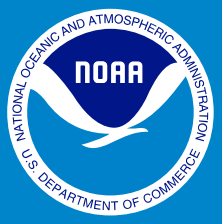

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MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT

CRUISE EX-18-02: Emerging Technology Demonstration and Mapping (Mapping)

Authors: Elizabeth 'Meme' Lobecker[1]

Other Contributors: Sam Candio[1]

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[1]Cherokee Nation Strategic Programs, at NOAA Ocean Exploration and Research

1. Introduction

The NOAA Office of Ocean Exploration and Research 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 and water column mapping data collection and processing methods used during the technology demonstration and mapping shakedown expedition EX-18-02, and to present a summary of the overall mapping results and mapping related cruise activities. A detailed description of the *Okeanos Explorer's* mapping capabilities is available in the 2018 NOAA Ship *Okeanos Explorer* Survey Readiness Report, available in the NOAA Central Library.

3. Cruise Objectives

EX-18-02 focused on conducting a shakedown of the mapping systems aboard the NOAA Ship *Okeanos Explorer* in preparation for the 2018 field season. Additionally, emerging technology demonstrations of the Cooperative Institute for Ocean Exploration, Research & Technology (CIOERT) midwater profiler system, the Navy Undersea Warfare Center's (NUWC) Instrumented Tow Cable (ITC), and the University of New Hampshire (UNH) EK80 split-beam sonars were performed throughout the cruise. The results of technology demonstration testing are not presented in the report. The cruise commenced and concluded in Pascagoula, MS, with acoustic data collection occurring between March 23 and April 5, 2018.

The mapping-related objectives of the EX-18-02 expedition were to ensure that all mapping systems and equipment were fully operational, and to perform the following calibrations: a Global Navigation Satellite System (GNSS) Azimuth Measurement Subsystem (GAMS) calibration of the Applanix POSMV, a patch test for the EM 302 multibeam sonar, and to calibrate the EK 60 split-beam sonars and test for interference.

The complete objectives for this cruise are detailed in the EX-18-02 Project Instructions, which are archived in the NOAA Central Library.

4. Summary of Mapping Results

EX-18-02 mapped 6,271 square kilometers of seafloor in the Gulf of Mexico during the 13 days at sea (Figure 1 and Table 1).

