
Ocean Exploration and Research

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# MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT

## CRUISE EX-17-02: 2017 American Samoa Expedition: Suesuega o le Moana o Amerika Samoa (ROV and Mapping)

**Authors:** Elizabeth 'Meme' Lobecker[1]
**Other Contributors:** Amanda Bittinger[2], Charlie Wilkins[3], Sam Candio[1]

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[1]Cherokee Nation Strategic Programs, at NOAA Ocean Exploration and Research
[2]Sunset Hydrographic LLC, University Corporation for Atmospheric Research
[3]NOAA Ship *Okeanos Explorer*

## 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 the remotely operated vehicle (ROV) and mapping expedition EX-17-02, and to present a summary of the overall mapping results and mapping related cruise activities. A complementary ROV cruise report entitled Cruise EX-17-02 - 2017 American Samoa Expedition: Suesuega o le Moana o Amerika Samoa (ROV/Mapping) is available in the NOAA central library. Additionally, a detailed description of the *Okeanos Explorer's* mapping capabilities is available in the 2017 NOAA Ship *Okeanos Explorer* Survey Readiness Report, available in the NOAA Central Library.

## 3. Cruise Objectives

EX-17-02 was conducted in support of the **C**ampaign to **A**ddress **P**acific Monument **S**cience, **T**echnology, and **O**cean **NE**eds (CAPSTONE), a multi-year effort focused on the systematic collection of baseline information in support of scientific and management needs within and in the vicinity of monuments and marine protected areas in the central and western Pacific. Exploration operations conducted during EX-17-02 were focused on deep-water areas in American Samoan waters, including operations within the National Marine Sanctuary of American Samoa. This expedition helped establish a baseline of information in the region to catalyze further exploration, research, and management activities.

This cruise consisted of a combination of ROV and mapping operations. The expedition commenced in Pago Pago, American Samoa, on February 16, 2017 and ended in Apia, Samoa on March 1, 2017. Mapping operations utilized the ship's deep water mapping systems (Kongsberg EM302 multibeam sonar, EK60 split-beam fisheries sonars, and Knudsen 3260 chirp sub-bottom profiler), as well as the ship's high-bandwidth satellite connection for daily transfer of incoming data to awaiting shoreside scientists.

The detailed objectives including mapping areas, ROV dive targets, and rationale for exploration for this cruise are provided in the EX-17-02 Project Instructions, available in the NOAA Central Library.

## 4. Summary of Mapping Results

EX-17-02 mapped 12,309 square kilometers of seafloor in the vicinity of American Samoa during the 14 days-at-sea (Figure 1 and Table 1).

