Acoustic Wave Propagation, Scattering and Attenuation in Sediments in Shallow Oceans

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Grant Number: N00014-00-1-0032
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LONG-TERM GOALS

Our long-term goal is to better understand the physics of the acoustic wave propagation, scattering and attenuation in sediments and in shallow oceans.

OBJECTIVES

(1) To better understand the coupled effects of spatial and temporal variability in water column and bottom sediments on the propagation of acoustic waves in shallow oceans.
(2) To better understand the physics of acoustic wave propagation, scattering, and attenuation and velocity dispersion within the sediments.
(3) To better understand the physics of acoustic wave attenuation in the sediments, to widen the database of acoustic wave attenuation in the sediments, and to experimentally show that the attenuation (α) of acoustic waves in the sediments is a sum of absorption (α_o) and scattering attenuation (α_s): $\alpha = \alpha_o + \alpha_o$.

APPROACH

(1) A PE model will be used to model the reciprocal and one-way acoustic transmission data collected at the SS and OS sites on the outer continental shelf off the coast of New Jersey during the SWAT 2000 experiment. Comprehensive environmental data by CTD, ADCP and chirp sonar were also corrected during the acoustic transmission tests. The acoustic data show the effects of internal waves, front, currents and bottom sediments on the acoustic wave propagation at 5.5 kHz. The effects of the temporal and spatial fluctuations of sound speed field on the acoustic propagation and scattering will be investigated though model-data comparisons.
(2) During the SWAT 2000 experiments, we collected quality backscattering data from sandy bottom at SS site at frequency of 5.5 kHz. A volume scattering model based on the Biot theory will be developed. Model-data comparisons will be made to investigate the effect of the Biot slow wave on acoustic scattering from sandy sediments.
(3) Medium frequency (1-10 kHz) acoustic cross-hole tomography will be conducted at the sandy bottom of Japanese Inland Sea with Japanese collaborators. High frequency (10-100 kHz) acoustic cross-hole tomography will be conducted in a large sand tank at the National Institute for Rural Engineering in Japan. The cross-hole acoustic data will be analyzed for acoustic propagation, scattering, attenuation through sandy sediments for a broad range of frequency.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **Acoustic Wave Propagation, Scattering and Attenuation in Sediments in Shallow Oceans**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Applied Marine Physics Division,,RSMAS, University of Miami,,4600 Rickenbacker Causeway,,Miami,,FL,33149**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

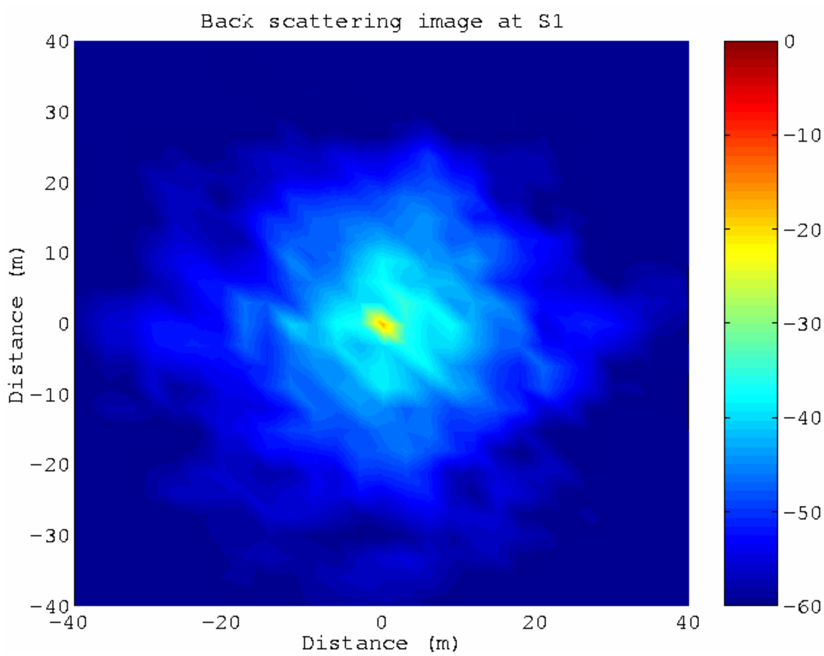
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