Cruise Overview Map

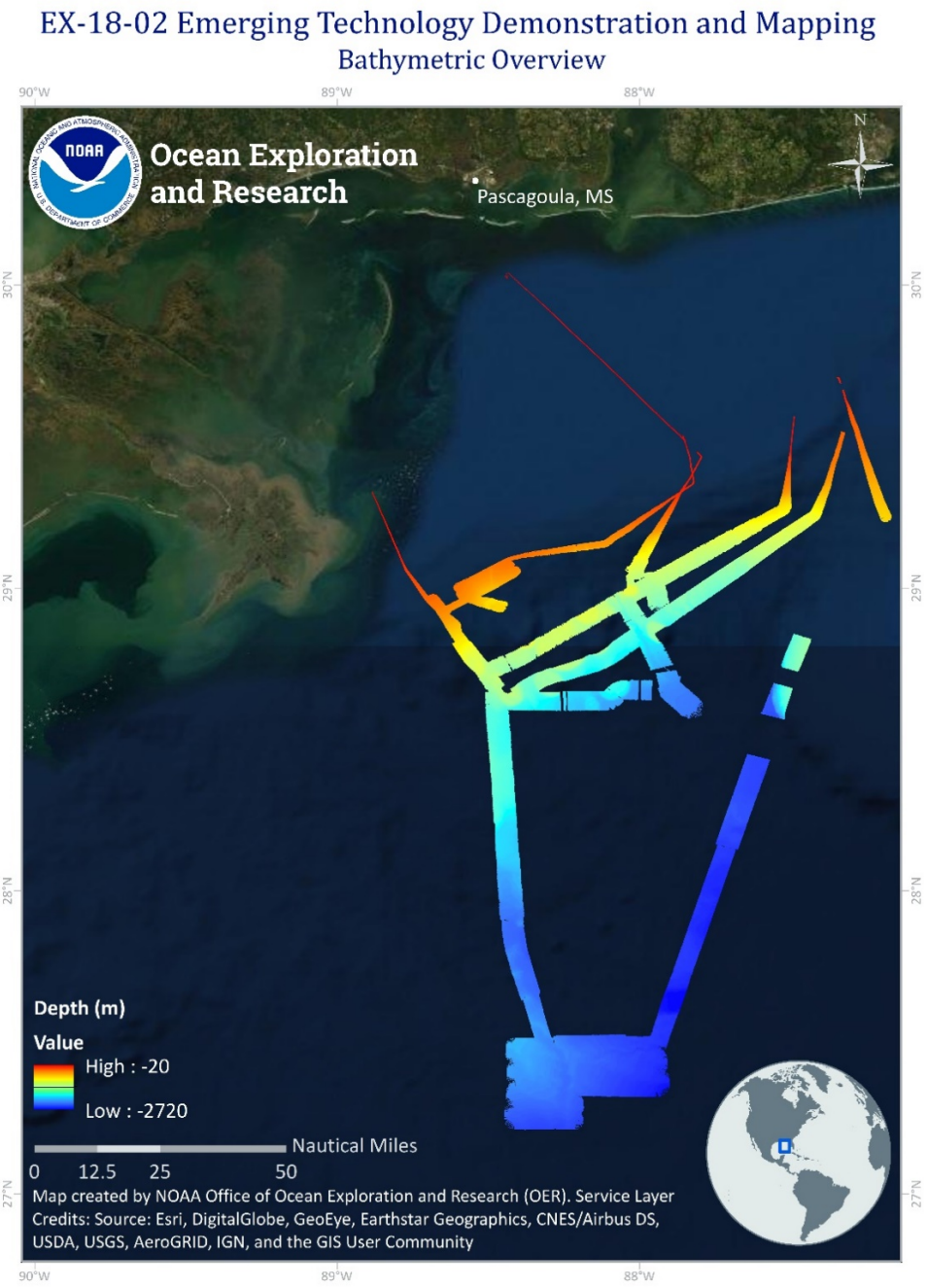

Figure 1. Overview of bathymetric mapping coverage completed during EX-18-02. Map generated in ArcMap.

5. Mapping Statistics

Table 1. Summary statistics of ocean mapping work completed during EX-18-02.

Dates of data collection	**March 23 – April 5, 2018**
Linear kilometers of survey with EM 302	**1,698**
Square kilometers mapped with EM 302	**6,271**
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files (.all)	**193 files/ 18.0 GB**
Number / Data Volume of EM 302 water column multibeam files	**193 files / 46.4 GB**
Number / Data Volume of EK 60 water column split-beam files (.raw)	**3,115 / 796 GB**
Number / Data Volume of sub-bottom sonar files (.segy, .kea, .keb)	**137 / 0.93 GB**
Number of XBT casts	**31**
Number of CTD casts (including test casts)	**7**

6. Mapping Sonar Setup

Kongsberg EM 302 Multibeam Sonar

NOAA Ship *Okeanos Explorer* is equipped with a 30 kilohertz (kHz) Kongsberg EM 302 multibeam sonar capable of detecting the seafloor in up to 10,000 meters of water and conducting productive mapping operations in 8,000 meters of water. The system generates a 150° beam fan containing up to 432 soundings per ping in waters deeper than 3300 meters. In waters shallower than 3300 meters the system is operated in dual swath mode, and obtains up to 864 soundings per ping by generating two swaths per ping cycle. The multibeam sonar is used to collect seafloor bathymetry, seafloor backscatter, and water column backscatter data. Backscatter represents the strength of the acoustic signal reflected from a target, such as the seafloor or bubbles in the water column. The system is patch tested annually and the results are reported in the annual readiness report. The 2018 NOAA Ship *Okeanos Explorer* Mapping Systems Readiness Report is available in the NOAA Central Library.

Simrad EK 60 Split-beam Sonars

The ship operated five Simrad EK 60 split-beam fisheries sonars: 18 kHz, 38 kHz, 70 kHz, 120 kHz, and 200 kHz. These sonars 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. These sonars were calibrated on this cruise, with the exception of the 38 kHz transducer which was unable to detect the calibration sphere at the target strength and is likely damaged. The 2018 EK 60 Calibration Report (https://doi.org/10.25923/6nb5-f816) is available in the NOAA Central Library.

Knudsen 3260 Sub-bottom Profiler

The ship is equipped with a Knudsen 3260 sub-bottom profiler 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 normally 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

The ship utilizes a 38 kHz Teledyne RDI Ocean Surveyor Acoustic Doppler Current Profiler (ADCP), with a ~1000 meter range; and a 300 kHz Teledyne RDI Workhorse Mariner ADCP, with a ~70 meter range. The ADCPs gather data prior to ROV deployments in order to assess currents at the dive site 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 interference issues.

