DSSV Pressure Drop: Descriptive Report

Puerto Rico Trench: Science Mission
July 2019

Report developed for Five Deeps Expedition by Cassie Bongiovanni

Internal Use Only

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0.0 Survey Information

0.1 Survey Limits

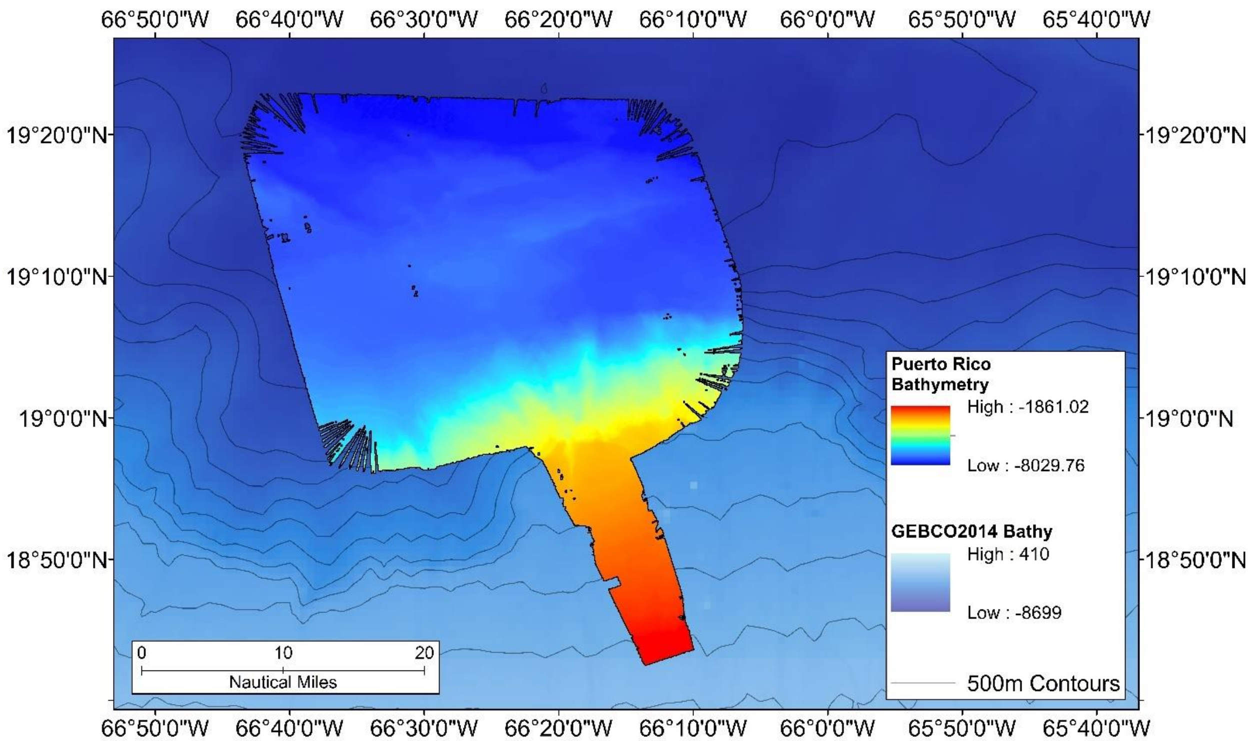

Figure 1: Puerto Rico Trench bathymetry collected with the Kongsberg EM 124 over GEBCO 2014 estimated bathymetry.

The Puerto Rico Trench (Figure 1) was surveyed for the second time with a Kongsberg EM 124 gondola-mounted to the hull of the 225-foot DSSV Pressure Drop. The survey was conducted over the course of four days –July 15-18, 2019. The data meet the requirements for IHO Special Order standards.

The Puerto Rico Trench data is within the following limits:

Northwest Limit	Southeast Limit
19°23'05.412"N	18°42'19.888"N
66°43'38.729"W	66°06'33.911"W

Table 1: Survey Limits

0.2 Survey Purpose

Multibeam data were acquired by the DSSV Pressure Drop as part of the 5 Deeps Expedition. These data were collected to meet scientific objectives relating to marine biology. Several dives were performed at sites of scientific importance. Bathymetry were collected as supplementary information and throughout the night. While little new bathymetric information was collected, it is anticipated that these data will help the greater scientific understanding of the area and contribute to the international effort to create a complete high-resolution map of the oceans (i.e. Seabed 2030).