**Cruise Overview Map**

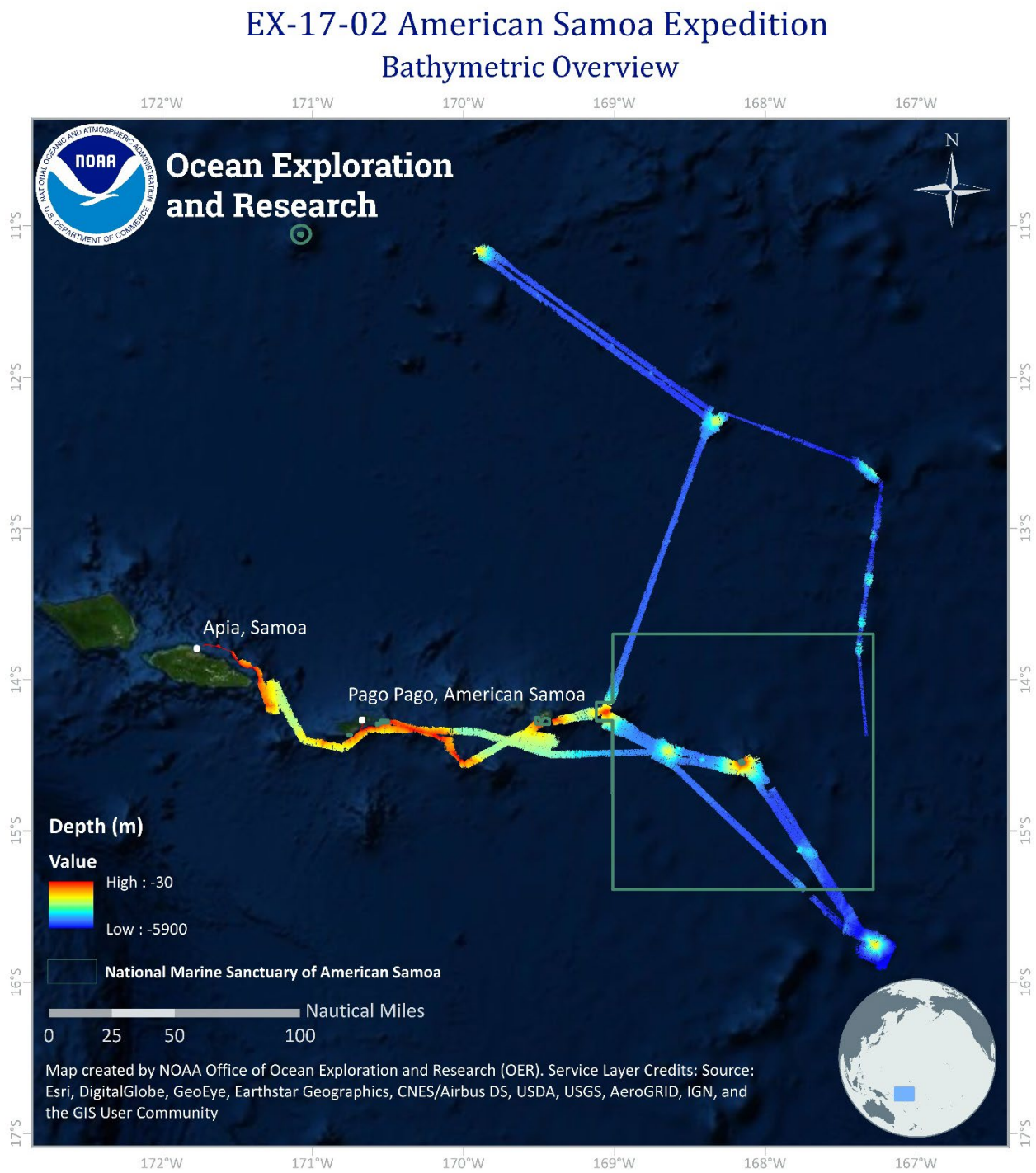


**Figure 1.** Overview of bathymetric mapping coverage completed during the American Samoa Expedition (EX-17-02). Map generated in ArcMap.

## 5. Mapping Statistics

**Table 1. Summary statistics of ocean mapping work completed during EX-17-02.**

| | |
|---|---|
| **Dates of cruise** | **February 16 – March 1, 2017** |
| **Ship's draft:**<br>**Start of cruise (02/16/2017)**<br>**End of cruise (03/1/2017)** | <br>**Fore: 14' 10'', Aft STBD: 14'3-1/4"**<br>**Fore: 13' 9"; Aft STBD: 14' 3-1/4"** |
| **Linear kilometers of survey with EM 302** | **2,622** |
| **Square kilometers mapped with EM 302** | **12,309** |
| **Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files (.all)** | **295 files/ 12.1 GB** |
| **Number / Data Volume of EM 302 water column multibeam files** | **295 files / 42.7 GB** |
| **Number / Data Volume of EK 60 water column split beam files (.raw)** | **74 / 5.23 GB** |
| **Number / Data Volume of sub-bottom sonar files (.segy, .kea, .keb)** | **367 / 2.13 GB** |
| **Number of XBT casts** | **25** |
| **Number of CTD casts (including test casts)** | **0** |

## 6. Mapping Sonar Setup

*Kongsberg EM 302 Multibeam Sonar*

The 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.

*Simrad EK 60 Split-beam Sonars*

The ship is equipped with four Kongsberg EK split-beam fisheries sonars, 18, 70, 120, and 200 kHz. These sonars are quantitative scientific echosounders calibrated to identify the target strength of water column acoustic reflectors - typically biological scattering layers, fish, or gas bubbles – providing additional information about water column characteristics and anomalies.

*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 are fundamental to helping geologists interpret the shallow geology of the seafloor.

*Teledyne ADCPs*

The ship utilizes a 38 kHz Teledyne RDI Ocean Surveyor Acoustic Doppler Current Profiler (ADCP), with a ~1000 meter range; and a 300 kHz Teledyne RDI Workhorse Mariner ADCP, with a ~70 meter range. The ADCPs gather data prior to ROV deployments in order to assess currents at the dive site in support of safe operations. They are kept running throughout the ROV dives. The ADCPs are typically not run concurrently with the other sonars while transiting due to interference issues.

