Ocean Exploration and Research

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MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT

CRUISE EX-19-02: ROV and Mapping Shakedown

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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.

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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 shakedown expedition EX-19-02, 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 2019 NOAA Ship *Okeanos Explorer* Survey Readiness Report, available in the NOAA Central Library. This report only presents information about ocean mapping work completed on the cruise. Information about the remotely operated vehicle (ROV) work completed on this cruise is contained in separate complementary cruise report available via the NOAA Central Library.

3. Cruise Objectives

EX-19-02 focused on conducting a shakedown of the ROV and mapping systems onboard the NOAA Ship *Okeanos Explorer* in preparation of the 2019 field season. The ship transited from Pascagoula, MS on May 12th and ended in Key West, FL on May 24th.

The mapping-related objectives of the EX-19-02 shakedown was to ensure that all mapping systems and equipment were fully operational, including conducting a GPS Azimuth Measurement Subsystem (GAMS) calibration of the APPLANIX POSMV, performing a patch test for the EM 302 multibeam, and calibrating the EK 60/80 split-beam sonars. In addition to routine shakedown operations, EX-19-02 also focused on integrating two new EK 80 wide band transceivers (WBTs) and a new sonar synchronization device (K-Sync), as well as collecting backscatter calibration data for an updated backscatter (BS) correction file from Kongsberg.

Acoustic data (multibeam, split-beam, and sub-bottom) were collected outside of calibration operations, including focused mapping conducted in the U.S. EEZ in the Florida Straits between the Florida Keys and Cuba.

The objectives for this cruise are further detailed in the EX-19-02 Project Instructions, which are archived in the NOAA Central Library.

4. Summary of Mapping Results

Cruise Overview Map

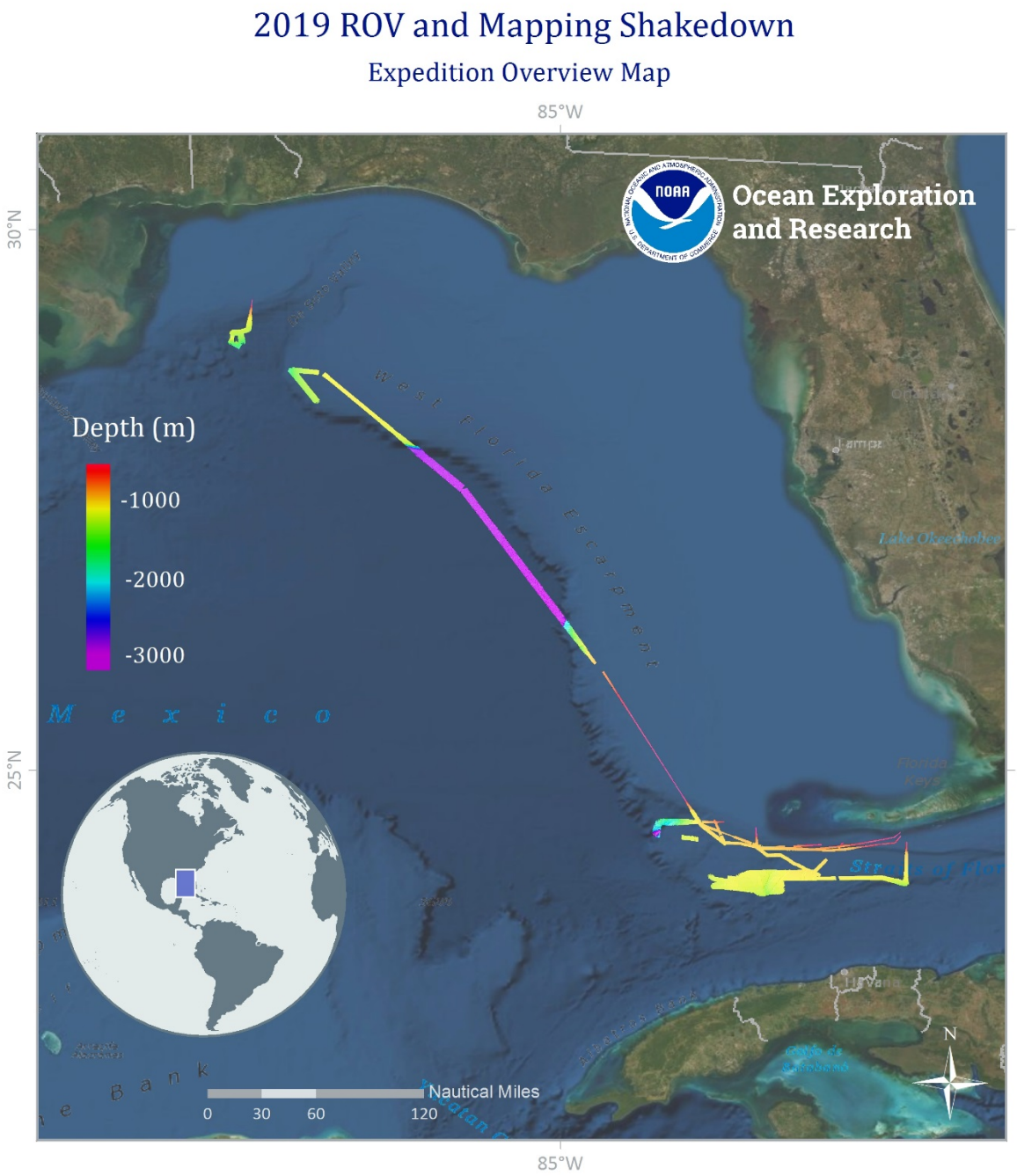

Figure 1. Cruise map showing EX-19-02 mapping coverage. Generated in ArcMap.

