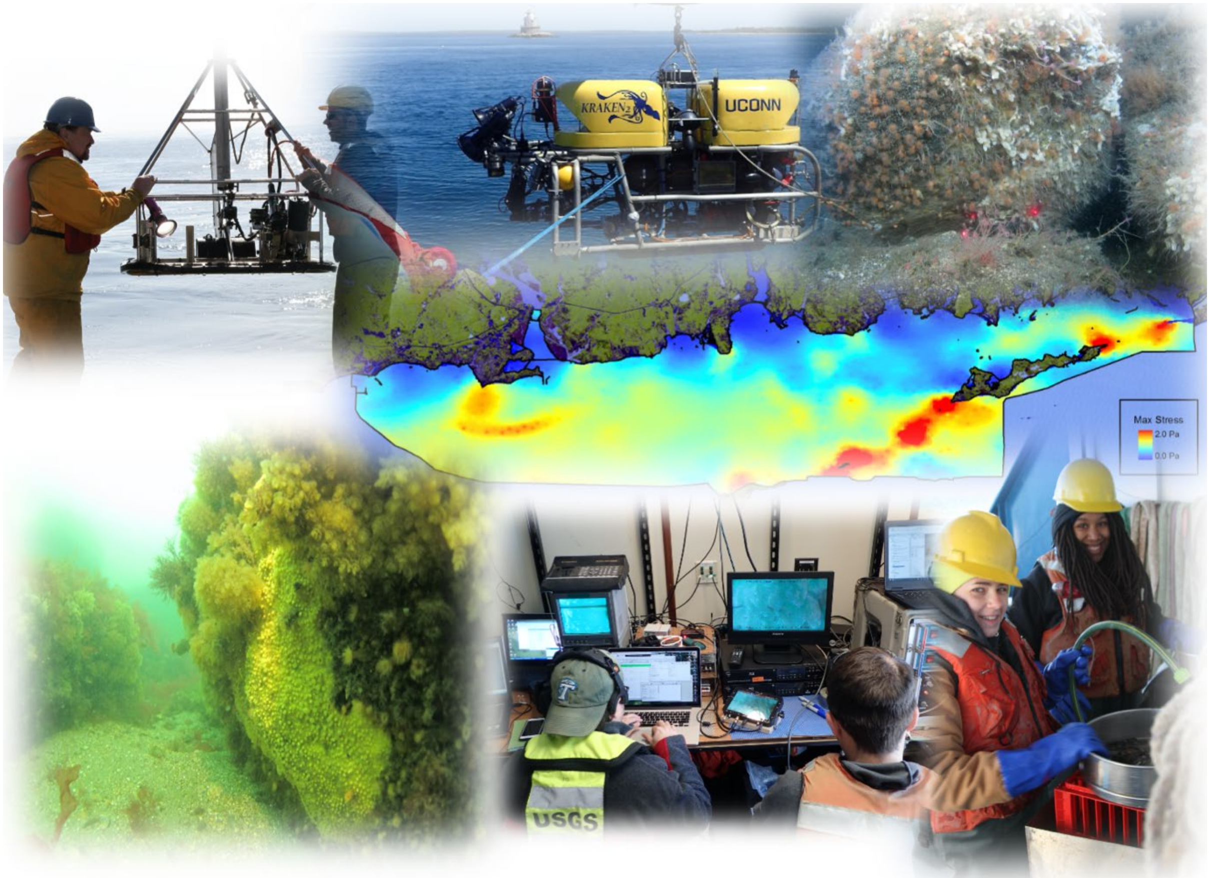
The Long Island Sound Habitat Mapping Initiative Phase II – Eastern Long Island Sound



Final Report

Submitted by:
The Long Island Sound Mapping and Research Collaborative
(LISMaRC)

August 23, 2021
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Long Island Sound Study
A Partnership to Restore and Protect the Sound

Connecticut Department of
ENERGY & ENVIRONMENTAL PROTECTION

2.0 SHALLOW WATER ACOUSTIC MAPPING

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Babb, I and Arbige, D. (2021). Historical Context. Section 2.2 in “Shallow Water Acoustic Mapping” p. 17-20 in “The Long Island Sound Habitat Mapping Initiative Phase II – Eastern Long Island Sound – Final Report” (Unpublished project report).

Babb, I and Arbige, D. (2021). New Data Acquisition. Section 2.3 in “Shallow Water Acoustic Mapping” p. 20-26 in “The Long Island Sound Habitat Mapping Initiative Phase II – Eastern Long Island Sound – Final Report” (Unpublished project report).

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Babb, I and Arbige, D. (2021). Discussion. Section 2.5 in “Shallow Water Acoustic Mapping” p. 30 in “The Long Island Sound Habitat Mapping Initiative Phase II – Eastern Long Island Sound – Final Report” (Unpublished project report).

Babb, I and Arbige, D. (2021). Summary/Conclusions. Section 2.6 in “Shallow Water Acoustic Mapping” p. 30 in “The Long Island Sound Habitat Mapping Initiative Phase II – Eastern Long Island Sound – Final Report” (Unpublished project report).

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2.1 Objectives

As with the Phase I Pilot, a principal focal topic for the Long Island Sound Mapping and Research Collaborative (LISMaRC) was the acquisition of acoustic data to map the seafloor. The acquisition of high-resolution bathymetry and backscatter data provide the stepping off point for all subsequent elements of the habitat mapping initiative. The bathymetry provides detailed information on the seafloor topography, while at the same time providing quantitative data that can be used to develop a number of derived products such as slope, rugosity and topographic roughness indices. The backscatter data provides a proxy for the nature of the seafloor with harder substrates providing a stronger acoustic return from the seafloor contrasted to the softer sediments that absorb much more of the sound from the acoustic survey systems. These variable seafloor reflectance values are typically displayed as gray-scale, with the harder substrates displayed as lighter shades, while the softer sediments are displayed with darker tones.

2.2 Historical Context

At detailed review of existing data was conducted by NOAA's National Centers for Coastal Ocean Science (NCCOS) prior to developing the scope of work (SOW) for the Phase II Acoustic Mapping element. This analysis generated a report (NCCOS, 2015) that listed existing acoustic data surveys (Figure 2.2-1). NCCOS utilized the existing surveys to develop unified bathymetry (Figure 2.2-2) and backscatter (Figure 2.2-3) mosaics for the Phase II area. These unified maps served as the baseline of existing acoustic data in the Phase II area to which newly acquired data was to be integrated.

