A Shallow-Water Swath Bathymetry System

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LONG-TERM GOAL

Our long-term goal is to understand the processes that create and modify the seabed in the coastal zone and to understand how seabed morphology can be studied using high-resolution swath mapping techniques (for bathymetry and backscatter).

OBJECTIVES

Swath-mapping techniques have proven extremely valuable to the study of sea-floor morphology on continental shelves, slopes and margins, mid-ocean ridges and in the deep ocean, but systems designed for continental shelf and deeper-water environments are not optimized for the shallow-water of coastal settings. Swath-mapping systems optimum for shallow water have recently become available; however, until our system became operational in late 1998 no shallow-water system existed in the U.S. academic community for use in marine research programs. Our objective is to fill this critical gap by obtaining, installing and using a research-grade shallow-water swath bathymetry system that can be moved between vessels as required. This kind of high-resolution morphological data will contribute to ONR programs in the coastal zone such as STRATAFORM and SAX99.

APPROACH

We have assembled a shallow-water swath bathymetry system that uses a Kongsberg Simrad EM 3000 multibeam echosounder which can operate in water depths of 0.5 to over 100 m. Other major system components include a TSS POS/MV (navigation, attitude and heading), Sun and SGI computers (data processing and display), gyroscope (heading), CTD (sound velocity structure) and tide gauge (water

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level). The EM 3000 is a research-grade shallow-water multibeam echosounder that operates at 300 kHz and creates echosounding beams with nominal widths of 1.5° and spaced 0.9° apart. The accuracy of the depth measurement is about 10 cm. The multibeam system can be operated with either one (EM 3000S) or two transducer (EM 3000D) heads. With one transducer head (our standard operational mode), about 120 beams are created, the maximum ping rate is about 20 times a sec and the maximum swath width is four times water depth. When an optional second head is used (we have been able to lease a second head for specific projects), the number of beams doubles, the maximum ping rate is 9 times a second, and the maximum swath width is 10 times water depth. The ratio between swath width and water depth decreases as water depth increases because of the attenuation of the 300 kHz sound in the water. In water depths of 10 m and at a speed of 10 kts, the resulting bathymetric and backscatter data has an along-track spacing of about 20 cm (50 cm when using two heads) and across track spacing of as little as 30 cm. This resolution is sufficient to map medium to large-scale bed forms and other features with dimensions of about 1 meter or more. The EM 3000 also collects backscatter data (side-scan sonar) which is processed with knowledge of seafloor bathymetry. Unlike other some shallow-water multibeam systems, the side-scan sonar record is co-located with the bathymetry record, allowing detailed correlations between bottom morphology and sediment composition. We initially installed our system on the R/V Onrust, a 60-foot research vessel operated by the Marine Sciences Research Center at Stony Brook, but the installation is not permanent and the system can be moved between vessels as research opportunities arise. This project is a cooperative effort between this group and Dale Chayes and Jay Ardai at the Lamont-Doherty Earth Observatory. Chayes and Ardai support the installation of this system on the R/V Onrust and other vessels through a separate contract from ONR while Flood owns and operates the equipment and directs the scientific operations.

WORK COMPLETED

The items in our basic system have been integrated into a system for use on the R/V Onrust and other vessels. The system is portable: the system, including transducer, has been removed from (and reinstalled on) the R/V Onrust a number of times. Also, we have installed the system on four other vessels: the R/V Clifford A. Barnes (University of Washington), the R/V Coral Sea (Humboldt State College), the R/V Tommy Munro (University of Southern Mississippi) and the R/V Prichard (a 28' aluminum work boat recently acquired by MSRC). We will soon (fall, 2000) be installing the system on the R/V Sea Wolf, a new 80' vessel at MSRC acquired to replace the R/V Onrust. We are using the SwathEd software package of the Ocean Mapping Group, University of New Brunswick, on our computers for post-processing and display of multibeam data. The SwathEd software package is optimized for rapid data reduction, allowing preliminary survey results to be available by the end of the cruise. The data products can be further processed and displayed by other packages such as GMT, ArcInfo and Adobe Illustrator.

In addition to local trials, we made two short research cruises as part of this project. We surveyed in the New Jersey STRATAFORM area in fall, 1998, to collect EM 3000S data in an area previously surveyed with an EM 1000 multibeam system (water depths ~10 to 200 m). We also installed our EM 3000 system on the R/V Coral Sea (Humboldt College) using a pole mount in September, 1999, to survey along the inshore end of the STRATAFORM S-Transect (water depths ~6 to 50 m). The portion of this survey deeper than 40 m overlaps with the EM 1000 survey previously done in this area.

RESULTS

Initial results of our surveys have demonstrated the high quality of the EM 3000 depth, backscatter, and imagery data and the range of morphological elements resolvable by the system (Figure 1). Indeed, our results have already provided new insight into the range of processes important for generating the morphology of the sea floor in the coastal ocean. We have used the system at speeds up to 10 knots and up to sea state 5. We have been able to resolve small-scale features in water depths to at least 100 m, and we have found a number of shipwrecks, most of which are not shown on existing charts. Sedimentary moats found around many of the shipwrecks suggest long-term sediment transport directions. Other morphological elements resolved include large and small sand waves, boulders with moats, bedrock outcrops, sand mining pits, drag marks, buoy anchors, debris dropped by barges and cargo ships, and unusual morphology apparently created by a hard-substrate communities (including corals and sponges).