In addition to successfully completing the shakedown objectives, EX-19-02 collected 8,123 square kilometers (2,368 square nautical miles) or 2,373 linear kilometers of bathymetry and associated water column data, including transit data from Pascagoula, MS to Key West, FL, and a systematic survey in the U.S. EEZ between the Florida Keys and Cuba (Figure 2). This survey directly edge-matched multibeam sonar coverage previously collected in the area during EX-17-10.

Figure 2. Bathymetry collected during the EX-19-02 seafloor mapping survey between the Florida Keys and Cuba.

5. Mapping Statistics

Table 1. Summary statistics of ocean mapping work completed during EX-19-02.

Dates of cruise	**May 12 – 24, 2019**
Ship's draft Start of cruise (05/12/2019) **End of cruise (05/24/2019)**	**Fore: 15', Aft: 14' 6.5"** **Fore: 14' 7"; Aft: 14' 4.5"**
Linear kilometers of survey with EM 302	**2,373**
Square kilometers mapped with EM 302	**8,123**
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files (.all)	**217 files/ 18.2 GB**
Number / Data Volume of EM 302 water column multibeam files	**217 files / 53.3 GB**
Number / Data Volume of EK 60 water column split beam files (.raw)	**646 / 150 GB**
Number / Data Volume of sub-bottom sonar files (.segy, .kea, .keb)	**160 / 1.07 GB**
Number of XBT casts	**39**
Number of CTD casts (including test casts)	**5**

6. Mapping Sonar Setup

Kongsberg EM302 Multibeam Sonar

The NOAA Ship *Okeanos Explorer* is equipped with a 30 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 less than 3300 meters, the system is operated in multi-ping, or dual swath mode, and obtains up to 864 soundings per ping, by detecting two swaths per ping cycle. The multibeam sonar is used to collect seafloor bathymetry, seafloor backscatter, and water column backscatter. Backscatter represents the strength of the acoustic signal reflected from a target, such as the seafloor or bubbles in the water column.

Simrad EK 60 Split-beam Sonars

The ship is equipped with four 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. It was determined during the EK calibrations 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, EK 60/80 split-beam, 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.

Simrad EK 60/80 split-beam water column sonar data were collected during most of the cruise, except when calibration lines were being conducted for the multibeam sonar. Figure 3 shows the EK 60/80 kHz data collected during EX-19-02.

Figure 3. Simrad EK 60/80 split-beam sonar data tracklines (in white) collected during EX-19-02.

Knudsen 3260 sub-bottom profiler data were also collected during the majority of the cruise. Figure 4 below shows the sub-bottom data collected during EX-19-02.

Overview map showing sub-bottom profiler data collection tracklines completed during the 2019 ROV and Mapping Shakedown cruise. Map created by NOAA Office of Ocean Exploration and Research (NOAA-OER).

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

Figure 4. Sub-bottom profiler data tracklines (in yellow) collected during EX-19-02.

8. Multibeam Sonar Data Quality Assessment and Data Processing

Figure 5 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 by SIS, then imported into QPS Qimera multibeam sonar processing 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. During the focused survey between the Florida Keys and Cuba, Qimera's TU Delft Sound Speed Inversion tool was employed to mitigate difficult sound speed conditions caused by the local oceanographic conditions. 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.

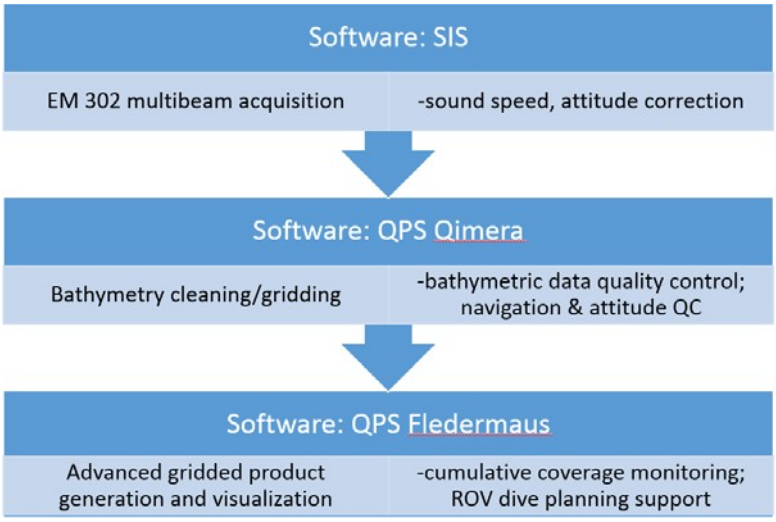

Figure 5. Shipboard multibeam data flow.

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-19-02 using the Cross Check Tool in QPS Qimera software (Figure 6). Mainscheme lines included in this analysis included lines 96-98 and 102-103 from 5/20/19 and lines 22, 23, 28-33, 44-49, 51-55, and 60 from 5/23/19. Crosslines (shown in yellow in Figure 6) are 56-58 from 5/23/19. This check was conducted in an area with highly variable sound velocity profiles, and therefore represents the most challenging survey conditions encountered during the cruise. The results from the crossline comparison are in the table below. These results show that, even with the effect of the highly dynamic oceanographic conditions experienced during EX-19-02, 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

Number of Points	1137563	**Ref. Z – Range**	-1579.57 : -869.11
Data Mean	-1060.05	**Diff Z – Range**	-741.59 : 202.33
Reference Mean	-1059.91	**Mean + 2*stddev**	16.963
Mean	-0.145	**Median + 2*stddev**	282.759
Median	-265.94	**Ord 2 Error Limit**	24.398
Std. Deviation	8.41	**Ord 2 P-Statistic**	.000688
Data Z – Range	-2022.12 : -855.71	**Ord 2 - # Rejected**	783
		ORDER 2	ACCEPTED

