Ocean Exploration and Research

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MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT

EX-18-12: Mapping Deepwater Areas in the Caribbean and South Atlantic Bight (Mapping)

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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 exploration expedition EX-18-12, 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-18-12, Mapping Deepwater Areas in the Caribbean and South Atlantic Bight, contributes to NOAA's Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE), a major multi-year, multi-national, collaborative ocean exploration program focused on raising our collective knowledge and understanding of the North Atlantic Ocean. Building on previous work in the North Atlantic, including the 2011-2014 Atlantic Canyons Undersea Mapping Expeditions (ACUMEN), NOAA's ASPIRE campaign will provide data to inform research planning and management decisions in the region, by broadening both the geographic focus to include more of the U.S. Atlantic and Canada, and the scope of partnerships to include U.S. federal agencies, such as U.S. Geological Survey (USGS) and Bureau of Ocean Energy Management (BOEM), as well as international partners from Canada and Europe.

The North Atlantic Ocean plays a pivotal role to humankind, providing biological and geological resources, ecosystem services such as seafood production and climate regulation, and a route for trade and travel between Europe and the Americas. With the signing of the Galway Statement on Atlantic Ocean Cooperation by The European Union, Canada and the U.S., and the Atlantic Ocean Research Alliance's deep-sea science and exploration efforts, there is significant momentum within the international community to cooperate on integrated exploration and research of the North Atlantic Ocean.

EX-18-12 departed from San Juan, Puerto Rico (PR) on November 28, 2018 and arrived in Charleston, South Carolina on December 14, 2018, for a total of 17 days-at-sea. EX-18-12 began with a transit from San Juan, PR to the Bahamas, where a group of scientists from the University of New Hampshire's (UNH) Center for Coastal and Ocean Mapping (CCOM), JASCO Applied Sciences, and the U.S. Navy Undersea Warfare Center (NUWC) joined. Then, six days of scientific objectives were performed in the Tongue of the Ocean, Bahamas, followed by systematic mapping on the Blake Plateau. The complete objectives for this cruise are detailed in the EX-18-12 Project Instructions, which are archived in the NOAA Central Library.

4. Summary of Mapping Results

EX-18-12 collected 16,937 square kilometers (4938 square nautical miles) and 1926 linear kilometers of bathymetry and associated water column data (Table 1). 4976 square kilometers of data were collected in the U.S. Economic Exclusive Zone (EEZ) in waters deeper than 200 meters. Multibeam bathymetry data coverage is shown in Figure 1.

Cruise Overview Map

Figure 1. Overview map showing bathymetry mapping coverage completed during the 2018 Mapping Deepwater Areas in the Caribbean and South Atlantic Bight (EX-18-12). Map created by NOAA Office of Ocean Exploration and Research (NOAA-OER), generated in ArcMap.

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community. Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors

5. Mapping Statistics

Table 1. Summary statistics of ocean mapping work completed during EX-18-12.

Dates of cruise	November 28 - December 14, 2018
Ship's draft Start of cruise (11/28/2018) End of cruise (12/14/2018)	 Fore: 15' 1'', Aft STBD: 14' 3.5" Fore: 14' 8.0"; Aft STBD: 14' 2"
Linear kilometers of survey with EM 302	1,926
Square kilometers mapped with EM 302	16,937
Square kilometers mapped with EM 302 in the US EEZ and deeper than 200 meters	4975.75
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files (.all)	308 files / 24 GB
Number / Data Volume of EM 302 water column multibeam files	308 files / 62 GB
Number / Data Volume of EK 60 water column split beam files (.raw)	70 / 8.03 GB
Number / Data Volume of sub-bottom sonar files (.segy, .kea, .keb)	359 / 4.79 GB
Number of XBT casts	62
Number of CTD casts (including test casts)	1

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 shoaler 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 is equipped with five Kongsberg EK 60 split-beam fisheries sonars, 18, 38, 70, 120, and 200 kHz. The 18 kHz transducer and transmits a 7° beam fan. 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. EX-18-02 cruise, and calibration values from that cruise were applied to the EK sonars for EX-18-12. The 2018 EK 60 & EK Calibration Report (https://doi.org/10.25923/6nb5-f816.) is available in the NOAA Central Library. At the time of writing this report post-cruise, it was determined that the 38 kHz transducer was compromised and it is therefore recommended not to use this data for quantitative determinations.

Knudsen 3260 Sub-bottom Profiler

Additionally, 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 is 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 while transiting due to interference issues.

7. Data Acquisition Summary

Mapping operations included EM 302 multibeam sonar, EK 60 split-beam (18, 38, 70, 120, and 200 kHz) sonars, and Knudsen 3260 sub-bottom profile data collection.

