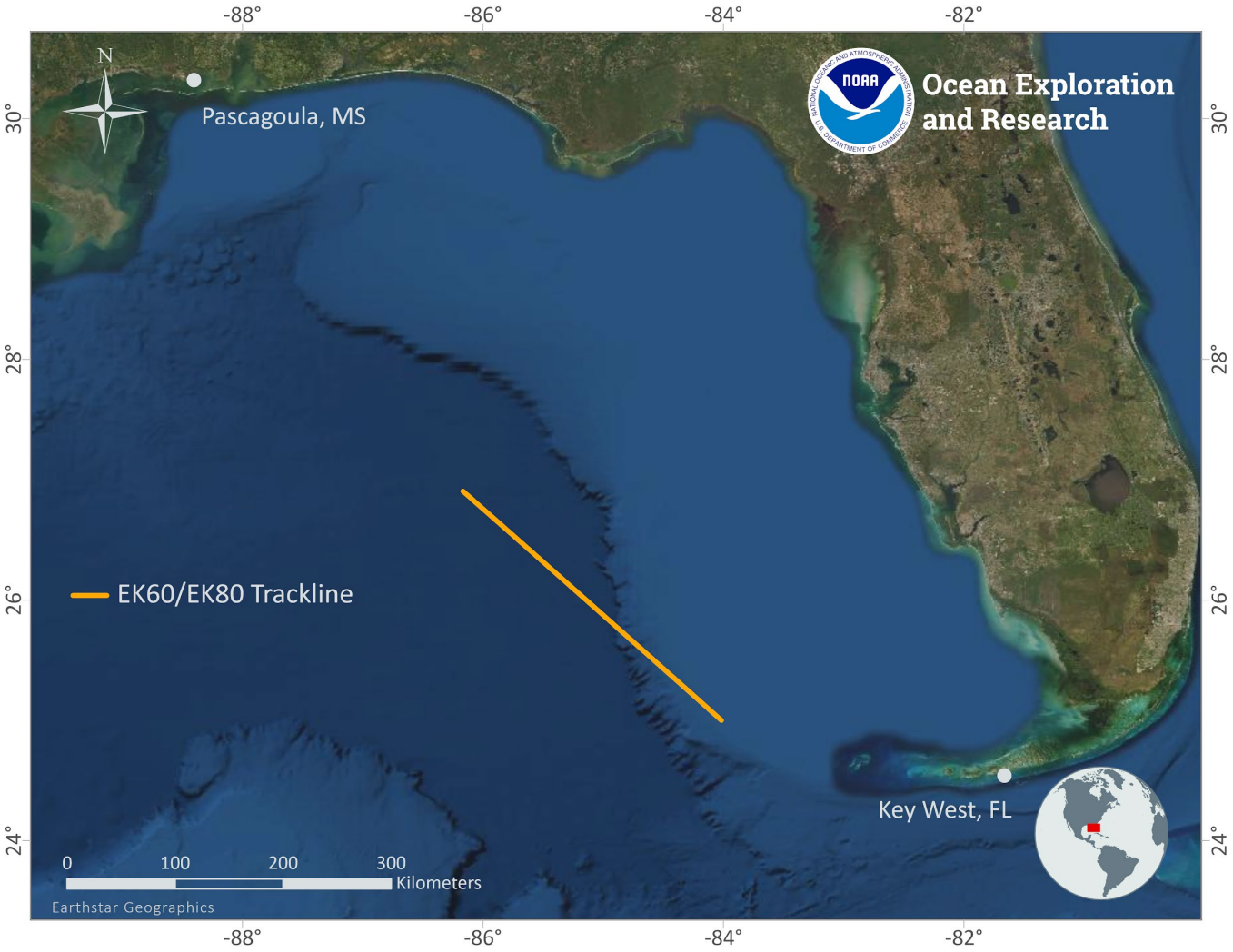

Figure 2. Simrad EK60/EK80 split-beam sonar data tracklines collected during EX-20-00.

