

Chirp Sonar Remote Sensing for Ripples DRI and SAX04

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LONG TERM GOALS

The long-term research objective is to develop a cost effective technique for mapping the top 20 meters of sediment properties using acoustic remote sensing and recent developments in modeling the physics of sediments acoustics. The procedures for remotely estimating the physical and acoustic properties of sediments are tested using sediment properties from core data and insitu measurements.

OBJECTIVES

- 1) Generate reflection profiles of a region about 1 km offshore of Fort Walton Beach in order to select an site containing sandy homogeneous sediments for the SAX04 experiments.
- 2) Generate BOSS (buried object scanning sonar) imagery at the SAX04 site to verify the placement of buried objects and to measure the performance of BOSS against those buried objects
- 3) Measure the normal incidence acoustic impulse response of the seabed at locations where insitu or core data is collected
- 4) Compare remote chirp sonar estimates of the acoustic and physical properties of the seabed with measurements made by other investigators conducting insitu acoustic experiments and coring surveys to determine the accuracy of acoustic remote sensing

APPROACH

In previous years, a chirp sonar was developed to provide quantitative, wideband reflection measurements of the seabed with a vertical resolution of 10 cm. Signal processing techniques were developed to estimate the acoustic and physical properties of sediments using reflection coefficient and attenuation measurements and the Biot model..

The technical approach is to collect normal incidence FM reflection data with a towed chirp sonar using a dual pulse mode where the sonar alternately transmits 40 msec 1.5 to 4 kHz and 10 msec 1.5-15 kHz FM pulses providing images of the top 40 meters of sediments and generating wideband data sets that can be used for estimating sediment properties needed by scientists modeling acoustic

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propagation. The multiband chirp technology allows the collection of normal incidence reflection data over a band of 1 to 15 kHz while the towed vehicle emulates a point acoustic source. Wide projector and receiver beamwidths reduce errors in the reflection coefficient measurements caused by scattering from a rough seabed interface and sonar vehicle motion. The point source is emulated using 2 piston sources that operate over different but overlapping frequency bands. Each single piston source has a wide beamwidth (greater than 40 degrees) over its band of operation. Multiple transducers can be driven simultaneously with chirp pulses with different bands to generate the wideband chirp pulse in the water that appears (in the far field) to emanate from a point acoustic source. Multiple rectangular receiving arrays of various sizes are used to control receiving beamwidth and scattering by spatial filtering. The 15 kHz bandwidth provides subsurface imagery with 10 cm vertical resolution. The enhanced bandwidth also improves the accuracy of attenuation and phase measurements needed for impedance inversion and dispersion measurements.

The Biot model is used to estimate the physical and acoustic properties of the seabed from reflection coefficient and attenuation measurements made with the chirp sonar. Bulk properties such as bulk density, porosity and sound speed are estimated from reflection coefficient measurements. Pore properties such as grain size and permeability are estimated from attenuation measurements

Dr. Schock supervises the research program including graduate and undergraduate students and at sea experiments

WORK COMPLETED

- 1) Conducted chirp sonar reflection profiling and BOSS 3D imaging surveys of the SAX04 site off Fort Walton Beach in September and November 2004.
- 2) Estimated sediment properties at SAX04 site and showed that an inversions of chirp sonar reflection coefficient measurements agree with insitu measurements of porosity and mean grain size at the SAX-04 site.
- 3) BOSS imagery showed that the planned and actual burial locations and burial depths agree for the SAX-04 target field based on a BOSS survey before Hurricane Ivan.

RESULTS

Chirp sonar surveys of the SAX-04 site were conducted on September 9, 2004 and November 5, 2004. Reflection data was collected at normal incidence over the operating band of 1.5 to 15 kHz. Figure 1 provides a map showing the boundaries of the surveys. The September survey (before Hurricane Ivan) consisted of 25 equally spaced west to east lines. The November survey consisted of 5 equally-spaced west to east lines.