## 7. Data Acquisition Summary

Mapping operations included data collection via the EM 302 multibeam sonar, EK 60 split-beam (18, 70, 120, and 200 kHz) sonars, and Knudsen 3260 sub-bottom profiler. Data were collected by each sonar concurrently, with mapping operations occurring 12-13 hours per day following the conclusion of daily ROV operations, as well as during all transits. Additionally, ADCP data were collected during ROV dives while the ship remained stationary to provide situational awareness of local currents to the ROV operators. ADCP data were not collected during mapping operations due to observed interference with the other sonars.

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

Throughout the cruise multibeam data quality was monitored in real time by acquisition watchstanders. Ship speed was adjusted to maintain data quality as necessary, and line spacing was planned to ensure at least ¼ swath width overlap between lines. Cutoff angles in the multibeam acquisition software Seafloor 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.

Multibeam data received real time surface sound velocity corrections at the sonar head via the thermosalinograph, as well as through profiles generated from Expendable Bathythermographs (XBTs) conducted at intervals no greater than 6 hours, as dictated by local oceanographic conditions.

EX-17-02 bathymetric data collected over the Vailulu'u Seamount were analyzed by personnel at NOAA's Pacific Marine Environmental Laboratory (PMEL) and compared to prior data collected in the region in 2006 and 2012. It was determined that the central cone, Nafauna, has grown noticeably in height and width due to ongoing volcanic activity. The preliminary results can be found in Figure 2 below, provided by Susan Merle, a senior research assistant at PMEL.