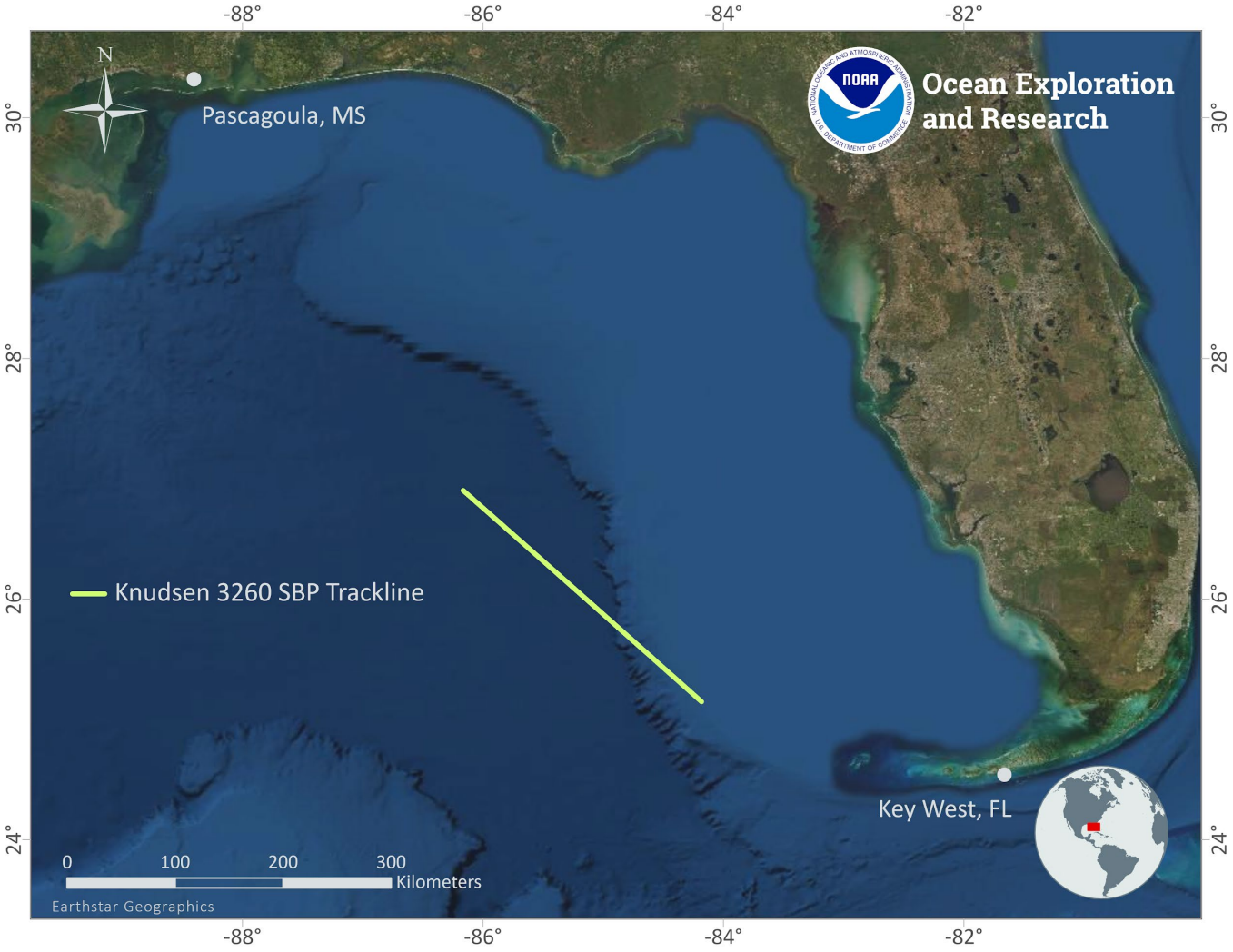

Figure 3. Sub-bottom profiler data tracklines collected during EX-20-00.

8. Multibeam Sonar Data Quality Assessment and Data Processing

EM 304 Built-in Self Tests (BISTs) were run throughout the cruise to monitor multibeam sonar system status. Throughout the cruise, bathymetry files were imported into QPS Qimera software for post-processing. In QPS Qimera software, the processing team quality checked the attitude and navigation time series and created a daily bathymetric surface, which was gridded using the Combined Uncertainty and Bathymetry Estimator (CUBE) algorithm. CUBE gridding was processed with the default settings and resolution algorithm set to the "number of samples and neighborhood" option. 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. **Figure 4** shows the onboard multibeam data processing workflow.

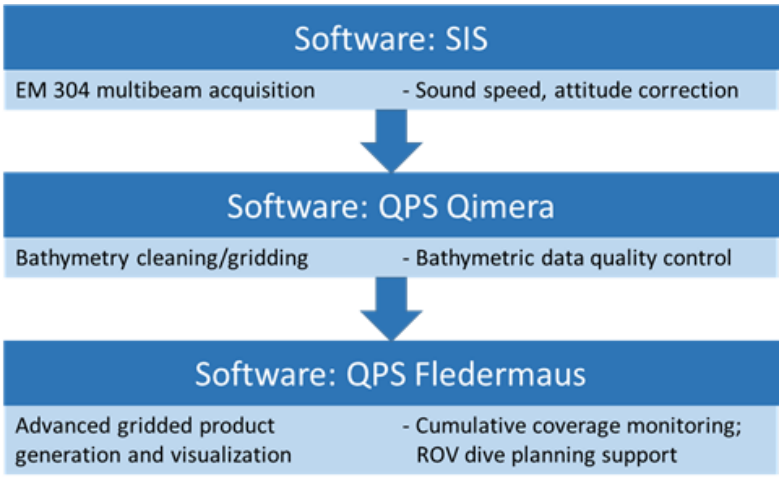

Figure 4. Shipboard multibeam data processing workflow.

On shore, the OER 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 or field-cleaning mistakes. Depth values were compared from orthogonal lines (crosslines) to evaluate the consistency of the multibeam sonar data collected during the cruise. 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). Then, the data package was prepared, which included exporting full-resolution processed point cleaned data files to generic sensor format (.gsf) and producing final gridded surfaces. All depth products maintain horizontal referencing to WGS84 (G1762) and vertical referencing to the assumed mean waterline.

