Ocean Exploration and Research

doi: 10.25923/fzh5-9b05

MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT:

EX-17-05, Mountains in the Deep – Exploring the Central Pacific Basin (ROV & Mapping)

April 27, 2017 to May, 19 2017

Pago Pago, American Samoa to Honolulu, Hawaii

Authors: Michael P. White[1]

Other Contributors: Charles Wilkins[2], Kevin Jerram[3], Neah Baechler[3]

April 20, 2020

[1] Cherokee Nation Strategic Programs, at NOAA Ocean Exploration and Research
[2] NOAA Office of Marine and Aviation Operations
[3] Cooperative Programs for the Advancement of Earth System Science, University Corporation for Atmospheric 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, and 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

1. Introduction 2
2. Report Purpose 4
3. Cruise Objectives 4
4. Summary of Mapping Results 4
5. Mapping Statistics 6
6. Mapping Sonar Setup 6
    - Kongsberg EM 302 Multibeam Sonar 6
    - Simrad EK6 Split-beam Sonars 7
    - Knudsen 3260 Sub-bottom Profiler 7
    - Teledyne ADCPs 7
7. Data Acquisition Summary 7
8. Multibeam Sonar Data Quality Assessment and Data Processing 12
9. Data Archival Procedures 16
10. Cruise Calendar 18
11. Daily Cruise Log Entries 19
12. References 22

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 mapping expedition EX-17-05, Mountains in the Deep: Exploring the Central Pacific and to present a summary of the overall mapping results and mapping related cruise activities. A separate report titled, 'Cruise Report: EX-17-05, Mountains in the Deep: Exploring the Central Pacific Basin (ROV & Mapping)' detailing ROV and other science objectives is available in the NOAA Central Library here: https://repository.library.noaa.gov/view/noaa/23495 (last accessed May 2020) A detailed description of the *Okeanos Explorer's* mapping capabilities is available in the 2017 NOAA Ship *Okeanos Explorer* Survey Readiness Report, in the NOAA Central Library.

3. Cruise Objectives

The EX-17-05 expedition addressed science themes and priority areas put forward by scientists and managers from NOAA, management agencies in the region, and the ocean science community. NOAA OER priorities for the expedition included a combination of science, education, outreach, and open data objectives that will support management decisions at multiple levels.

This expedition was part of the three-year Campaign to Address the Pacific monument Science, Technology, and Ocean NEeds (CAPSTONE) (last accessed April 2020), an initiative to collect deepwater baseline information to support science and management decisions in and around U.S. marine protected areas (MPAs) in the central and western Pacific.

An online summary of all mission objectives be found here: https://oceanexplorer.noaa.gov/okeanos/explorations/ex1705/logs/summary/welcome.html (last accessed April 2020)

The complete objectives for this cruise are detailed in the EX-17-05 Project Instructions, which are archived in the NOAA Central Library here: https://repository.library.noaa.gov/view/noaa/14965 (last accessed April 2020)

4. Summary of Mapping Results

The expedition commenced from Pago, Pago, American Samoa on April 27, 2017 and concluded in Honolulu, Hawaii on May 19, 2017. EX-17-05 mapped 37,521 square kilometers (km) (10,939 square nautical miles) of seafloor during the 23 days-at-sea (Figure 1 and Table 1).

