Sea Technology

Seafloor Mapping
Sonar Systems
Vessels

FEATURING:
Real-Time 3D Imaging
Aquaculture Bathymetry
Arctic Ships
For many years, extreme shallow water areas (0 to 5 m) were considered to be so dynamic that mapping them, given the survey inefficiencies, navigation hazards and operational costs, was prohibitive. The maps are obsolete before the boat makes it back to the dock, was the commonly heard maxim. However, nearshore shallow-water environments are invaluable coastal resources; estuaries in particular are among the world’s most productive ecosystems, and mapping the seafloor can provide useful information with regard to benthic habitats, ecosystem state, aquaculture status, sediment transport and other biological, chemical and physical characteristics and processes. These data, while critical to other scientists, modelers and engineers, are becoming increasingly central to coastal resource managers.

The combination of extreme shallow-draft survey platforms and phase-measuring side scan sonars (PMSS) allows for mapping of the seafloor in areas otherwise difficult to obtain synoptic, quantitative 2D and 3D data. Further, acoustic methods have long been used to map in environments inhospitable to optical methods such as LiDAR, vertical aerial photography and other multispectral data. Turbid waters in many nearshore environments prevent optimal performance due to limited penetration through the water column. In addition, LiDAR, as of yet, provides only elevation information, though experimental data layers similar to side scan imagery are in the early stages of development. A PMSS allows for both high-resolution side scan imagery and bathymetric data in extreme shallow and/or turbid waters.

The Coastal Processes and Ecosystems (CAPE) Lab, a joint research laboratory between the School for the Environment at University of Massachusetts, Boston and Seafloor Mapping Program at the Center for Coastal Studies in Provincetown, Massachusetts, is working on projects in extreme shallow waters, mainly 0- to 5-m depth.

Terminology

The primary acoustic instrument for shallow-water seafloor mapping in the CAPE Lab is the EdgeTech 6205, a phase-measuring side scan sonar, which has been in use since 2014. Given the evolving nature of the industry, terminology continues to evolve and has led to confusion when referring to this newer technology. The term “interferometric sonar,” while prevalent, refers to an older method of measuring the phase difference of the returning acoustic energy. The term “phase-differencing bathymetric sonar” could be construed as redundant, as all phase-differencing sonars yield bathymetry, but perhaps
more importantly does not emphasize that a “true” side scan sonar is the primary instrument. We propose to use the term “side scan sonar” and the modifier “phase-measuring,” yielding: “phase-measuring side scan sonar.” “Phase-differencing side scan sonar” is also used, and seems synonymous with PMSS, but we prefer the latter. EdgeTech refers to these instruments as multiphase echosounders (MPES).

Setup

The operating frequencies for our instrument are 550 and 1,600 kHz for backscatter (collected simultaneously) and 550 kHz for bathymetry. The side scan sonar range resolution is 1 cm, and the horizontal beam width is 0.5° at 550 kHz. The corresponding quantities at 1,600 kHz are 0.6 cm and 0.2°. The bathymetric range and vertical resolution are both 1 cm. The respective bandwidths at 550 and 1,600 kHz are 67 and 145 kHz. A Teledyne TSS DMS-05 motion reference unit (MRU) mounted on the sonar collects data on heave, pitch and roll, measuring heave to 5 cm and roll and pitch to 0.05°. A Hemisphere GNSS V110 vector sensor is used to measure heading. Two differential GPS receivers spaced 2 m apart yield heading accuracies of less than 0.10° RMS. A Trimble GNSS receiver utilizing real-time-kinematic GPS (RTK-GPS) is used for positioning and tide correction for vessel-based surveys. Ideally, both GPS units are mounted onto the survey pipe that holds the sonar and MRU. The Cape Lab has multiple research vessels from which to conduct acoustic surveys, ranging from medium-sized, shallow-draft vessels (e.g., 8.2 m loa, 0.5-m draft) to an extreme shallow-draft pontoon boat (4.3 ft. loa, draft 0.15 cm).

Projects

A tidal restoration project for the Herring River in Wellfleet, Massachusetts, is in the design and analysis stage. Salinity in this small tidal estuary ranges from 0 ppt at the head of the river to 32 ppt at the tidal restriction that controls flow between the estuary and Wellfleet Harbor. The estuary is largely within Cape Cod National Seashore, is very shallow and has no boat ramps or access points. The pontoon boat was deployed and retrieved via a low sloping hillside into the water.

