An Exploration of the Potential for 'Opti-Acoustic' Seabed Classification

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LONG-TERM GOAL

Seabed classification is the organization of the seafloor and shallow subsurface sediment into classes based on defined characteristics (Collins et al. 1996). Optical and acoustical data processing are two powerful remote sensing techniques for sea floor classification. Our research goal is to explore the potential for the fusion of these two data sets to extend classification capabilities beyond traditional methods.

OBJECTIVES

Specific objectives are (1) to evaluate the utility of optical and acoustical mapping for shallow water bottom mapping using feature extraction and statistical processing methods; and (2) to evaluate the utility of integrated "opti-acoustical" processing in relation to individual optical and acoustical methods. This work represents a research collaboration between the University of Miami and Quester Tangent Corporation (QTC).

APPROACH

The primary field site for the research is Lee Stocking Island (LSI), Bahamas. The work builds on initial data collected as part of ONR's Coastal Benthic Optical Properties (CoBOP) program. Airborne hyperspectral data for the LSI area, which were collected using NRL's Portable Hyperspectral Imager for Low Light Spectroscopy (PHILLS) imager in 1999 and 2000, serve as a baseline for survey design. A second study area is the Andros reef tract, in the vicinity of the AUTEC Naval base at Freshwater Creek, Andros Island, Bahamas. A few lines of PHILLS data were collected in the Andros area during CoBOP in May 2000.

The research program brings together tools to acquire and process optical and acoustical data. A shallow water acoustic data acquisition package (QTC VIEW^{tm}) integrated with a global positioning system (GPS) is configured to collect and digitize backscatter data from the seabed. A Satlantic hyperspectral tethered spectral radiometer buoy (HTSRB) is used to acquire hyperspectral data from the sea floor simultaneously with the acoustic system. Underwater digital video recordings are also collected to serve as ground truth data for acoustic and HTSRB classification. Survey lines are set to

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14. ABSTRACT **Seabed classification is the organization of the seafloor and shallow subsurface sediment into classes based on defined characteristics (Collins et al. 1996). Optical and acoustical data processing are two powerful remote sensing techniques for sea floor classification. Our research goal is to explore the potential for the fusion of these two data sets to extend classification capabilities beyond traditional methods.**					
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cross as many distinct bottom features as possible. All data are logged and quality assurance is performed in the field. Post-acquisition processing is carried out in the laboratory.

Sonar data are processed using QTC IMPACT^{tm} software. In this application, the window surrounding only the first echo is analyzed by a series of algorithms that derive 166 feature descriptors (Collins and Lacroix 1997). Some of these features are based on echo shape, and others on spectral characteristics. The echo waveform is rich in bottom information because backscatter coefficients are particularly responsive to the physical properties of sediments when insonofied by near-normal sonar (Bornhold et al. 1999; Preston et al. 1999). Principal components analysis is used to reduce the information to three "Q" values representing linear combinations of the features most useful in distinguishing seabed types. Points defined by the three Q coordinates are plotted in 3-dimensional space for visual inspection of clustering. Class assignments are based on multivariate distances between echoes to be classified and clusters representing the acoustic properties of selected seabed types.

In a novel approach to analyzing optical data collected using an HTSRB, we will apply methods of acoustic sediment classification to HTSRB data. QTC IMPACT^{tm} will be used to classify HTSRB data based on feature extraction and multivariate statistical analysis of spectral shape. Following classification, data are plotted to generate maps of benthic diversity.

An additional processing technique that will be investigated is integrated "opti-acoustical" processing. This will require concatenation of the individual feature sets to generate a combined feature set. Multivariate statistical processing will be performed on the integrated data. An "opti-acoustical" diversity plot will be generated and a correlation analysis will be made with the individual classification plots.

The final component of data processing will be an evaluation of results against ground-truth data. Video data will be classified independently and compared to optical and acoustic classification maps. Additional ground-truth information will be collected in a field program in spring 2002. All data will be compiled and presented in GIS format.