Survey lines were planned to maximize either bathymetry edge matching of existing data or data gap filling in areas where existing bathymetry coverage existed. 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 Acquisition 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. Data were corrected for sound velocity in real time using the Reson SVP-70 data at the sonar head, and profiles from Expendable Bathythermographs (XBTs) that were conducted at intervals no greater than 6 hours, or as dictated by local oceanographic conditions (typically between 2-4 hours in this region).

Simrad EK 60 split-beam water column sonar data were collected during the entire cruise (Figure 2) as well as Knudsen 3260 sub-bottom profiler data (Figure 3).

EK 60 / EK 80 Data Collection Tracklines

Figure 2. Overview showing tracklines of Simrad EK 60/80 split-beam sonar data (in green) collected during the first leg of the 2018 Mapping Deepwater Areas in the Caribbean and South Atlantic Bight (EX-18-12). Map created by NOAA Office of Ocean Exploration and Research (NOAA-OER), generated in ArcMap.

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community. Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors.

Knudsen Sub-bottom Profiler Data Collection Tracklines

Figure 3. Overview showing tracklines of Knudsen sub-bottom profiler data (in yellow) collected during the first leg of the 2018 Mapping Deepwater Areas in the Caribbean and South Atlantic Bight (EX-18-12). Map created by NOAA Office of Ocean Exploration and Research (NOAA-OER), generated in ArcMap.

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community. Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors.

8. Multibeam Sonar Data Quality Assessment and Data Processing

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 by SIS, then imported into QPS Qimera for processing the multibeam sonar data. In Qimera, 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 created 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.

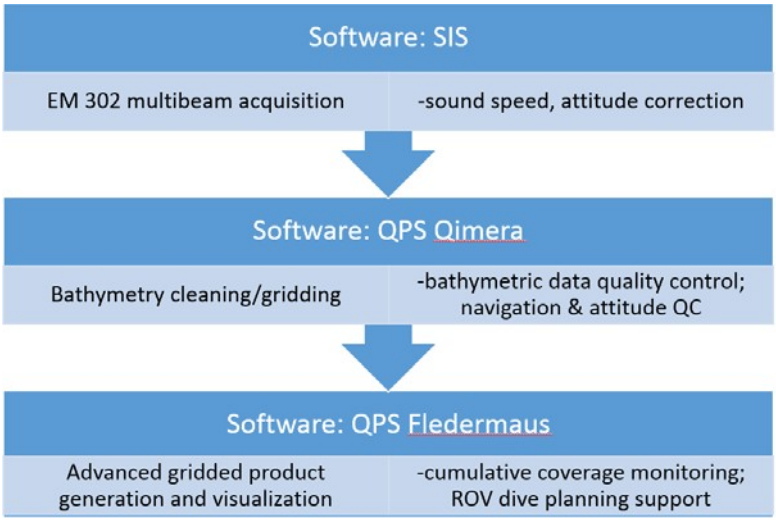

Figure 4. Shipboard multibeam data flow.

Crosslines

Comparing depth values from orthogonal survey lines is a standard hydrographic quality control measure to evaluate the consistency of the multibeam sonar data being collected during a cruise. Crossline analysis was conducted on data collected during EX-18-12 using the Cross Check Tool in QPS Qimera software (Figure 4).

Mainscheme line files used for this analysis were

0159_20181213_084323_EX1812_MB.all
0160_20181213_094326_EX1812_MB.all
0161_20181213_094933_EX1812_MB.all
0166_20181213_105912_EX1812_MB.all
0171_20181213_142859_EX1812_MB.al
0179_20181213_175352_EX1812_MB.al

0180_20181213_185352_EX1812_MB.all
0184_20181213_202216_EX1812_MB.all

and the crosslines files were

0120_20181212_042335_EX1812_MB.all
0121_20181212_052334_EX1812_MB.all
0122_20181212_062336_EX1812_MB.all.

This check was conducted in an area with variable sound velocity, therefore, this analysis is conducting on data during challenging survey conditions. The results from the crossline comparison are in the table below (See Table 2). These results show that, even with the effect of the highly dynamic oceanographic conditions and poor weather experienced during EX-18-12, the data collected still meets International Hydrographic Organization (IHO) Order 2 data quality requirements.

Table 2. Statistics provided from QPS Qimera software Cross Check Tool, with depth values reported in meters.

Number of Points	6182511
Data Mean	-649.000956
Reference Mean	-649.003536
Mean	0.002580
Median	0.002580
Std. Deviation	1.74
Data Z – Range	-785.08 : -571.57
Ref. Z – Range	-782.69 : -574.75
Diff Z – Range	-26.60 : 22.54
Mean + 2*stddev	3.49
Median + 2*stddev	3.49
Ord 2 Error Limit	14.960540
Ord 2 P-Statistic	0.000040
Ord 2 - # Rejected	246
ORDER 2	ACCEPTED

9. Data Archival Procedures

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-18-12 project instructions which is 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 WCD review log if data were reviewed for presence of seeps in QPS 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/will be available in the NCEI Water Column Sonar Archives:

https://www.ngdc.noaa.gov/maps/water_column_sonar/index.html (last accessed 12/11/2019).