WORK COMPLETED

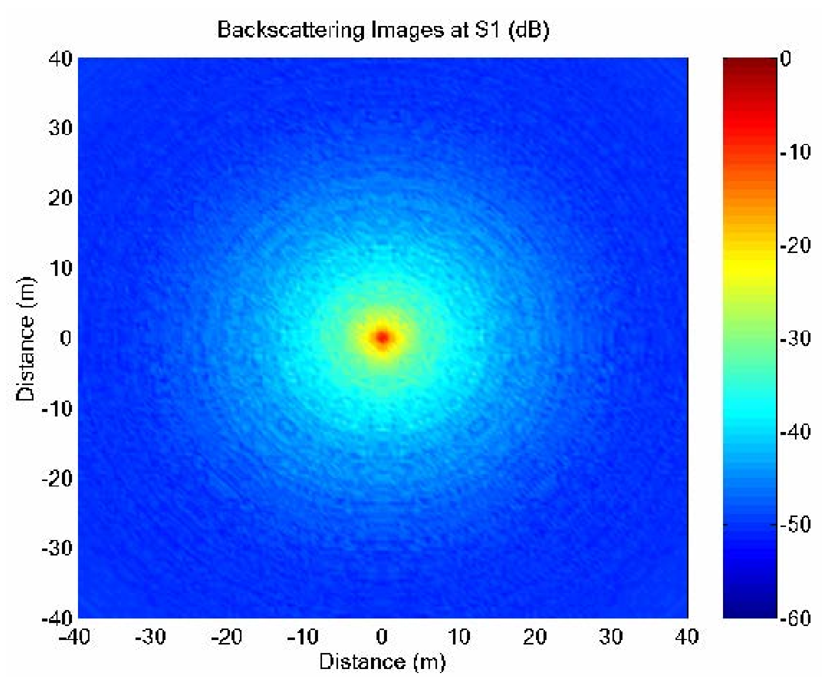
(1) A PE model based on the Miami-Monterey PE code has been constructed. Preliminary model-data comparisons of medium frequency pulse propagations revile that various oceanographic phenomena such as internal waves, warn water intrusions, tides affect the temporal-spatial coherency of the acoustic signals in different manors.
(2) The 5.5 kHz backscattering data from the silty sand site have been processed to investigate the effects of coherent and incoherent processings on the acoustic back scattering and their physical implications.
(3) Three mechanisms of acoustic attenuation within the sediments for 100 Hz to 100 kHz have been identified from theoretical investigations. They are the classical Biot mechanism, the patchy-saturated Biot mechanism, and the volume scattering attenuation mechanism.
(4) Three field experiments and six laboratory experiments of sediment attenuation using cross-hole tomography measurements have been completed.

RESULTS

(1) The SWAT 2000 medium frequency (5.5kHz) acoustic propagation data show that the warm water intrusion forms a thin wave guide near the seabed that creates an avalanche effect of acoustic propagation. The data also show that the domination of 100 minute fluctuation of coherent acoustic signal identifies the internal wave activities (Yamaoka and Yamamoto, submitted).
(2) The 5.5 kHz acoustic backscattering data from sandy bottom show that the incoherent backscattering strength of the bottom is roughly 10 dB higher than the coherently processed backscattering strength of the same bottom. The incoherent acoustic backscattering from a bottom is spatially homogeneous while the coherent bottom backscattering is spatially inhomogeneous as shown in Figure 1a and b (Yamaoka and Yamamoto, submitted).
(3) The patchy-saturated Biot mechanism is found to be a dominant mechanism of acoustic wave attenuation in the sediments based on the numerical analysis (Pride et al, 2003). New and comprehensive measurements of acoustic wave attenuation in the sediments for frequency range between 1 and 100 kHz reveille: the attenuation in sands $1/Q_p$ 0.0308±0.0127 and in clays 0.00830±0.00014. The attenuation in sands is possibly due to a combination of the classical Biot mechanism, the patchy-saturated Biot mechanism, and the scattering attenuation while the attenuation in clays is possibly due to a combination of the patchy-saturated Biot mechanism and the scattering attenuation.



(a)



(b)

Figure 1. (a) The coherent acoustic backscattering strength from a sandy bottom at frequency 5.5 kHz and (b) the incoherent backscattering strength of the same bottom. The 5.5 kHz acoustic backscattering data from a sandy bottom show that the incoherent backscattering strength is roughly 10 dB higher than the coherently processed backscattering strength of the same bottom.

IMPACT/APPLICATIONS

The newly discovered attenuation mechanism, the Biot mechanism in patchy-saturated sediments, has a general impact on acoustics, seismic and earthquake seismology (Pride et al, 2003).

RELATED PROJECTS

Dr. Robert Field, NRL on PE modeling of 5.5 kHz acoustic propagation on the continental shelf off the coast of New Jersey during SWAT 2000 experiments (Yamaoka et al, submitted).

Dr. Dr. Zack Hallock, NRL on oceanographical observation during SWAT 2000 experiments (Yamaoka et al, submitted).

Dr. Altan Turgut, NRL on the geoacoustic structures of the continental shelf of SWAT 2000 experiments.

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