Crosslines

A crossline was run on March 5, 2020 during the 1000 m reference survey, as shown in **Figure 5**, and the results are below in **Table 2**.

Crossline file:

0051_20200305_002525_EX2000_MB.kmall

Mainscheme line files:

0057_20200305_044226_EX2000_MB.kmall

0059_20200305_054023_EX2000_MB.kmall

0061_20200305_063135_EX2000_MB.kmall

0063_20200305_072228_EX2000_MB.kmall

0065_20200305_081641_EX2000_MB.kmall

0067_20200305_090938_EX2000_MB.kmall

0068_20200305_095413_EX2000_MB.kmall

0070_20200305_121421_EX2000_MB.kmall

0072_20200305_130620_EX2000_MB.kmall

0074_20200305_140905_EX2000_MB.kmall

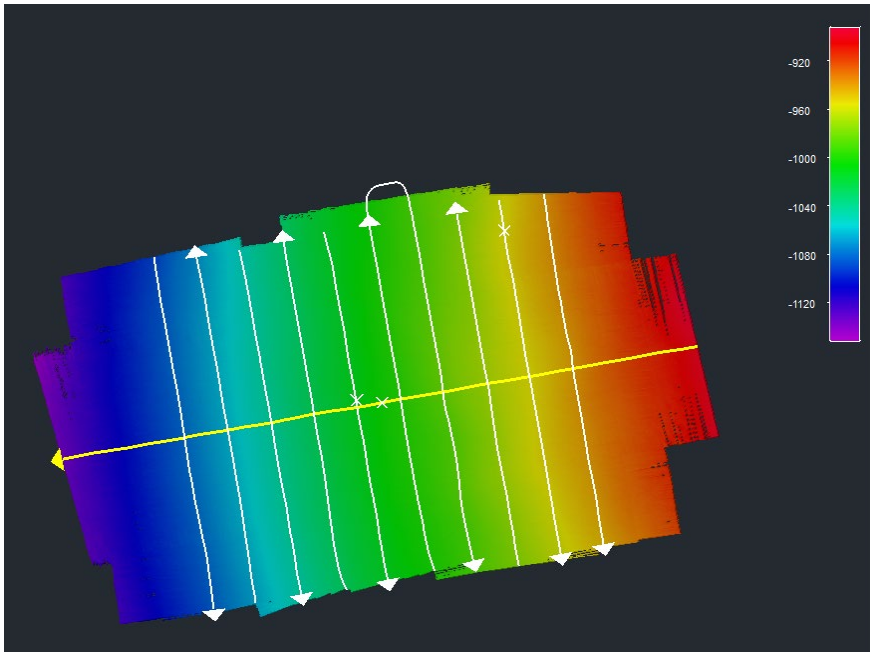

Figure 5. EX-20-00 crossline (shown in yellow) used for comparison against the bathymetric grid generated via orthogonal multibeam survey lines. Depth in meters.

Table 2. Crosscheck Results

Statistic	Value
Number of points of Comparison	10964542
Grid Cell Size (m)	20.00
Difference Mean (m)	0.019
Difference Median (m)	0.060
Difference Std. Dev. (m)	1.735
Difference Range (m)	[-27.956, 30.289]
Mean + 2*Std. Dev. (m)	3.489
Median + 2* Std. Dev. (m)	3.529
Data Mean (m)	-1006.362
Reference Mean (m)	-1006.381
Data Z-Range (m)	[-1154.009, -889.727]
Reference Z-Range (m)	[-1150.613, -892.381]
Order 1 Error Limit (m)	13.0925
Order 1 # Rejected	456
Order 1 P- Statistic	.0000415
Order 1 Survey	**ACCEPTED**

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

9. Data Archival Procedures

All mapping data collected by NOAA Ship *Okeanos Explorer* are archived and publicly available within 90 days of the end of each cruise 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 cruise) is available as an appendix in the EX-20-00 project instructions, available in the NOAA Central Library.[9] For each data type, raw data (Level 00), processed data (Level 01), derived products (Level 02), and ancillary files may be provided, depending on the dataset and the level of staffing for the cruise. **Table 3.1 - 3.5** 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 Procedures Manual.[10]

Table 3.1 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 Geotif), .kmz, .sd, .scene
Ancillary Files	Mapping watchstander log, weather log, sound speed profile log, multibeam acquisition and processing log, backscatter correction file, built-in-system-test logs, processing unit parameters, telnet session records	.xlsm, .xlsx, .txt

[9] https://doi.org/10.25923/srya-9r44 (last accessed: 11/24/2020)

[10] https://doi.org/10.25923/jw71-ga98 (last accessed: 11/24/2020)

Table 3.2 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-system-test logs, processing unit parameters, recorded telnet sessions	.xlsm, .xlsx, .txt