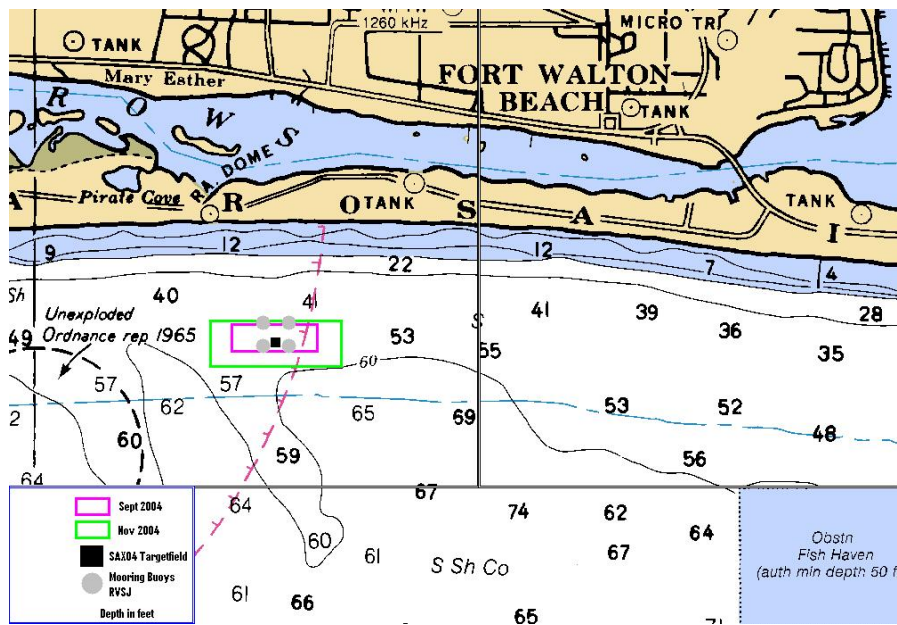


Figure 1. Regions at SAX-04 site surveyed by chirp sonar on September 9, 2004 and November 5, 2004.

The chirp sonar data collected during the November 4, 2004 survey was inverted to estimate surficial sediment properties. The sonar data was calibrated using air-water interface reflection data collected at a lake in West Palm Beach, Florida and corrected to compensate for the effects of sound speed on spherical spreading and the effects of seawater impedance loading on the chirp acoustic source level. A map of the reflection coefficient measurements made during the November survey is shown in Figure 2. The reflection coefficient measurements varied from a maximum of -7.6 dB to a minimum of -9.1 dB with a mean of -8.4 dB. The reflection coefficient map shows a general trend of increasing reflection coefficient traveling northward (corresponding to decreasing porosity and increasing grain size traveling northward)

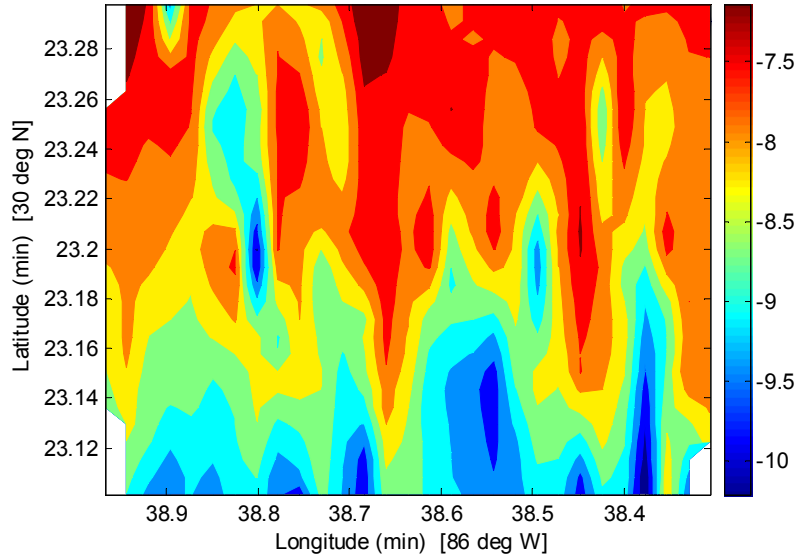


Figure 2. Reflection coefficient of seabed at 2 kHz measured during November 2004 survey of SAX-04 site. The reflection coefficient of the sandy seabed varied between -7.6 and -9.1 dB with a mean of -8.4 dB.