7. Data Acquisition Summary

Mapping operations included data collection via the EM 302 multibeam sonar, EK60 split-beam (18, 70, 120, and 200 kHz) sonars, and Knudsen 3260 sub-bottom profiler. Data were collected by each sonar concurrently during operations. Additional testing of EK80 data were conducted by UNH personnel throughout the cruise.

Survey lines were planned to either maximize edge matching of existing bathymetric data, or to fill data gaps in areas with existing bathymetric coverage. In regions with no existing data, lines were planned to optimize potential exploration discoveries.

Throughout the cruise multibeam data quality was monitored in real time by acquisition watchstanders. Ship speed was adjusted to maintain data quality as necessary, and line spacing was planned to ensure at least ¼ swath width overlap between lines. Cutoff angles in the multibeam acquisition software Seafloor Information System (SIS) were generally left wide open for maximum exploration data collection and routinely adjusted on both the port and starboard side to ensure the best data quality and coverage.

Multibeam data received real time surface sound velocity corrections via the Reson SVP-70 probe at the sonar head, as well as through profiles generated from Expendable Bathythermographs (XBTs) conducted at intervals no greater than 6 hours, as dictated by local oceanographic conditions. Reson sound velocity values were constantly compared against secondary derived sound speed values from the ship's onboard thermosalinograph flow-through system as a quality assurance measure.

Simrad EK 60 split-beam water column sonar data were collected throughout the majority of the cruise. 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 cruise.

8. Multibeam Sonar Data Quality Assessment and Data Processing

Figure 2 shows the multibeam data processing workflow for this cruise. EM 302 Built-in Self Tests (BISTs) were run throughout the cruise to monitor multibeam sonar system status and are available as ancillary files in the sonar data archives. Raw multibeam bathymetry data files were acquired in SIS, then imported into QPS Qimera for processing. In Qimera, the attitude and navigation data stored in each file were checked, and erroneous soundings were removed using 2-D and 3-D editors. Gridded digital terrain models were exported utilizing QPS Fledermaus software and posted to the ship's ftp site for daily transfer to shore. Final bathymetry QC was completed post-cruise onshore at the Center for Coastal and Ocean Mapping at the University of New Hampshire. With the vast majority of surveying completed in deep water, depth measurements were not adjusted for tides, as they are an essentially insignificant percent of the overall water depth. Data cleaning projects were in UTM zone projections for the operations area. Final data products were exported and archived as field geographic WGS84 coordinate reference frame (i.e., unprojected).

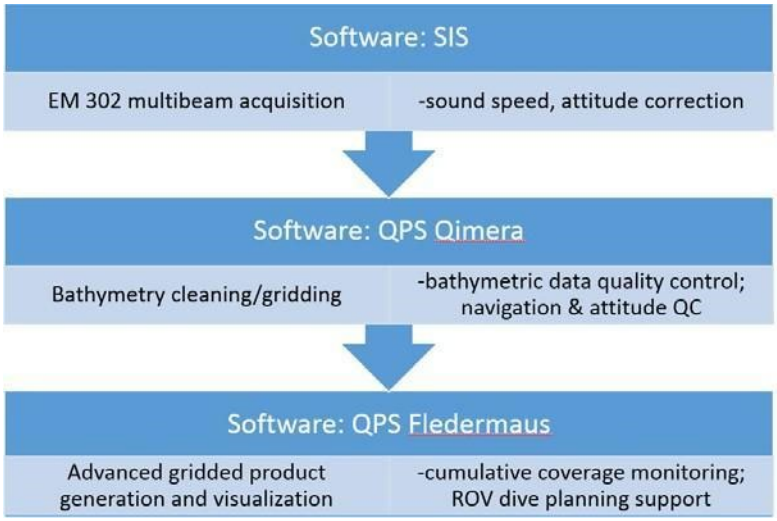

Figure 2. Shipboard multibeam data processing workflow.

Crosslines

Comparing depth values from orthogonal survey lines is a standard hydrographic quality control measure to evaluate the consistency of the multibeam sonar data collected during a cruise. Crosslines were run on April 4 as shown in Figure 3. Crossline analysis was completed using the Crosscheck Tool in QPS Qimera software to confirm that the survey meets the requirements for an International Hydrographic Order 1 survey. The results are shown below.