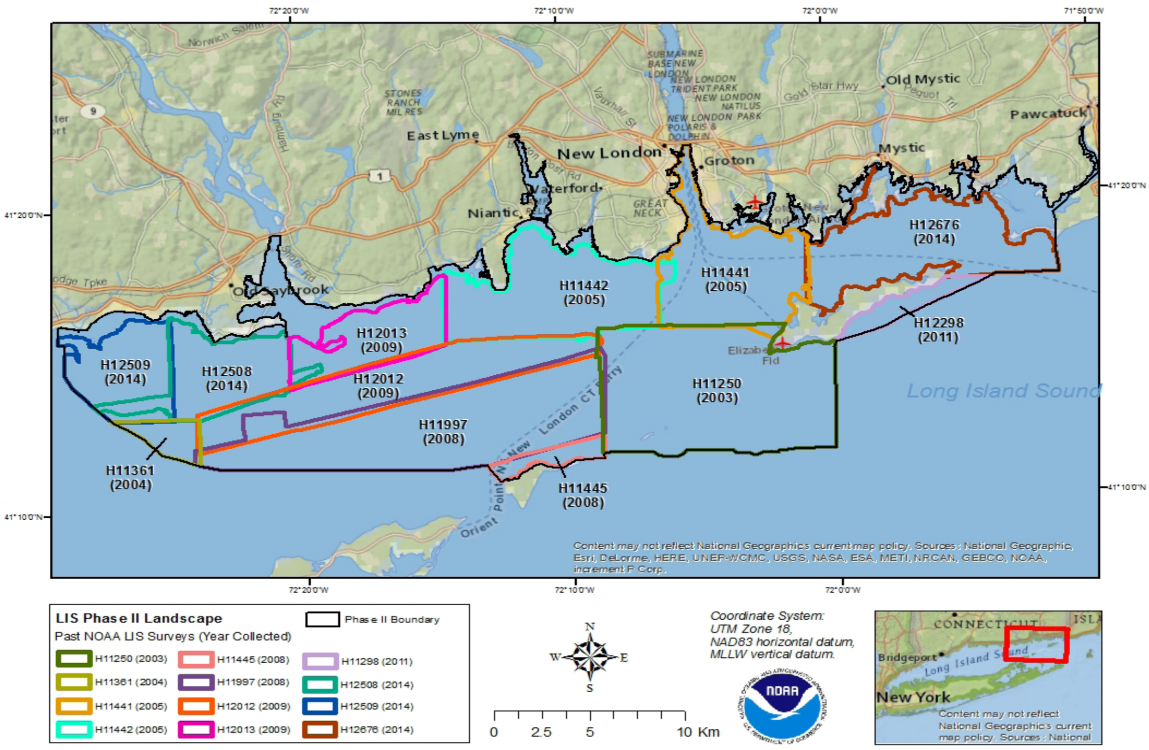

Figure 2.2-1 Map of previous NOAA surveys in the Phase II area.

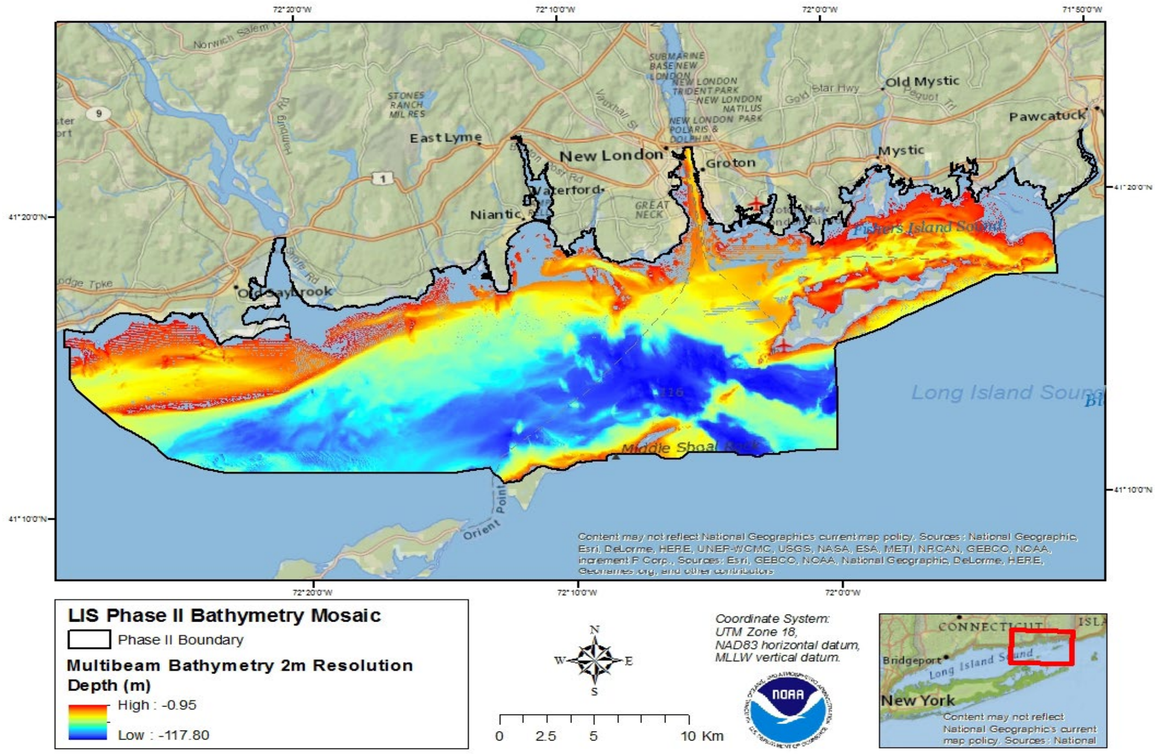

Figure 2.2-2 Unified bathymetry mosaic developed by NCCOS

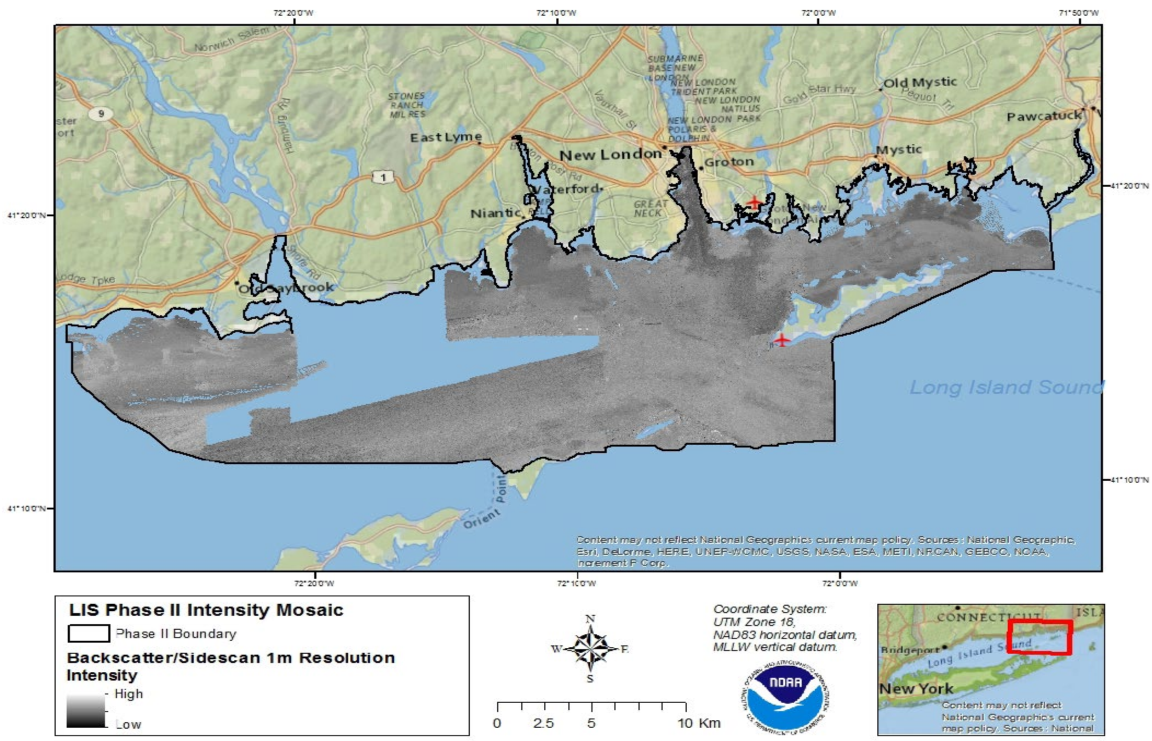

Figure 2.2-3 Unified backscatter mosaic developed by NCCOS

2.2.1 Gap Analysis and Survey Block Selection

The NCCOS 2015 report also identified remaining data gaps for both bathymetry and backscatter and previously un-surveyed areas in the Phase II area (Figure 2.2-4).