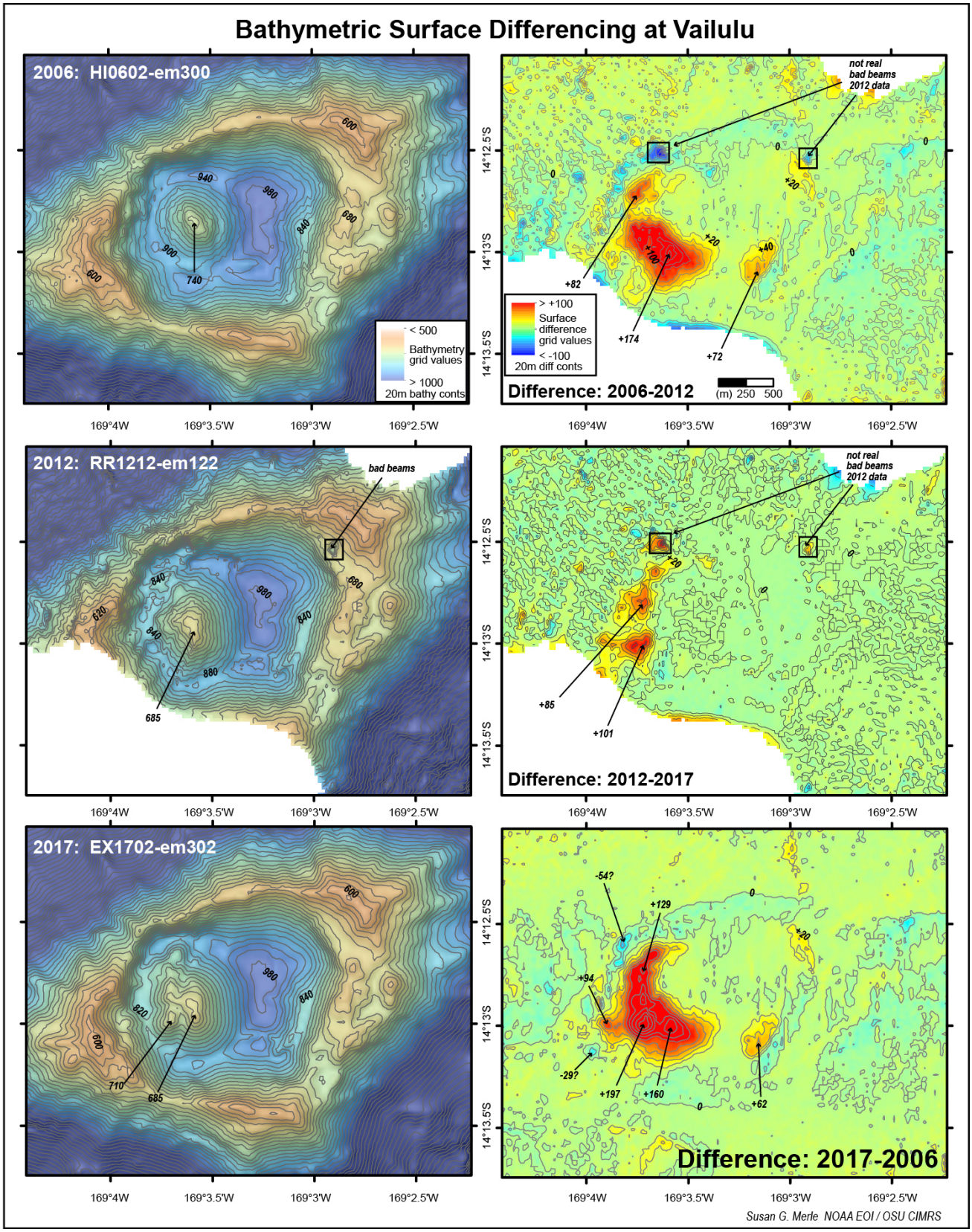


**Figure 2.** Maps comparing three bathymetric surveys collected at Vailulu'u in 2006, 2012, and 2017 (left) and depth comparisons between them (right). Red areas show positive depth changes due to eruptions at Nafanua cone between the surveys. Image credit: Susan Merle, Oregon State University / NOAA EOI/CIMRS.

Water column data were reviewed daily throughout the cruise to determine the presence of anomalies. One strong anomaly was detected in numerous survey lines at the Vailulu'u Seamount (Figure 3). The 3D Scanning function in SIS was used while holding station over the suspected volcanic gaseous plume. The single plume was detected in several passes of the multibeam, as listed in Table 2. The ROV was unable to confirm the precise location and content of the source of the plume due to low visibility and the effect of high acoustic noise in the ROV's forward scanning sonar data in the steep, tight terrain in the vicinity of the seep.

**Table 2. Coordinates and depths of water column anomaly detections on distinct multibeam passes.**

| Longitude (decimal degrees) | Latitude (decimal degrees) | Depth (meters) |
|---|---|---|
| -169.0597667 | -14.20949444 | -890.86 |
| -169.059925 | -14.21003056 | -919.39 |
| -169.0599583 | -14.21011667 | -917.83 |
| -169.0598694 | -14.209925 | -908.39 |
| -169.0595583 | -14.20995278 | -922.08 |
| -169.059975 | -14.20975556 | -908.71 |
| -169.0597389 | -14.21026667 | -913.01 |