Table 3.3 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 that were used for calibration	.xlsm, .xlsx, .txt, .pdf, .xml, .raw, .idx

Table 3.4 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. These files are 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 3.5 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,[11] and searchable through OER's Digital Atlas,[12] which provides access to all of the data collected during a cruise. The locations for specific data types (at the time of writing this report) are detailed in **Table 4**. For any challenges accessing data, send an inquiry to NCEI,[13] or contact the OER Mapping Team.[14]

[11] https://www.ngdc.noaa.gov/ (last accessed: 11/24/2020)

[12] https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm (last accessed: 11/24/2020)

[13] ncei.info@noaa.gov (last accessed: 11/24/2020)

[14] oar.oer.exmappingteam@noaa.gov (last accessed: 11/24/2020)

Table 4. Locations of data collected during EX-20-00 (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/ *Last accessed: 11/24/2020*
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 *Last accessed: 11/24/2020*
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: 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 *Last accessed: 11/24/2020*
Sound speed profiles	Ancillary sound speed profiles are available along with all mapping data per cruise in the NCEI data archives, or within the oceanographic archive for the cruise.	https://maps.ngdc.noaa.gov/viewers/bathymetry/ or through the oceanographic archives at: www.ncei.noaa.gov *Last accessed: 11/24/2020*
Reports	Reports are archived in the NOAA Central Library's Ocean Exploration Program (OEP) institutional repository	NOAA Central Library home: https://library.noaa.gov/ *Last accessed: 06/15/2020* OEP institutional repository: https://repository.library.noaa.gov/cbrowse?pid=noaa%3A4&parentId=noaa%3A4 *Last accessed: 06/15/2020*

10. Cruise Calendar

All times listed are local ship time, -6 hours from UTC

March 2020

Sun	Mon	Tues	Wed	Thur	Fri	Sat
01 Mission personnel arrived in Pascagoula, MS.	**02** Mobilization continued.	**03** Departed from Pascagoula. Conducted GAMS and began Patch Test.	**04** Completed Patch Test and deep roll verification. Began the 1000 meter reference surface.	**05** Completed the 1000 meter reference surface and the speed noise test. Began the 3000 meter reference surface. Weather deteriorated.	**06** Ended the 3000 meter reference survey early to begin transit to Key West, FL. Weather conditions remained poor.	**07** Continued transit to Key West, FL. Weather conditions remained poor.
08 Arrived in Key West, FL. Demobilization occurred and mission personnel departed the vessel.						

11. Daily Cruise Log Entries

Generated from the daily expedition situation reports. All times listed are in local ship time (-6 hours from UTC)

March 01

For the purpose of data management this cruise will be named EX-20-00.

The EX-19-02 (UTM 16) Hypack project is being used for this expedition as they occur in the same place and use the same patch test lines.

March 02

18 Boxes of Deep Blue XBT probes (12 in each) were loaded onto the ship. The XBT Autolauncher was taken out of storage and received a preliminary inspection by the visiting NOAA Atlantic Oceanographic and Meteorological Laboratory Technician.

Global Mapper 21.1 was installed on MBPROC 3. Currently MBPROC 3 is listed as GEOAUTH 4 for the left screen and SCI UTILITY RT for the right screen. This will be renamed in the Keyboard Video Mouse (KVM) system before EX-20-01.

Line plans for the EM 304 calibration and accuracy testing have been developed to maximize the time at sea for testing. These plans satisfy the Kongsberg SAT protocol and include additional data collection to evaluate accuracy across the swath in different modes and any significant post-shipyard changes in ship noise levels that could affect multibeam performance.

The survey team reviewed POS MV and EM 304 pre-SAT configurations against the post-EX-19-02 shakedown report and noted / made a few changes, outlined below:

- **EM 304 offsets**: SIS v5 was installed on the Multibeam KVM workstation; all linear and angular offsets (including waterline) were updated to the post-EX-19-02 EM 302 configuration
- Surface sound speed: We are currently investigating an issue receiving the Reson surface sound speed probe data in the EM 304 and EK systems.
- **POS MV offsets:** No changes were detected in any POS MV offsets; the current configuration reflects the post-GAMS, post-EX-19-02 settings that should still apply as no POS MV hardware was removed / reinstalled during the winter maintenance period.
- **Position and clock datagram output:** As recently as EX-19-02, the position (GGA) and clock (ZDA) datagrams for the multibeam came from POS MV COM port 4 at 38400 baud. The EM 304 now receives these datagrams from POS MV COM 3 output, which also now includes attitude (PASHR) datagrams. The reasons for these changes are not clear at present, but do not cause any particular issue for these feeds to the EM 304.
- **Position and clock datagram input:** There may be a hardware failure for EM 304 processing unit (PU) COM port 1, which is the standard input port for GGA and ZDA messages, as used previously for the EM 302. It appears that PU COM port 4 is also inactive. Kongsberg will

provide a new CPU board if reseating/rebooting does not fix the issue. Meanwhile, the PU will receive GGA and ZDA messages on PU COM 3 for the SAT.