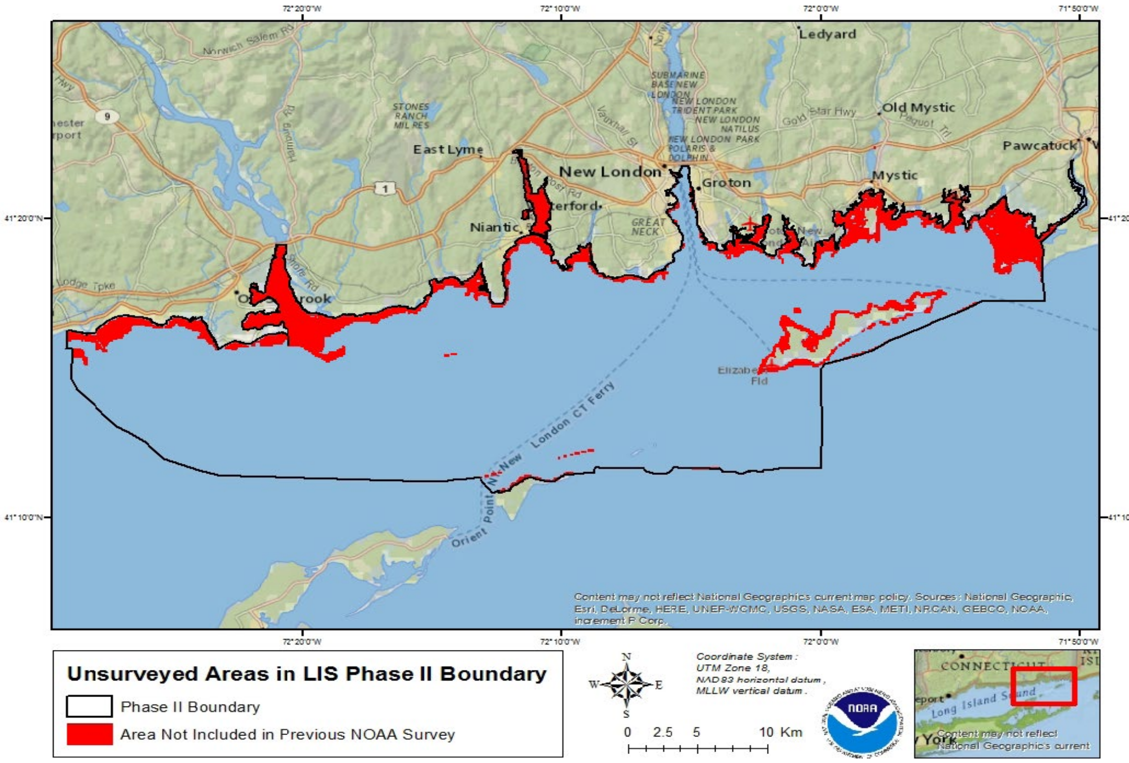

Figure 2.2-4 Map of areas within the Phase II region not previously surveyed by NOAA.

Each of these areas were prioritized by the gap density, i.e. areas with most data gaps were the highest priority, as opposed to some other determinant e.g. management or ecological priority.

The unmapped areas were parsed into two shallow blocks (1-3 fathoms) and 30 deeper blocks (>3 fathoms) (Figure 2.2-5). The decision was made not to attempt to map the two shallow blocks due primarily to the challenging nature of working in these areas (ie. minimum water depths of 1.4 meters less than the survey vessels' draft and the degree of effort needed to map these areas, ie. shallower waters require tighter678 line spacing and therefore more time on the water to complete). Teams from the Lamont-Doherty Earth Observatory (LDEO) consortium (Stony Brook University) and the Long Island Sound Mapping and Research Collaborative (LISMaRC) (UConn) coordinated efforts to map the deeper water priority sites using their respective technologies. Stony Brook utilized a Kongsberg EM3000D dual-head multibeam sonar system deployed from their RV Pritchard, while UConn utilized its Geoswath Phase-Differencing Bathymetric Sonar (PDBS, also called an interferometric system) from the RV Weicker.

This collaboration manifest in a division of labor between the LISMaRC UConn and SOMAS teams to collect new acoustic data in the gap areas (Survey Blocks) identified by NOAA for new data acquisition. The LISMaRC team surveyed Blocks 23, 24 and 25, which were adjacent to the UConn Avery Point campus. This resulted in the acquisition of 1.35 square miles (3.49 square kilometers) for Block 23 and 4.95 square miles (12.8 square kilometers) for Blocks 24 and 25, for a total of 6.3 square miles (16.29 square kilometers). The SoMAS team surveyed the remaining Blocks, and also collected some new data in Blocks 24 and 25 for comparison purposes, acquiring 35.1 square miles of new bathymetry and backscatter data (91.0 square kilometers). The total area of new bathymetry and backscatter data collected for the Phase 2 study was thus 41.4 square miles (107.2 square kilometers).

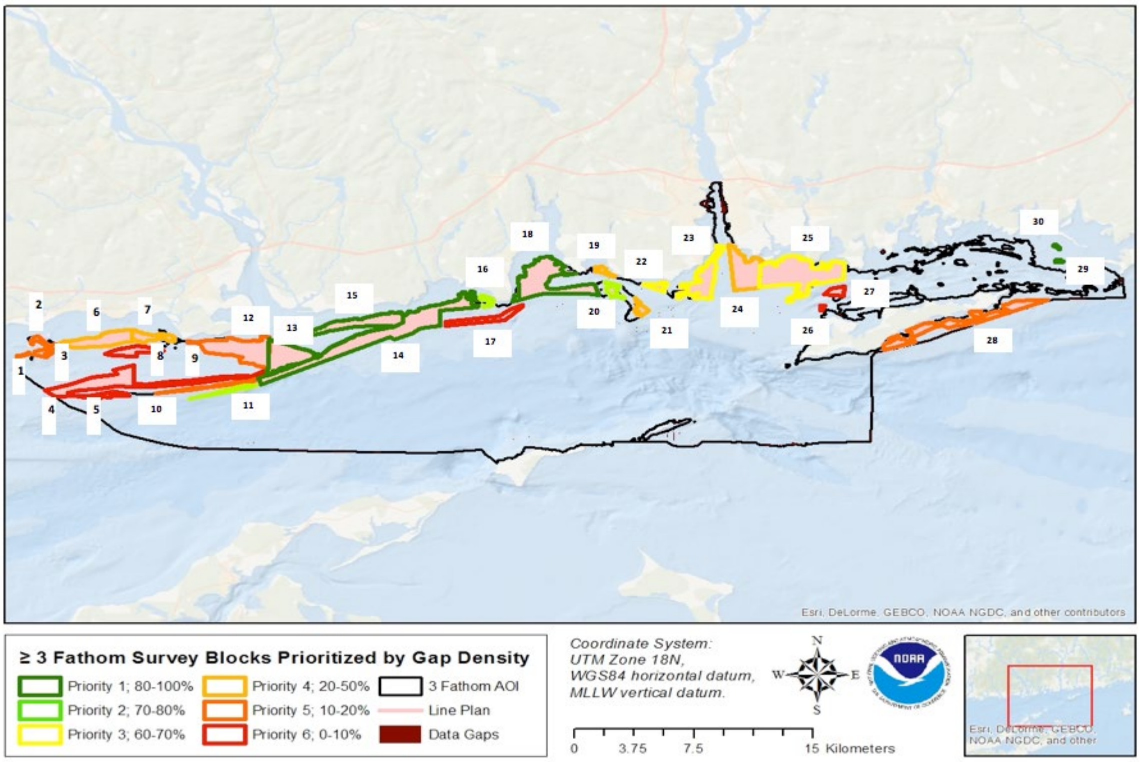

Figure 2.2-5 Map of the deeper (>3 fathom) shallow water gaps prioritized by NOAA.

