Changes in bottom morphology of Long Island Sound near Mount Misery Shoal as observed through Repeated Multibeam Surveys

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Abstract

High resolution swath sonar surveys provide an opportunity to investigate seafloor morphology and backscatter patterns. Data from bathymetric surveys may be used to define seafloor topography and interpret seafloor geomorphology. Through the comparison of multiple surveys, morphological changes and migration trends of seafloor features can be assessed.

Introduction and Methods

Mount Misery Shoal lies in Long Island Sound, north of Port Jefferson Harbor (Figure 1). The study area extends from the northern edge of Mount Misery Shoal, offshore for approximately 1 km to a depth of 28 m, and for 2 km alongshore. The surveys were done in October, 1998, and March, 2000. A comparison of data collected in the two surveys shows definite topographical and backscatter changes, apparently related to sediment movement.

The Kongsberg Simrad EM3000 multibeam echosounder was used to produce bathymetric and backscatter maps of the study site. A multibeam transducer mounted on the ship's hull emits sound waves at a maximum rate of 20 pings per second. The system operates at a frequency of 300 kHz, forming about 120 beams in a swath and with a width four times the water depth. Water depth is determined from the measured travel time and orientation of each beam. Differential GPS navigation, supplemented by inertial navigation, is accurate to about 1 meter.

A sun-illuminated map highlights small bathymetric features that are otherwise difficult to identify. Minor equipment-related depth anomalies are also sometimes present. Features such as sand waves, large rocks, drag marks caused by anchors and trawls, debris, and possible shipwrecks are clearly distinguishable. For example, there is a predominant north-dipping ridge located directly to the north of Mount Misery Shoal here called the central ridge and a smaller one to the west here called the smaller ridge. There are sand waves and depressions to the north of the central ridge as well as well as sand waves near the smaller ridge. Many elongate or symmetric scoured depressions are seen in the flatter northern area appear to be caused by flow around large objects. These objects range from 2 to 5 or more meters in size. The majority of them appear round and may be boulders of glacial origin whereas some of the more angular obstacles may be pieces of sunken ships or barges. The scoured areas generally have elevated backscatter, suggesting they are floored by coarser material (Flood, 1999). However, this remains to be determined through grain size analysis.

Sand wave migration, morphological changes, and sediment distribution changes were ascertained by comparing the bathymetric, sun illuminated, and backscatter images of the two surveys. Both surveys were processed using identical vertical and horizontal offsets, pixel size, and resolutions. To establish survey error, comparisons were made of stationary objects. Comparisons were then done of the sand waves, determining what change occurred over the two year period. A comparison of backscatter data was also done to determine any changes in sediment type or distribution. Twenty seven sediment samples were taken during the 2000 cruise to better understand the backscatter patterns.

Initial Results

A horizontal survey error was calculated by identifying objects in both data sets presumed to be stationary, such as the glacial boulders. The difference in position between the objects in both surveys was measured (Figure 2). From this difference the direction and magnitude of the offset was determined. The maximum offset was 3.12 m, and the minimum 0.56 m. The average offset, 1.54 m, is within the acceptable range considering our positions are thought to be accurate to within one meter for each survey. The average offset is greater than 1 m, but the navigation system was not performing optimally during the 1998 survey. The offsets were predominately to the southwest and southeast directions, 7 of the 24 objects moving southwest and 7 objects moving southeast and the other 10 moving in other directions (Figure 3). This comparison suggests that we might expect differences of up to a few meters for stationary objects. However, differences in position of more than a few meters may well suggest that sea bed features have moved.

Once it was determined that the surveys were comparable, the areas near the ridges were analyzed. Both the smaller western ridge and larger central ridge consist of 14 and 15 identifiable sand waves respectively (Figure 4). Sand waves either grew, migrated, changed shape, emerged, disappeared, or remained the same. For each sand wave a beginning and end point was marked on both surveys. The direction and magnitude of sand wave migration as well as any length change was calculated by taking the difference between the positions of the sand waves in each survey. In addition, the locations of distinctive junctions were identified on one of the images and the feature was searched for on the other image.

This procedure was sufficient for determining overall direction and movement, and change in size of the sand waves, however subtle changes in shape have also occurred in certain areas over the two year span. An example of this is sand wave 6 located on the smaller ridge (Figure 5). On the 1998 survey the ridge curves smoothly but by 2000 a bump has formed. A 12.4 m increase in length is also observed. Another aspect of the morphological change occurring in the Mount Misery Shoal area is the apparent rapid migration of some sand waves and appearance of one or more new sand waves. Examples of this can be seen west of the central ridge between sand waves 4 and 6 (Figure 6). These sand waves seem to be moving rotationally, the southern ends appear to be migrating eastward approximately 9 m/yr while the northern ends seem to be migrating westward at a slower rate, approximately 4 m/yr. New sand waves seem to be emerging between sand waves 4 and 5.

Backscatter differences between the two surveys indicate that there has also been an identifiable change in sediment distribution. The 1998 survey has a larger area of high backscatter around the central ridge (Figure 7). Higher backscatter is an indication of rougher, more irregular, or more reflective type sediment. Sediment samples taken during the 2000 cruise from areas of both high and low backscatter suggest that this sediment is coarse sand. However, samples from the higher backscatter areas were significantly larger in volume than samples taken from lower backscatter areas. These small samples collected from the low backscatter areas may be an indication of a much harder substrate there since the sampler was unable to penetrate as far down into the sediments. Further analysis of the samples will help us better explain backscatter patterns found in this area.

Conclusions

Morphological changes were examined through the comparison of multiple multibeam surveys in the Mount Misery Shoal area of Long Island Sound. Analysis of multibeam data demonstrates subtle changes in the sea bed over the two year period, including the appearance of new sand waves and the migration of existing waves. Knowledge about sediment type and substrate was obtained through sediment samples and their associated backscatter values. From 1998 to 2000, changes also occurred in backscatter patterns, which indicate that sediment was transported. Temporal analysis provides information that allows for the estimation of transport trends and rates and this study demonstrates that the comparison of multiple multibeam surveys can provide information about seafloor changes over time in active transport areas.

Figures

Figure 1. Long Island Sound, north of Port Jefferson Harbor (Flood, 1998)

Figure 2. Stationary objects identified on sun illuminated images. Magnification of green box to right of survey highlights stationary objects numbered in red. Instrumental artifacts, straight sharp lines, are seen in 2000 survey.

Figure 3. Direction and magnitude of navigation offset calculated by the difference in position of stationary objects. Axis units are in meters.

Figure 4. Ridges with sand waves as seen on a sun illuminated image. 1998 survey (Flood, 1998)

Figure 5. Sand wave that has changed shape over time. Shape has transformed from a smooth curve in 1998 to one with a bump in 2000 as seen in circled area. Circular anomalies seen in 1998 survey are caused by bad data points.

Figure 6. Change in number and orientation of sand waves, west side of central ridge. Anomalies seen in 2000 image were caused by instrumental artifacts.

Figure 7. Changes in backscatter intensities ass seen around central ridge. Sediment samples collected at positions marked in red. Dark vertical marks are instrumental artifacts caused at the time of data collection.

References

Flood, R.D. (1999). Multibeam Mapping in Long Island Coastal Waters. Geology of Long Island and Metropolitan New York, LI Geologists.