- **Other small POS MV changes noted in comparison to the EX-19-02 report:**
    - The COM port 5 update rate was reduced from 2 Hz to 1 Hz at some point. As of EX-19-02, this port was expected to be configured in the future for feed to the dynamic positioning (DP) system, once Kongsberg confirmed the DP software would handle 9600 baud.
    - Heave bandwidth was reduced from 14 s to 8 s; this change should not significantly impact operations in the Gulf of Mexico.
- **K-Sync:** The K-Sync is currently not connecting to the computer. Will be investigated tomorrow.

After configuration review, the EM 304 was pinged dockside to test the general functionality, new survey setup, data logging, and .kmall import into Qimera. The system reported repeated Compact Beamformer (CBMF) board errors that correlated with missing port side receive (RX) detections. (CBMF boards replace the functionality of EM 302 BSP boards.) RX data show all 800 expected beam formed, and 400-600 reporting detections. Some complications may be related to operating in extremely shallow water dockside. The CMBF board errors stopped and the port side bottom detections returned to normal after reducing the depth range under Runtime Parameters from 30 m to 10 m maximum. The .kmall files collected dockside opened normally in Qimera 2.0.3 (installation parameters did not parse properly in 1.7.6).

EM 304 output has been split into .kmall (bathymetry, seafloor backscatter) and .kmwcd (water column backscatter). The default setting for splitting the line is 30 minutes. At this time SIS 5 was unable to change this setting to the normal 60 minutes. More investigation will occur tomorrow.

March 03

The charger for the mapping watchstander laptop is missing. A new one will be ordered by the Global Foundation for Ocean Exploration (GFOE).

Qimera was updated on MBPROC 1 and 2 from version 2.0.2 to 2.1.1. Licenses were applied without issue.

The Auto Launcher was installed. Test XBT casts were performed with no issue.

Connection to the K-Sync was fixed. The ARCGIS Ethernet cable was connected to the wrong port. However, the K-Sync is still unable to trigger the EM 304. The Kongsberg Technicians will continue to work on this issue.

SIS was updated from v5.3.1 to a more recent release brought by The Kongsberg Engineer.

After the upgrade, the Reson surface sound speed input to SIS stopped working (the feed was still visible in the EK80 COM6 port monitor). SIS was downgraded back to v5.3.1 and the Reson SVP feed was redirected directly to COM3 on the PU. These changes fixed the surface sound speed issue in SIS.

The position and clock feeds on COM 1 became inactive. After trying to reset the COM port selection in SIS, we powered off the PU and relocated the GGA/ZDA feed from COM1 to COM4 (COM3 was taken by the SVP feed). The position and clock ports were set to COM4 in SIS and these feeds became active again. As a test, the Ethernet cable was moved back from COM4 to COM1 on the back of the PU (while not pinging, but still turned on with SIS open), the ports were updated in SIS, and the feeds became active again. The solution seems to be resetting the baud rate (to None or Off and then back to 9600), which appears to reset that port and may be a simpler way of handling this problem in the future.

The telnet session indicated a very high rate of CBMF board errors (timeout, missing 3 samples), and if the depth range was extended too far the pinging would time out and a restart of the PU was required. The Kongsberg Engineer made a change in a configuration file (not in SIS) and restarted the PU with this change, which modified the way the receiver sends samples to the CBMF boards. The receiver was previously configured to send 'bursts' of RX samples with each ping; it is now configured to send 'continuous' RX samples. This is a setting used on other systems with dual use of RX arrays (e.g., EM 122 with SBP 120 sub-bottom profiler sharing a RX array). The configuration change seems to have eliminated the CBMF board timeout issue and does not present any other complications for the data.

To note, it seems like SIS 5 will only allow the coverage angles to open up to 70/70 not out to 75/75.

After 12 hours of surveying the difference between the PU and the ZDA clock drifted to 275 milliseconds (usually around 1). GFOE installed a PU Clock monitor and SIS was restarted. The difference was brought down to 1 and we will monitor to see if it drifts during following surveys.

A series of three GAMS calibrations were performed during transit toward the patch test site. Each calibration converged quickly (e.g., 3-5 minutes for heading threshold to fall below 0.5 deg and 1-2 minutes for the final GAMS calibration wizard to complete). The first test yielded antenna baseline components very similar to the initial baseline configured from survey results. The second and third tests were completed while the vessel moved at slightly higher speeds, and there are corresponding differences in the X (alongship) component. In all cases, the Y component is within a few mm and the Z component is within a few cm. The GAMS calibrations confirm no major discrepancies resulting from unknown/undetected modification of antennas during the winter maintenance period, and the original baseline vector / GAMS parameters were reapplied immediately following the GAMS calibration.

The initial Attitude 1 angles in SIS were configured from a screenshot in the EX-19-02 report appendix. After closer inspection, the screenshot in that appendix shows pre-calibration settings and needs to be updated. The calibration section in the body of that report includes the correct results for the EX-19-02 calibration, and the EX-20-00 pre-cal configuration has been updated to these angles. Since no hardware has been moved or reinstalled since the last calibration, this re-cal setup using the 'last known' calibration results should yield smaller adjustments during the present calibration compared with restarting from zero for Attitude 1.