WORK COMPLETED

The project commenced April 1, 2001. The first six months have been devoted to instrumentation acquisition, training, and data collection. Purchase and training in use of the QTC acoustic system in April and May 2001 were followed by a field program at Lee Stocking Island in June. Acoustic, HTSRB, and video data were collected at LSI along survey lines that cover the entire area spanned by CoBOP PHILLS flight lines (Figure 1). Field data are currently being processed, as discussed below. A second field program is scheduled at Andros Island during October 2001.

The June 2001 survey was designed with a hierarchical spacing of transect lines (Figure 1). Selected regions that were studied intensively during CoBOP (Reid 1999, 2000; Louchard et al. submitted) were surveyed at high resolution. Region A (Fig. 1), west of Normans Pond Cay, was covered at 400x400 m spacing. Region B (Fig. 1), between LSI and Normans Pond Cay and northwest of LSI was surveyed at 200x400 m line spacing. Region C (Fig. 1), covering Adderly Cut and the Rainbow South area of the CoBOP closure experiment, was surveyed at 100x100m line spacing. A small area over the Rainbow Gardens Reef, region D (Fig. 1), was covered at 10x10m line spacing. This hierarchical design of survey grids will allow us to investigate the effects of line spacing on classification results. The results will be important in efficient planning and design of future surveys.

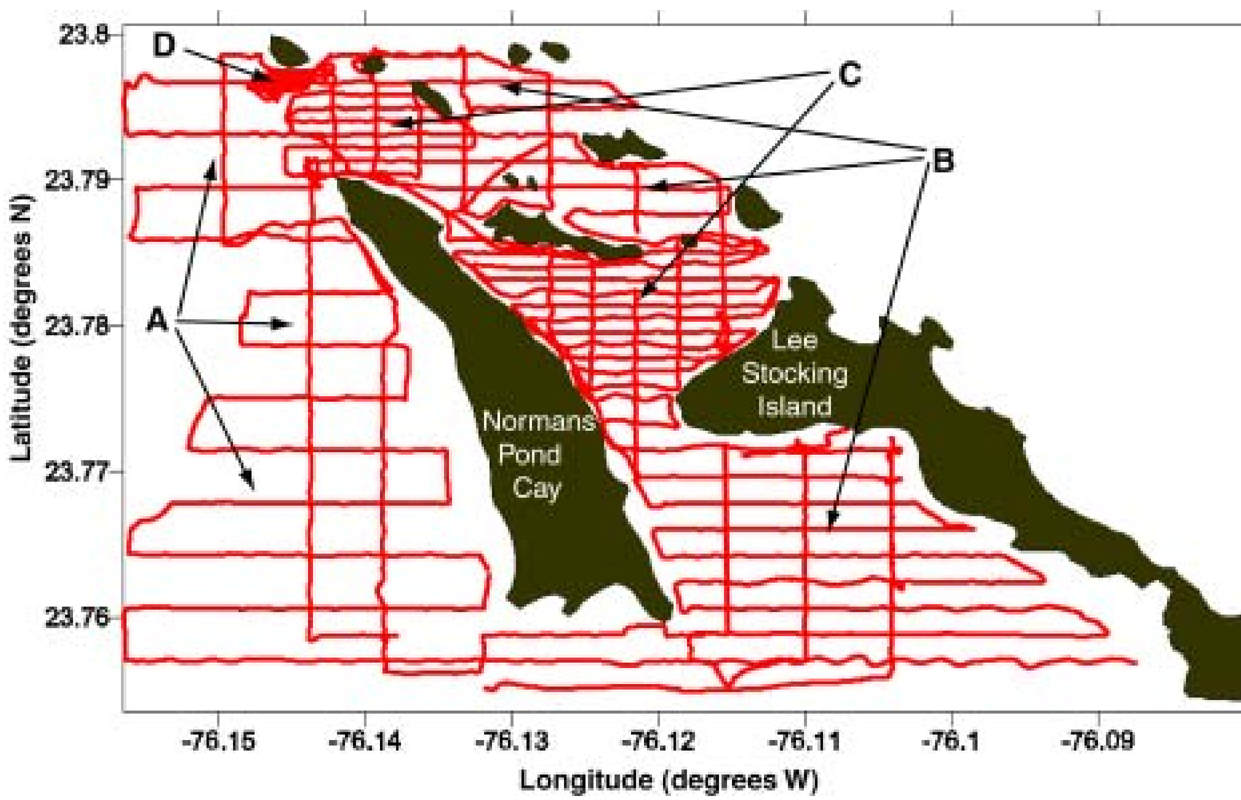

Figure 1. June 2001 survey lines
(Acoustic and hyperspectral HTSRB data were collected along transects (red lines) in the vicinity of Lee Stocking Island, Bahamas between June 16 and 20, 2001. Islands are drawn in black. The overall extent of the survey corresponds to the area acquired by the PHILLS instrument during CoBOP in 1999 and 2000. Regions A-D have hierarchical line spacing,as described in the text.)