0.3 Survey Plans

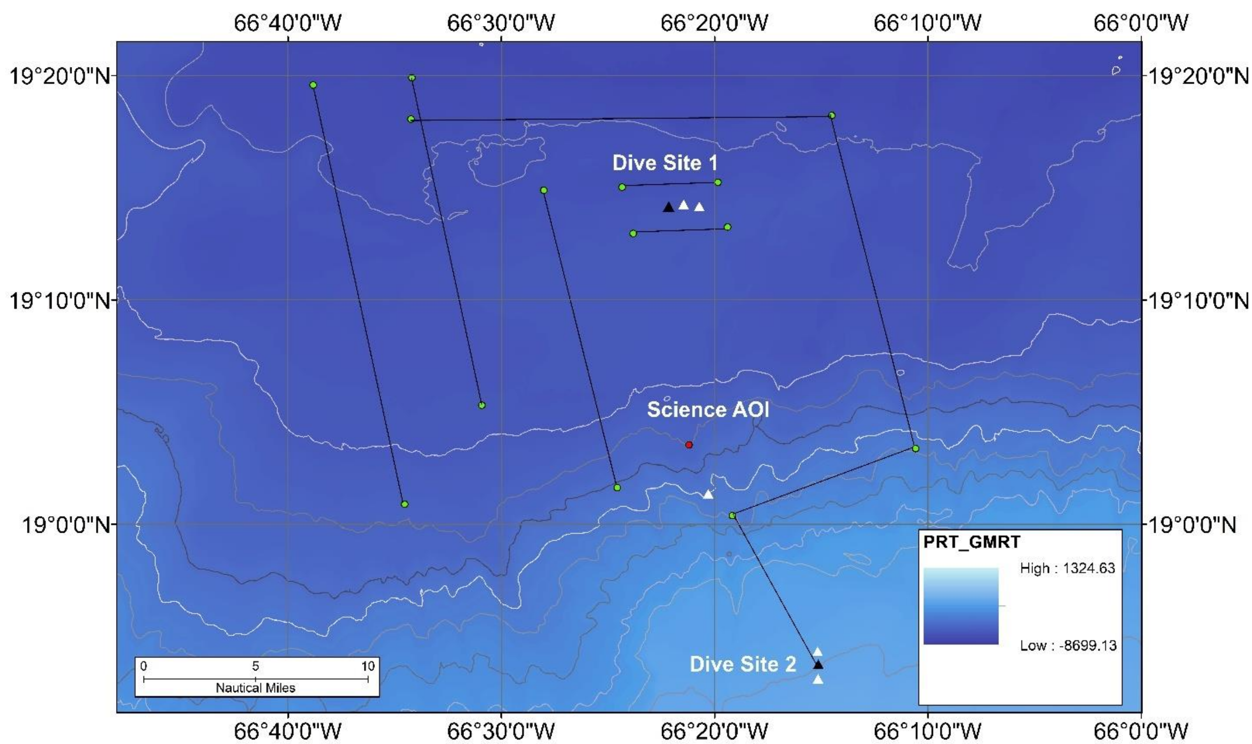

Figure 2: Puerto Rico Trench area with GEBCO 2014 bathymetry and with possible deep location delineated by red dot. PRT line plan with green waypoints. Black triangle is location of sub dives and white triangles are lander drop spots for science.

The return to the Puerto Rico Trench was entirely fueled for scientific objectives – in particular, searching for a specific species of deep-sea fish that were claimed to have been seen at the red dot in Figure 2. As such, mapping data were collected opportunistically between lander and sub ops. Lines were run at 10 kts to maximize coverage in limited time windows. The final line plan is shown in Figure 2.

0.4 Survey Quality

These data meet IHO Special Order specifications and should supersede any prior data for all intents and purposes.

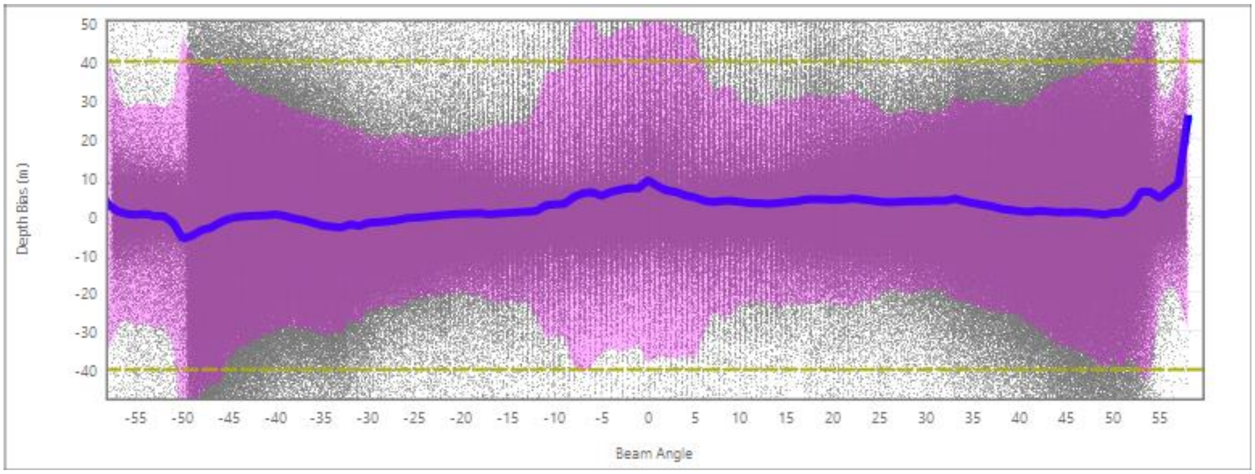

Figure 3:Uncertainty of the Puerto Rico Data (purple) in comparison to the IHO Special Order requirements (the yellow dotted lines). 98% of the PRT data collected meet or exceed Special Order requirements.

0.5 Survey Coverage

No notable holidays (or gaps in coverage) were created during this survey. Few times a sudden change in heading resulted in slight fanning, but nothing substantial.