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-18-12 Knudsen 3260 sub-bottom raw and processed data.

EM 302 bathymetry data, supporting informational logs, and ancillary files were/will be available in the NCEI Data Archives accessible at https://maps.ngdc.noaa.gov/viewers/bathymetry/(last accessed 12/11/2019).

10. Cruise Calendar

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

November 26 – December 16, 2019

Sun	Mon	Tues	Wed	Thur	Fri	Sat
	26 Mission Personnel arrive to ship in San Juan, Puerto Rico.	27 Alongside pier training.	28 Start of cruise. Depart from San Juan, Puerto Rico.	29 Transit mapping en route to Bahamas.	30 Transit mapping en route to Bahamas.	1 Transit mapping en route to Bahamas.
2 Small boat transfer of arriving mission personnel. Full-depth CTD cast.	3 NUWC objectives during the day and UNH objectives overnight.	4 NUWC objectives during the day and UNH objectives overnight.	5 NUWC objectives during the day and UNH objectives overnight.	6 NUWC objectives during the day and UNH objectives overnight.	7 NUWC objectives during the day and UNH objectives overnight.	8 Offload mission personnel via small boat transfer. Overnight mapping around Grand Bahama Island while taking refuge from weather.
9 Continued Grand Bahama Island Mapping. Departed Bahamas at 1600.	10 Transit mapping en route to Blake Plateau.	11 Transit mapping en route to Blake Plateau.	12 Successfully recovered DEEP SEARH LANDER. Began systematic survey on Blake Plateau.	13 Continued systematic survey. Departed for Charleston due to inclement weather.	14 Arrived in Charleston, South Carolina. End of Cruise.	15 Began demobilization.
16 Demobilization complete.						

11. Daily Cruise Log Entries

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

November 27

Engineers reported a malfunctioning air conditioning (AC) in the sonar closet over the weekend. It was discovered the units were low on refrigerant and AC tech rep showed Engineers how to refills AC units. Neither the multibeam transreceiver unit (TRU) or EK general purpose transceiver (GPTs) were powered on, so closet remained relatively cool during AC interruption. AC units are back on and working normally.

EM 302 started up smoothly and first BIST was a full pass. New to the team mapping lead / physical scientist Shannon Hoy setup SIS survey for Pureto Rico (PR) to Bahamas Transit. EK 60 and Knudsen came online smoothly as well.

November 28

Upon departure of San Juan, surveying began with the transit to Nassau, Bahamas. The EM 302, EK 60, and Knudsen are all performing normally and recording data. While attempting to connect to the server to retrieve synthetic profiles within Sound Speed Manager (SSM), the server did not come online. During troubleshooting, deep enough waters were reached to take an XBT cast. The issue with World Ocean Atlas (WOA) and SSM has yet to be resolved.

November 29

Mapping during the transit to Nassau, which included crossing the Puerto Rico Trench. Data collected by the EM 302 in the PR Trench was of poor quality with little coverage (as little as 5/5 angular coverage at some points), however this is to be expected as the depths were beyond optimal range. Once exiting, data quality and coverage improved, however there was noticeable drop outs in the first sector starboard from nadir. These dropouts continued intermittently for 67 kilometers. Data quality has been good since.

When conducting an XBT cast, the ML realized that the ASVP file sent from SSM was a small 3 KB file, while all previous were 15 KB. Upon inspection, the file had low resolution profile information with large depth gaps around 30 meters. The text files from the NOAA Atlantic Oceanographic and Meteorological Laboratory (AOML) software associated with the XBT autolauncher seemed fine and were exported at full resolution. Further troubleshooting resulted in 2 potential reasons for this unintended profile thinning: either SSM is thinning the file without input from the user, or something was wrong with the XBT cast. We redid the cast and the issue seemed to be fixed. A look through previous cruises revealed that this issue has occurred in the past at a seemingly random frequency. HydrOffice has been contacted for their input.

November 30

Surveying while transiting to Nassau continued. The majority of data from all three sonars was of expected quality in the operational depth range. For a span of about 10 minutes, intermittent interference was observed across all sonars. This was found to be caused by operational ship noise (needle gunning). Once the operation stopped, the interference was no longer observed and the data quality improved.

Regarding the issue of the small ASVP file that was discussed in yesterday's report, HydrOffice responded with this being the result of a feature in SSM that exports ASVPs that meet the specifications of SIS.