RESULTS

Quality control and analysis of the data collected at LSI in June 2001 are underway. All of the digitized acoustic waveforms have been processed by QTC's IMPACT software to merge navigation information and reduce the 166 feature descriptors derived from each waveform to their first three principal components. Quality control of these data, which consists of filtering echoes that have not been bottom picked correctly, has been completed for about 60% of the survey lines. Erroneous bottom picks can arise from too much wave motion rocking the boat, or very shallow water, less than 1 meter below the transducer. Error rates to date have been low-- less than 1% of the total data collected. We have performed some initial unsupervised classifications within IMPACT to verify the data were acquired and processed properly, but have not progressed to the point where we can interpret the results of acoustic classifications with confidence.

HTSRB data is being prepared for classification using a new software program developed for this project by Curt Mobley, Sequoia Scientific, to back-calculate upwelling radiance (L_u) from the depth of the sensor (60cm) down to the bottom. The software, AO 1.0, is a modified version of Hydrolight. It applies an iterative process to estimate bottom reflectance from measured upwelling radiance, water depth, and water inherent optical properties. All data must be truncated at the same wavelength to ensure the QTC software will not classify bottom types based on wavelengths attenuated by deeper water. Quester Tangent has finished writing an interface to import the normalized HTSRB data into IMPACT, and they are working on an interface that will import, concatenate and classify co-located acoustic and optical waveforms.

A number of steps remain before useful products can be generated. Quality control needs to be completed on the acoustic and hyperspectral data. Classifications of each of these data sets will be generated for the entire area. These classifications initially will be assessed using interpretations from the video as ground truth, as well as internal statistical measures such as consistency of classification at tie line intersections. The final product will include independent acoustic and optic classifications as well as a combined opti-acoustic classification. We will return to LSI in spring 2002 to validate the classified maps.

IMPACT/APPLICATION

We anticipate that this research will lead to identification of benthic parameters, including physical properties that cannot be differentiated using optical and acoustic signatures individually. By using optical and acoustical technologies in tandem within the photic zone, classification schemes may be extended beyond water depths where significant spectral reflectance can be detected by optical sensors on airborne or satellite platforms.

The novel and potentially key use for this new data type (opti-acoustic sea floor diversity) will be as support for an integrated (physical, chemical and biological) geo-spatial model of the target environment. Once validated at a small scale, this technique can be used to characterize broader tracts of sea floor quickly and systematically.

TRANSITIONS

The results to-date suggest that optical and acoustical data can be acquired simultaneously with limited negative impact on data quality or efficiency of acquisition. The successful outcome of technology and data integration will be a system capable of greater resolution of seabed diversity. The system will establish a key link between airborne and satellite remote sensing techniques and direct seabed sampling. We expect such a system to be used by those responsible for large-scale systematic mapping of shallow marine environments. The increased sea floor resolution offered by the opti-acoustic system will also support rapid, detailed environmental assessment for site specific investigations.

RELATED PROJECTS

Our research on opti-acoustic sea-floor classification is closely related to the CoBOP program. In particular, the opti-acoustic research will generate a bathymetry map for shallow water areas in the LSI vicinity, which will aid interpretation of PHILLS hyperspectral imagery, collected as part of CoBOP (e.g. Louchard et al, submitted). In addition, PHILLS imagery provides an additional data set for optical bottom classification, which can be compared with acoustic, video, and HTSRB classifications in the opti-acoustic study. HTSRB measurements in the opti-acoustic study are compared with *in situ* reflectance measurements made using the DiveSpec underwater spectrometer, which was developed by Charles Mazel (Physical Sciences Inc.) as part of CoBOP.

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