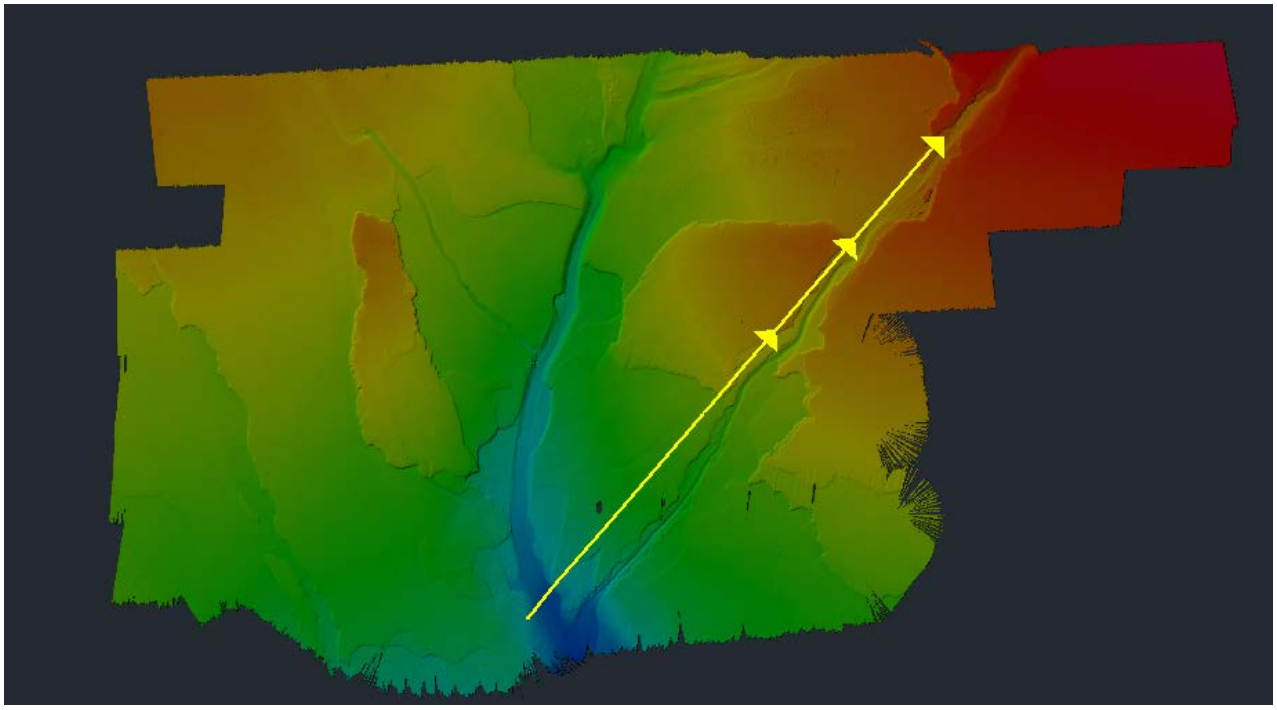

Figure 6. EX-19-02 crosslines used for cross check (Crosslines = (5/23/19) 0056, 0057, and 0058)

EM 302 Patch Test

A multibeam patch test was conducted over the Pascagoula Dome in the northern Gulf of Mexico on May 13, 2019 (EX-19-02), using the same location as the EX-18-02 patch test. 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 2019 *Okeanos Explorer* Survey Readiness Report. Angular offset results are shown in Table 3.

Table 3. Angular offsets for Transmit (TX) and Receive (TX) transducer and attitude sensor for the EM302 multibeam sonar.

	Roll	Pitch	Heading
TX Transducer	0.128	-0.392	359.98
RX Transducer	-0.015	0.092	0.03
Attitude	-0.11	-0.42	0.0

EM 302 Backscatter Calibration

Multibeam sonar data lines were acquired on this cruise over areas of seafloor with low slopes and relatively homogenous backscatter characteristics with the intent to be processed by Kongsberg in order to generate a new backscatter correction file. This calibration will be used in the multibeam acquisition software during real time data collection, and is expected to normalize the values of backscatter among the various sectors of the multibeam swath and among the various power modes of the sonar. Data was gathered in accordance with Kongsberg guidance on site selection and sonar modes and sent for processing at the end of the cruise. The full procedures and results are described in the 2019 *Okeanos Explorer* Survey Readiness Report. The multibeam sonar data files collected for this calibration are indicated in the multibeam log archived with the raw data.

EK 60, EK 80 Calibration

EK 60 and EK80 calibrations were conducted in the Gulf of Mexico in March 2019, west of Key West, Florida. During the calibration, the 38 kHz transducer showed impedance issues and there was not able to be calibrated. The 18 kHz, 70 kHz, 120 kHz, and 200 kHz sonars were successfully calibrated in continuous wave mode (CW). The 70 kHz sonar has a wide band transceiver (WBT) and was calibrated for both CW and frequency-modulated (FM) pulses. Complete details about the EK 60/80 calibrations are described in the EX-19-02 EK Calibration Report.

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-19-02 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
- Multibeam WCD review log if data were reviewed for presence of seeps in Fledermaus MidWater

EM 302 water column data are available in the NCEI Water Column Sonar Archives: https://www.ngdc.noaa.gov/maps/water_column_sonar/index.html (last accessed 7/3/2019).