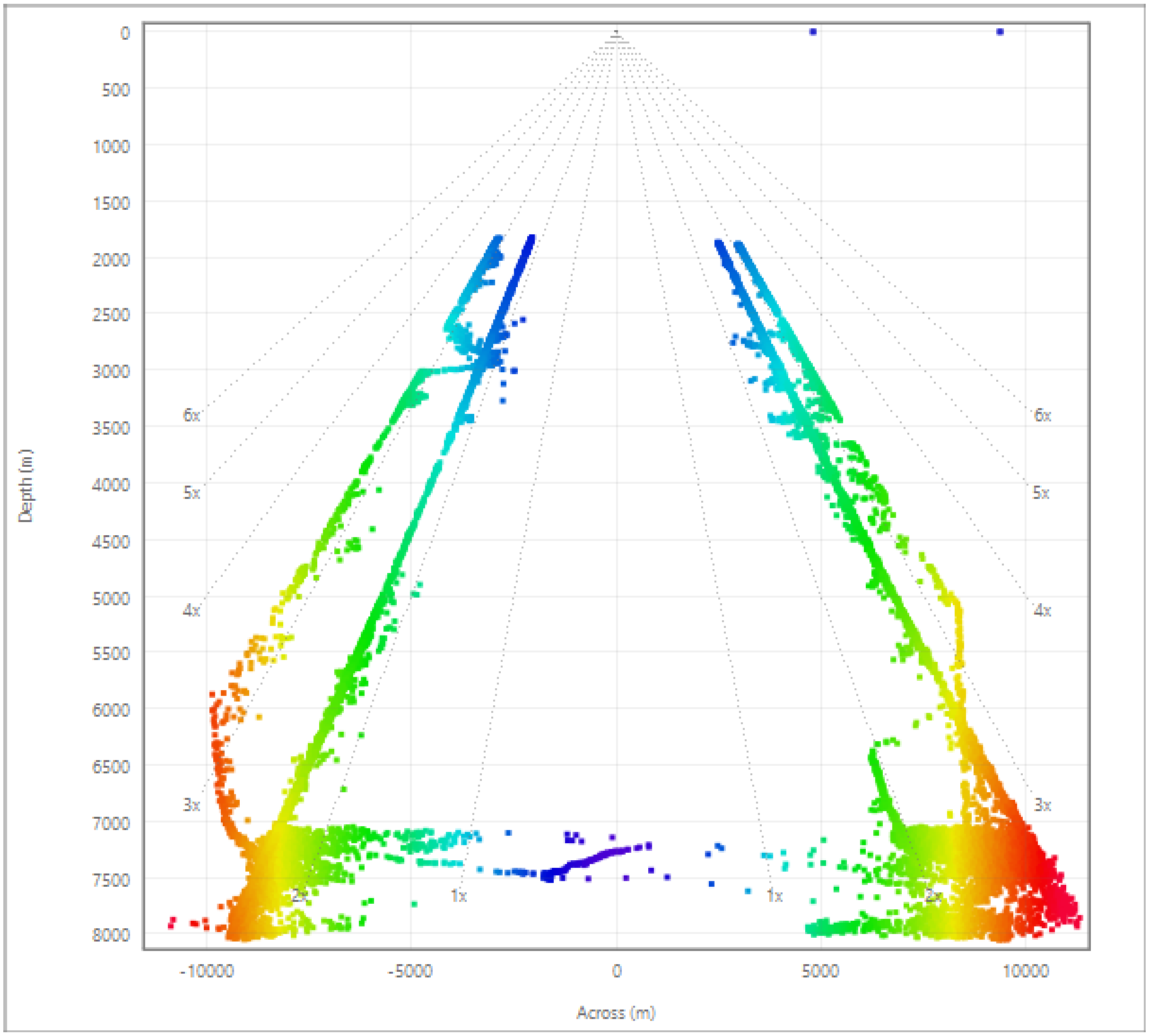

Figure 4: EM 124 July 2019 Puerto Rico Trench survey extinction plot.

Inside the trench, we achieved swath widths around 20 km with 50-55° coverage on either side of nadir ~ 2.5x water depth (Figure 4). During the sonar installation, Kongsberg technicians determined that the DSSV Pressure Drop inherently produces 65-70 dB of noise which can contribute to the smaller swath widths.

0.6 Survey Statistics

The following tables lists the survey mileage for this survey:

	Vessel	Total (km)
Line Type	SBES Mainscheme	0
	MBES Mainscheme	475
	SBES/MBES Combo	0
	MBES Crosslines	0
Number of Bottom Samples		0
Survey Area (KM^2)		2,865

Table 2: Survey Statistics

The following table lists the specific dates of data acquisition for this survey:

Date	Julian Day
07-15-2019	196
07-18-2019	199

Table 3: Julian Day, survey dates

Survey lines were run with a 12 kHz multibeam echosounder. Statistics were calculated in ESRI ArcGIS 10.6.1 (*personal license*).

1. Data Acquisition and Processing

1.1 Equipment and Vessel

Refer to the Data Acquisition and Processing Report (DAPR) for a complete description of data acquisition and processing systems, survey vessels, quality controls, and processing methods. Additional information will be discussed in the following sections.

The following vessels were used for data acquisition during this survey:

Vessel	DSSV Pressure Drop
LOA	72.6 meters
Draft	4.18 meters

Table 4: Vessel Used

The following systems were used for data acquisition during this survey:

Manufacturer	**Model**	**Purpose**
Kongsberg	EM 124	Multibeam Echosounder (MBES)
Kongsberg	Seapath 380+	Positioning and Attitude System
Reson	SVP70	Fixed Mount Sound Speed
Seabird	SBE49 Fast Cat CTD	Sound Speed/CTD System

Table 5: Systems used during data acquisition

The DSSV Pressure Drop single beam echosounder (SBES) was turned off during data acquisition as interference becomes visible in the MBES due to the frequency of the two signals. The Seabird CTD was attached to the Limiting Factor submarine vehicle and each of the Caladan science landers. These data were collected during the deep dive and were used during post-processing for ray-path corrections.

1.2 Uncertainty

Total propagated uncertainty values were derived from fixed values with instrumental detailed in the DAPR, vessel characteristics, and uncertainty associated with the sound speed measurement and data processing (Table 6). The Seabird SBE49 derived full-ocean depth sound velocity from temperature and conductivity sensors while surface sound speed was determined by the Reson SVP70.

MANUFACTURER	SOURCE	CONTRIBUTION
QIMERA	Roll & Pitch	0.02°
	Heading	0.075°
	Heave Fixed	0.05m
	Heave Variable	5%
	Roll Offset	0.05°
	Pitch Offset	0.05°
	Heading Offset	0.05°
SEABIRD	Conductivity Accuracy	± 0.0003 S/m
	Temperature Accuracy	± 0.002 °C
	Pressure Accuracy	± 0.1% of full-scale range
RESON SVP70	Sound Velocity Accuracy	0.05 m/s
	Sampling Time	50 ms to 10s

Table 6: Uncertainties associated with processing and sound velocity measurements.

For Special Order surveys, the maximum allowable horizontal uncertainty is 2 m at 95% confidence while the maximum allowable vertical uncertainty is $\pm\sqrt{(0.25)^2 + (0.0075 \times d)^2}$ of a given depth (d) at 95% confidence. The Puerto Rico survey area has a depth range between 1,861 – 8,030 m. With these values, the range of allowable TPU is ± 14 – 60.23 m at 95% confidence.

TPU statistics were generated for the Qimera CUBE uncertainty surface in the ESRI ArcGIS.

