Utilizing Autonomous Underwater Vehicles for Seafloor Mapping, Target Identification, and Predictive Model Testing: Updated Results of the Indian Rocks Beach Experiment and Subsequent Activities

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LONG-TERM GOAL

Our long-term goal is to define and then understand how the present shallow seafloor is represented physically (texturally and topographically) and biologically (distribution/structure of benthic communities) in the present state on small (m) and large (km) spatial scales. In conjunction, it is our long-term goal to understand how the modern seafloor evolved in geologic time to its present condition. Finally, it is our long term goal to understand the physical and biological changes of the seafloor on short temporal scales (minutes to decades) to ultimately predict and model seafloor evolution.

OBJECTIVES

Three goals were outlined for ONR N00014-96-1-5032: 1) testing AUV deployment and multisensor remote sensing capabilities during different hydrological conditions (operational mode); 2) seabed classification and target identification using the AUV remote sensing capabilities (applied mode); and, 3) using the seabed classification data for incorporation into, and refinement of, existing mine burial models thereby facilitating greater predictive capabilities. Specific objectives of this experiment were:

1) Perform several deployments of the AUV Ocean Explorer (OEx) with 100 and 390 kHz chirp side-scan sonar, 8 mm video, and magnetometer in the Indian Rocks Beach test bed area.
2) Compare OEx acquired data to data acquired by surface towed vehicle (ship-towed side-scan sonar) and fixed-platform rotary side-scan.
3) Evaluate the performance (stability, navigation, etc.) and data acquisition capabilities of the OEx under low and high energy conditions.
4) Evaluate the evolution of the seabed in response to changing energy conditions accompanying frontal passage, and the effects on mine or bomb burial.
5) Evaluate mine detection capabilities.
6) Test OEx and ambient noise sonar array experiment.

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7) Test OEx with turbulence package.
8) Test OEx in conjunction with coherent path acoustic experiment.
9) Test ship-towed mine detection sonar.

Objectives 2 and 4 (above) included the following specific objectives of the USGS component of this experiment:
1) provide ground-truth bedform information from rotary sidescan sonars on two bottom mounted towers.
2) observe and quantify the temporal evolution of the bedforms and bottom roughness over storm events.
3) acquire sufficient wave, current, and boundary layer flow field data to interpret the processes responsible for the observed bedform migration, wave-current friction factors, and sediment transport.
4) acquisition of comprehensive meteorological data from a land-based station located immediately shoreward of the experiment site.
5) acquisition of velocity data from bottom mounted sensors at a high frequency for comparison with AUV mounted turbulence probes.

APPROACH

Between February 17 and March 7, 1998, experiments were conducted offshore of Indian Rocks Beach and Clearwater, Florida (Fig. 1) under the auspices of the University of South Florida, Florida Atlantic University, and the U.S. Geological Survey. Subsequent activities were performed by Naval Research Laboratory personnel on August 28, 1998. Experiments were designed to meet the objectives outlined above.

WORK COMPLETED

This experiment required the coordination of several different research vessels including the *R/V Suncoaster* (Florida Institute of Oceanography), the *R/V Subchaser* (USF-Department of Marine Science), the *R/V Price* (USF-Department of Marine Science), the *R/V Gilbert* (USGS-Center for Coastal Geology) and the autonomous underwater vehicles *Ocean Explorer Magellan* and *Ocean Explorer Drake* (FAU-Department of Ocean Engineering). The *R/V Seward Johnson* (Harbor Branch Oceanographic Institute) subsequently performed research activities in the area.

Instruments deployed included: ship-towed EG&G Model 272 DT 100/500 kHz side scan sonar; AUV-mounted 100/390 kHz side scan sonar, magnetometer, 8 mm video, CTD, turbulence package, and acoustic modem; long baseline acoustic transponder array; passive sonar array; coherent beam path instrument; 2 rotary side-scan sonar towers with optical backscatter sensors, triaxial current sensors, and pressure gauges, and; 2 acoustic doppler profilers.

Targets deployed included: 3 inert Mk 52 mines (2 buried, 1 exposed); 3 inert Mk 82 bombs (1 buried, 2 exposed); 6 10" x 60" mine-like objects (exposed); 2 side-scan sonar towers w/battery packs also served as targets, and; 2 ADPs also served as targets.

Data acquired includes: ship-towed 100 and 500 kHz side scan sonar data (full coverage) in N-S and E-W directions; AUV-acquired 100 and 390 kHz side-scan sonar mosaics in N-S (full coverage) and E-W (partial coverage) directions; AUV-acquired bathymetry, current data, magnetometer data, and video; sound velocity profiles; 2.25 MHz rotary side scan sonar data from towers; passive sonar data;

coherent beam path data; sediment porometry data; sediment grain size data; sediment mineralogy; current data; wave data; water temperature; wind data; barometric pressure.

RESULTS

Objective 1: The Ocean Explorers Magellan and Drake were launched and recovered numerous times in the Indian Rocks Beach test bed area, and in lower Tampa Bay. A number of technical problems were encountered, most of which could be traced to human error. The Ocean Explorer Magellan successfully completed two side-scan sonar surveys of the area using an onboard doppler velocity logger for navigation. The first survey was during calm weather, the second was during a high energy event accompanying frontal passage.

Objective 2: Considerable surface-towed data were acquired at 500 kHz and 100 kHz in north-south and east-west directions. 500 kHz data were also acquired of the same area one month later (April 3, 1998). These data are being compared to each other and to data acquired in preceding years (OEx '97 experiment and data from Harrison, 1996) to assess temporal seabed variability, possible sand ridge migration, the nature of mine burial, and the degree of navigational error inherent in these surveys. Data were also acquired from fixed rotary side-scan towers in the area which demonstrate the mobility of the sediment and the nature of bomb burial. These data are in the process of being compared to the AUV acquired data.