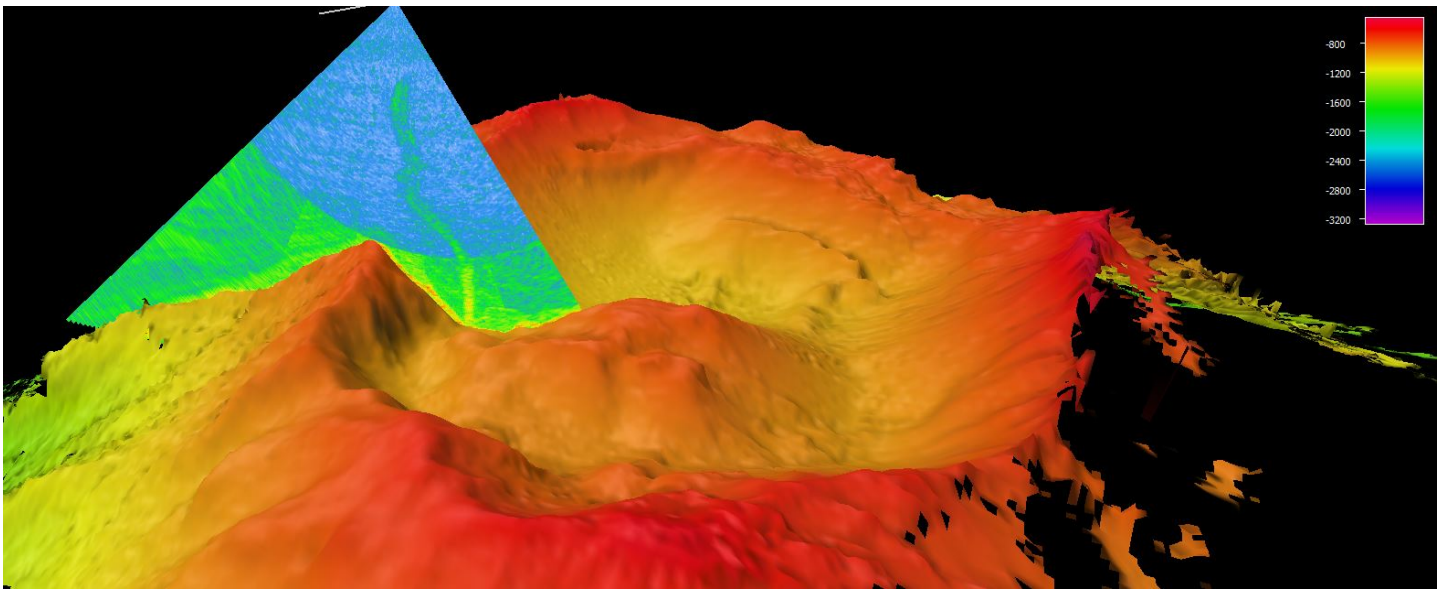


**Figure 3.** Water column imagery draped on the bathymetric surface generated from data collected on Vailulu'u Seamount, depicting the water column anomaly. Image created by NOAA Office of Ocean Exploration and Research (NOAA-OER), generated in QPS Fledermaus, vertical exaggeration 3x, color bar indicating depths in meters.

## 8. Multibeam Sonar Data Quality Assessment and Data Processing

Figure 4 shows the multibeam data processing workflow for this cruise. EM 302 Built-in Self Tests (BISTs) were run throughout the cruise to monitor multibeam sonar system status and are available as ancillary files in the sonar data archives. Raw multibeam bathymetry data files were acquired in SIS, then imported into QPS Qimera for processing. In Qimera, the attitude and navigation data stored in each file were checked, and erroneous soundings were removed using 2-D and 3-D editors. Gridded digital terrain models were 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.

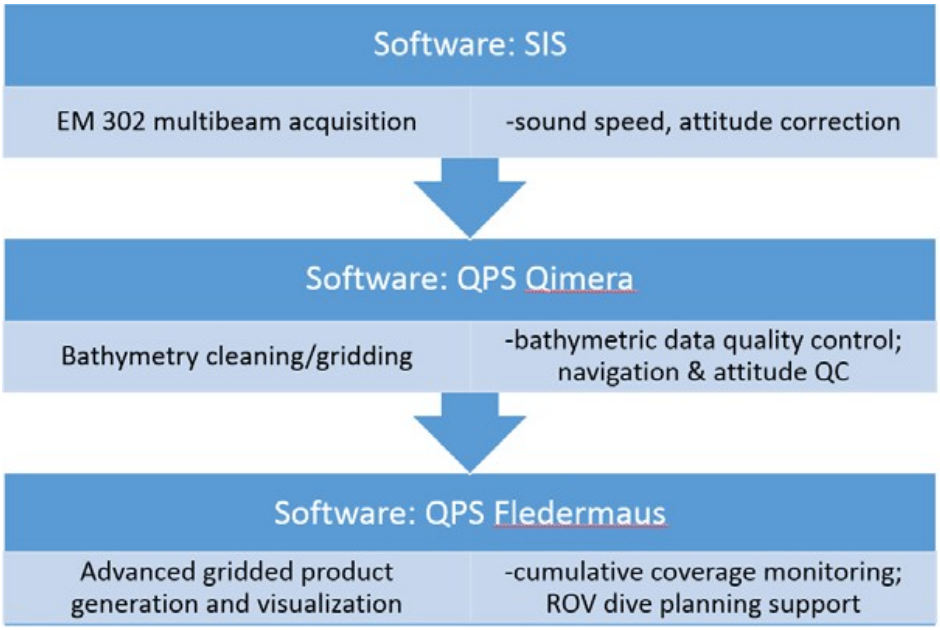


**Figure 4.** Shipboard multibeam processing workflow.

*Crosslines*

To evaluate the internal consistency of surveyed soundings, a crossline analysis was conducted on data collected from orthogonal survey lines run opportunistically during EX-17-02 via the Cross Check Tool in QPS Qimera software (Figure 5). The results from the crossline comparison are displayed in the table below. These results confirm that the data collected meet International Hydrographic Organization (IHO) Order 2 specifications for data quality.