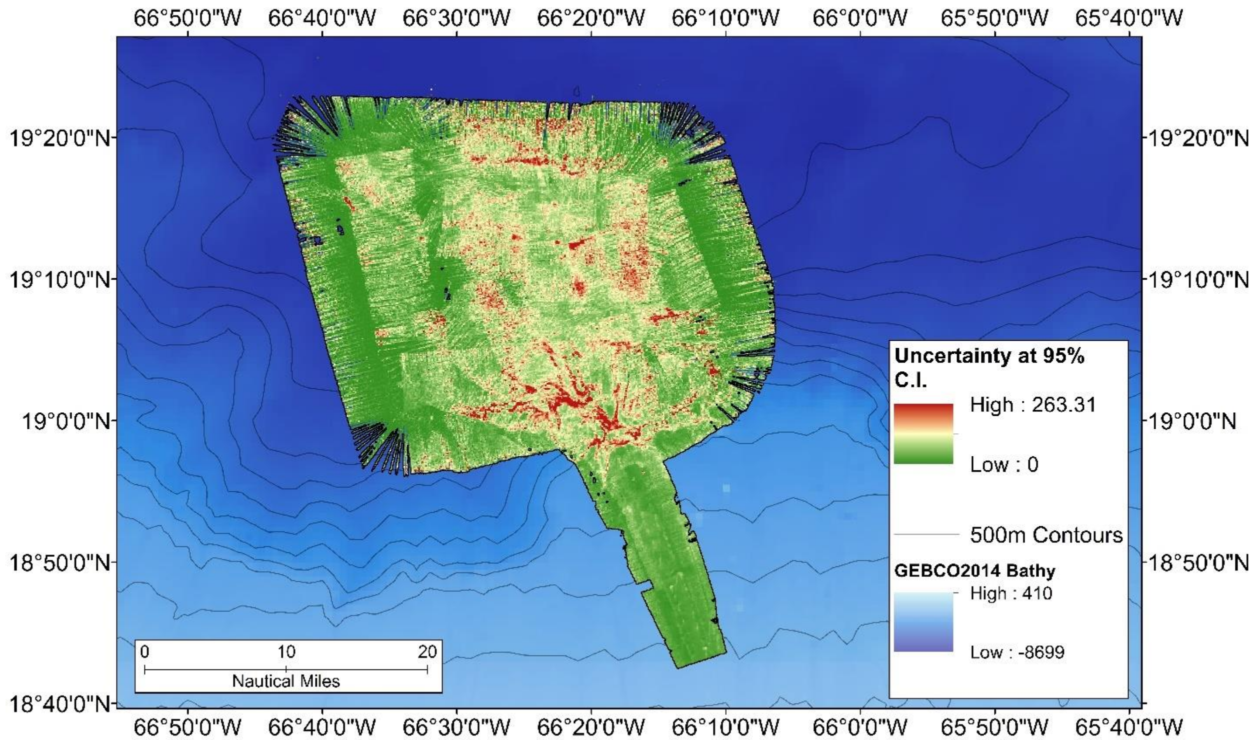

Figure 5: EM 124 Puerto Rico Trench bathymetry uncertainty at 95% confidence - red indicating areas of higher uncertainty.

The average estimated uncertainty of the Puerto Rico Trench survey area is 18 m. This falls well below the average acceptable value for this survey based on the TPU estimates for the depth range. Figure 5 shows that uncertainty surface mapped to a color range with a minimum of 0. It should be noted that high uncertainties outside the acceptable range are observed, but the dataset still meets the IHO Special Order specifications.

1.3 Junctioning Surveys

1.3.1 GEBCO 2014 Comparison

General Bathymetric Chart of the Ocean (GEBCO) is an international effort funded by the Nippon Foundation that focuses on maps of the ocean. The GEBCO 2014 world ocean grid is the widely used standard of known bathymetric information and vertically referenced to mean sea level (MSL). The portion of the data covering the Puerto Rico survey area was extracted from the GEBCO website (https://www.gebco.net/data_and_products/gridded_bathymetry_data/) and used as a base-layer map to help with line-planning and deep dive location identification. This surface was differenced with the EM 124 Puerto Rico survey data in ESRI ArcGIS.

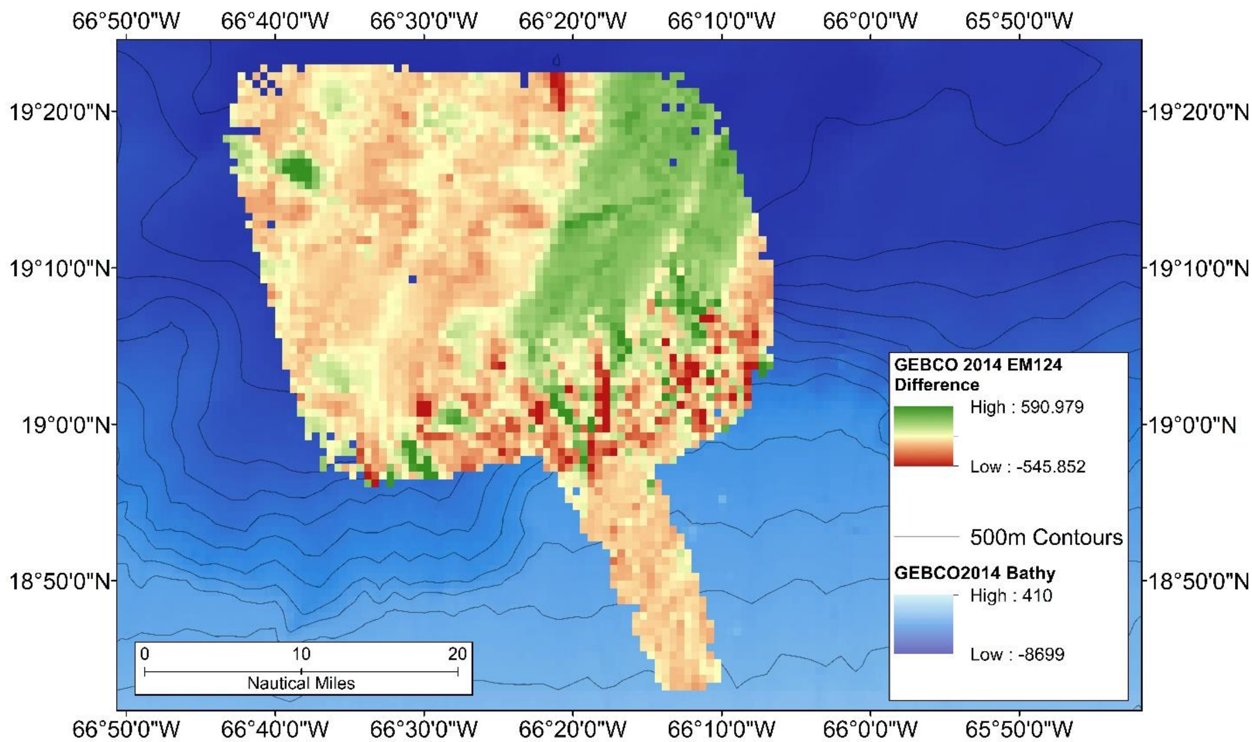

Figure 6: GEBCO 2014 bathymetric grid differenced with the Puerto Rico data. Green indicated areas where Puerto Rico is deeper than GEBCO estimates.