Temporal comparisons reveal that there are distinct variations in the distribution of sediment components on the seabed on an annual basis. The transition between poorly sorted coarse sediment patches (mostly gravel size carbonate grains) and sand bodies (sand waves and ridges) may shift by as much as 10-20 meters during the course of a year. The response to storm energies is such that 1 meter wavelength bedforms are produced in the coarse sediment, sediment transitions may migrate up to 10 meters, and scouring occurs around mines and other objects on the seafloor. Mine and bomb burial appears to be facilitated by a combination of scouring around the object during high energy events, followed by settling of the object, then deposition of sand within the scour pit under low energy conditions. Comparison of data acquired during repeated passes over the same area indicate that navigational error inherent in our system may account for navigational inaccuracies on the order of 5 meters.

Objective 3: Data acquired from the different platforms are currently being processed and evaluated. The stability of the AUV platform under low energy conditions (<1 meter seas) appears to be excellent. Stability under higher energy conditions (1 meter seas) was poorer but could have been improved by cruising deeper. Navigation was performed using differential GPS and an onboard doppler velocity log (DVL). Both systems performed well. Problems were encountered with the long baseline system (LBL) so navigation by LBL was not accomplished.

Objective 4: A high energy event occurred during the final day of the cruise. Winds were out of the northwest at 20-30 knots with seas running approximately 1 meter. Data during this time period have been analyzed for bottom impacts. In addition to the storm related data collected by the AUV missions, detailed information regarding evolution of bedforms during the same cold front passage and a subsequent cold front on March 20-21 was obtained from bottom mounted instrumentation. Data were recovered from the two bottom-mounted ADPs, the seabird wave gauges associated with those ADPs, from the shore-based meteorological station, and from the ADVOcean, pressure sensor, OBS, and two sonar systems mounted on the rotary sidescan sonar towers. Following is a summary of those data:

The sonar bottom images and transects collected every four hours show a remarkable variety of bedform size and shape, from 5 cm crest-crest ripples to 2-4 m wide sand waves and scour pits. There were several periods in which the sand bedforms show multiple scales and directions. A movie presentation of the sonar images and accompanying wave/current information can be found at; http://www.marine.usf.edu/margeo.html

The corresponding wave data in most cases did not show a corresponding multiplicity of scales and directions. This observation is in agreement with the wavetank studies of Wilson and Hay (1995), but is counterintuitive, and suggests the need for further investigation.

In general, the bedforms correspond to those observed in much shallower water (1-3 m depth) with the exception of the sand waves and scour pits, which lack the regularity of the linear and lunate mega-ripples observed in the nearshore. Sand ripple size, spacing, pattern and heights were measured by hand for each image. The ripples sizes were compared to existing empirical models, and ripple patterns were classified according to a scheme originally derived by Clifton (1976) and modified by Wilson and Hay (1995). Ripple patterns were compared to estimated bed shear stress and found to follow the ranges derived in the nearshore and wavetank (Wilson and Hay 1995).

Three months of ADP data from two bottom mounted locations demonstrate strong tidal modulation of longshore velocities, the passage of 7 storm fronts, and the rectification of the tide by southward flowing coastal currents. There does not appear to be significant Ekman spiral in the data. The velocities do increase from bed to surface, in general. This demonstrates that the experiment location is in a wave-current regime in which bottom and surface boundary layers overlap frequently. There appears to be a cusp in the speed/depth profile at 2.5 m above bottom which is consistent with tide boundary layer thickness. Model estimates of sediment transport and observations from OBS, ripple migration, and ADV-Ocean amplitudes are still being processed.

Objective 5: The AUV-mounted side-scan sonar data are still being processed, but it is apparent that the data resolve man-made targets on the seafloor (bombs, mines, rotary side scan towers, battery packs, ADPs). These targets were also acquired using the ship-towed 500 and 100 kHz side scan sonar. However, targets are not always readily distinguishable from natural objects. A firm understanding of the local geology is vital to the recognition of the targets, and additional sensors are important. Video was rendered useless by high water column turbidity. Magnetometer data are still being processed.

Objective 6: Excellent data were acquired using the passive sonar array. These data are available online at http://www.oe.fau.edu/~acoustics/usf1.htm

Objective 7: Problems with the OEx Drake with the turbulence package prohibited acquisition of turbulence data.

Objective 8: Tests of the OEx with the pinger experiment were successful.

Objective 9: Instrument problems (temporary loss of towed vehicle off of Boca Raton) required us to reschedule this experiment for the Fall of 1998.

IMPACT/APPLICATION

These data are aiding us in our understanding of the temporal variability of the distribution of sediment components in the nearshore environment and the mechanisms responsible for those variations. The result is a greater understanding of the nature of mine burial, and a database that is being used for testing predictive models of mine burial. This experiment also provided vital field testing of AUV components, and performance evaluations, under highly variable weather conditions and sea states.

TRANSITIONS

We are preparing for a Fall experiment in the Navy Test Range offshore of Ft. Lauderdale which will allow further evaluations of AUV components including mini-AUVs and docking stations.

We are transitioning into a project to determine the characteristics of suspended sediments, resuspension mechanisms, and their influence on optical remote sensing in a new study area off of Sarasota, Florida.

RELATED PROJECTS

1 - The West Florida Shelf project is a collaborative project between USF and the USGS that is focusing on sediment distribution on the shelf in this area.

2 - Mark Hafen at USF is preparing a Ph.D. dissertation which focuses on the controls on the distribution and morphology of sand bodies on the West Florida Shelf, including the IRB study area.

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