The mainscheme line files were:

0010_20170217_055447_EX1702_MB

0021_20170217_114206_EX1702_MB

0162_20170223_130826_EX1702_MB

0117_20170221_081943_EX1702_MB

0169_20170224_042147_EX1702_MB

0228_20170226_133314_EX1702_MB

The crossline files were:

0027_20170217_145033_EX1702_MB

0095_20170219_170113_EX1702_MB

0129_20170221_154202_EX1702_MB

0215_20170225_160814_EX1702_MB

0256_20170227_155135_EX1702_MB

0266_20170228_114302_EX1702_MB

0271_20170228_154441_EX1702_MB

| Statistic | Value |
|---|---|
| Number of points of comparison | 1,040,539 |
| Grid Cell Size | 100 |
| Difference Mean | 0.18 |
| Difference Median | -0.42 |
| Difference Std. Dev | 12.89 |
| Difference Range | [-403.32, 119.30] |
| Mean + 2*Stddev | 25.97 |
| Median + 2*Stddev | 26.21 |
| Data Mean | -2,241.73 |
| Reference Mean | -2,241.92 |
| Data Z-Range | [-5,649.48, -238.64] |
| Reference Z-Range | [-5,667.11, -329.70] |
| Order 2 Error Limit | 51.57 |
| Order 2 # Rejected | 25169 |
| Order 2 P-Statistic | 0.02 |
| **Order 2 Survey** | **ACCEPTED** |