Cruise Overview Map

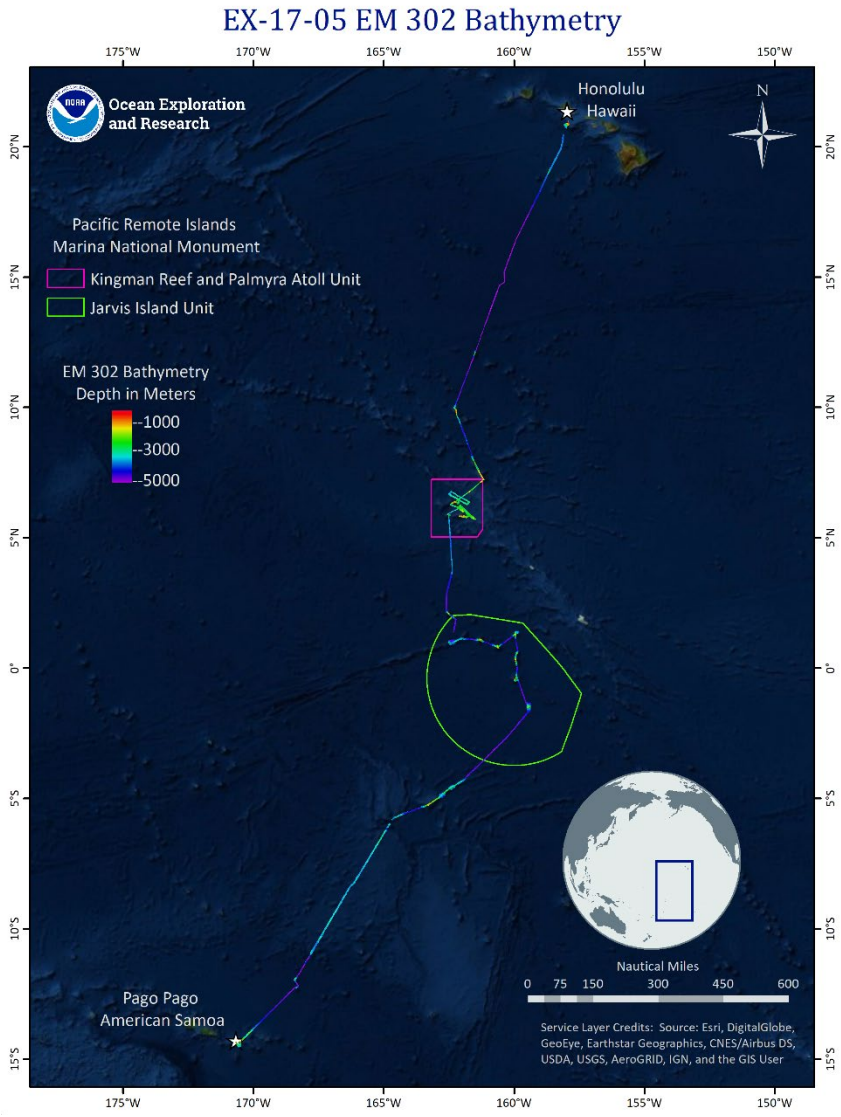

Figure 1. Overview of bathymetric mapping coverage completed during the American Samoa, Kingman/Palmyra, and Jarvis expedition (EX-17-05).

5. Mapping Statistics

Table 1. Summary statistics of ocean mapping work completed during EX-17-05.

Dates of data collection	April 27 to May 19, 2017
Linear km of survey with EM 302	6,200
Square km mapped with EM 302	37,521
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files (.all)	476 files / 26.3 GB
Number / Data Volume of EM 302 water column multibeam files	476 files / 94.7 GB
Number / Data Volume of EK60 water column split-beam files (.raw)	133 files / 13.8 GB
Number / Data Volume of sub-bottom sonar files (.segy, .kea, .keb)	366 files / 4.59 GB
Number of XBT casts	52
Number of CTD casts (including test casts)	0

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 conducting mapping operations in up to 8,000m of water depth. The system generates a 150° beam fan containing up to 432 soundings per ping in waters deeper than 3300m. In waters shallower than 3300m 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. System calibration to determine

the angular offsets (Patch Test) is conducted annually and the results are reported in the annual readiness report. The 2017 NOAA Ship *Okeanos Explorer* Survey Readiness Report at the time of writing this report was planned for archival in the NOAA Central Library.

Simrad EK6 Split-beam Sonars

The ship operated five Simrad EK60 split-beam fisheries sonars: 18 kHz, 38 kHz, 70 kHz, 120 kHz, and 200 kHz. The 38 kHz was only operated during ROV dives. 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 the EX-16-09 cruise, and calibration values from that cruise were applied to the EK sonars for EX-17-05. The 2016 EK60 Calibration Report is archived at the NOAA Central Library. The 38 kHz was not successfully calibrated and the transducer was later determined compromised.

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 ~1000m range; and a 300 kHz Teledyne RDI Workhorse Mariner ADCP, with a ~70m 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 using the EM 302 multibeam sonar, EK60 split-beam (18, 38, 70, 120, and 200 kHz) sonars, and Knudsen 3260 sub-bottom profiler. Data were collected by each sonar concurrently during the transits.

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. EX-17-05 when possible included focused overnight mapping of the ROV dive location.

Figures 2 shows multibeam bathymetry collected using the Scanning Feature in Seafloor Information System (SIS). The Scanning Feature changes the pitch of the emission signal by a set increment i.e. one half or one degree, from forward to aft. The data was collected during dynamic position system testing. Figure 3 illustrates focused overnight mapping in preparation of the immediately following ROV dives. A previously unmapped seamount is shown in Figure 4. This seamount was south of Jarvis Island within the Jarvis Island unit of the Pacific Remote Islands Marine National Monument (PRIMNM). Much of the data collected on EX-17-05 was the first mapping data collected over these remote seafloor features Figure 5 is an example of strategic mapping data collected over seafloor features of interest during transits between ROV dive sites.