2.3 New Data Acquisition

2.3.1 Survey Methods

Prior to conducting the acoustic surveys of the selected blocks, LISMaRC contacted the Center for Coastal Ocean Mapping at the University of New Hampshire to provide an on-site consultation of the technologies and proposed approach to mapping. This visit took place on May 4th, 2017 and involved a review of the Geoswath PDBS sonar installation on board the RV Weicker, a review of system configuration and data acquisition settings. Several hours were spent on board the vessel with Val providing insights and recommended strategies for the system's operation. Most significant was the importance of keeping the gain, pulse length and power at same levels throughout the entire survey.

The Geoswath system was mounted in the moonpool on the RV Weicker and the acquisition system located on nearby workbench (Figure 2.3-1).

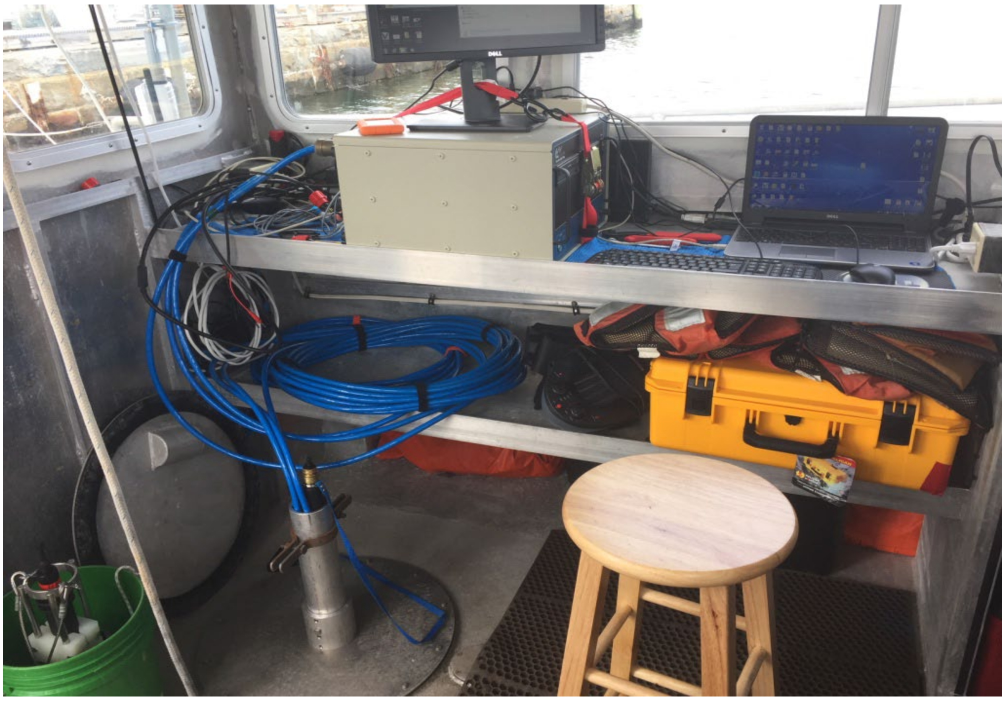

Figure 2.3-1 Geoswath setup on the RV Weicker, moonpool cover is in the lower left.

The surveys were conducted at a vessel speed between 4-5 knots (10 km/hr) to ensure data density sufficient to meet the NOAA recommendations. Due to the sampling gap at nadir generated by the PDBS a 100% swath overlap was implemented to provide the recommended 100% coverage of bathymetric and backscatter data. The swath width (line spacing) was also maintained to not exceed the 5 times water depth, which in reality is a conservative approach for an interferometric system (Figure 2.3-2). A survey line spacing of 25 meters/side was used in shallow areas, while a 30-meter spacing was adopted for deeper areas.

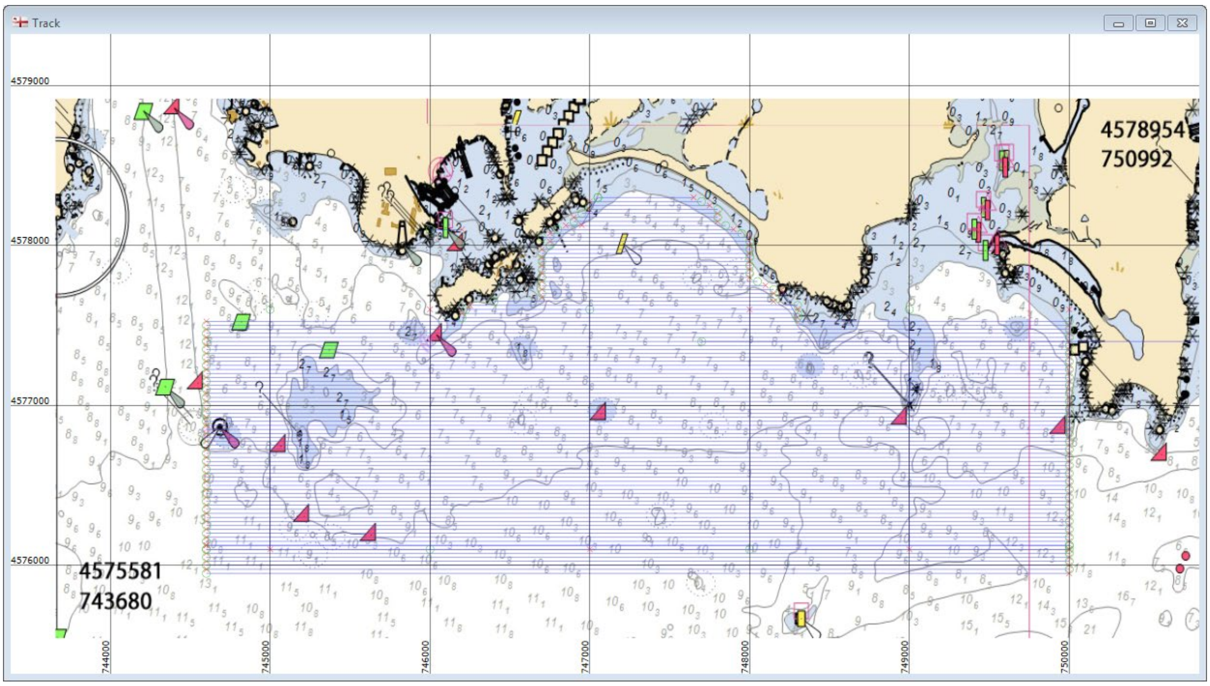

Figure 2.3-2 Screen capture from the RV Weicker's navigation system illustrating the tight spacing of the survey lines for Survey Blocks 24 and 25.

To improve survey accuracy and precision LISMaRC utilized UConn's ACORN (Advanced Continuously Operating Reference Network) that is composed of several receivers (GPS) that stream data to on-campus computers. The computers distribute the information to surveyors and mappers to help them in their work. ACORN allows highly accurate positioning in real time. This means that a location anywhere on or above the earth can be pinpointed within the space of a dime. The ACORN maintains nine base stations in the state of Connecticut including two that provide coverage within the Phase II area. LISMaRC worked with ACORN staff to integrate this real-time network (RTN) into the navigation system on the Weicker to provide this much improved accuracy. A description of the ACORN can be found at: http://naturally.uconn.edu/2014/07/29/this-is-not-your-cars-gps/ and the site network is http://acorn.uconn.edu

Sound velocity profiles (SVP) were conducted every three hours to acquire sound speed data using UConn's Valeport SVP system. Sound velocity data was imported into the processing software for sound speed corrections.