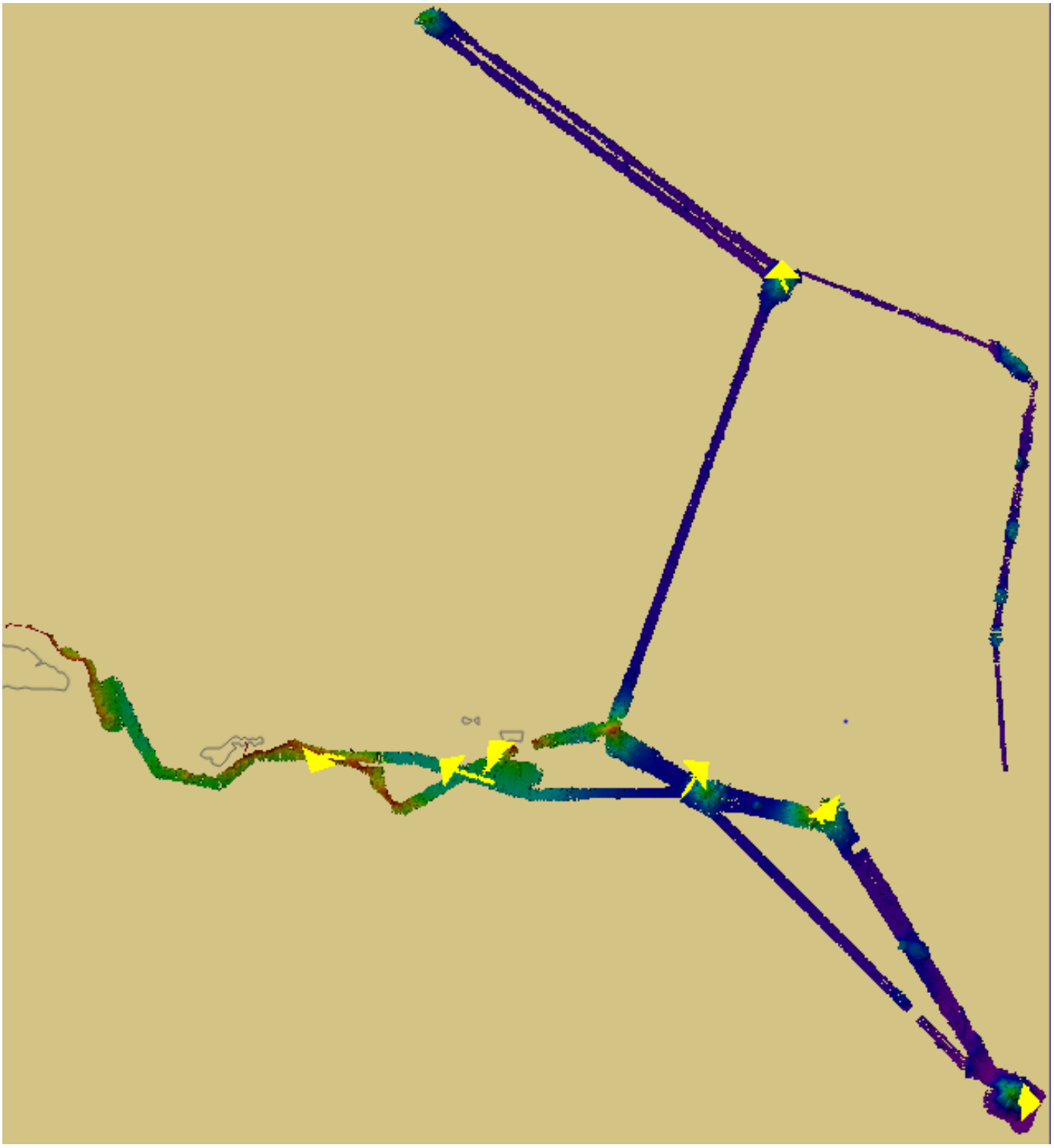

**Figure 5.** Overview of the spatial distribution of crosslines (in yellow) selected for analysis. All crosslines were compared to a 100m dynamic surface generated from strictly mainscheme lines. Screengrab taken in Qimera.

*EM 302 Patch Test*

A multibeam patch test was conducted near Oahu, Hawaii on December 2, 2016 (during EX-16-08). 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 2017 NOAA Ship *Okeanos Explorer* Survey Readiness Report.

*EK 60 Calibration*

EK 60 calibrations were conducted during EX-16-09 south of Molokai and west of Lanai in Hawaii on December 13, 2016. The 18 kHz, 70 kHz, 120 kHz, and 200 kHz sonars were successfully calibrated in continuous wave mode (CW). Complete details about the EK 60 calibrations are described in the EX-16-09 NOAA Ship *Okeanos Explorer* EK60 Calibration Report archived at the NOAA Central Library.

## 9. Data Archival Procedures

All mapping data collected by the NOAA Ship *Okeanos Explorer* are archived and publicly available within 90 days of the end of each cruise via the National Centers for Environmental Information (NCEI) online archives. The complete data management plan (which describes the raw and processed data formats produced for this cruise) is available as an appendix in the EX-17-02 project instructions, available in the NOAA Central Library.

Ancillary and supporting files are archived with the sonar datasets. These include:

*EM 302 Multibeam bathymetry and bottom backscatter dataset:*

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

*Simrad EK split-beam water column dataset:*

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

*Knudsen 3260 Sub-bottom Profiler dataset:*

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

*EM 302 Multibeam water column dataset:*

- Mapping watch stander log
- Weather log

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

EM 302 and EK 60 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 01/08/2020).

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 01/08/2020).

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 01/08/2020).

## 10. Cruise Calendar

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

**February / March 2017**

| Sun | Mon | Tues | Wed | Thur | Fri | Sat |
|---|---|---|---|---|---|---|
| | | | 15<br>Ship tours. | 16<br>Depart Pago Pago, American Samoa. Nearshore mapping. | 17<br>Morning/evening transit mapping, focused mapping south of Tau Island. | 18<br>Morning/evening transit mapping. Focused mapping at Vailulu'u Seamount and Rose Atoll. |
| 19<br>Morning/evening transit mapping. Focused mapping at Seamount 'D'. | 20<br>Sonars secured for weather. Transit mapping northward in heavy seas. | 21<br>Transit mapping in morning /evening. Focused mapping at unplanned ROV dive site #1. | 22<br>Transit mapping in morning/evening. Focused mapping at unplanned ROV dive site #2. | 23<br>Transit mapping in morning/evening. | 24<br>Transit mapping in morning/evening. Focused mapping at Vailulu'u Seamount including 3D Scanning. | 25<br>Transit mapping in morning/evening. Focused mapping at Seamount 'D'. |
| 26<br>Transit mapping in morning/evening. Focused mapping at Malulu Seamount. | 27<br>Transit mapping in morning/evening. | 28<br>Transit mapping in morning/evening . Test CTD cast to 10m. Data collection in Samoan waters. | 1<br>Arrive Apia, Samoa (day shifts forward 25 hrs upon reaching port). | 2<br><repeat March 1> due to time crossing International Date Line. | 3<br>Ship tours. | 4<br>Visiting mapping team departs ship. |

## 11. Daily Cruise Log Entries

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

*February 13*
Mission personnel arrive to the ship in Pago Pago, American Samoa.

*February 14*
Prepare for departure.

*February 15*
Ship tours conducted, with over 200 local students touring in heavy rain.