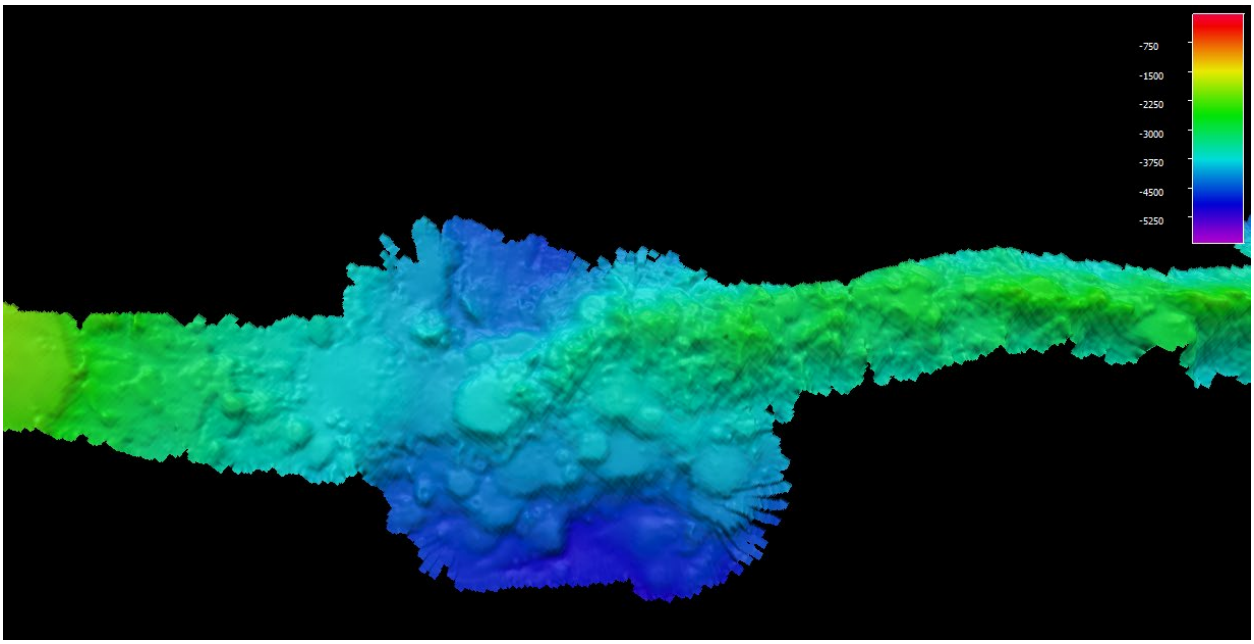

Figure 2. This saddle-like feature was mapped on May 1 between an unnamed seamount and ridge, just north of the Cook Islands. Data like these are important because they help scientists to understand the importance between ridge areas and plateaus, as well as the connection between this region and others. Vertical exaggeration 3x, 70m cell seize, depth in meters.

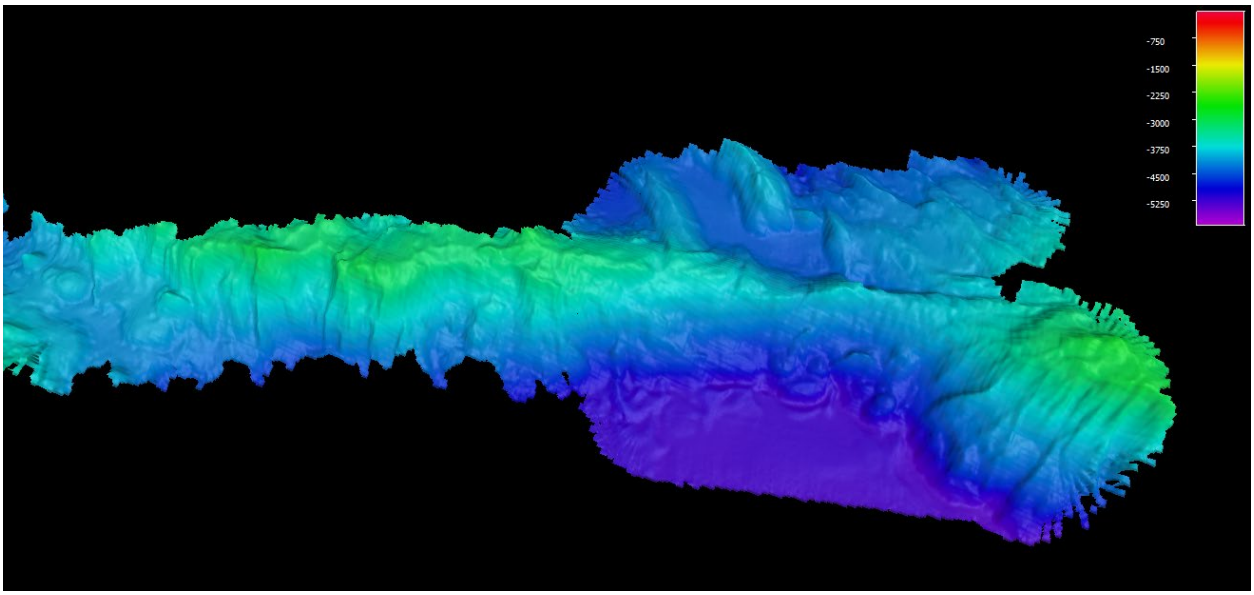

Figure 3. Focused mapping of the eastern end of the Nova-Canton Trough in the Jarvis unit of PRIMNM. Vertical exaggeration 3x, 70m cell seize, depths in meters.