Sub-bottom data, supporting data, and informational logs are available in the NCEI Data Archives accessible at https://www.ngdc.noaa.gov/ (last accessed 7/3/2019).

EM 302 bathymetry data, supporting informational logs, and ancillary files are available in the NCEI Data Archives accessible at https://www.ngdc.noaa.gov/ (last accessed 7/3/2019).

10. Cruise Calendar

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

May 2019

Sun	Mon	Tues	Wed	Thur	Fri	Sat
5	6 Mission personnel (including Roger Davis) arrive (Pascagoula, MS) for Alongside portion of EX-19-02	7 Alongside portion of shakedown	8 Alongside portion of shakedown	9 Alongside portion of shakedown	10 Remaining mission personnel arrive. Alongside portion of shakedown.	11 Last day of alongside mobilization.
12 Depart Pascagoula, MS and commence EX-19-02. Transit to MB patch test.	13 Complete MB patch test and collected data for the deep modes for backscatter calibration.	14 ROV engineering Dive 1 (~1300 m). Overnight transit to dive location 2.	15 ROV engineering Dive 2 (~3000 m). Overnight transit to dive location 3.	16 ROV engineering Dive 3 (~600 m). Overnight transit to shallow backscatter calibration site.	17 Complete backscatter calibration. Overnight transit to small boat location.	18 Small boat transfer. Most of Global Foundation for Ocean Exploration (GFOE) team departs. Mapping personnel arrive. Transit to EK calibration/K-Sync testing location.
19 Attempted EK calibration during the day with no successes due to excessive macroalgae. K-Sync operational and overnight testing occurred.	20 Attempted EK calibration during the day at a new site with no successes due to excessive currents. Again overnight K-Sync testing occurred.	21 10 successful EK calibrations completed despite strong currents. Again overnight K-Sync testing occurred and transit to small boat transfer location.	22 Small boat transfer, Kongsberg tech departing and Teledyne tech arriving. Testing of Underway CTD (UCTD) unsuccessful and dummy probe lost at sea. Opportunistic multibeam surveying overnight.	23 Opportunistic multibeam surveying and finalizing all shakedown troubleshooting objectives.	24 Arrive Key West, Florida.	25

11. Daily Cruise Log Entries

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

Alongside

May 07

The computers in the rack room were booted up and checked for correct mapping within the KVM system. One thing to note is that there is a compatibility error (between the processor and the OS) on each computer requesting update to the newer Windows version, we will follow this up with Fernando tomorrow. The sonar closet was inspected along with the internal motion unit (IMU) located in the fan room, yielding no concerns.

Roger Davis from the Hawaii Mapping Research Group (HMRG) of the University of Hawaii, updated the iMac reserved for the real-time backscatter mosaicking software (SMD) to Mojave (overlaying it on the previously installed OS: High Sierra). To note, 600 GB of data on this computer was not removed, but a follow up task will be to determine if it should remain on the computer. The version of SMD was updated to the latest, and full integration with the mission network and multibeam computer will happen tomorrow.

May 08

We booted up the EM 302's TRU this morning. Upon startup, the BIST test failed highlighting issues with the TX boards. Further inspection revealed a loose Ethernet connection on one of the TX boards. We replaced the Ethernet cable, which fixed the issue. The next BIST test was successful with all tests passed. We performed a ping test, and the multibeam performed normally as can be expected given the shallow depths.

Roger Davis, along with help from the GFOE team (thank you!), successfully fixed the network connections between SIS and the real-time mosaicking software, including receiving the ship's position. The software is now fully operational, restoring our capability to build near real time backscatter mosaics in high resolution. Derek and Shannon received additional training on the SMD software and confirmed the validity of the standard operating procedure (SOP). To note, the upgrade to the EM 304 will likely break this configuration, requiring another visit from Roger to get the software operational. However, the bigger issue will be the transition from the native .all data format to the new .kmall data format, as Roger will need to update his scripts to work with this format. He has requested any documentation we may have regarding the .kmall format so that he can begin making these updates.

Senior Survey Technician Charlie Wilkins picked up the UCTD gear from the Port Office, and we will perform an inspection of it tomorrow. Charlie also inventoried the handheld XBT's. There were 2 primary XBT launchers that connect to mk21, 1 XBT launcher that connects to the Autolauncher, and 3 back-up XBT launchers that connect to mk21. Two of the back-up launchers were already stripped for parts, and thus, were thrown away. Therefore, the inventory stands:

- 2 Primary handheld XBT launchers (MK21 connection)

- 1 Back up handheld XBT launcher (MK21 connection)
- 1 handheld XBT launcher (connects to AOML Autolauncher)

May 09
We did a complete inventory of the UCTD equipment which is now aboard. All components of the system are accounted for and ready for testing with the Teledyne technician at the end of the cruise. An inventory sheet with pictures of everything was compiled and will be stored with the equipment.

Each tube in the XBT Autolauncher was checked for connectivity with the control software and for the proper function of each release pin mechanism - all are working correctly. Three handheld XBT launchers (that connect via MK21) were checked and verified for proper function as well. Based on this testing, we are ready to use all of our XBT capabilities except for the hand launcher that connects via the Autolauncher (which we plan to test while underway).

A newer version of Sound Speed Manager (2019.0.6) was installed on both 'CTD1' and 'CTD2' computers.

All of 2018 field season sonar data was moved to the 'Mapping Ref' folder. This will keep it separate from this field season's cruises. We are working with the onboard data team to restore network drive connections on every mission computer - this process was delayed due to network troubleshooting.