Crossline files:

0177_20180404_023306_EX1802_MB

0178_20180404_033306_EX1802_MB

Mainscheme line files:

0150_20180403_070755_EX1802_MB

0152_20180403_083844_EX1802_MB

0158_20180403_133020_EX1802_MB

0161_20180403_153247_EX1802_MB

0166_20180403_195515_EX1802_MB

0169_20180403_221602_EX1802_MB

0172_20180403_234420_EX1802_MB

Statistic	Value
Number of points of comparison	435,255
Grid Cell Size	50.000
Difference Mean	-0.479
Difference Median	-0.611
Difference Std. Dev	2.821
Difference Range	[-16.58, 18.25]

Mean + 2*Stddev	6.121
Median + 2*Stddev	6.254
Data Mean	-2326.775
Reference Mean	-2326.296
Data Z-Range	[-2510.01, -2161.55]
Reference Z-Range	[-2516.15, -2169.23]
Order 1 Error Limit	30.245977
Order 1 # Rejected	0
Order 1 P-Statistic	0
Order 1 Survey	**ACCEPTED**

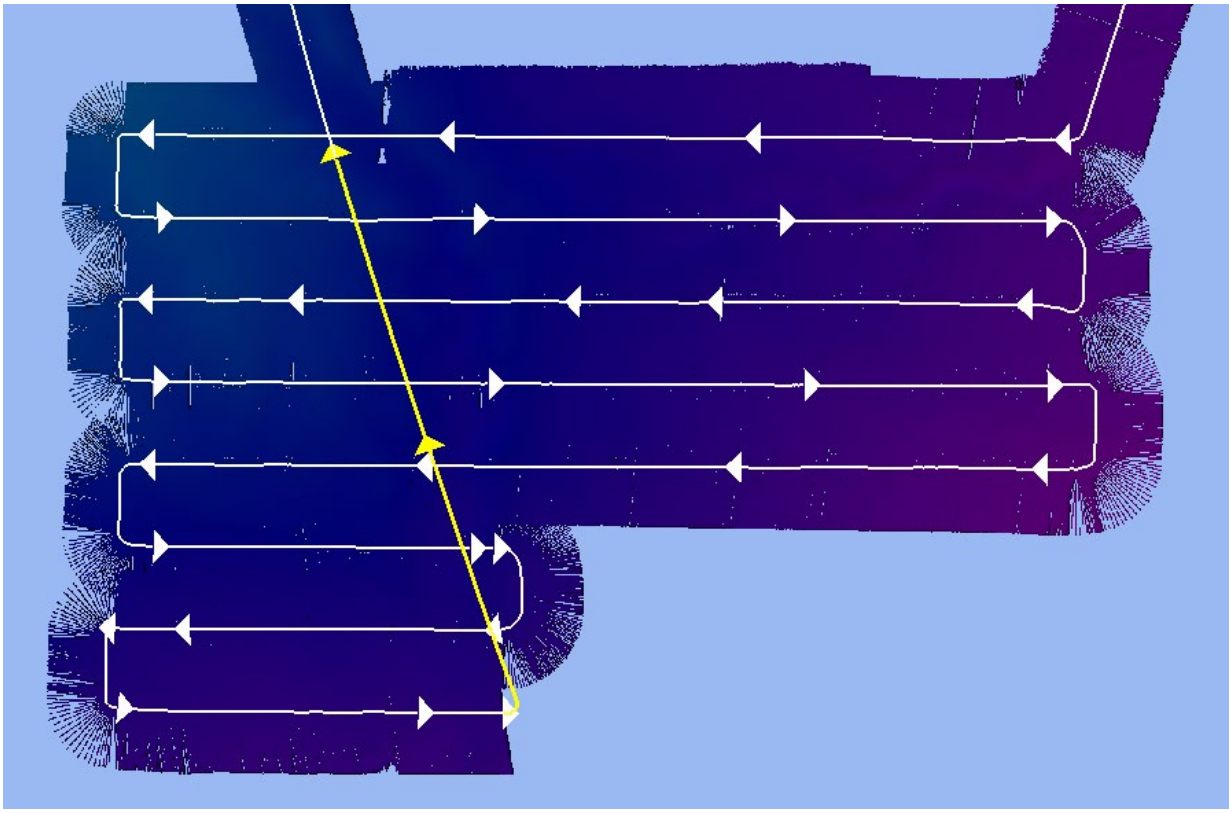

Figure 3. EX-18-02 crosslines (shown in yellow) used for comparison against the 50-meter bathymetric grid generated via orthogonal multibeam survey line. Image generated in QPS Qimera.