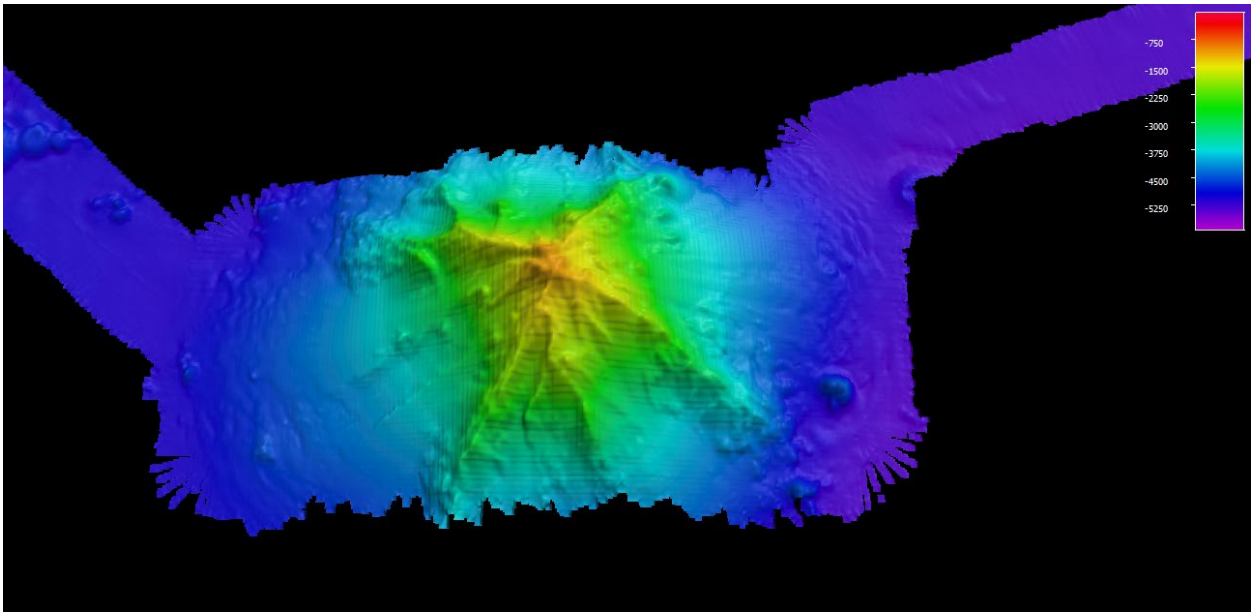

Figure 4. An unnamed seamount south of Jarvis Island within the Jarvis Island unit of PRIMNM. Satellite altimetry (Tozer et al, 2019) data predicted this ridge feature existed and it was selected it as a target for high-resolution bathymetric mapping. This mapping cruise confirmed the satellite altimetry prediction, however, the seamount turned out to be over 1.5 km higher than predicted. Vertical exaggeration 3x, 80m cell size, depths in meters.

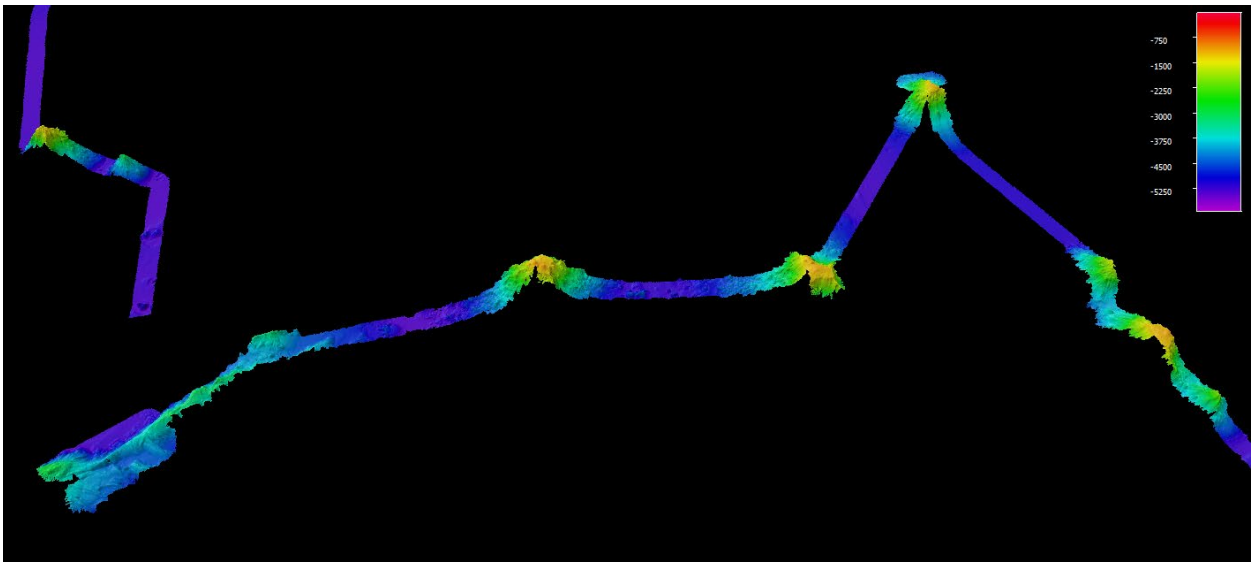

Figure 5. EM 302 data transit data collected over unnamed seamounts in and around the northern part of the Jarvis Island Unite of PRIMNM. Transit mapping lines are planned to target seafloor features of interest. Vertical exaggeration 3x, 80m cell size, depths in meters.

Throughout the cruise, multibeam data quality was monitored in real time by acquisition watch standers. 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 Sound Velocity Probe (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. Sound velocity profiles were also generated from the ROV CTD sensors at the end of each dive. Reson sound velocity values were constantly compared against secondarily derived sound speed values from the ship's onboard thermosalinograph flow-through system as a quality assurance measure.

Simrad EK60 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. Figure 6 shows the EK60 data collected during EX-17-05. The 38 kHz EK60 was only turned on during ROV dives.

Knudsen 3260 sub-bottom profiler data were also collected during the majority of the cruise. Figure 7 shows where sub-bottom data were collected during EX-17-05.