May 10
Today we powered up and performed a ping test for the EM 302, Knudsen, and all of the EKs, and all sonars appear to be operating normally. We also logged data with the Knudsen and the EKs to check the functionality of the scripts that automatically transfer the data from the local drive to the network drive. The Knudsen files did successfully transfer, however the EKs did not. This requires further troubleshooting by the data team. We also checked the consistency of software versions across all of the mapping computers and their licensing status. The Hypack license was updated to the current 2019 license file. Also, the Hypack project was setup for the first leg of the expedition. The rest of our mission team for the first portion of the cruise arrived (after a few flight delays), and we went over the general schedule.

We provided feedback to the video engineers on the relative priority of computers and user stations for mapping operations. This information will be used to make improvements to the rack room and keyboard video mount equipment (KVM) to enhance the resilience of the KVM to potential failures and to minimize the downtime of key mission computers in the case of equipment problems.

The K-Sync unit was installed in the rack room by Chief Electronics Technician (CET) Blessing. It is mounted on a sliding tray for easy access and adjacent to the spare EM 302 computer. Wiring information from Kongsberg was printed out and discussed in order to inform connections needed from sonar acquisition computers to the K-Sync. Once operational, this unit will replace the currently used "Trigger-Jigger" syncing mechanism.

Mapping data files were deleted from the local sonar acquisition machines (EM 302, Knudsen, EK 60) to free up space on the local drive and as a data management housekeeping action.

May 11

The mapping team completed dockside preparations for calibration, such as running all BISTs, finalizing the patch test waypoint plan and time estimates, and reviewing all pre-calibration system geometry for the EM 302 and POS MV. The TRU was powered down to check wiring in the remote switch box for Kongsberg technicians ahead of the K-Sync integration. The EM 302 had difficulty reconnecting all boards after repowering but was successfully restarted after several attempts.

QPS software versions were confirmed to be the latest releases.

Extensive onboard alongside testing of the EK Autocal gear was completed by Adrienne Copeland today. The EK 60/EK 80 Calibration SOP was reviewed, and an inventory of all necessary gear was completed. During the inventory check, we identified that four extension cords were not included in the kit as they were originally provided by the ship. The ship no longer provides extension cords for use during calibration so the mission team purchased two 25 foot and two 50 foot extensions cords to be included in the kit for future calibrations. The two required software and drivers to control the automated calibration gear were downloaded on the field laptop. The routers and downrigger control boxes were set up in the positions outlined in the SOP and the network was tested using the 'XCTU' software. All control boxes and routers had good/adequate signal strength (below -50 decibels (dB)) and all equipment needed appears to be behaving properly. Detailed steps for testing the network are included in the SOP. The 'echocal64' software that remotely controls the outrigger poles was opened on the field laptop and appears to be working properly. This software was able to identify and communicate to the three control boxes for the downriggers. All testing of the gear has been completed. Future setup of the poles and downriggers will be done underway prior to calibration to minimize the impact on other ship operations.

We examined seafloor backscatter at the proposed deep backscatter calibration area and confirmed mostly homogenous backscatter characteristics which is ideal for this calibration. The electronic log template was updated and set up on the Watchlog Laptop and is planned to be run from the M: (MAPPING) drive, for backup and accessibility purposes.

At Sea

May 12

While underway to the multibeam patch test site (performing the same calibration lines as EX-18-02) we turned on all systems (the EM 302, all EK frequencies, WH300 acoustic Doppler current profiler (ADCP), and the Knudsen). The EM 302 was consistently dropping pings and the Telnet session was showing numerous timeout errors (mainly on TX board 1 and TX board 11). Kevin Jerram and SST Wilkins reseated the Ethernet cables to all TX boards, which appears to have improved the issue. Upon restarting SIS we lost the timing signal 'PPS' and sound velocity input. We shutdown SIS and rebooted the EM 302 computer, and when restarted, SIS seemed to no longer have these issues. However, one persistent issue, that has yet to be fixed, is that the Grid Engine is not currently operational. We were able to get the real-time mosaic up and running which is currently substituting for a grid-engine.

The EK 38 kHz is on and no interference is noted in the EM 302 data.

We were unable to perform a Global Positioning System Azimuth Measurement Subsystem (GAMS) calibration prior to our patch test because the first operational window for GAMS fell in the late evening (~2030pm). We are hopeful to find time later in the expedition to perform a GAMS calibration followed by a quick heading patch test.

Once beyond the sea buoy SST Wilkins turned on the TSG which appears to be operating normally. The Reson SVP-70 probe was intermittently dropping out, requiring a hard restart. We will follow up with ET Blessing to determine and fix this. While performing our first XBT using the Autolauncher, we noticed that the pathways to World Ocean Atlas (WOA) were broken in our install of SoundSpeed Manager (SSM). Every other step of the AXBT operation was successful. These pathways were fixed and Watch leader Baechler amended the SSM SOP to include this process. SST Wilkins worked on troubleshooting the CTD to establish communication with the device. Communication was established and a test cast will be performed tomorrow.

May 13

The mapping team completed an overnight geometric calibration ('patch test') to correct residual angular biases between the EM 302 and POS MV. Calibration lines were run along the same Pascagoula Dome site used during EX-18-01. Reasonably small biases were clearly indicated in the bathymetry and corresponding corrections were applied in SIS. A calibration report with all of the details is being compiled. Angular offset values to pitch and roll were input into SIS, no adjustment was deemed needed for heading.

Early in the morning we encountered a severe storm, with wind gusts up to 50 knots, heavy rain, hail, and extreme lightning. All sonars lost the bottom due to intense surface disturbance and we decided to turn off each sonar and isolate the breakers. After an hour, when the storm had abated, we turned back on the systems. A BIST test was conducted and all passed.