There is an average difference of 42 m, with the EM 124 survey (on average) being deeper (Figure 6). The GEBCO 2014 grid has a resolution of ~900 m which is of lower quality in comparison to the 75 m Puerto Rico survey. This resolution discrepancy likely contributes to some of the large difference values explicitly evident at the southern edge of the trench where smaller-scale submarine channels are completely missed in the GEBCO dataset.

1.3.2 Summary

According to the GEBCO 2014 grid sources available at the time of survey,, ~20% of the area we covered was interpolated from satellite estimates, meaning 20% of the area has never been mapped before (Figure 7). About 80% of the area was mapped previously with either a multibeam system or from single beam echosounders.

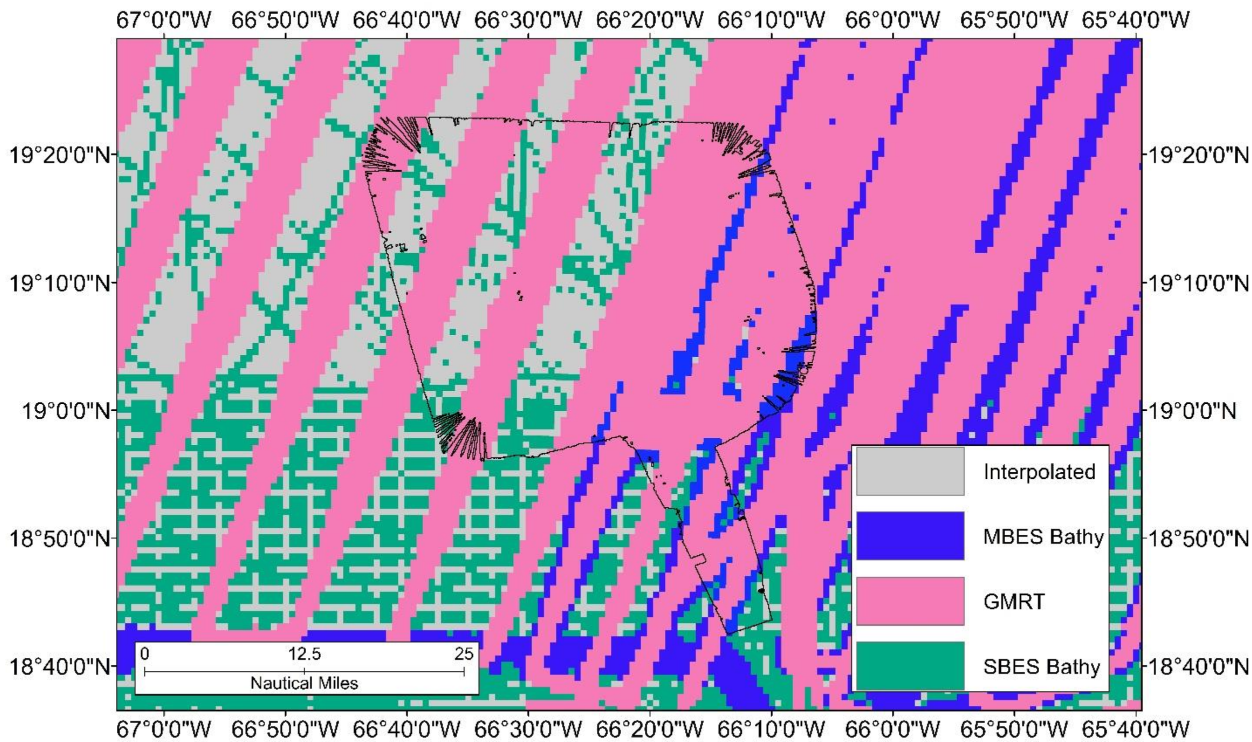

Figure 7: GEBCO data sources. Grey represents areas that were interpolated, and blue and pink are previously collected bathymetry data. The black outline is the area in the PRT where EM 124 data were collected.

While our efforts were not the first to map the Puerto Rico Trench, we did collect many full-ocean depth CTD data that were used to provide full-ocean sound velocity profiles for these data. Thus, it is likely we have the most accurate dataset of the trench to date. It is anticipated that these data will be a fundamental contribution to the scientific community.

1.4 Sound Speed

Synthetic profiles and XBT sound speed profiles were generated as needed during the survey operations using Sound Speed Manager. Full-ocean depth sound velocity profiles were collected by the Limiting Factor's (submersible) onboard CTDs and lander CTDs.

A static salinity value of 30 ppt inherent in the XBT collection program causes inaccuracies in the estimated sound speed. The WOA estimates a salinity at this location between 32-34 ppt. This discrepancy directly influences the sound velocity estimates we receive. To fix this issue, a MATLAB code was developed to take the raw XBT data and add the synthetic salinity estimates to recalculate the sound velocity at the time of the XBT deployment.

A true full-ocean depth sound speed profile was collected during the dive and later applied to the data from the entire survey area during post-processing. The sub CTD data were sampled at 1 Hz (1 per second) for the entire round-trip voyage, totaling over 70,000 data points. To make this a more manageable dataset for SIS and Qimera, these data were brought into MATLAB 2018a (*personal license*). Code was written to average the sound speed values at each depth in 1 m depth increments (Figure 8)

```
%% Minimizing the CTD data from the Sub
x=0;

for i=1:(max(SubCTD(:,3))+1)

    %pull out the pressure
    c=SubCTD(:,3);

    %Identify which points fall between a certaint interval
    n=find(c>=x & c<x+1);
    %take the maximum pressure value from the interval
    %(i.e. between 1-2,take 2)
    m=max(c(n));
    %take the average of those points and add to a new matrix
    l(x+1,1:1:4)=[mean(SubCTD(n,1)) mean(SubCTD(n,2)) m mean(SubCTD(n,4))];

    %add one more to the interval
    x=x+1;

end
```

Figure 8: MATLAB (personal license) *code created to average the sound speed values at each depth.*

Additionally, a code was obtained to translate pressure (dbar) into depth (m) (Figure 9). These depths were used for a final sound velocity profile.

```
function DEPTHM = sw_dpth(P,LAT)

% DEPTHM = depth in meters
% P = pressure in decibars
% LAT = latitude in decimal degrees north

DEG2RAD = pi/180;
c1 = +9.72659;
c2 = -2.2512E-5;
c3 = +2.279E-10;
c4 = -1.82E-15;
gam_dash = 2.184e-6;

LAT = abs(LAT);
X    = sin(LAT*DEG2RAD);  % convert to radians
X    = X.*X;
bot_line = 9.780318*(1.0+(5.2788E-3+2.36E-5*X).*X) + gam_dash*0.5*P;
top_line = (((c4*P+c3).*P+c2).*P+c1).*P;
DEPTHM   = top_line./bot_line;
end
```

Figure 9: MATLAB (personal license) *code used to translate pressure in dbar to depth in meters.*

The sub CTD data were applied to all Puerto Rico data.