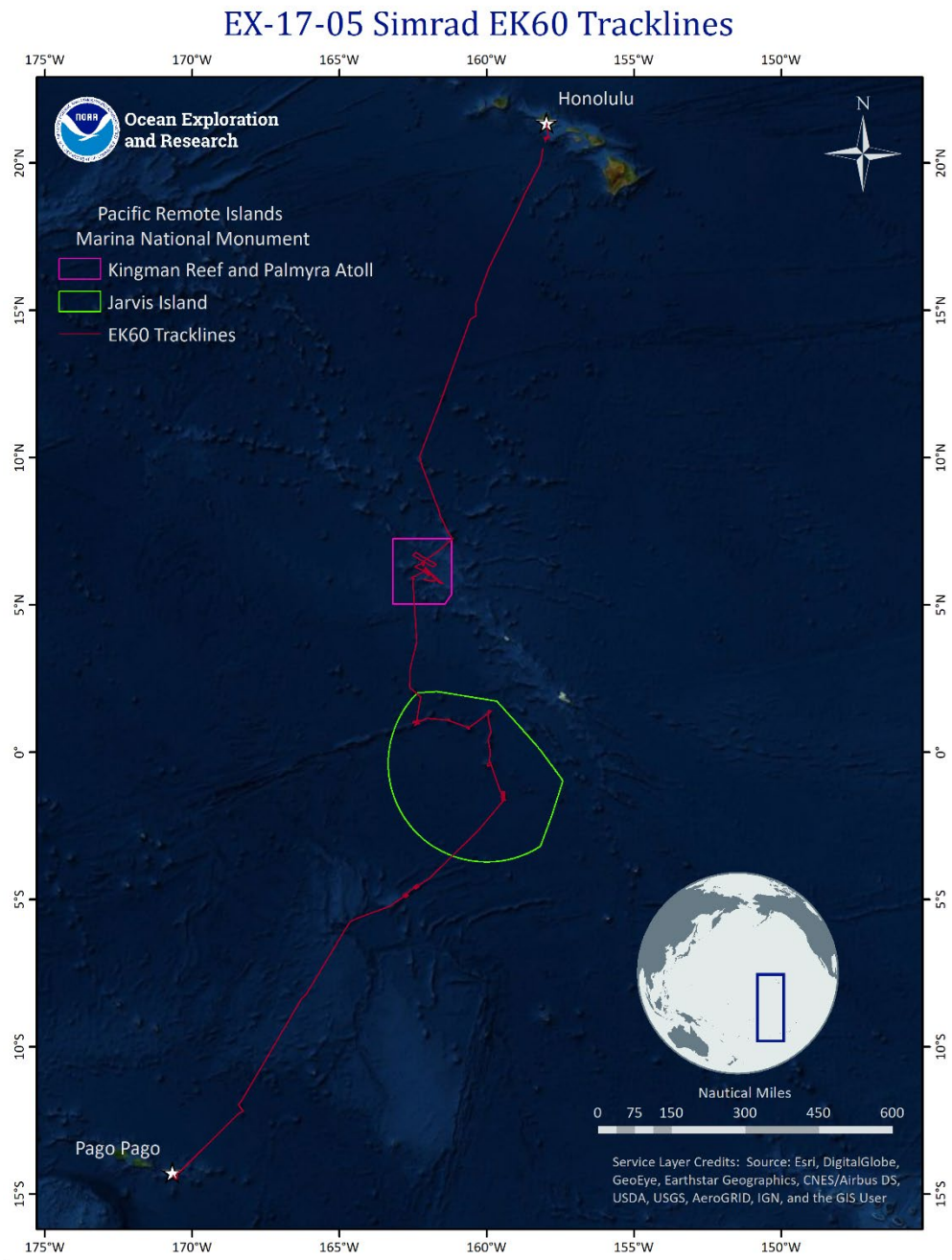

Figure 6. Simrad EK60 split-beam sonar data tracklines (in red) collected during EX-17-05.

