Quantitative Side-Scan Research for Sediment Characterization and the Development of a Multibeam Subbottom Profiler

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LONG-TERM GOALS

The long-term goals of this work are to contribute to the understanding of bottom backscatter at high frequencies, provide techniques for determining sediment characteristics based on backscatter, and to support experiments within the context of the high-frequency, underwater communications and bottom scattering experiments such as KauaiEx and SAX04. An additional goal, recently established for this project, is to contribute to an improved understand of shallow-subbottom backscatter at mid-range frequencies.

OBJECTIVES

Our main objective is to contribute to the understanding of seafloor backscatter at high and mid-range frequencies. Additionally, in support of bottom scattering projects, another principal objective is to provide wide-area, high-resolution data to describe the nature of the bottom/subbottom and to develop a means of classifying bottom characteristics based on backscatter signals. These objectives require an understanding of the statistical nature of the backscatter signal and how to delineate changes in the bottom based on changes in the statistics of backscatter through the collection of several data sets including KauaiEx and SAX04 data. This work contributes particularly an understanding of the broad-area, spatial variation of the statistics of backscatter. Often bottom-scattering is determined for a series of isolated bottom points with little or no spatial connectivity.

APPROACH

The main focuses of our work in FY06 were to further the high-frequency backscatter analyses of the KauaiEx and SAX04 data and to plan and construct the Multibeam SubBottom Profiler (MSBP) that was initiated later in FY05 by ONR with Defense University Research Instrumentation Program (DURIP) funding. Several presentations were made as a result of these analyses and several are pending. A paper was completed on the Kauai work and submitted. No new data collection efforts were initiated in FY06. Other resources to support new data collection have been sought and secured for new surveys in early FY07.

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WORK COMPLETED

Further analyses of data collected for the KauaiEx and SAX04 experiments were carried out that resulted in several presentations and a paper [1-3]. Ref. [3] is a paper recently submitted to IEEE that is based on an analysis of the backscatter data at KauaiEx that developed a technique for determining the properties of sand ripples, including their height, which normally is not available from backscatter data.

Based on this ONR-sponsored research, a project supporting mine-warfare application has been initiated with the Naval Oceanographic Office. This work will conduct side-scan surveys in a NAVO test range off the Alabama coast in October to identify sediments, characterize their spatial changes (called "segmentation"), and explore the ability to detect targets in the observed environments. Because of a shortfall in DURIP funding for the development of the MSBP, that NAVO project included additional funding to complete the final contract for the electronic subsystem of the MSBP.

The contract was let for the tow system in FY05 and this year that system was received. With the new NAVO funding the contract for the electronic subsystem was processed and will be let in the first week of FY07. We have begun design and construction of the tow body. The MSBP is expected to be completed in March, 2007. We are seeking a small augmentation of funding for software development in FY07 so that data collection and analysis with the MSBP can begin in early FY08.

RESULTS

A paper was presented at the June 2006 meeting of the Acoustical Society of America [1]. This paper discusses recent basic, high-frequency, bottom-backscattering research conducted in conjunction with sediment-classification projects and the ONR bottom scattering research projects, KauaiEx and SAX04. This work has a bearing on statistical analyses and bottom change detection relevant to the detection of objects on or near the bottom in shallow water. The research discussed here includes the analyses of data from three surveys made between 2002 and 2004. The primary contributions of this work are based on the use of probability density functions (PDFs) of the backscatter signals to specify the various regimes of bottom sediments and to detect spatial changes in these regimes based on chi-square and other tests applied to these PDFs. A simple, quantitative test for non-Rayleighness of a PDF was also applied. At a SAX04 meeting in March, 2006 [2], seafloor characteristics in the SAX04 test area off Ft. Walton Beach, Florida, at 150 and 300 kHz based on side-scan sonar data were discussed. The main feature -- a distinct change in the NE part of the SAX04 test area -- of this work had been presented earlier, but was discussed in greater detail. This feature change was strongest in the lower-frequency data. It is unknown if this feature would continue into even lower frequencies.

In support of the high-frequency, channel-characterization experiment (KauaiEx), three days of side-scan sonar (SSS) surveys were conducted off the northwest coast of Kauai, Hawaii in 2003 a modified Marine Sonic Technology, Ltd, system. A paper [3] discussing analyses the digital backscattering data has been submitted to IEEE J. of Oceanic Engineer. Previous reports discussed the system characteristics and analyses of the standard tiff images produced by the MSTL system. The digital data are high-resolution in space and in dynamic range and offer improved interpretations of the character of the bottom in the KauaiEx range. The data in the range yielded interpretations of sand ripples parallel to the depth contours with wavelengths of about 1 m and heights of a few centimeters. These ripples appear to cover the entire KauaiEx area. Data taken at a shallow-water site nearby provide additional information on bottom characteristics that include lava flows, mud, and sand. The main new

contribution of this work is a means of a direct determination the heights of the sand ripples by a direct means under the assumption of Lambert scattering. A previous report on sand-ripple height determination was based on matching simulated sand-ripple-profile scattering with experimental data [4].