Data acquisition was performed using the Geoswath+ acquisition software and saved as .rff files for subsequent post-processing. The system recorded bathymetry and side scan sonar data along with heave, pitch and roll data from a Seatex MRU-5 mounted on the Geoswath transducer.

2.3.2 Field Survey Results

The acoustic surveys were conducted over the course of approximately one year from 2017-2018. Seasonal considerations, ship and crew schedules were the primary drivers for the protracted survey period. Table 2.3-1 lists the dates and times for the survey legs, showing a total survey investment of about 15 days to map the Survey Blocks 23, 24 and 25. LISMaRC had originally estimated a 20-day mapping period as part of its contribution to the new acoustic data acquisition.

Table 2.3- 1. Survey Log from UConn Geoswath Surveys 2017-2018.

Date	**Depart (UTC)**	**Return (UTC)**	**Hours**	**Comments**
4/31/2017	13:00	18:50	5.833	
5/4/2017	12:00	15:30	3.500	Engine problems
5/8/2017	13:00	17:48	4.800	Rerun lines from 5/4
5/17/2017	13:00	20:05	7.083	
5/18/2017	12:55	19:30	6.583	
6/21/2017	14:57	19:09	4.200	
6/22/2017	13:00	18:38	5.633	
6/23/2017	13:00	17:17	4.283	
Subtotal			41.917	
7/26/2017	15:00	20:31	5.517	
7/27/2017	13:00	19:07	6.117	
7/28/2017	16:00	19:00	3.000	
7/31/2017	16:00	20:06	4.100	
Subtotal			18.733	

8/14/2017	13:00	15:00	2.000	Overheat problems with transmitter
8/15/2017	14:00	17:10	3.167	
8/16/2017	11:30	16:45	5.250	
8/17/2017	12:00	16:50	4.833	
Subtotal			15.250	
6/5/2018	13:30	19:30	6.000	
6/6/2018	13:30	19:30	6.000	
6/7/2018	13:50	20:15	6.417	
6/11/2018	14:00	19:00	5.000	
6/19/2018	14:00	15:00	1.000	Overheat problems with deckbox
6/20/2018	14:20	18:32	4.200	
6/21/2018	14:10	18:55	4.750	
Subtotal			33.367	
7/17/2018	14:30	17:10	2.667	
7/18/2018	14:30	17:20	2.833	Overheat problems with deckbox
7/19/2018	13:00	18:38	5.633	
Subtotal			11.133	
Grand Total Hours			120.400	
Grand Total Days (8 hour days)			15.050	

2.3.3 Data Processing

2.3.3.1 Geoswath Data Processing

Processing of the acoustic data collected via the Geoswath+ system to develop the data products recommended by NOAA was problematic. Prior to the surveys UConn upgraded the software to Geoswath GS4 that generated data in a format that was unreadable by earlier versions of the CARIS software that uses the CUBE (Combined Uncertainty and Bathymetric Estimator) algorithm. According to the Center for Coastal and Ocean Mapping: "CUBE (Combined Uncertainty and Bathymetric Estimator), is an error-model based, direct DTM generator that estimates the depth plus a confidence interval directly on each node point of a bathymetric grid. In doing this, the approach provides a mechanism for automatically "processing" most of the data and, most importantly, the technique produces an estimate of uncertainty associated with each grid node." (CCOM: http://ccom.unh.edu/theme/data-processing/cube.) This feature is built into the CARIS software, recommended by NOAA for acoustic data processing, however, UConn's CARIS license had lapsed at the time of the survey.

Therefore, the bathymetry data were originally processed using the Geoswath GS4 software, while the backscatter data was processed using Kongsberg's Geotexture software. These data products were reviewed by NOAA and were deemed to be very "stripy" and several conversations were had to explore how to address this result. Over the course of several months in 2018-2019 UConn worked with NOAA to test several approaches to improve the output. Suggestions were made to export the Geoswath data in a .gsf (general sonar file) format to perhaps allow NOAA technicians to import the data into CARIS, which was done and sent to NOAA in September, 2018. An issue arose from this attempt as all of the necessary survey offsets were removed during the generation of the .gsf file format, essentially forcing them to work with unfiltered data. Further Webex meetings were held in October, 2018 to discuss other methods to address the issues with the data. Another suggestion was to attempt additional nadir filtering. To that end a three-meter gap along the nadir was filtered out, since there was additional data to fill in the gaps from the adjacent overlapping lines. However, in the final analysis, the striping was still just as evident. UConn felt that the major part of the striping was from the density (and noise/scatter) of the data at the edges of the swaths, even though the swath width was trimmed very aggressively; essentially using only 4 to 5 times water depth for usable swath width (vs the 10-12 times water depth claimed by Geoswath). The Geoswatch backscatter (side scan sonar) data was also problematic to process, and several attempts to work with NOAA (LTJG Jennifer Kraus) were made, including sending geotiff files for import into CARIS. No improved results were returned.

2.3.3.2 CARIS Data Processing

Ultimately, the decision was made to acquire the latest version of the CARIS software to ascertain how well it could address the striping issue, along with its capability to run the CUBE algorithm to address the data uncertainty. The CARIS software was acquired in late 2019 and a second round of data processing was initiated. There were several upgrade issues, hardware problems and operating system incompatibilities that had to be addressed before the CARIS software was finally operational on one of UConn's computers.

A schematic of the CARIS processing workflow is illustrated in Figure 2.3-3. The first step is to create a Vessel File (eg., RV_Weicker.hvf). This vessel file contains all the physical offsets between the various sensors used in the data acquisition (transducers, GPS antennas, gyro, heave sensor, pitch sensor, roll sensor, etc.). It also contains timing delays, and transducer error corrections for pitch, roll, and yaw which are determined during pre-survey "Patch Tests." The vessel file also contains the uncertainty values (standard deviation) for the various sensors and measurements which are then used to compute the horizontal and vertical Total Propagated Uncertainty (TPU). Note the creation of a "HIPS file" is also an automatic part of CARIS processing. Figure 2.3-4 is a screen shot of the TPU values that were input into the .hvf file as part of the CARIS processing.