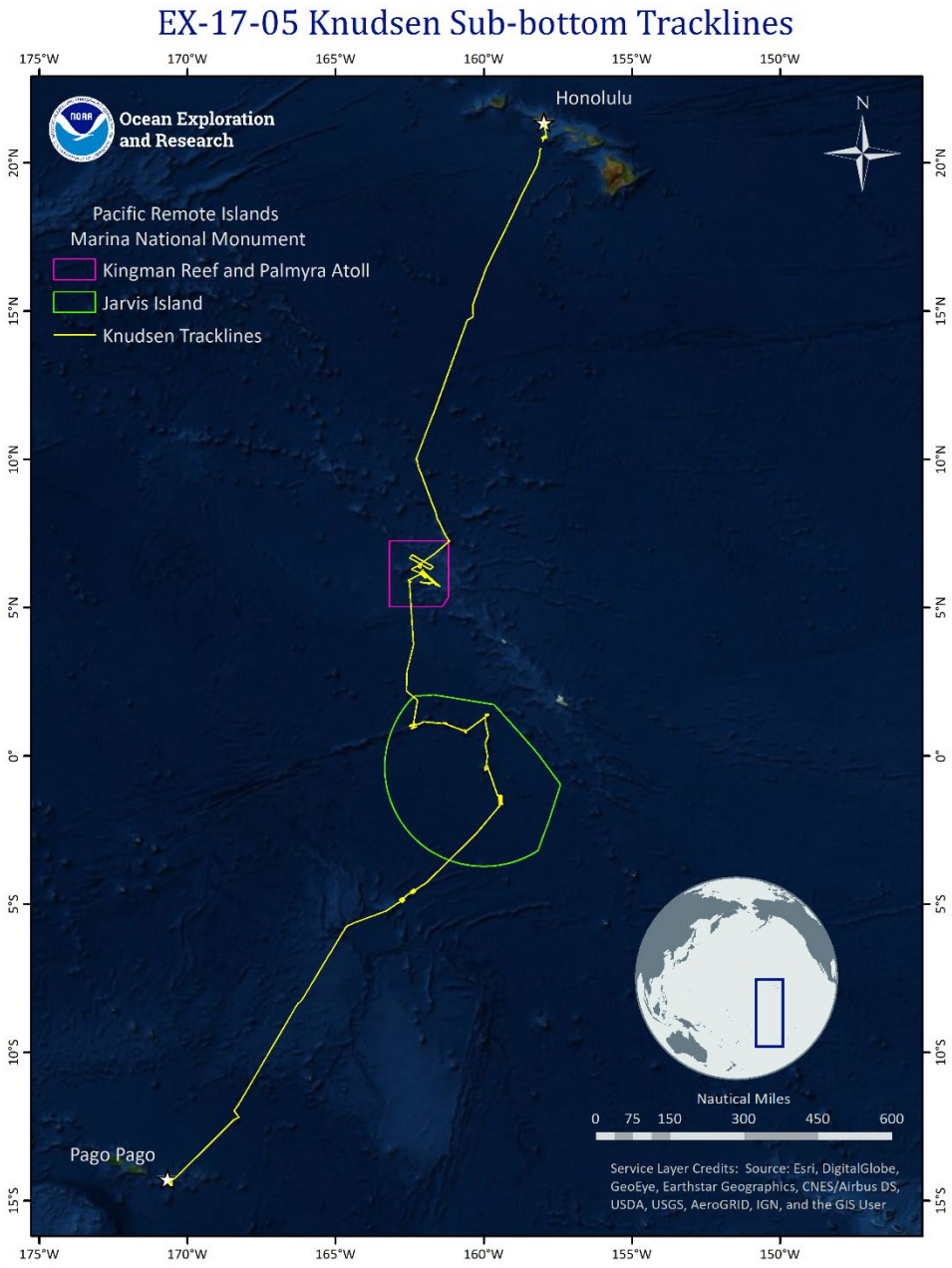

Figure 7. Sub-bottom profiler data tracklines (in yellow) collected during EX-17-05.

8. Multibeam Sonar Data Quality Assessment and Data Processing

Figure 8 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 2D and 3D 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).

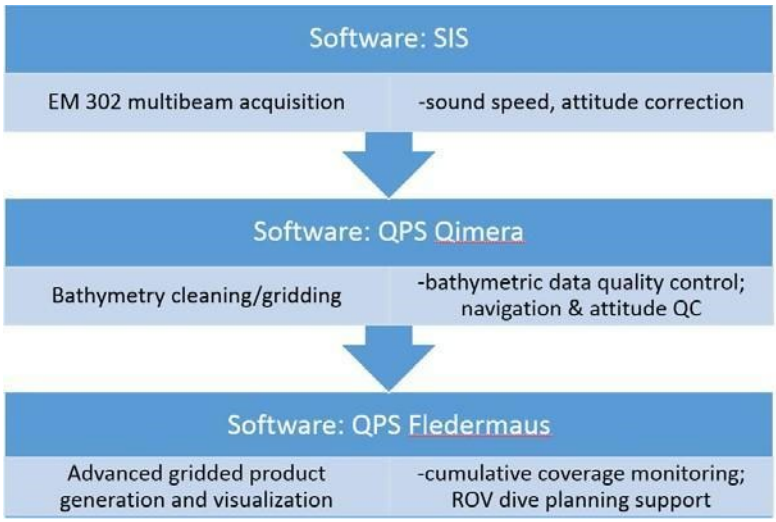

Figure 8. Shipboard multibeam data processing workflow.

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. A crossline was run on May 08, 2017 as shown in Figure 9. Crossline analysis was completed using the Crosscheck Tool in QPS Qimera software to evaluate if the survey meets the requirements for an International Hydrographic Order 1 survey. The results are shown below.

<u>Crossline file:</u>

0243_20170508_142711_EX1705_MB.all

Mainscheme line files:

0234_20170508_105811_EX1705_MB.all

0235_20170508_112502_EX1705_MB.all

Statistic	Value (in meters)
Number of points of comparison	77873
Grid Cell Size	80
Difference Mean	-1.165123
Difference Median	-0.845066
Difference Std. Dev	13.655760
Difference Range	[-99.82, 99.12]
Mean + 2*Stddev	28.476643
Median + 2*Stddev	28.156586
Data Mean	-4173.014787
Reference Mean	-4171.849665
Data Z-Range	[-5147.65, -3145.03]
Reference Z-Range	[-5139.04, -3145.07]
Order 1 Error Limit	54.236351
Order 1 # Rejected	197
Order 1 P-Statistic	0.002530
Order 1 Survey	**ACCEPTED**