December 01

Transit data of good quality continued to be collected. The terrain is flat, sedimented, and deep. Wobbles similar to those identified during EX-18-10 are apparent in the data. Other than that, all systems are running as expected.

December 02

Systems continue to function normally. Overnight there were some issues with the keyboard video mouse (KVM) systems as we prepare for Tongue of the Ocean (TOTO) work, leaving the mapping computer inaccessible for some time. Since seafloor relief was minimal, this had no noticeable impact on operation.

CCOM and JASCO successfully launched the hydrophone array today. After launch, a small survey was done to locate the hydrophone. Mapping team helped manage deployment and subsequent survey. Mapping team also assisted in identifying the array within the EM 302 water column data.

A successful full depth CTD cast down to 1700 m was completed to meet multiple mission objectives – CCOM/UNH objectives. Overnight mapping will focus on CCOM objectives.

December 03

Systems continue to function normally. Mapping continues to support overnight CCOM objectives.

December 04

Systems continue to function normally. Mapping continues to support overnight CCOM objectives.

December 05

Systems continue to function normally. Mapping continues to support overnight CCOM objectives.

December 06

Systems continue to function normally. Mapping continues to support overnight CCOM objectives.

December 07

Systems continue to function normally. Mapping continues to support CCOM objectives.

December 08

The ship began its transit from Nassau to the Blake Plateau. Upon leaving the Tongue of the Ocean the EK 60's and Knudsen were turned on. All sonars have been operating normally.

While transiting, it was discovered that the forecast for our intended area was unfavorable due to the developing storm system in the southeast (35 knot winds and 10 - 15 foot swells). Options were discussed with the ACO, which included hugging the shore while transiting northward to Charleston, or taking refuge in the Bahamas and waiting for a weather window to transit to the Blake Plateau. While the first option puts the ship in a better position to map ASPIRE priorities if/when a window occurs, weather conditions even near shore seemed no better than offshore. As well, the ship would be operating in shallower depths, gaining smaller swaths of coverage. Note, the ship will also need to stay offshore to make water and discharge. Therefore, as well as being in agreement with the ship's assessment of the weather conditions and their solution to remain in the Bahamas for refuge, a better use of ship-time is to add coverage of the seafloor around Freeport, Bahamas.

The weather will be closely monitored for a safe window to transit to Charleston, and to map the most coverage possible in the ASPIRE priorities that the weather allows.

December 09

All sonars have been working normally. The EM 302 data is looking excellent in the Grand Bahama Island. While leaving Freeport, multiple diversions were made for traffic.

December 10

The quality of the multibeam data is greatly varying with the weather conditions throughout the day. As the ship has been operating in the axis of the Gulf Stream, XBT casts have been performed more frequently (every 2 – 4 hours) to mitigate consequent sound speed issues. Wobbles in the outer beams of the swath in 600 – 800 meter depths have been noticed. It is difficult to troubleshoot if these are caused by sound speed or the potentially unreliable survey offsets of the multibeam receive array, or something else entirely.

The CTD is being dismantled for its yearly calibration.

December 11

The multibeam data was as good as can be expected with regard to the weather conditions and highly fluctuating sound speed in the Gulf Stream.

December 12

At 1400 the ship began the 7 hour transit to the survey area. The seas had subsided but the current of the Gulf Stream limited the maximum speed to 7 knots. Operating within the Gulf Stream is also greatly affecting the quality of the data with severe variation in sound speed. XBT cast frequency has increased to

ever hour, however refraction issues remain. The mapping team will attempt to fix these issues in post processing.

December 13

A survey was conducted in one of the priority areas identified by OER and its partners. As a result of operating within the Gulf Stream, even with performing XBT's every hour, the multibeam data still has major sound speed artifacts. Mapping Watch Leads are working diligently to address these refraction issues in post processing. Utilizing the methodologies of EX-18-05 to mitigate similar issues in a nearby area, they have successfully reduced the majority of the refraction issues.

The methodology follows the following workflow in Qimera using the new Delft Inversion Tool:

1. Import survey lines
2. Remove turn lines
3. Add survey lines to dynamic surface
4. Apply a Very Strong Spline filter to the selected lines
5. Run Delft Inversion tool on selected lines
6. Proceed with Slice and 3D editing.

The post-processing of this dataset is likely to be ongoing after EX-18-12.

December 14

The ship arrived into port (Charleston, SC). Ended the cruise early due to inclement weather.

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-18-12 Project Instructions can be obtained from the NOAA Central Library. The EX-18-12 Data Management Plan is an appendix of the project instructions.

EX-18-02 EK 60 / 80 Calibration Report can be obtained in the NOAA Central Library at https://doi.org/10.25923/6nb5-f816.