Prior to the Patch Test there was extreme interference for about 3 hours. The watchstander assumed it was due to the nearby vessels and oil rigs as the EK and Knudsen were not pinging and they expected the ADCPs to not be pinging. However, when the Expedition Coordinator (EC) came on watch they checked and the ADCPs were both pinging. It looks like they were remote started by UHDAS on March 1st.

Lost POS feed from COM 1 during pitch line 1. Restarted SIS and feeds were reactivated. Next time we will try simply changing the baud rate and then changing it back to 9600. Pitch line was broken up into files 0007 and 0008 due to SIS restart and then concatenated with Cygwin to create one file (0007-0008_20200304*.kmall). The break between files is over the flat top of the Pascagoula Dome; the critical slopes on either side were fully surveyed, so the ship was able to continue on the line without delay.

Currently we are still working on getting the thermosalinograph (TSG) sensor into SIS as a backup surface sound speed probe.

March 04

The Kongsberg Engineer was able to successfully trigger the EM 304 with the K-Sync. The communication protocol for the EM 304 is different from the EM 302, and needed changing. The details will be documented in a standard operating procedure (SOP).

After restarting the PU and SIS, the PU - ZDA difference has remained less than 3 milliseconds, and requires no further troubleshooting at this time.

While transiting in deeper waters (~2300 m), the EC noticed that we were getting less coverage than expected in Deeper Mode (EM 302's Deep' mode) and that FM was not being utilized when this mode should employ a mixed CW/FM pulse. The Kongsberg Engineer realized this was due to an incorrectly set setting in the installation parameters that was previously not necessary for the EM 302. The details will be documented in an SOP. After changing the setting, the swath width achieved the expected coverage, even with the software limitation of 70/70 degrees rather than 75/75 degrees.

There has been consistent crashing when opening a second "installation" window, while surveying with the Helmsman application open. The Kongsberg Engineers will continue to investigate tomorrow. A crash occurred during one of the Deep Roll verification lines, but this should not impact the test results. A current quirk of SIS 5 is that after a crash the line count does not increase, therefore there are multiple lines with the same number (different timestamp).

The calibration / patch test proceeded smoothly under calm seas. XBTs were collected prior to the pitch and calibration lines. Because no sensors were modified or moved since EX-19-02 and the GAMS parameters were left unchanged after GAMS calibration, all SIS Attitude 1 settings were set to the post-EX-19-02 calibration results as a starting point for the EX-20-00 calibration. Calibration data processing indicated no changes necessary for the pitch, roll, or heading installation angles for Attitude 1. These results indicate no appreciable changes to the mapping system hardware during the winter maintenance period and improve confidence in correct integration of the EM 304 hardware.

Note that the initial roll calibration data suggested no change necessary (< +/-0.005 deg adjustment, not configurable in SIS); the deep roll verification lines suggested a possible adjustment of +0.01 to +0.02 deg; and the 1000 m accuracy crosslines, used as a final roll check, suggested a possible adjustment on the order of -0.01 deg. These small differences (centered around zero) may be due to the sound speed environment (even with XBTs) coupled with uncertainty in the RX and TX array installation angles last surveyed after RX array replacement in 2018. Taken together, there is no compelling data for adjustment of any of the SIS Attitude 1 installation angles at this time.

A Deep Roll verification was performed in 2300 meters of water. This line was also planned to survey the known location of the USS Peterson shipwreck, as this is a known site that is well documented, underwater cultural heritage protocols were not invoked. Initial investigation revealed no indication of the 172-meter wreck in the 2300 meters of water. While performing the Deep Roll Verification, data to provide information on the difference in storage for High Resolution, Low Resolution, and no Water Column phase information was collected. These tests were also repeated during the 1000-meter reference survey crosslines.

The EC noticed that the bathymetry and water column data were not recording to separate files (due to forgetting to set this when setting the survey after downgrading the SIS software). The data is split into KMALLs and KMWCDs starting with line 0038.

Multiple issues were incurred when trying to process the data with QPS. Firstly, the data in Qimera was showing all the fringe noise - typically this noise is automatically processed out by utilizing Quality Indicators from the bathymetry files. The Kongsberg Engineers checked that the files were correctly recording the quality flags, and suspect the issue to be with Qimera's parsing of the KMALL file - more investigation will continue. Secondly, there are multiple broken steps in the processing chain:

1. SDs produced in Qimera 2.1.1 will not open in Fledermaus 7.8.7
2. GSFs produced in Qimera 2.1.1 will not open in FMGT 7.8.9

This is most likely due to incompatible old versions of Fledermaus and FMGT. Newer versions will be downloaded and tested tomorrow.

The GFOE and Mapping team discussed renaming the XBT and ASVP files to include the timestamp to support automatic identification when restricting data for underwater cultural heritage procedures. This has been discussed with NCEI and will be changed moving forward.