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

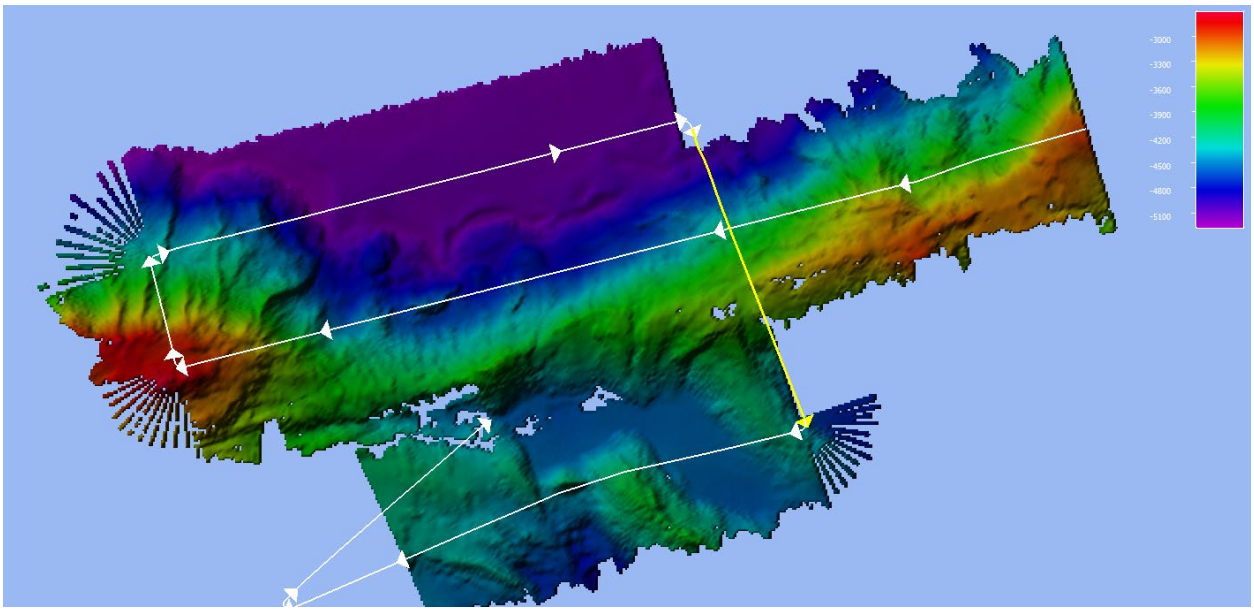

Figure 9. EX-17-05 crossline (shown in yellow) used for comparison against the bathymetric grid generated via orthogonal multibeam survey lines.

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-17-05 project instructions, available in the NOAA Central Library here: https://repository.library.noaa.gov/view/noaa/14965 (last accessed April 2020). 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 EK60 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 or QPS Qimera

All sonar data is permanently discoverable at https://www.ngdc.noaa.gov/ (last accessed April 2020).

At the time of writing this report, EM 302 and EK60 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 April 2020). The Digital Object Identifier (DOI) for EX-17-05 EM 302 water column data is: http://doi.org/10.7289/V5MS3R0V (last accessed April 2020) and the DOI for EK60 data is: http://doi.org/10.7289/V5RJ4GPQ (last accessed April 2020).

Sub-bottom data, supporting data, and informational logs are available in the NCEI Data Archives accessible at https://maps.ngdc.noaa.gov/viewers/geophysics/ (last accessed April 2020). For any challenges accessing SBP data, send an inquiry to ncei.info@noaa.gov requesting access to EX-17-05 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 April 2020)

10. Cruise Calendar

All times listed are local ship time, -11 hours from UTC

April – May 2017

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			26 Mobilization	27 Depart Pago Pago, American Samoa, Dive 01, overnight transit mapping	28 24 hour transit mapping	29 24 hour transit mapping
30 Dive 02, transit mapping	May 01 Dive cancelled, dynamic positioning testing, 24 hour transit, 3D scanning and focused mapping	02 Dive 03, transit mapping	03 24 hour transit and focused mapping	04 Dive 04, transit mapping	05 Dive 05, transit mapping	06 Dive 06, transit mapping
07 Dive 07, transit mapping	08 Dive 08, transit mapping	09 24 hour transit mapping	10 Dive 09, transit mapping	11 Dive 10, transit mapping	12 Dive 11, transit mapping	13 Dive 12, transit mapping
14 Dive cancelled (weather) 24 hour transit mapping	15 Dive cancelled (weather) 24 hour transit mapping	16 Dive cancelled (weather) 24 hour transit mapping	17 Dive cancelled (weather) 24 hour transit mapping	18 Dive cancelled (weather) 24 hour transit mapping	19 Arrival, Honolulu Hawaii, demobilization	

11. Daily Cruise Log Entries

Generated from the daily expedition situation reports. All times listed are in local ship time (-11 hours from UTC)

April 26
Mobilization, Pago Pago, American Samoa.

April 27
Dive 01. Watch schedules have been set-up. All systems are functioning properly and the multibeam passed all built-in self-tests (BISTs) on the first test. Daily products will be produced starting today, and will be placed in the File Transfer Protocol (FTP) folder for push to shore by 1800 local ship time, around 0200 Eastern. The "four hour" watch log is being used to monitor hardware/software status. Qimera 1.5 has been installed on MBPROC 1 & 2. The XBT autolauncher has been cleaned and secured. The next step in troubleshooting will be to repair the deck boxes and probably to upgrade the CTD computer to eliminate any communications issues. With one additional mapping watch stander than typical for ROV cruises, the mapping team plans to process and produce backscatter and sub-bottom products. It will also allow for additional products, such as maps and images to be used for interactions and/or engagement, to be produced on the ship.

April 28
Mapping operations continue smoothly as the ship transits from American Samoa to our first dive site in the Cook Islands vicinity. Data quality is good despite transit speed due to calm seas. Sub-bottom and backscatter products are being produced daily. Numerous pancake volcanoes have been mapped. All systems are functioning normally, with the exception of the EM302 which continues to experience POS MV dropout errors with no definite resolution of the cause.

April 29
Mapping data acquisition continues to go smoothly due to very calm seas and winds. All sub-bottom data and backscatter continues to be processed. As requested the EK60 are being run during the ROV dives to better understand the interaction between the ROVs and biology in the water column. Discussion has begun regarding additional summary products. The rest of the American Samoa mapping data collected by Okeanos this year as well as the Anu'u dive site will be added to the cumulative EX American Samoa data map and shared. Watch standers will begin training on the SeaScribe annotation software tomorrow to serve as a data logger during parts of the ROV dives. Senior Survey Technician (SST) is still following up on CTD status.