EM 302 Patch Test

A multibeam patch test was conducted over the Pascagoula Dome in the northern Gulf of Mexico between March 23 and March 25, 2018. In addition to the patch test, a speed noise test was performed on the EM 302. The full procedures and results are described in the 2018 *Okeanos Explorer* Survey Readiness Report.

EK 60 Calibration

EK 60 calibrations were conducted in the Gulf of Mexico in March 2018. The 18 kHz, 70 kHz, 120 kHz, and 200 kHz sonars were successfully calibrated in continuous wave (CW) mode. The 38 kHz sonar was not successfully calibrated, and is believed to have a damaged transducer. Complete details about the EK 60 calibrations are described in the EX-19-02 EK Calibration Report (doi:10.25923/6nb5-f816), available in the NOAA Central Library.

9. Data Archival Procedures

All mapping data collected by the 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-18-02 project instructions, available in the NOAA Central Library. Ancillary and supporting files are archived with the sonar datasets. These include:

EM 302 Multibeam bathymetry and bottom backscatter dataset:

- Mapping watch stander log
- Weather log
- Sound velocity profile log
- Multibeam acquisition and processing log
- Built-In-System-Tests (BISTs)
- Processor Unit Parameters
- Text files of telnet sessions on the EM 302 transceiver unit (TRU)

Simrad EK split-beam water column dataset:

- Mapping watch stander log
- Weather log
- EK data log

Knudsen 3260 Sub-bottom Profiler dataset:

- Mapping watch stander log
- Weather log
- Sub-bottom data log

EM 302 Multibeam water column dataset:

- Mapping watch stander log
- Weather log
- Sound velocity profile log
- Multibeam acquisition and processing log
- Built-In-System-Tests (BISTs)
- Processor Unit Parameters
- Text files of telnet sessions on the EM 302 transceiver unit (TRU)
- Multibeam water column data review log if data were reviewed for presence of seeps in Fledermaus MidWater

All sonar data is permanently discoverable at https://www.ngdc.noaa.gov/

At the time of writing this report,

EM 302 and EK 60 water column data, supporting data, and informational logs were available in the NCEI Water Column Sonar Archives:

https://www.ngdc.noaa.gov/maps/water_column_sonar/index.html (last accessed 01/30/2020).

Sub-bottom data, supporting data, and informational logs will be available in the NCEI Data Archives accessible at https://www.ngdc.noaa.gov/. For any challenges accessing SBP data, send an inquiry to ncei.info@noaa.gov requesting access to EX-18-02 Knudsen 3260 sub-bottom raw and processed data.

EM 302 bathymetry data, supporting informational logs, and ancillary files are available in the NCEI Data Archives accessible at https://maps.ngdc.noaa.gov/viewers/bathymetry/ (last accessed 01/30/2020).

10. Cruise Calendar

All times listed are local ship time, -5 hours from UTC

March - April 2018

Sun	Mon	Tues	Wed	Thur	Fri	Sat
					23 Ship underway from Pascagoula, MS. Multibeam patch test commenced over the Pascagoula Dome.	24 Multibeam patch test continued. CIOERT technology demonstrations commenced.
25 Multibeam patch test completed. EK80 testing occurred over Biloxi Dome.	26 Final CIOERT deployments completed. Focused mapping conducted over the Naval Oceanographic Command's requested area. EK80 testing continued.	27 Transit mapping. Arrived pierside at NUWC at 1600.	28 Ship underway at 1600. Transit mapping to EK60/80 calibration site.	29 EK calibration postponed due to weather. NUWC ITC testing commenced. Opportunistic acoustic data were collected.	30 EK calibrations commenced. Overnight transit mapping.	31 First 24-hour deployment of the NUWC ITC. EK80 data collection over the Biloxi Dome.
1 EK calibrations continued.	2 EK calibrations continued. NUWC ITC deployment. Transit mapping.	3 Focused mapping on BOEM bathy compilation gap.	4 Transit mapping to Biloxi Dome. NUWC ITC static deployment. EK80 data collection over Biloxi Dome seeps.	5 Transit mapping. Arrive in Pascagoula at 0800.		