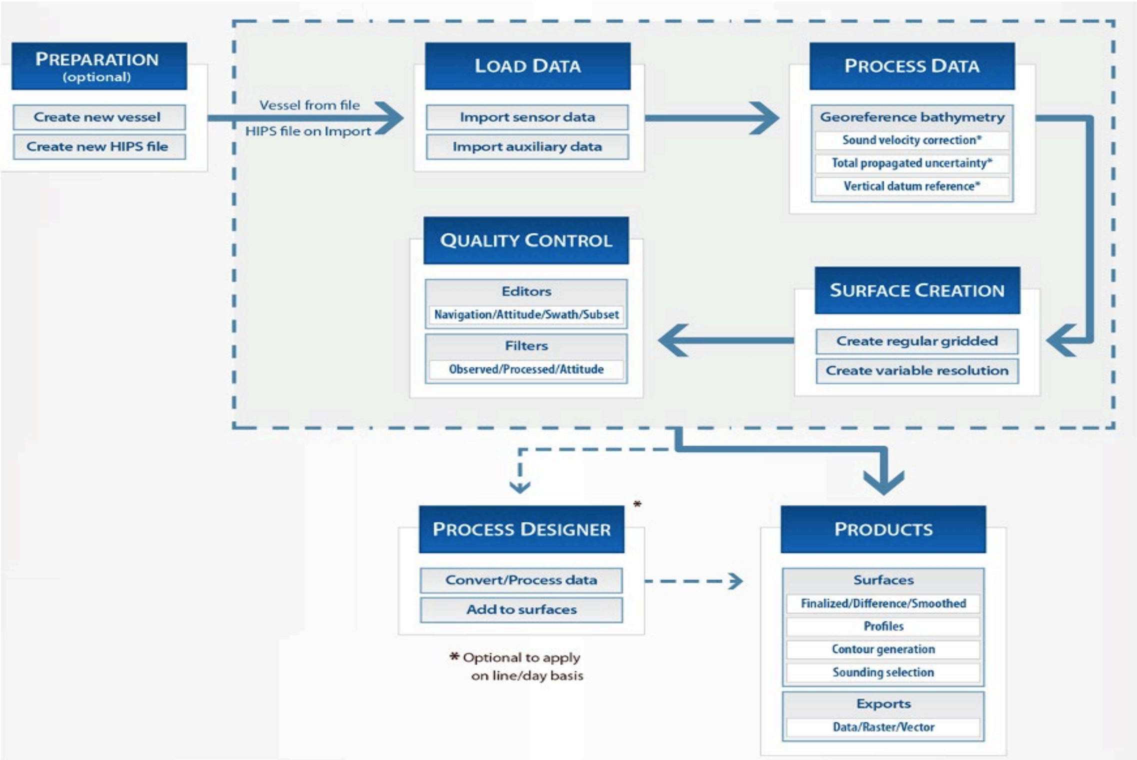

Figure 2.3-3 Schematic of the CARIS data processing workflow (from Teledyne CARIS 2021 Version 11)

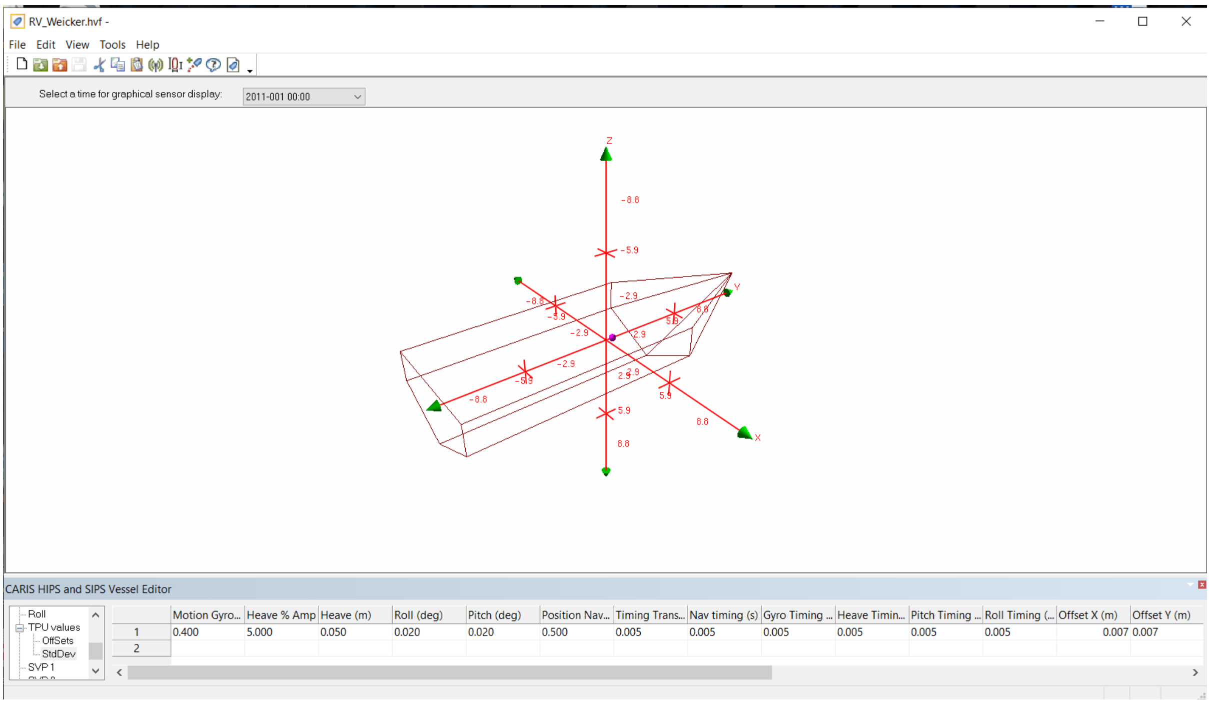

Figure 2.3-4 Screenshot from the CARIS software's Vessel Editor used to input the uncertainty values for the RV Weicker used for the LISMaRC acoustic acquisition.

The next processing step was to load the sensor data. The Geoswath acquisition software uses the original "linename" supplied by the operator, then creates 9 support files using that "linename.xxx" format. Of these files, the .rff file is the raw sensor data that CARIS imports to begin its processing. The tide and sound velocity profile data were then formatted for CARIS and imported as the auxiliary data. These raw data files have been uploaded to the Lamont Doherty Earth Observatory (LDEO) LIS Map Archive.

The next box in the flow diagram is the Process Data. This step is known as "Georeferencing Bathymetry." This process converts the raw data trackline depths into latitude, longitude, and depth by combining the ship navigation with horizontal and vertical offsets from the vessel file. This geographically references the sounding position and depth. Other corrections such as Sound Velocity Correction, Total Propagated Uncertainty (TPU), and Vertical Datum Reference are added at this step.

The CARIS processing software then allows for the generation of four different types of Regular Gridded Surfaces. These are Swath Angle, Shoalest Depth True Position, Uncertainty, and CUBE (Combined Uncertainty and Bathymetry Estimator). The CUBE was selected as the method of choice for generating the gridded surface, as this met the NOAA requirements.

The next step in the process was quality control editing. After creation of a "regular gridded surface", it was necessary to review and edit/clean the raw data before it could be used to create Final Products. This was done with a series of automatic and manual editing tools; including Navigation Editor, Attitude Editor, Swath Editor, and Subset Editor.

The final step was to generate the Geotiff imagery and .PDF standardized map template data products proposed in the original scope of work.

2.4 Data Processing Results and Integration

The results below represent the map products generated by the above processing procedures and represent new acquisition of 3.49 km2 for Block 23 and 12.8 km2 for Blocks 24 and 25 combined (Table 2.4-1). The map images included in this report have been reduced significantly for this report and the .PDF standard map template versions are provided in Appendix One. Full size images are available on the Long Island Sound Mapping website (https://lismap.uconn.edu) or the Lamont Doherty Earth Observatory Long Island Sound Data Portal: MGDS (http://www.marine-geo.org/portals/lis/). These results were also provided to NOAA via a Google Drive.

Table 2-4-1 LISMaRC Phase II New Acoustic Data Acquisition

Survey Name	Survey Blocks	Survey Area (km^2)	Deployment		Blocks Completed?
		Total UConn Survey Area: 16.29 km ^{2}	May - August, 2017 & June, 2018 (MJ)	June-July 2018 (JJ)	C = Complete P = Partial
B2, B3, B4, B5, B6,	24, 25	12.8	MJ		C
A1, A2, A3, A5, A6	23	3.49		JJ	C

2.4.1 Geoswath Processing Results

A mosaic of the bathymetry data from Survey Blocks 23, 24 and 25 generated by Geoswath GS4 software is seen in Figure 2.4-1. The striping of the data generated from the survey lines is evident in this image. The color ramp has orange as the shallowest water ranging to the blue deeper areas. Despite the striping issue the bathymetry map does provide a very good representation of the seafloor topography of this part of the Long Island Sound. This Geoswath image has a "shaded relief image" that has slightly exaggerated "z" elevation and "sun lighting" which give it the dramatic shadow effects.