April 30

After the Dive the SIS and EM 302 took a little effort to get going. Mapping team re-seated the #0 Transmit (TX) board and did a soft restart on the SIS computer. Telnet was also restarted. The EK60 was on and logging during the entire dive today with some interesting results. Qimera is running slower than expected, i.e. there is not that much memory draw but it is having some difficulty. With the Dynamic Positioning tests tomorrow, we are planning on working with the Scanning Feature on the multibeam. Watch lead began training on the SeaScribe annotation software and will serve as a data logger during parts of the ROV dives

May 01

Mapping operations continue to go smoothly. With the DP tests today, team spent time practicing using the Scanning Feature in SIS. Cutting the beam swath angles and the forward/aft angles resulted in cleaner data with less yaw artifacts. Scanning was done for a considerable time on station and did create a good deal of noise in the data, but it unclear if this was simply due to the time spent on station or other factors. Overnight mapping went well, despite some building seas.

May 02

The overnight mapping team supplied bathy, slope and backscatter products for today's dive. The bathy data revealed a 1 kilometer difference between the satellite and multibeam data, forcing a selection of a shallower dive site. EK60s were running during the dive today and screenshot's were recorded. The EK60 data potentially revealed some avoidance behavior in a lower biomass layer, but the layer reformed after the ROVs passed through. Tonight mapping team will be completing a long transit line edge-matching existing data up to the southern Jarvis area.

May 03

Mapping proceeding smoothly. Mapping team will map the rest of the South Jarvis Seamount tonight and some of the flanks of Jarvis Island in the early morning. The next four dive sites already have data, collected on EX-17-01. Scene files are being created. The onboard team is observing POS MV dropouts.

May 04

No updates, mapping operations continue to proceed without issues.

May 05

Mapping continues to go well. Overnight the team mapped 3 previously unmapped seamounts between Jarvis Island and the eastern Jarvis seamount. Team also mapped over some holes in the EX-17-01 data (due to bad weather) on our way to the dive site.

May 06

The multibeam passed all BISTs post dive but had trouble establishing a ping and finding bottom. SIS was restarted and power to the Transmit Receive Unit (TRU) was cycled. Board 0

was reseated. Telnet was restarted and multibeam came back with no further issues. The ADCPs are intermittently displaying high temperatures. Based on directions from UHDAS onboard team are monitoring the temperatures. If they are sustained at a high temp, then team will test. It is unclear whether the temperature is coming from the deck box or the transducer. The mapping team is learning to use the "Check Out" system in Qimera 1.5 - analogous to something like GitHub, it allows users to "check out" areas of projects, edit and then update the main project.

May 07
During the transit from Jarvis to Palmyra the mapping team took steps to update logs and work on additional projects. Separate files were recorded during the Man over Board drills. During the transit team collected data over two previously unmapped seamounts.

May 08
Transit mapping, no updates.

May 09
Transit mapping, no updates.

May 10
With the dive called early, mapping team adjusted with new survey lines to fill in gaps between Extended Continental Shelf (ECS) data. While heading northwest our data was affected by conditions, however this was mitigated when the ship turned on to a southeast course. Overnight mapping data was good and covered more ground than originally calculated. The first BIST run post-dive passed. Onboard team are trying out a Qimera project locally to see if it runs any faster compared to editing over the network. Updated versions of the project are being stored on the drive as backups.

May 11
Mapping continued overnight to fill in data gaps between ECS surveys. Data looks fine, considering sea state. Mapping team are attempting a Qimera project locally, with a backup copy on the ":J" drive - so far it is much faster, but will see what happens as the project grows.

May 12
All systems are functioning properly. With the dive called early we will get a jump on filling in gaps in ECS data. Dry dock preparations are being made.

May 13
Transit mapping, no updates.

May 14

With the cancelled dive the mapping team has been transit mapping throughout the night and day. Lines have been planned to edge match as much as possible data from EX-17-01. The weather is affecting the data, but overall looks good for the conditions. All systems are working fine.

May 15
With the cancelled dive transit mapping will continue. Current sea states are affecting the data. Otherwise systems are fine.

May 16
Elevated sea states are resulting in poorer quality data. Lines have been planned to edge match as much as possible data from EX-17-01. An EK80 Acquisition Software Standard Operation Procedure (SOP) is being worked on.

May 17
Transit mapping, no updates.

May 18
Transit mapping, no updates.

May 19
Arrive Honolulu, Hawaii, systems secured, demobilization

12. References

NOAA Office of Ocean Exploration and Research, 2017. The 2017 NOAA Ship *Okeanos Explorer* Survey Readiness Report NOAA is available at the NOAA Central Library.

NOAA Office of Ocean Exploration and Research, 2017. EX-17-05 Project Instructions: https://repository.library.noaa.gov/view/noaa/14965 (last accessed April 2020). The EX-17-05 Data Management Plan is an appendix of the project instructions.

NOAA Office of Ocean Exploration and Research, 2016. The 2016 EK60 Calibration Report can be obtained by contacting oar.oer.exmappingteam@noaa.gov or at the NOAA Central Library.

NOAA Nautical Charts, 2020: https://www.charts.noaa.gov/InteractiveCatalog/nrnc.shtml, (last accessed April 2020)

NOAA Autogrid, 2020: https://www.ngdc.noaa.gov/maps/autogrid/, last accessed April 2020

Tozer, B. , D. T. Sandwell, W. H. F. Smith, C. Olson, J. R. Beale, and P. Wessel, 2019. Global bathymetry and topography at 15 arc seconds: SRTM15+, Accepted Earth and Space Science, August 3. https://doi.org/10.1029/2019EA000658 (last accessed April 2020)