We performed a test CTD and a full depth CTD cast prior to the deep backscatter calibration. We were able to use the down cast profile from the CTD, however some sensors displayed issues in need of further troubleshooting and the up cast values from both salinity sensors were not useable. A new termination of the CTD may be needed, and further troubleshooting work will occur tomorrow. We discovered how to reference a CTD salinity profile rather than a WOA profile in Sound Speed Manger, and the process is being amended to the SOP.

The Reson SVP probe was still periodically dropping out and CET Blessing noticed some faulty cabling. He organized the cables, which seemed to fix the issue in the SCS display. However we later noticed that the SVP probe was not feeding into SIS or SSM. Troubleshooting yielded the wrong type of cable being used, once replaced the feed returned and dropouts subsided. We are monitoring the robustness of this feed.

The mapping team collected data for backscatter calibration in Deep and Very Deep modes in a region of benign bathymetry and consistent sediment type, per instructions from Kongsberg. Due to the cumulative delay from the storm, originally unplanned operations, and extensive troubleshooting, we were unable to collect the suggested amount of pings for the deep backscatter calibration. The recommended number of pings is 2500 per mode per reciprocal lines, which equates to about 4 hours a line in Deep and Very Deep mode. To stay on schedule for tomorrow's operations we were able to achieve about 1500 pings per line.

We do not know the effect this will have on Kongsberg's backscatter calibration process, but believe this will be adequate data since the backscatter at the calibration site is very homogenous.

The EM 302 continue to experience intermittent pings with very high and very low backscatter values. This issue was first noted during the 2018 field season, but the intermittent nature has complicated troubleshooting. The TRU reports occasional "TSP" Sequence Timeout errors that seem to be related but not correlated one-for-one with the backscatter anomalies. This issue affects backscatter primarily, and the system still produces bottom detections during these anomalous pings. Watch Lead Jerram created a script to detect very high and very low mean backscatter values, then write new .all files without those pings. These files are used to produce better backscatter mosaics and are noted in the MB Log.

There are KVM issues with our EX-CTD1, EX-CTD2, and EX-HYPACK computers with them flickering in and out, hindering use of them for much of the day. GFOE quickly setup remote desktop connections to these computers, so that we could continue using them during our operations. This issue is being further investigated by the video engineers.

May 14
The deep backscatter calibration lines were completed last night. Weather was mild with a gentle sea state. There were sporadic pings that had blown out backscatter values - these were a small percentage of the overall survey.

We started a new multibeam survey today and tried to tighten the Ethernet connections on the TRU and the connection problems have been absent since these steps were taken. In other multibeam notes, the grid engine in SIS is not functioning - despite restarting SIS, starting new surveys with different gridding parameters, and restarting HDDS computer. We will work to resolve this with KM when their engineer is onboard later this cruise – it only affects display, not the data quality. The MBPROC1 computer has occasionally frozen and required a hard restart; the data engineers are investigating. Several SOPs and log templates have been updated. XBT autolauncher is working well. We are running the 38 kHz WBT in single band or CW mode and the 70 kHz WBT in wide band or FM mode and have not noticed any interference with the EM 302 thus far.

A straight line transit was planned for tomorrow's dive site to make up some time. We dropped the originally planned deep roll verification line, but do not believe it is essential at this time and may get to it later.

May 15
No calibration tests are planned for our mapping systems today. While transiting between dive sites we continued to have the backscatter blowout issue associated with the Telnet errors. Each time we have these errors it seems like ensuring better Ethernet connections on the TRU boards temporarily fixes the issue.

After starting up from Dive 2, we noticed much more apparent wobbles in the outer swath. We tried to fix with an updated sound velocity profile and turning yaw stabilization off and on. Neither of these made a difference. These wobbles could be the wobbles that we are used to seeing, potentially caused by the

highly dynamic oceanographic conditions in this area, or something else entirely. We plan to restart the TRU tomorrow to cover our troubleshooting bases.

We also observed the effect of the EM 302 operating in FM mode on the EK 80 70 kHz in FM mode. When the EM 302 goes into FM mode, which occurs in Deep, Very Deep, and Extra Deep ping modes, it severely interferes with the upper water column of the EK 80 70 kHz. The team proceeded to observe the potential FM/CW combinations between the EM 302 and the EK 80 70 kHz and documented the findings to be used in future discussions.

May 16
The transit following the extended dive was modified to a straight shot (no edge matching) in order to make sure we arrived at the shallow backscatter calibration site on time for the morning CTD cast planned for 0800. The TRU was rebooted and checked for loose Ethernet cables prior to surveying. Sun photometer measurements are being collected for the National Aeronautical and Space Agency's Maritime Aerosol Network (AERONET) whenever the sun is unobstructed by clouds. CET Blessing and SST Wilkins spent most of the day troubleshooting and fixing the CTD. A new slip ring was installed and the CTD was re-terminated to try get the CTD in the best condition possible for the next day's cast. SST Wilkins swiftly followed UCH procedures for SCS during the shipwreck discovery.

May 17
Following a safety evaluation on the bridge, the CTD was deployed at approx. 0800. The cast was conducted to get as close to the seafloor as possible, to get a full profile of the water column for complete characterization of the absorption profile, as is desired for backscatter calibration. Thanks to much troubleshooting by CET Blessings and SST Wilkins, the sensors all worked flawlessly. We completed an XBT cast immediately afterward to compare with the CTD-derived sound velocity profile. The comparison showed extremely close agreement, and was a good validation of data quality.