Figure 10 shows the difference between each of the sub CTDs for each of the three dives. While the profiles for each instrument are consistent between the three dives, they are not consistent against each other. This means, that the readings from SUB1 and SUB2 are quite different from each other for each dive. This is further recorded in the table of depths below.

Dive	Dive 1	Dive 2	Dive 3
Date	7/15/2019	7/16/2019	7/18/2019
SUB1	789	2,997	7,182
SUB2	767	2,974	7,162

Table 7: Sub CTD records for each of the three dives in Puerto Rico.

These differences are attributed to the sensor calibration becoming out of date/accuracy. It has been recommended that they be recalibrated as soon as possible.

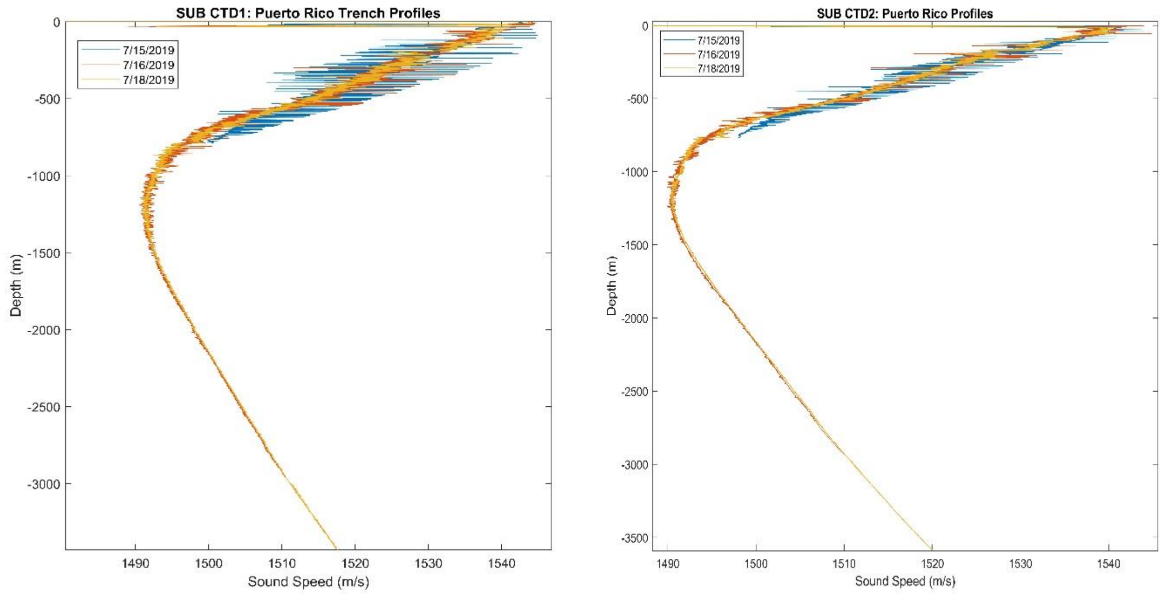

Figure 10: Matlab comparison of all collected sound speed profiles from sub.

1.5 Data Corrections

No corrections were needed.

1.6 Calibrations

1.6.1 Sonar Acceptance Test (SAT)

A Sonar acceptance test was performed on the new Kongsberg EM 124 by Cassie Bongiovanni and four Kongsberg technicians/engineers beginning December 13, 2018. More information on the survey plan is outlined in the SAT Plan report.

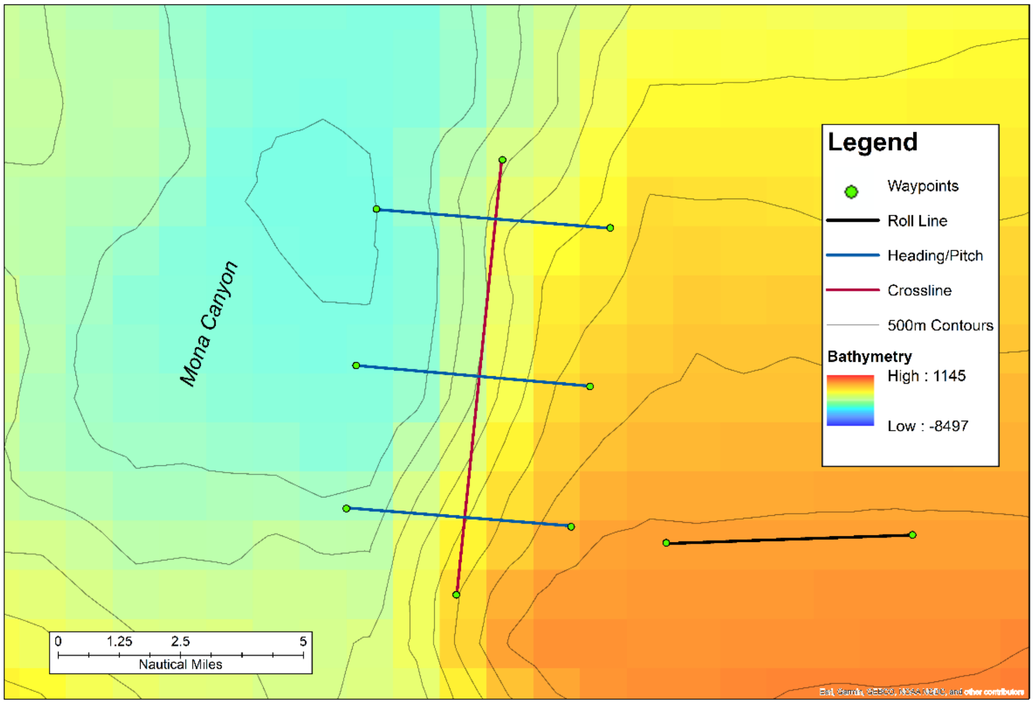

Figure 11: Sonar Acceptance Test (SAT) plan in the Mona Canyon offshore Puerto Rico and near the Puerto Rico Trench.