The surficial properties of sediments at the SAX-04 site were estimated using reflection coefficient measurements, the Biot model and an inversion procedure described by Schock[1]. Schock[1] showed that the accuracy of the sediment properties improved using the attenuation rolloff measurement; however, attenuation rolloff measurements cannot be made at the SAX-04 site because there are no substantial subsurface impedance contrasts to generate an echo with sufficient SNR to make the attenuation rolloff measurement. Figure 3 is a reflection profile collected along the southernmost survey line (DT1) of the November 2004 survey and shows there are no substantial subsurface impedance contrasts usable for attenuation rolloff measurements. The lack of subsurface layering was by design because the SAX-04 site was selected to ensure there were no substantial impedance contrasts that would complicate acoustic modeling efforts.

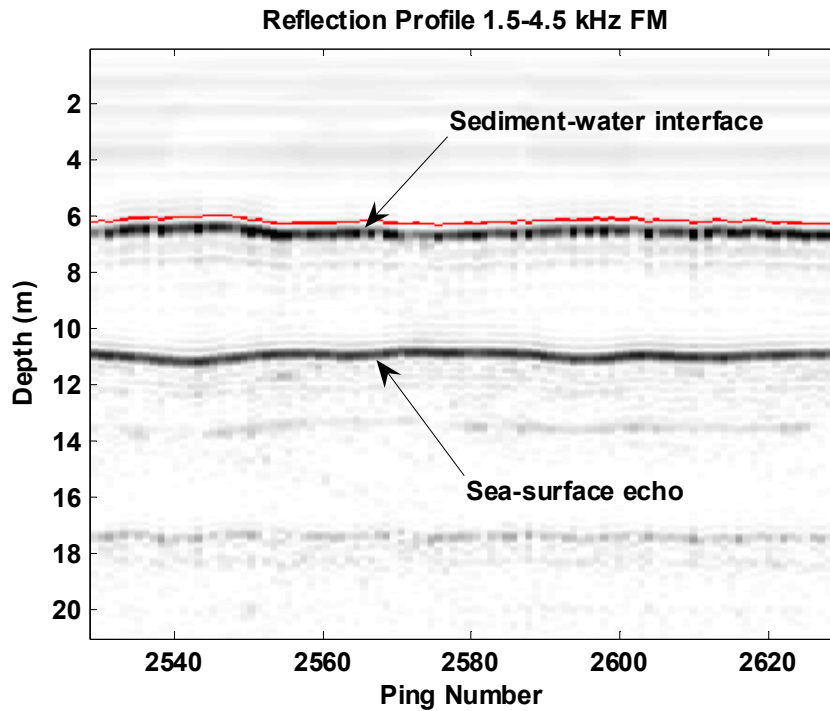


Figure 3 Reflection profile of seabed collected by chirp sonar on 5 Nov 2005 during survey line DT1. The image shows there are no significant subsurface sediment impedance contrasts indicating that the top 4 meters of sediments appears to be acoustically homogenous.