We began the "shallow" (700 meter) portion of the backscatter calibration today. We found an area at this suitable depth with homogenous backscatter SW of the Dry Tortugas. It is gently sloping, but moving along the slope contour is the flattest area in the region, which meets the rest of the calibration's requirements. In the time allotted, we completed two reciprocal lines for MEDIUM and DEEP mode, and one line for SHALLOW mode. We hope to collect the remaining line for the SHALLOW mode following EK calibration. CET Blessing prepared most of the cabling for connecting the K-Sync device to our sonars. All connections will be finalized with Kongsberg tomorrow following the small boat transfer.

The EK calibration site selection was finalized based on review of wind and current models. The site is planned for a 150 meter area west of the Dry Tortugas, which should have some of the mildest conditions in the region and be safe for drifting during the calibration. Sun photometer measurements continue for NASA AERONET.

May 18
We surveyed overnight while transiting to the small boat location. We also performed interference testing and began conceptualizing synchronization schemes in preparing for the install of K-Sync tomorrow.

Kongsberg immediately set to working with the EC, CET and GFOE Data Manager on getting the K-Sync (new sonar synchronization device) wired correctly and tested. After overcoming some setbacks, the system was operational by the end of the day and will be extensively tested overnight. We discussed our problems getting the gridding engine to work in SIS, and the fix appears to require an upgraded installation of SIS on the multibeam computer.

Adrienne Copeland set up and tested all of the EK automated calibration gear and confirmed that everything was working properly and ready for the next day. She developed a plan for the calibration and attended the OPS meeting to ensure good communications on the plan. We evaluated current models, weather, and depths in the region and selected the calibration site for the following day.

The new deck headset radios were demonstrated by Roland, who trained the mapping team on how to use them. They have excellent range and sound quality and many useful features.

May 19

Just after sunrise EK calibration equipment setup was completed on deck. A GAR (green, amber, red) assessment was completed on the bridge followed by a CTD cast to 100 meters. Deck Department helped mission team setup the initial EK calibration lines and the rest of the day was dedicated to attempting EK calibrations. The weather was sunny with light winds and < 1 meter seas. Currents at the selected site were under 0.2 knots based on ADCP data. The ship was drifting throughout the day for the calibrations. The auto calibration gear partially worked. We tried the option to send the sphere to the x,y,z location under the sonar pod, but it would not respond or move the reels correctly. After trying this for numerous attempts we manually (but largely remotely) ran the reels out to the locations we knew were correct. The port reel was not forwarding and reversing correctly. This was later fixed, and was due to the line having been previously double-backed on the reel. The starboard side reels were run off the remote controls throughout the day without control problems.

This area turned out to have a great deal of *Sargassum* macroalgae both at the surface and dispersed throughout the upper water column. We worked on calibrations throughout the day for 38, 70, and 120 kHz frequencies. Each one was able to obtain target measurements throughout the beam pattern as required, but the final RMS values exceeded the threshold for acceptable calibrations considerably. Interference in the measurements was a constant problem, and we had to pull up the sphere assembly several times to physically pull off conglomerations of macroalgae from our equipment. Despite a long day of giving it our best shot, this site clearly had too much seaweed to enable success. There are not many suitable locations in the region, given the dominance of the strong Loop Current and Gulf Stream. We decided to leave this area and not return tomorrow. We are going to try a location nearby Key West that EX was able to successfully use back in 2014. We can only hope for less *Sargassum*.

We tried to calibrate the EK 70 kHz in wide band mode and were unable to get sphere detections. This was odd, because we could center the sphere on axis in CW mode for that sonar - but when we switched to FM pings it disappeared. The onboard Kongsberg engineer did not know why that was happening and is conferring with other reps to help us troubleshoot.

May 20

Just after sunrise EK calibration equipment setup was completed on deck. A GAR (green, amber, red) assessment was completed on the bridge followed by a CTD. Deck Department helped mission team try to setup the initial EK calibration lines. The very strong current pushed all weight on the bow deployment line to one side, and it became impossible to clear the sonar blister bump or bow thruster crease which is notorious for being a catch point for getting the lines past the bow of the ship and centered on the sonars. We tried various line maneuvers to clear the catch point, but were ultimately unable to get the lines free. After evaluating our options it was decided that the excessive currents would likely prevent a good calibration (as the sphere would be too hard to control and have high uncertainty values) even if we were successful in getting all the lines set right. We evaluated the option of moving into the Florida Keys National Marine Sanctuary (FKNMS) boundary, but the nearby area is specified as Area to Be Avoided on the nautical charts, we lacked pre-permission from FKNMS, and it would have had us drifting too close to the reef for safety. We determined a better use of ship time was to map a survey gap southwest of our location for the rest of the day.

After finishing the short gap survey we will transit to the new (and final) EK calibration site. It is recommended that if possible future shakedown cruises avoid planning to do EK calibrations in this region of the Gulf of Mexico due to the dominance of *Sargassum* and the limited areas available to be outside the Loop and Gulf Stream currents.

The plan to update to a newer version of SIS was postponed until tomorrow since we needed the multibeam right away for the gap survey. Kongsberg engineer Tony Dahlheim, CET Blessings, and Fernando Aragon were able to set the OS 38 ADCP to be externally triggered by the K-Sync, which will be useful for potentially running the OS 38 and EK 38 kHz during ROV operations. To do so, they re-terminated an already run Ethernet cable with a BNC connector. Next repair period we should aim to replace this temporary solution with a BNC cable.

May 21

The latest version of SIS compatible with the EM 302 was successfully installed today on the multibeam computer, and is being fully tested tonight. Tony was able to get the EM 302's depth datagram to send to K-Sync, which allows calculated ping-rates based on depth (a situation we would use for synchronizing the Knudsen). Neah Baechler continued to work on a K-Sync SOP.