The survey was funded by the Massachusetts Division of Ecological Restoration (Mass-DER) and conducted on board the pontoon boat June 2016. More than 9 km of

(Top) Data from Herring River Estuary, Wellfleet, Massachusetts. Left: raw side scan imagery (1,600 kHz). Height above bottom ranges from 10 to 50 cm. Upper right: still imagery taken from underwater video of widgeon grass, approximate location denoted by arrow. Lower right: single line of bathymetry from same area shown in side scan imagery to the left. (Bottom) Upper: side scan imagery (550 kHz) of lobster pot trawl. Lower: same area with single line of bathymetry overlain. Line can be seen in bathymetry, denoted by arrows.
survey lines were needed to map 10.6 hectares with an average depth of 0.8 m. The average height above the bottom at nadir was 0.73 m and ranged from 0.10 to 4.9 m. The sonar performed well at these shallow depths. Typical swath widths of side scan imagery were 40 and 24 m for the 550 and 1,600 kHz, respectively, with approximately 90 percent of that swath width being usable.

At 0.10 m above the bottom, approximately 90 to 95 percent of the 24-m swath from the 1,600-kHz frequency was usable.

The changes in salinity in the Herring River estuary mentioned above did not render the data unusable or noticeably degraded. Some survey lines were collected from the head of the river to the mouth, and changes in salinity were not detectable based on visual inspection of the side scan imagery or bathymetric data.

With regard to bathymetric data, our experience with this instrument suggests a consistent usable swath width to depth ratio between 6:1 and 8:1, in 0 to 10 m of water. While the data are noisier than those from multibeam echosounders, and hand cleaning of PMSS data is more time-consuming, our operators have found that 6 hours’ worth of survey data will require approximately 8 to 10 hr. of processing, including filtering and hand cleaning. This is a generalization, and the time needed can be much longer given equipment problems, environmental conditions and other expected survey complications. However, it should be noted that the PMSS technology can map the seafloor at a higher rate than the MBES, in most cases two to three times faster. Therefore, the ratio of area mapped versus processing times is comparable to MBES, and the survey times are significantly reduced and have the added benefit of co-registered side scan imagery. The processing times for the imagery are consistent with traditional side scan instruments.

Recent and ongoing projects funded by NOAA and the National Fish and Wildlife Foundation (NFWF) to locate, identify and retrieve derelict fishing gear using vessel-based acoustic methods have demonstrated the utility of PMSS. The co-location of these data sets allow for detailed 2D and 3D spatial analyses of these areas and are often complementary. For example, the side scan imagery is of high enough resolution to clearly identify lobster pots, the connecting line (2.54-cm diameter), slight variations in bottom grain sizes and small oscillatory ripples (30- to 40-cm spacing). However, the bathymetry shows that the areas of finer grain sizes are up to 50 cm higher than the surrounding area; this is at first counterintuitive. Cape
Cod, in southeastern New England, is a glaciated coast, and these finer-grained areas are likely outcrops of more erosion-resistant glacial material. The bathymetry alone would still allow for identification of targets that may or may not be lobster pots, but the bathymetry coupled with the side scan imagery is determinative and together provides information not attainable with either data set alone.

Some of this derelict fishing gear has been submerged for decades and now provides habitat for aquatic life. Scuba divers were used to collect information about the state of the gear and surrounding habitat, collect images and video and sediment samples, and aid in retrieval. Combining diver and acoustic surveys has provided useful information to ascertain the habitat value and extent with regard to derelict fishing gear, as well as ground-truthing the acoustic data.

Coastal municipalities are performing more nearshore resource assessments in order to balance the economic drivers of coastal and ocean tourism with responsible stewardship of these ecosystems. Keeping shallow navigation channels open while avoiding protected submerged aquatic vegetation (SAV) is difficult to perform and document. Typically, one would collect bathymetry to do a pre-dredge survey in a navigation channel or a traditional side scan sonar to map eelgrass beds, however, when both were needed, the PMSS allowed one survey to collect both co-located data sets.

The Town of Chatham, Massachusetts, was concerned about maintaining a heavily used, shallow navigation channel and potential impacts to eelgrass beds. A shallow-water survey was done August 2017, and the eelgrass beds were clearly identified on the side scan imagery, as well as in the bathymetry. The identification of the SAV as eelgrass would have been problematic with only the bathymetric data, and a pre-dredge survey with a side scan sonar would not provide the 3D data needed. These co-located data sets also provide useful information with regard to sediment transport pathways (erosion and accretion), anthropogenic impacts to SAV, and other issues of interest to managers.

Coastal resources are under increasing pressure from development, tourism and competing uses. These stressors are compounded given the current regime of climate change and projected rates of sea level rise and the increasing frequency and magnitude of coastal storms. Mapping these extreme shallow water environments provides much needed quantitative, spatial data to develop largely unavailable baseline inventories of these resources but also to measure future change in a rigorous and repeatable way. Phase-measuring side scan sonars coupled with shallow-draft survey platforms is one way to collect these data rapidly, efficiently and safely.