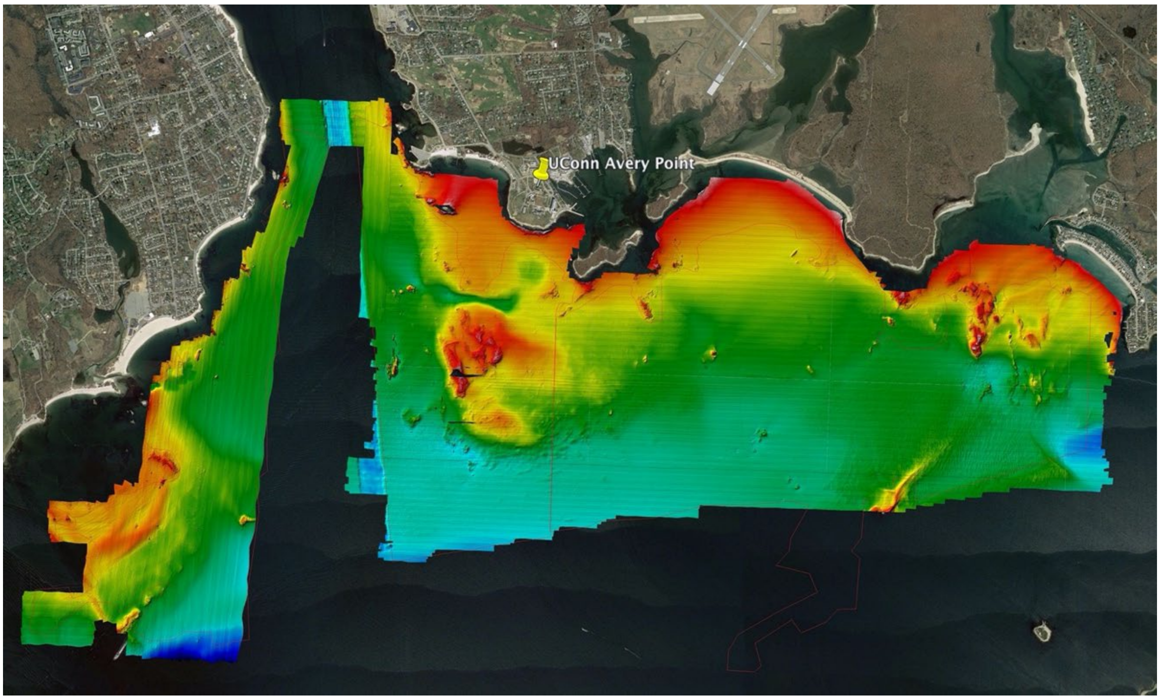

Figure 2.4-1Mosaic of bathymetry data from Survey Blocks 23, 24 and 25 generated by the Geoswath GS4 processing.

As described above, the Geoswath backscatter data was more problematic and the striping issue is evident in the output seen in Figure 2.4-2. However, the image does provide useful information on the nature of the seafloor in this part of the Sound. For these maps the reflectance value was used (vs absorption) with higher reflectance producing darker color areas to depict harder bottom areas and lighter reflectance in areas with softer substrates.

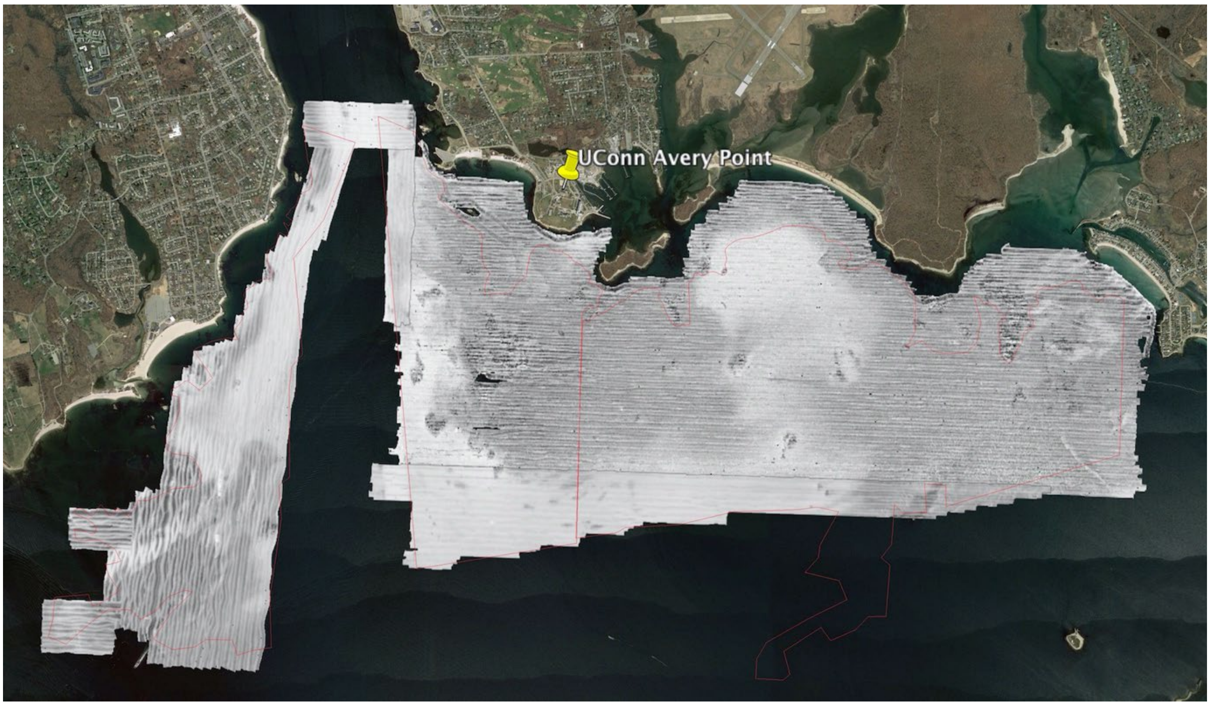

Figure 2.4-2 Mosaic of backscatter data from Survey Blocks 23, 24 and 25 generated by the Geoswath GS4 processing.

2.4.2 CARIS Processing Results

The results of the CARIS processing for the Survey Blocks 23, 24 and 25 can be seen in Figure 2.4-3 and Figure 2.4-4. As can be seen in Figure 2.4-3 the filtering applied to the surface reduced the striping issue at the expense of topographic resolution. This is particularly evident in the shallower (orange-red) and rougher seafloor areas. Figure 2.4-3 was generated with only "color shaded" by depth, lacking the sun illumination and hill shading seen the in Geoswath imagery. Figure 2.4-4 was generated with a 5x vertical exaggeration, which does provide greater relief, but also enhances the striping. Also of note is that the CARIS processed data includes additional data to the south of Survey Blocks 24 and 25, which was acquired after the decision was made to process the data using CARIS, and was therefore missing in the Geoswath processed images.