11. Daily Cruise Log Entries

Generated from the daily expedition situation reports. All times listed are in local ship time (-5 hours from UTC)

March 23
Ship underway from Pascagoula, MS without the NUWC winch and instrument tow cables. EM 302 and EK60/80 sonars all began pinging and collecting good data. The EchoClient software used for Knudsen 3260 data acquisition continually crashed while attempting to collect data, and therefore is unable to record. The patch test site at the Pascagoula Dome was reached just before midnight and pitch and roll lines were conducted.

March 24
ADCP WH300 would not start up, troubleshooting is ongoing. Multibeam patch test lines were collected between CIOERT technology demonstrations and other field operations. EK80 data were collected during CIPERT deployments while holding station over the Pascagoula Dome.

March 25
Multibeam patch test was completed and offsets were updated within SIS. Repeated EK80 lines were run on the Biloxi Dome seeps. A CIOERT deployment was coordinated over a particularly strong seep. Extra and possibly redundant TSG feeds to the EM 302 hydrographic work station were reported and continued to be investigated.

March 26
0000 and 0500 CIOERT deployments occurred. Due to increasing seas, the final deployment was cancelled, and CIOERT began demobilization in advance of returning to Pascagoula. Focused mapping occurred over an area requested by the Naval Oceanographic Command. Minor sound velocity artifacts were observed in the outer beams of the multibeam data. Multiple lines of EK80 data were collected over the Biloxi Dome seeps.

March 27
Transit mapping until 50m water depth was reached. Arrived pierside at 1600 at the Naval Undersea Warfare Center. CIOERT equipment were offloaded and Navy equipment were onloaded. The ship spent the night alongside.

March 28
The ship got underway at 1600, and transit mapping occurred en route to the EK calibration site. The Knudsen 3260 continued to crash when attempting to record data.

March 29
The sea state prevented the deployment of the EK calibration gear. The first NUWC ITC deployment was conducted. Knudsen 3260 file recording was restored via remote support from Knudsen. Acoustic data were collected intermittently throughout the day.

March 30
EK calibrations commenced in borderline weather conditions that improved throughout the day. Calibrations continued into the evening when target signal strengths dropped below the threshold necessary for calibration, potentially due to biomass. Overnight transit mapping data were collected en route to the Biloxi Dome.

March 31
The NUWC ITC was deployed at 0830 for the first full 24-hour deployment. EK80 data were collected over the Biloxi Dome seeps, with line direction adjustments made to account for heavier seas. ADCP troubleshooting was ongoing.

April 1
The NUWC ITC was recovered at 0630. Following a CTD cast, EK calibrations continued until 1830. Overnight EK data collection occurred over an area requested by a marine ecologist from Florida International University.

April 2
EK calibrations continued. EK60 18 kHz 8 ms calibrations were unsuccessful do to a large presence of biomass. The EK80 18 kHz 8 ms calibration was successful due to the better resolution achieved from the frequency modulated signal. Transit mapping occurred overnight to an area not included in the new BOEM bathy compilation grid.

April 3
Focused mapping operations conducted in an area not covered by the BOEM compiled dataset. Significant interference observed in the EK 18 kHz data. Apparent correlation observed with a 160 RPM shaft speed.

April 4
Transit mapping conducted en route to the Biloxi Dome. EK data interference continued to be observed. EK80 data were collected over Biloxi Dome seeps until commencing the transit back to Pascagoula, MS.

April 5
Transit mapping occurred until reaching depths shallower than 50 meters. Arrived at the pier in Pascagoula, MS at 0800.

12. References

The 2018 NOAA Ship *Okeanos Explorer* Survey Readiness Report can be obtained in the NOAA Central Library or by contacting the NOAA OER mapping team at oar.oer.exmappingteam@noaa.gov.

The EX-18-02 Project Instructions can be obtained from the NOAA Central Library. The EX-18-02 Data Management Plan is an appendix of the project instructions.

The 2018 EK 60 Calibration Report (https://doi.org/10.25923/6nb5-f816) is available in the NOAA Central Library or by contacting the NOAA OER mapping team at oar.oer.exmappingteam@noaa.gov

The following data were used as background data throughout the expedition:

- Tozer, B. , D. T. Sandwell, W. H. F. Smith, C. Olson, J. R. Beale, and P. Wessel, Global bathymetry and topography at 15 arc seconds: SRTM15+, Accepted Earth and Space Science, August 3, 2019. https://doi.org/10.1029/2019EA000658
- NOAA Nautical Charts

Various datasets downloaded from the NCEI archives via NOAA AutoChart.