Data was collected over all lines twice. To be certain of the offset values, the calibration was processed in Qimera, SIS, and Kongsberg proprietary software. All three resulted in near zero offsets for all three major components (Roll, Pitch, and Heading).

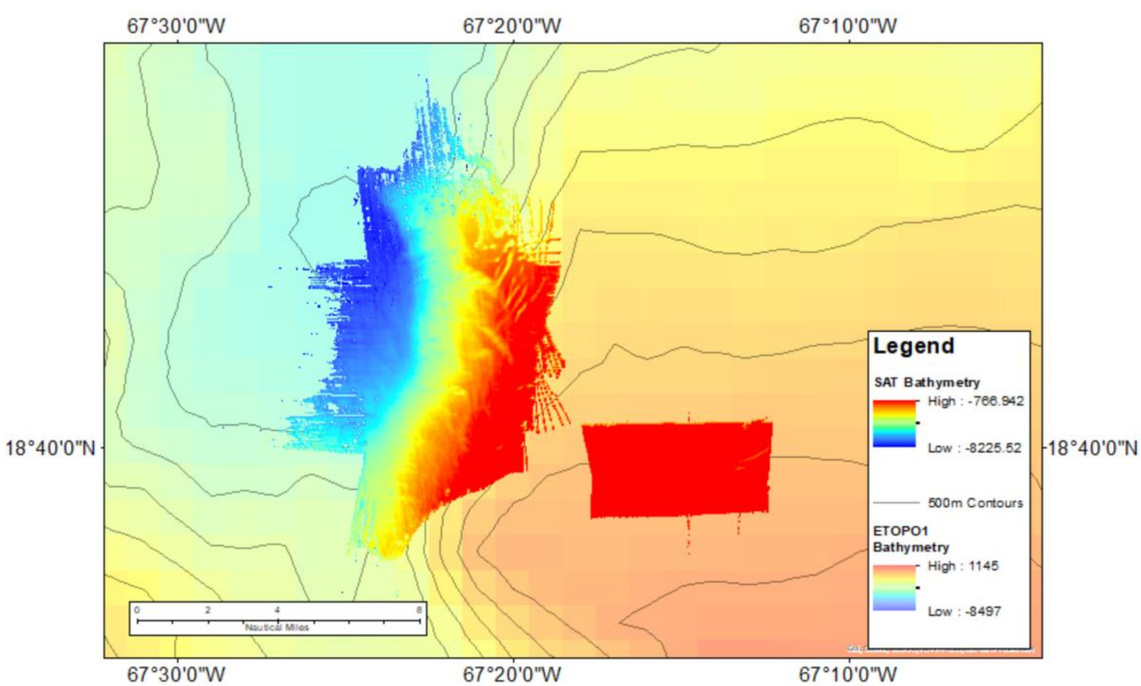

Figure 12: SAT resulting bathymetry

As such, no offsets were input. However, occasional latency (timing between the positioning data and the feed to the sonar) issues were observed and an offset value of 0.185 (seconds) cleared the problem primarily visible in the outer beams of the swath.

1.6.2 Backscatter Calibration

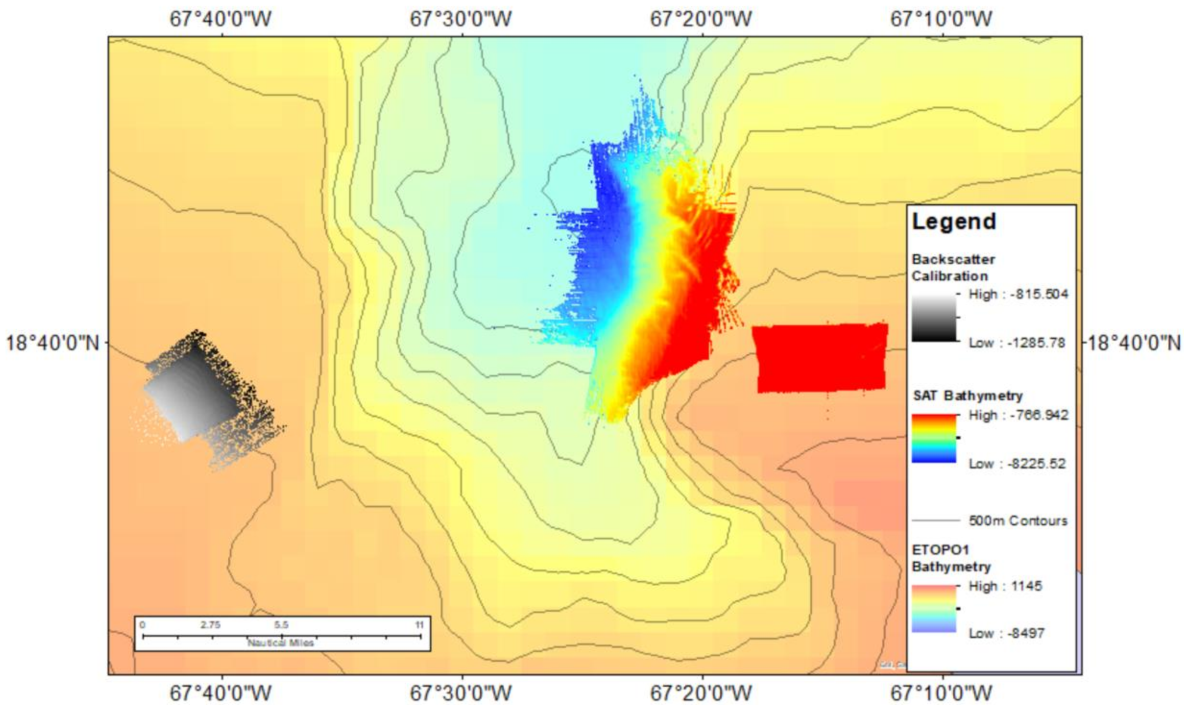

Figure 13: Backscatter calibration in relation to the SAT calibration site.

During the SAT, time was devoted to a backscatter calibration. This was accomplished by running short lines (< 1 nm) in all depth modes (Shallow, Medium, Deep, Deeper, and Very Deep) in two directions – East to West, and West to East. Running a line in opposite directions over flat ground can help determine the scattering components and allow for more accurate backscatter products, which is particularly of interest geologically (structurally) and biologically (for habitat mapping).