An abstract has been submitted for presentation at the November, 2006, meeting of the Acoustical Society on the DURIP/ONR sponsored development of the MSBP for inclusion in the session on recent developments in subbottom profiling technology [5]. The USM/MSBP is being constructed from three T70 Neptune Sonar transducer modules in a line. Each T70 has five 11.5-kHz elements in each of two parallel lines. The resulting system is composed of fifteen elements in each line with a total length of 1.3 m separated by about 8.5 cm. Each line has a full beamwidth to the 3-dB points of about 5 x 70 degrees. The system will be used in an interferometric mode between the two lines.

An early version of that ASA talk was presented to NAVO. That presentation resulted in NAVO funding for additional work on the MSBP. In particular NAVO is installing the large Sinrad EM120, 12 kHz, multibeam system on its larger survey ships. That multibeam system has a new augmentation of software called the SBP120 that allows for the EM120 data to be used for SubBottom Profiling. The USM/MSBP is smaller, in part by virtue of its interferometric technology, and can be used in shallower water and as a trainer for NAVO's larger, deep-water system. As part of our grant from NAVO for the MSBP, funds have been included for USM to engage in a survey in a NAVO test range off Orange Beach, Alabama.

In separate work with Ralph Goodman, we continued some analysis of propagation data we collected during the Scripps Pier Bubble Experiment in 1997. The results of this analysis was presented at the June, 2006, meeting of the Acoustical Society [6]. This analysis addressed pulse distortion of a signal propagating through a highly attenuative bubbly medium.

IMPACT/APPLICATIONS

The University of Southern Mississippi's side-scan sonar collects data for the quantitative basic research and analyses of backscatter at 150 and 300 kHz. The wide-area coverage allows for the recognition and interpretation of backscattering variation that is regionally based, whereas often such variations must be treated is simply statistical. Basing the analysis of probability density functions, as is done in this work, is important because of the importance of PDFs in signal processing, and, therefore, understanding regional variability on the PDFs is an application.

This work is expected to contribute to such navy problems as Mine Warfare and Antisubmarine Warfare. In particular, it should support NAVO efforts to contribute environmental data for Fleet applications.

RELATED PROJECTS

This project includes the continued analyses of data collected in the two ONR projects KauaiEx and SAX04. We now have a project that supports NAVO with two tasks: A side-scan survey in one of their mine-warfare support ranges and an interest in wide-angle subbottom profiling.

REFERENCES

[1] J.W. Caruthers, "Statistical and Change-Detection Analyses using Quantitative Side-Scan Sonar Data," presented at the 151st Meeting of the Acoust. Society Amer., abst. published in *J. Acoust. Soc. Am.*, v. 119, p. 3447, 2006.

[2] J.W. Caruthers, "Comments on Seafloor Characteristics in SAX04 Area Based on 150 & 300 kHz Side Scan Sonar Data," presentation at the SAX04 mtg in New Orleans, Mar. 2006.

[3] J.W. Caruthers, "Analysis of High-Frequency Acoustic Backscatter from KauaiEx with an Emphasis on Computing Sand-Ripple Properties," Submitted to IEEE, J. Oceanic Eng.

[4] Dajun Tang, K.L. Williams, E.I. Thorsos, and K.B. Briggs, "Remote Sensing of Sand Ripples using High-Frequency Backscatter," Technical Report, AD-A408366; NRL/PP/7430--02-0006 Applied Physics Lab

[5] J. W. Caruthers and S. Griffin, "A multibeam subbottom profiler," an abstract for the Hawaii mtg of the ASA, Nov. 2006.

[6] R. Goodman, J.W. Caruthers, and Timothy Ruppel, "The Direct-Path Impulse Response in Bubbly Shallow Water," Invited Paper presented at the 151st Meeting of the Acoust. Society Amer., abst. published in *J. Acoust. Soc. Am.*, v. 119, p. 3274, 2006.

PUBLICATIONS

[1] J.W. Caruthers, "Statistical and Change-Detection Analyses using Quantitative Side-Scan Sonar Data," presented at the 151st Meeting of the Acoust. Society Amer., abst. published in *J. Acoust. Soc. Am.*, v. 119, p. 3447, 2006.

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