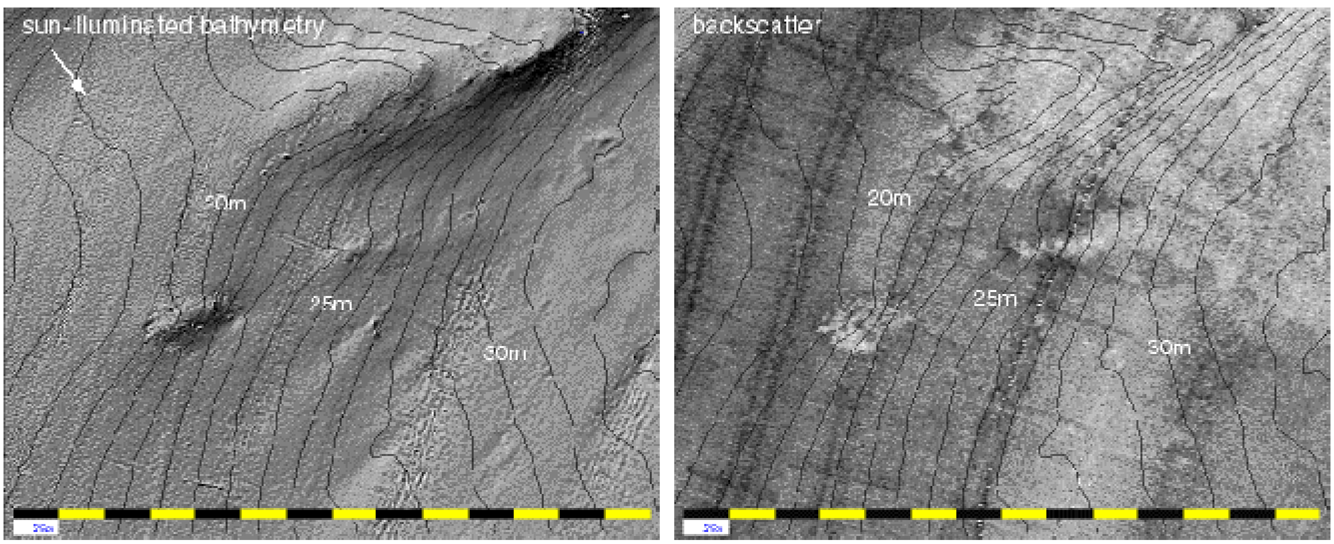

Figure 1. Example EM 3000 multibeam images from western Long Island Sound collected as part of the MSRC REU program.

Left: image of seabed morphology created by synthetically shining a light across the bottom topography from the upper left (sun-illuminated bathymetry). One meter contour intervals are labeled.
Right: image of backscatter for the same section of the seabed (higher backscatter is lighter gray shade). Ship tracks trend NNE-SSW; gridding interval is 1 m. The images show natural features (e.g., east-west ridge in upper part of image with probable outcropping bedrock and sediment tails) and man-made features (e.g., circular feature in upper right that was probably created by debris dumped by a ship). Sediment tails behind small features on the sun-illuminated bathymetry show bottom flow to the lower left. Some of the topographic features in the sun-illuminated bathymetry are associated with backscatter anomalies, but many are not. Similarly, not all areas of high backscatter are associated with bathymetric features. Alternating bands on scale bar are each 25 meters wide.

IMPACT/APPLICATIONS

Our work to date clearly demonstrates the high quality of the data generated by our research-grade EM 3000 multibeam system as well as the importance of multibeam data in understanding seabed morphology in the coastal regions. Our system will provide important data in support of studies into a number of acoustical and environmental problems. The system can be installed on a variety of vessels after the design and installation of appropriate mounting systems.

TRANSITIONS

We have moved from the testing and evaluation phase to the application phase, and we are applying our research-grade shallow-water multibeam system to a number of coastal problems.

RELATED PROJECTS

This EM 3000 system was used in two additional surveys in late 1998. Shinnecock Inlet (Long Island south shore) was surveyed as part of a study of inlet dynamics being undertaken by WES (Waterways Experimental Station, US Army Corps of Engineers). Also, about 20 miles (two segments) of the Hudson River were surveyed as part of a NYSDEC (New York State Department of Environmental Conservation) study of benthic habitats. Some of our survey data from the New Jersey STRATAFORM site will also be used to support the scientific drilling programs being proposed by Austin, Mountain, and others. Additional studies undertaken in 1999 include continued mapping of the Hudson River under NYSDEC support (40 river miles have now been mapped), mapping from about 10 to 40 m water depth off Grays Harbor (southwest Washington State, supported by the Washington State Department of Ecology; we used a dual-head system for this survey), and as part of the ONR-supported High Frequency Sound Interaction in Ocean Sediments DRI (SAX99) off western Florida. Participation in educational programs includes classes with SUNY Stony Brook WISE (Women in Science and Engineering) and UREC (Undergraduate Research program) students as well as participation in the MSRC/SUNY Research Experience for Undergraduate (REU) programs. Users of our multibeam data for both the SAX99 and the Washington State studies say that our results caused experiments using bottom-mounted arrays to be revised to take into account local topography. This kind of impact is possible using our system because preliminary results of the survey are available shortly after the survey is completed.