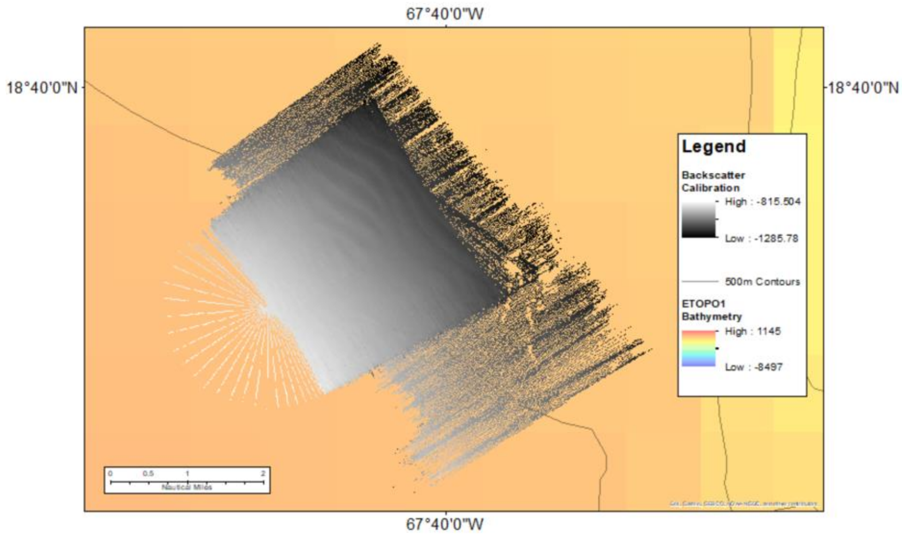

Figure 14: Backscatter calibration bathymetry.

The location chosen for the site was originally going to be the SAT roll line but was moved to the other side of the Mona Channel to avoid large swells. The data were processed by Kongsberg engineers and the results were input directly into SIS so they are automatically applied to all future data collection.

1.7 Backscatter

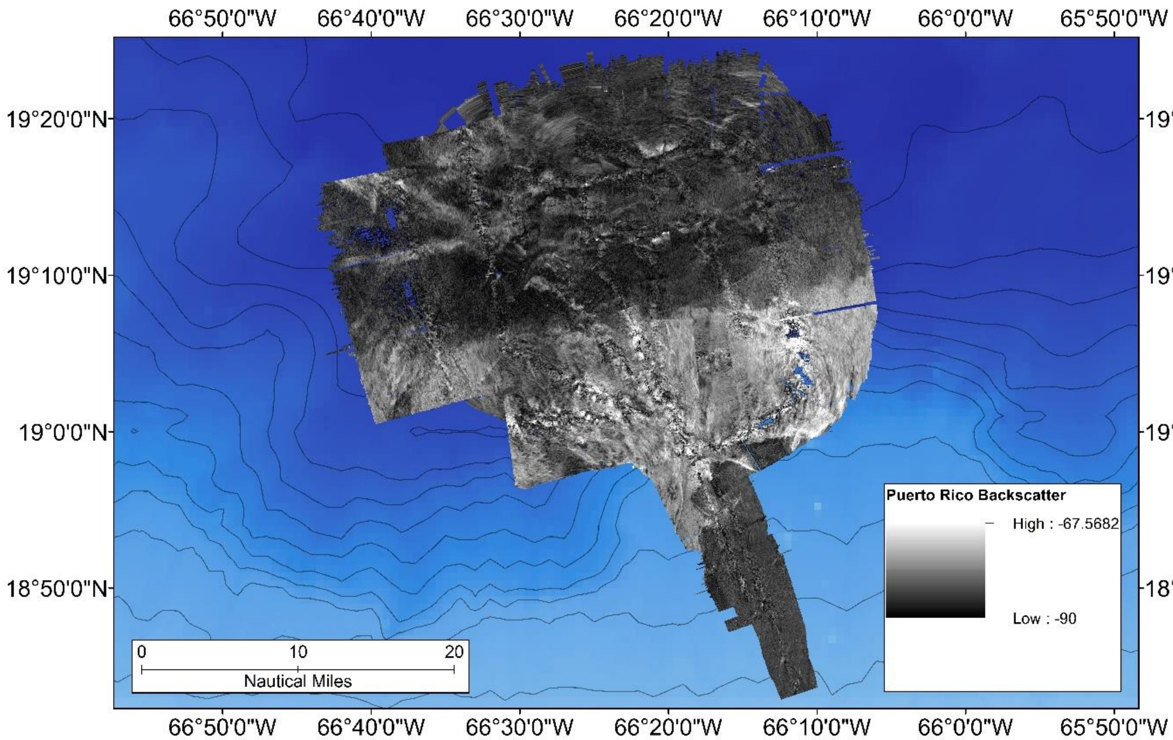

Figure 15: Puerto Rico Trench backscatter mosaic. Mosaic created in QPS FMGT.

Backscatter data were collected from the EM 124 during bathymetric data collection. Data were processed in QPS FMGT and a mosaic was created (Figure 15). No sediment samples were taken for verification.

1.8 Processing Software

Name	Manufacturer	Version	Installation Date
Qimera	QPS	1.7.5	12/04/2018
Hydro Office Sound Speed Manager	UNH CCOM/ Hydro Office	2018.1.50	12/06/2018
Matlab*	Matlab	R2018a	09/18/2018
Fledermaus & FMGT	QPS	7.8	12/04/2018
ArcMap/ArcGIS*	ESRI	10.6.1	09/18/2018

*Table 8: Processing software. *personal license*

More detailed information on processing software is outlined in the DAPR.

1.9 Surfaces

The following surfaces and/or BAGs are submitted with these reports:

Surface Name	Surface Type	Resolution	Depth Range
PRT2_CUBE_75m.xyz	CUBE	75 m	-1,861 m to -8,030 m
PRT2_95Uncertainty.tiff	Uncertainty	75 m	N/A
PRT2_Surface_75m.bag	Surface	75m	-1,861 m to -8,030 m
PRT2_backscatter.tiff	Mosaic	35 m	N/A

Table 9: Final mission surfaces.

1.10 Patch Test

As the system was calibrated only a few months before, a patch test was not needed.

2. Vertical and Horizontal Control

2.1 Vertical Control

All data are referenced to the geoid (MSL). No further vertical corrections were applied.

2.2 Horizontal Control

No horizontal corrections were applied.