*February 16*
The ship got underway in the morning from Pago Pago, American Samoa. An XBT was conducted immediately and multibeam data were collected to map the under keel clearance at the dock in the harbor. The data were brought to the attention of the NOAA hydrographic branches for possible incorporation into the chart, which currently has out of date soundings. Mapping was conducted as the ship transited to the site of ROV Dive 01, just outside Pago Pago harbor. The dive was cancelled and did not reach bottom. Mapping data were collected during the transit to Tau the next morning, with additional focused mapping conducted south of Tau.

*February 17*
Mapping operations consisted of focused mapping south of Tau in the morning, and immediate analysis for planning that day's ROV dive track. In the evening, transit mapping was conducted to Rose Atoll after the ROV was secured on deck. Focused mapping at Vailulu'u Seamount along the way revealed at least one major active gaseous plume, potentially a few minor plumes, and an increase in the height and girth of Nafanua, the recently discovered volcanic cone in the crater.

*February 18*
Rose Atoll's eastern flank was mapped and data analyzed just prior to ROV launch in the morning. Transit mapping to Seamount 'D' (unofficial name) overnight.

*February 19*
Partial mapping of Seamount "D" in the morning with immediate data analysis just prior to ROV launch to pick dive track. Dive aborted immediately due to rapid degradation of weather, ship steamed north to get above the tropical storm track. Sonars secured for part of the day in heavy seas, data collection resumed in heavy seas later in the day, with poor data quality.

*February 20*
Partial mapping of U.S. portion of 'Leoso' Seamount (unofficial name) with immediate morning dive planning. Transit mapping in evening northward to continue to avoid tropical storms blasting American Samoa to our south.

*February 21*
Partial mapping of 'Utu' Seamount (unofficial name) with immediate morning dive planning. Evening transit mapping to 'Moki' Seamount (unofficial name), ship continues to move north to avoid storm and dive on seamounts.

*February 22*
Partial mapping of U.S. portion of 'Moki' Seamount (unofficial name) with immediate morning dive planning. Evening transit southward back towards 'Utu' Seamount for a second, deeper dive.

*February 23*
Additional morning mapping / rapid data turn over for second 'Utu' Seamount dive. Evening transit southward towards Vailulu'u, storms have passed through.

*February 24*
Morning mapping at Vailulu'u including 3 passes at 8 knots to image the plume. Evening additional water column mapping of plume including several 2-3 knots passes, and use of the multibeam sonar acquisition software's 3D Scanning functionality to collect dense EM302 data at the plume site while holding station. Evening transit to Rose Atoll eastern flank.

*February 25*
Morning mapping of Rose Atoll eastern flank shallow site. Evening transit mapping southward to Seamount 'D' (unofficial title).

*February 26*
Morning mapping completing Seamount 'D' coverage, early turnover of data to plan the day's ROV dive. Evening transit northward towards Malulu Seamount.

*February 27*
Morning survey added coverage over Malulu Seamount. Evening mapping en route to dive site south of Tutuila.

*February 28*
Morning transit mapping to dive site, evening mapping into Samoan waters to reach the sea buoy.

*March 1*
Morning mapping including small focused survey in Samoan waters until reaching sea buoy at 0800. Day will skip ahead 25 hours upon ship reaching port.

*March 2*
See March 1. Ship arrived in Apia, Samoa at 0930.

*March 3*
Ship tours. Survey team finalized reporting and cruise maps.

*March 4*
Visiting mapping team personnel depart the ship.

## 12. Acknowledgements

The crew of the NOAA Ship *Okeanos Explorer* provided excellent support for executing the offshore mission. Susan Merle provided bathymetry data processing support and comparison to previous datasets at Vailulu'u Seamount. Jules Hummon and Toby Martin of University of Hawaii Data Acquisition System (UHDAS) provided at sea support for the ADCP sonars.

## 13. References

The 2017 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-17-02 Project Instructions can be obtained from the NOAA Central Library. The EX-17-02 Data Management Plan is an appendix of the project instructions.

EX-17-02 EK 60 Calibration Report can be obtained in the NOAA Central Library or by contacting the NOAA OER mapping team at oar.oer.exmappingteam@noaa.gov

The following were used for reference throughout the cruise:

Sandwell, D. T., and W. H. F. Smith, Global marine gravity from retracked Geosat and ERS-1 altimetry: Ridge Segmentation versus spreading rate, J. Geophys. Res., 114, B01411, doi:10.1029/2008JB006008, 2009.

NOAA Nautical Charts

NCEI Bathymetric Data Archives