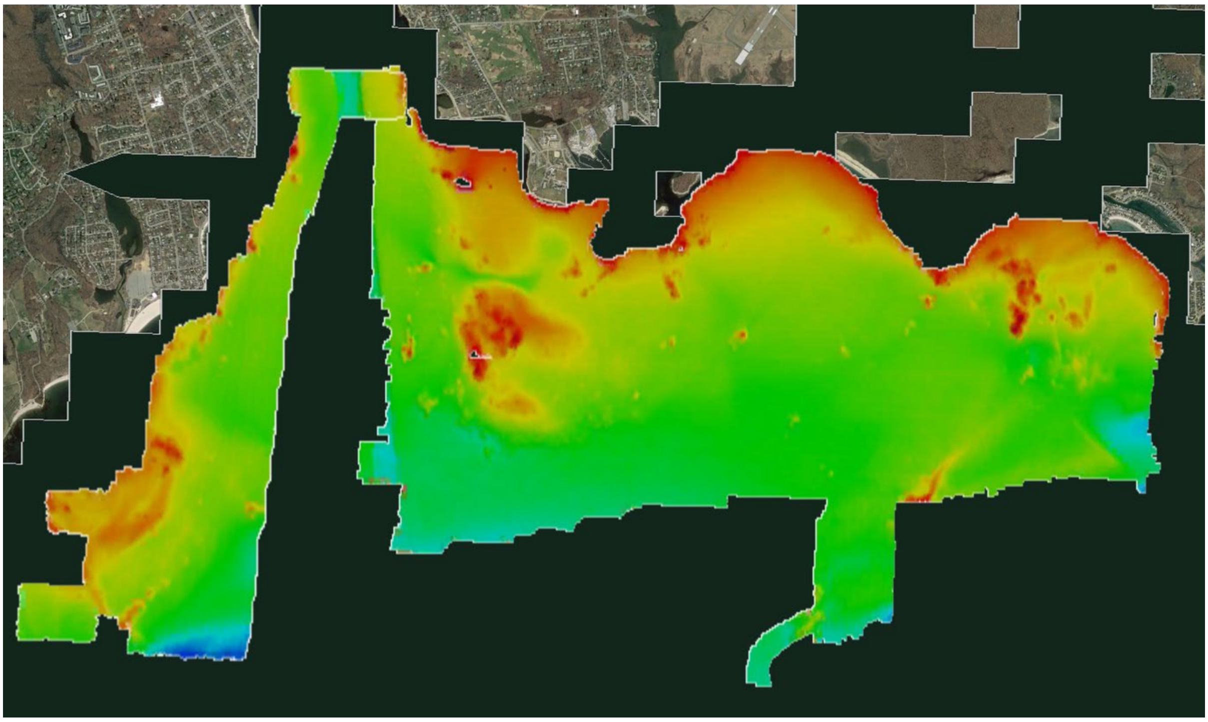

Figure 2.4-3 Mosaic of bathymetry data from Survey Blocks 23, 24 and 25 generated by the CARIS processing.

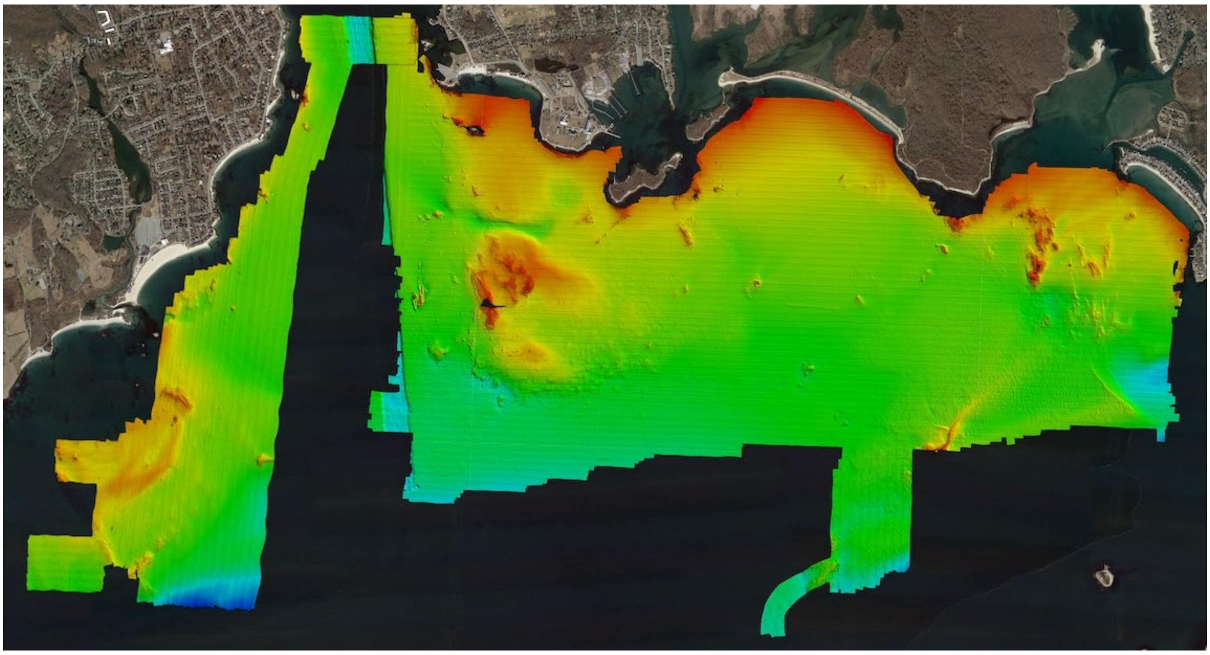

Figure 2.4-4 Mosaic of bathymetry data from Survey Blocks 23, 24 and 25 generated by the CARIS processing with a 5x vertical exaggeration applied.

The results of CARIS processing of the backscatter data can be seen in Figure 2.4-5. It appears that this image presents a bit more striping, particularly in the lighter (lower reflectance) areas.

Figure 2.4-5 Mosaic of backscatter data from Survey Blocks 23, 24 and 25 generated by the CARIS processing.

2.5 Discussion

All of the original raw data files, tide, sound velocity profiles, field logs and all of the CARIS files and subdirectories and final Geotiff data products were copied onto an external hard drive and sent to Frank Nitsche at the Lamont Doherty Earth Observatory (LDEO) at Columbia University for upload to their Long Island Sound data depository. Delivery of the data was confirmed by Dr. Nitsche on 6/2/2020. Subsequently, metadata files using the recommended LIS Cable Fund Word Doc template were developed and also sent to the LDEO repository. Due to all of the back and forth with NOAA during most of 2019, they were not able to integrate LISMaRC's CARIS data into their final unified map products they generated as part of their deliverables. No decision has been made as to how to further proceed with any future integration of this data.

There is a part of the Block #24 that was surveyed with the LISMaRC Geoswath system and by Roger Flood using the Kongsberg beam-forming multibeam sonar. There have been discussions about developing an overlay map of this area to compare the results of the two systems directly, however, fiscal and temporal resources are lacking to conduct this comparison.

2.6 Summary/Conclusions

The process of identifying the gap areas to be mapped in the Phase II area was very effective, as was the division of labor to conduct the new data acquisition between LISMaRC and Stony Brook University. The UConn Geoswath Phase Differencing Bathymetric Sonar was able to acquire data within the three sample blocks (23, 24 and 25) from the RV Lowell Weicker over an extended time period from 2017-2018. The processing of the newly acquired data, however, was challenging, owing primarily to ongoing system and software updates by the Geoswath company that affected integration of the data to the standards established by NOAA in the original scope of work. Acquisition of the latest version of the CARIS software allowed for the required process steps to meet the requirements and generate a product that could be integrated with the existing and newly acquired (by the Stony Brook University group) acoustic data.

However, given the inherent noise generated by the Geoswath Phase Differencing Bathymetric Sonar (interferometric) system and the challenges associated with trying to filter this raw data (both bathymetry and backscatter) using both the Geoswath and the CARIS software suites, it is not recommended to utilize this system for future Long Island Sound mapping efforts. This is particularly the case since there is currently a proposal being processed as part of the EPA's Long Island Sound Study Enhancement Grant (LISS EG) program for acquisition of a new dual head Kongsberg multibeam sonar for use in LIS. This effort is being led by Roger Flood at Stony Brook University (SBU) and the University of Connecticut is also involved to be part of the operations team to operate this new system. Furthermore, the proposal includes time to install, test and utilize this new system on both SBU's RV Seawolf and UConn's RV Connecticut to demonstrate that it can serve as a truly regional resource for seafloor mapping in the Sound. It is envisioned that future acquisition of acoustic data as part of the LISS EG as well as the Phase III of the Long Island Sound Cable Fund will be conducted using this new, state of the art system.

2.7 References

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