Just after sunrise EK calibration equipment setup was completed on deck. A GAR (green, amber, red) assessment was completed on the bridge followed by a CTD. Deck Department helped mission team try to setup the initial EK calibration lines. Conditions were optimal for EK calibration, and mostly proceeded quickly throughout the day. We calibrated the following sonars and pulse lengths:

- 18 kHz EK 60: 1.024, 4.096 pulses (tried the 8 millisecond (ms) pulse, but the root mean square (RMS) values were too high)
- 70 kHz EK 80 CW mode 2.048, 1.024
- 70 kHz EK 80 FM mode 1.024, 2.048, 4.096, 8.192 ms
- 120 kHz EK 60: 1.024 ms
- 200 kHz: 1.024 ms

We attempted calibrations on the 38 kHz EK 80 sonar, but quickly realized that three out of the four sonar quadrants consistently had very low target strength values and that something was wrong with it. Kongsberg believes it is the transducer (the WBT deck unit is brand new). This transducer is already planned for replacement in the next dry dock and OMAO has already procured it. It was already needing replacement in order to handle wide band pings, but now it is also clear that it is also not working correctly. This testing confirms that there is a problem with the old one and it is not possible to calibrate it until the new transducer is installed. Mapping team will now have to evaluate the value of running this sonar this year and necessary metadata to warn potential data users of its status. Adrienne Copeland led this extensive testing work and is to be commended for her perseverance and technical abilities with the EKs. It was a major team effort, and numerous calibrations were also led skillfully by Kevin Jerram.

We worked up until sunset. The lines became tangled while being recovered and led to a delay in our planned departure time. We had to cut out some knots and will need to do some maintenance work on the calibration gear tomorrow. The auto calibration gear worked for much of the day, but one of the reels needed manual support in the afternoon.

May 22

Morning UCTD testing started with two successful casts without the use of the tailspool (i.e. shallow warm up casts). We then did a full depth cast with the maximum amount of line on the tailspool and this cast was also successful. The fourth cast was also a full depth cast. When rewinding this cast on the winch, we observed a sudden jerk with about half the line reeled in. The line then lost a lot of its tension and we knew it was not right. The end of the line came back snapped and the dummy probe was lost at sea. The line failure was not at the splice used to attach the probe. This was the same sequence of events that happened during previous testing of this equipment. The Teledyne representative had never observed this before. These two line snapping events, along with the frequent major line tangles experienced by the UCTD lead us to the final conclusion that we have no confidence in its ability to work for our sound velocity profiling needs and will cease risking other equipment and spending staff time on its use. The Teledyne representative confirmed his understanding of this position and emailed an immediate report of findings to his managers along with a request to develop a customer service response plan.

We have packed up all the UCTD equipment and plan to offload it in Key West. We will have to develop a plan to seek permission to store there until its fate is determined – or ship back to the manufacturer or Rhode Island EX home facility to free up onboard storage space. SST Wilkins did an excellent job setting up and preparing the UCTD equipment yesterday and helping with the field testing today.

We conducted 4 GAMS calibrations, decreasing the value for the required error threshold each run. The final numbers were within a couple millimeters to the measured offsets between the antennas in the x, y plane and no adjustments to existing numbers were deemed necessary.

A speed noise test was carried out, yielding low RX noise levels at 2, 4, and 8 knots. The tests at 6 and 10 knots showed inconclusive results and we will perform additional testing at these speeds tomorrow.

The SIS gridding engine was fixed after the new install of SIS. However, if the survey setting box is clicked (i.e. default window view setup preferences changed) the gridding engine stops working again. A SIS restart can fix this.

May 23
The K-Sync SOP was finalized by Neah Baechler and the 2019 Mapping Readiness Report was finalized by Shannon Hoy.

The EK calibration values have all been applied in the EK 80 software - all data collected moving forward this field season is calibrated (except data collected by the EK 38 kHz). The EK calibration report was completed by Adrienne Copeland.

The UCTD equipment is being moved off the ship in port and put on a pallet to be ready to be shipped (location TBD). This frees up substantial storage room in the survey stores area.

We did a second abbreviated speed noise test on the multibeam to see if elevated noise at 6 and 10 knots from the first test could be replicated. 6 knots was low noise this time (the first test appeared to be an anomaly caused by wave slapping on the hull). 10 knots was still relatively loud. The ship's Operations Officer provided us with information on what generators were during the tests, in case there is a relationship there. It could be other equipment, cavitation noise from the props, or some other factor.

The area we have been surveying is southwest of Key West near the Exclusive Economic Zone boundary between the US and Cuba. The bathymetry is fascinating, with apparent slump features, many individual "rubble" features, and extremely distinct channels. The newly resurrected seafloor mosaic display software on the iMac generated an impressive mosaic of the area. The backscatter is stunning and unique and should be of high interest to marine geologists.

May 24
Last day of the cruise. Overnight mapping operations finished the focused survey on Tortugas Terrace south of Dry Tortugas and north of the Cuban EEZ boundary. A multibeam crossline was run across the survey area. All sonars were secured on the approach transit to Key West. Mission spaces were cleaned in the morning. The ship was docked at the pier in Key West by 10 AM EDT. The cruise data package was assembled and copied to external hard drive. Part of the mission team departed in the late afternoon, with the rest slated to depart in the morning.

12. References

The 2019 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-19-02 Project Instructions can be obtained from the NOAA Central Library. The EX-19-02 Data Management Plan is an appendix of the project instructions.

EX-19-02 EK 60 / 80 Calibration Report can be obtained in the NOAA Central Library or by contacting the NOAA OER mapping team at oar.oer.exmappingteam@noaa.gov