March 05

EM 304 RX noise testing was carried out opportunistically during the 1000 m accuracy test to ensure completion of this SAT requirement before sea state increased. SIS 5 supports 'continuous' BIST monitoring (when not pinging), which was used to record batches of ~30-50 RX Noise Level BISTs over a wide range of speeds from 0-150 RPM. Speeds over ground at 0 and 150 RPM were ~1 knot (kt) and ~10.5 kt, respectively; these speeds are used as a proxy for speed through water. A single continuous BIST was also recorded as the vessel accelerated slowly from ~2 kt to full speed. These results confirm

a general improvement (reduction) in noise levels perceived by the EM 304, likely due to improved receiver electronics. Observed noise levels were generally lower across all speeds compared to historical EM 302 noise trends (RX noise vs. speed has been tracked since EX-1-705) and indicate no vessel noise complications arising from the winter maintenance period. Testing can be repeated throughout the season to monitor for the effects of biofouling on flow noise and machine changes on vessel-borne noise.

Data collection was completed for the 1000 m EM 304 accuracy test. Two accuracy crossline settings were selected based on the depth region and expected transition between Deep (CW only) and Deeper (CW/FM, formerly known as Deep' or Deep 2 with the EM 302). Two crosslines on opposite headings were collected at typical survey speed (8 kts) for each setting. (These crosslines were also evaluated for additional roll calibration / verification.) The reference survey consisted of 10 lines spaced at 1 water depth; this area was surveyed at 6 kts to achieve high sounding density, using Deep CW to evaluate backscatter in this mode. XBT profiles were collected at intervals of 3-4 hours throughout the 1000 m accuracy test. Analysis of the crosslines is ongoing.

Weather deteriorated following the 1000 meter reference survey. There was much bubble interference on the transit to and during the 3000 meter reference survey, causing the data to also degrade.

The ZDA and PU drifted again overnight. Further investigation will occur tomorrow.

The EK80 software had no connection to the transducers, due to an incorrect cable in one of the ports. This was fixed and all the EKs were recognized by the software. The new 2021 licenses were applied to the WBTs.

The Kongsberg Engineer updated K-Sync to a newer version which should be more compatible with Windows 10. All sonars were able to be externally synchronized and triggered as expected.

Further optimization of the new Hydrographic Workstation occurred. An 'Energy Efficient' setting was disabled for one of the network components and the network card "Receive Buffers" were set at 2048, as recommended by Kongsberg.

Fledermaus, FMMidwater, and FMGT were all updated to the latest version. All errors reported in yesterday's SITREP were fixed with these updates.

March 06

A reference survey in 3000 meters' depth was collected in Very Deep (FM) mode to assess swath accuracy. Data collection was compromised by an elevated, confused, and increasing sea state. Crosslines planned for Deeper (CW/FM) mode were eliminated, as this is the 'shallower' of the two modes appropriate for this depth. Analysis is ongoing. Preliminary accuracy results from the 1000 m reference site show acceptable performance for Deep (CW) and Deeper (CW/FM) modes.

There is much more increased noise, especially outer fringe noise when the EM 304 is operating in deeper waters and utilizing FM. This was previously thought to be due to Qimera not correctly

reading the quality flags, however further investigation showed that the issue lies with acquisition, not processing. When operating in deeper waters there is increased noise, sector biases, and incorrect bottom detections in the outer swaths.

A series of tests were conducted with Kongsberg support to assess a pattern of intermittent and variable depth biases observed in the FM outer sectors (CW sectors generally look excellent under normal mapping conditions). Data were collected during transit over flat seafloor at 3200 m depth under the four permutations of attitude velocity data feeds enabled/disabled and yaw stabilization enabled/disabled. These changes did not appear to make any appreciable difference in the FM sector behavior. Additional lines were collected with Attitude 2 (attitude velocity) installation angles changed from zero (initial configuration) to match Attitude 1 (attitude). It is not clear at present whether the FM sector Doppler correction process utilizes these installation angles (SIS 4 did not require them explicitly, or they were assumed internally to equal Attitude 1 angles). Data collected before and after this change do not indicate any appreciable improvement; regardless, the Attitude 1 and 2 installation angles are now set identically.

During testing the impacts of realtime attitude velocity on FM sector biases, it was observed in Qimera that the number of erroneous bottom detections was reduced when the realtime attitude velocity feed was disabled. (These bottom detection issues are discussed elsewhere as 'fringes' and occur especially along the outer swath in deep water with FM enabled; these are distinct from the FM sector biases discussed above.) The EM 304 reported using FM transmit pulse forms even without the realtime attitude velocity feed, and it is believed the EM 304 transmitted FM pulses and completed the RX and bottom detection processes as normal, but without the benefit of Doppler correction during this test. The 'fringes' and number of erroneous bottom detections subsequently increased when the realtime attitude velocity (Attitude 2) feed was re-enabled.

The excess noise and sector biases have been flagged for Kongsberg who will be continuing investigation on shore, as this is a concern for the upcoming field season. The Mapping Team will also contact Ifremer (who has had an EM 304 since September 2018), and University of New Hampshire Center for Coastal and Ocean Mapping expertise for diagnostic help.

SIS 5 and Sound Speed Manager are still unable to successfully connect. The GFOE Data Team confirmed that data is leaving the Hydrographic Workstation and arriving at the CTD 1 computer and Sound Speed Manager. It is likely that the MRZ data packet is either not being written or parsed correctly by either of the software programs. Ifremer's EM 304 report also mentioned issues with the MRZ packet in their report.

Investigation continued into the drift between the PU and the ZDA message, even after testing out using the rising edge rather than the falling edge. The PU-POS does not show signs of drifting and consistently has roughly a 130 millisecond delay. This indicates that the drift is likely not with the PU's internal clock, but rather the arrival of the ZDA message. It is also unclear at this time if this difference/drifting characteristic is abnormal or negatively affecting the data. This is not expected to be causing the 'fringe' noise as discussed above.

Following the 3000 meter reference survey, pinging commenced with the EKs and the Knudsen. Data will be recorded during the transit to Key West. All sonars are being synchronized with the K-Sync as expected.

March 07

During the overnight transit a few issues with SIS were reported by the Watch Lead.

- When in 'Auto' mode, the ping mode did not change from 'Very Deep' to 'Deeper' automatically. Once the Watch Lead toggled Auto OFF and ON, SIS was able to find the correct ping mode for the depth.
- When the Sound Velocity Profile is loaded into SIS, the surface sound speed appears on the readout for only a few seconds before disappearing.
- The gridding engine, the "Zoom to Ship" function, and displaying the Water Column data in real-time concurrently failed. Restarting HDDS brought the grid back for a few minutes. These issues are thought to be due to the transit, with 'larger' spatial bounds and therefore larger allocated memory. At this time, a new survey must be started to fix these issues.

The TSG was connected to COM 4 on the EM 304's processing unit. Now both the Reson SVP (COM 3) and TSG (COM 4) can be used as surface sound speed input, with the TSG reserved for back-up.

The Kongsberg Engineers and Chief ET continued to work on troubleshooting the EM 304. They noticed that though no errors were shown when 'Continuous Sampling' was utilized, there were still numerous CBMF board failures resulting in dropped packets. They found out that 2 of the cables between the PU and the EM 304 were faulty. The cables were terminated and the CBMF timeout issues resolved. Due to weather and operational depth, it could not be determined if the outer sector issues were resolved with this change. Data was collected overnight that will allow comparison of EX-19-02 EM 302 data and EX-20-00 EM 304 data in 1000 meters' water depth. Testing will continue during EX-20-01.

The Kongsberg Engineer discovered a fraction error with the calculation of the PU-ZDA timestamps and the previously reported ~200 millisecond delay and drift is actually a 20 millisecond difference, which is more within normal bounds. Monitoring will continue on subsequent cruises, but it is not expected to be an issue at this time.

Currently, the K-Sync is unable receive the DPT (depth) datagram from the EM 304, which was previously used for calculating the ideal ping rate for the Knudsen, as it does not send a ready to transmit signal to the K-Sync (This can be done manually, having the depth datagram just makes it easier). The mapping team will work with GFOE to identify current device intercommunication requirements, and the GFOE network / sysadmin teams will evaluate these requirements and implement the appropriate infrastructure.

Overnight there were two AXBT casts that stopped displaying data collection after 200 and 400 meters. The visiting AOML Technician suggests restarting the software if this happens again.

Throughout this cruise the SST and visiting AOML Technician have diligently worked on improving and calibrating the XBT Autolauncher, below is a record of that work.

- Dismantled and cleaned launcher exterior, replacing all the hardware and fasteners.
- Disassembled launchers sealed electronic assembly box; ran diagnostics on internal components; conducted thorough visual inspection for defects and depreciation.
- Motors for tubes 4 & 6 were determined to be in need of replacement. Replacements made with spare components brought aboard.
- Cleaned launcher stopper-pins of rust and residue for smooth extending and retracting.
- Performed complete test of tube connectors and resistance readings on tube-cap pins with test probe.
- Resealed launcher electronic assemble box and coated fasteners with Room Temperature
- Vulcanizing Silicone for long term heavy weather endurance. Also replaced desiccant bags for extra moisture protection inside the electronics box.
- Created inventory of launcher external parts to be shipped to the EX in KW for replacement or spares (i.e. latches, small fasteners, latch lever cover, U-bolts, hooks).
- Performed successful cast with systems individual probe hand launcher.
- Conducted post-repair tube loading and probe test to validate repairs and future functionality.
- Practiced method for rescuing and reutilizing probes that have already had pins pulled
- Reset the protective cover for future weather endurance.
- Transcribed "wish list" of updates for ease of use in future versions of software.

March 08

After further inspection, the Kongsberg engineer changed the Attitude 2 angles back to zero, rather than matching Attitude 1. He suspects that having them equal Attitude 1 will double the application of the angular offsets.

Screenshots of all acquisition program parameters were collected and archived on the ship and within the EM 304 Sea Acceptance Testing report.

12. References

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