The inversion of chirp sonar reflection coefficient data yielded sediment properties estimates that agree with insitu sediment property measurements near the SAX-04 site. The inversion of the reflection coefficient data (range of -7.6 to -9.1 dB) provides a range of porosity from 0.3 to 0.4 with a mean of 0.35. The inversion also provided an expected mean grain size range of 0.5 to 0.22 mm with an average mean grain size of 0.35mm. At the September 2005 ONR review meeting at Scripps, Dr. Wheatcroft reported that the average porosity (based on insitu resistivity measurements) at the SAX-04 was 0.35 between 1 and 3 cm under the seabed and Dr. Rubin reported that optical measurements of mean grain size varied between 0.1 to 0.4 mm with a mean of 0.3 mm in the vicinity of the 17 meter water depth contour. Table 1 summarizes the comparison between the average values of chirp sonar based property estimates and insitu property measurements for the SAX-04 site.

Table 1 Comparisons between chirp sonar predictions and insitu measurements of surficial sediment porosity and mean grain size show agreement between remote and insitu estimates.

Sediment Property	Chirp sonar estimate	Resistivity probe	Optics
Porosity	0.35	0.35	
Mean Grain size	0.35mm		0.3 mm

The BOSS data collected at the SAX-04 site in September was used to verify the locations and burial depths of targets in SAX-04 target field shown in Figure 1. The target field burial locations of all targets were verified by BOSS with the exception of 1 inch diameter cylinders which were not detected by BOSS. Figure 4 shows an example of the good alignment between the planned target field and BOSS images of targets.

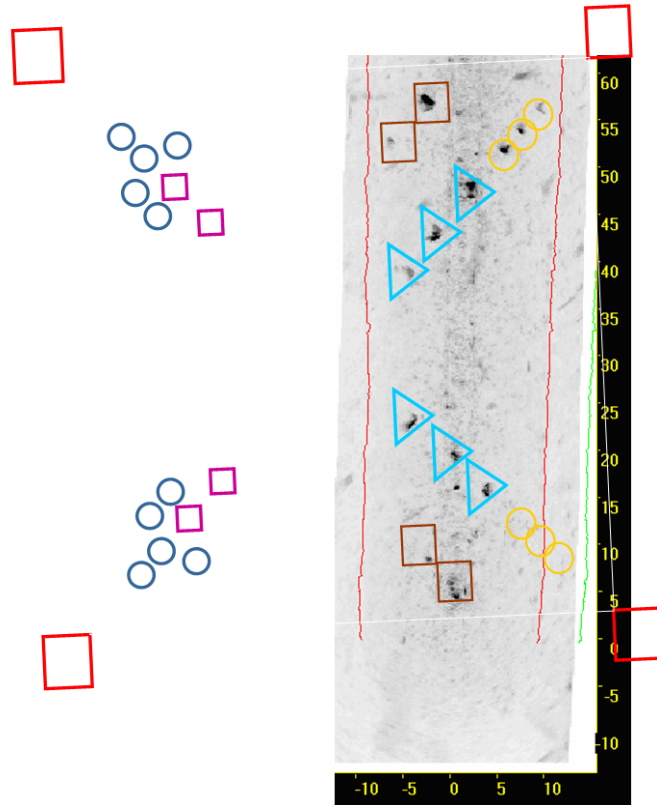


Figure 4 BOSS image showing plan view of target field generated during line 18C and overlay showing planned locations of targets in SAX-04 field. The figure shows that images of the NSWC targets (triangles), acoustic clutter targets (brown boxes) and Lim's 2, 3, and 4 inch OD cylinders (yellow circles) are in alignment with the planned target field.

The target field was substantially altered by Hurricane Ivan. The post Ivan BOSS survey during the period of 4-6 November 2005 showed that seabed scattering significantly increased due to scattering from sand ripples which did not exist during the September BOSS survey (before Hurricane Ivan). Figure 5 shows the interference from echoes caused by sand ripples. The echo level for the sand ripples is of the same order as the echo level of the buried 14 inch focusing sphere. Sand ripple scattering makes the detection of flush buried targets difficult when the sonar is focusing at an angle orthogonal to the ripples crests. Figure 5 also shows that the echo from the flush buried sphere appears to originate about 50 cm below the sediment-water interface. The delayed echo is an expected result for a focusing sphere.

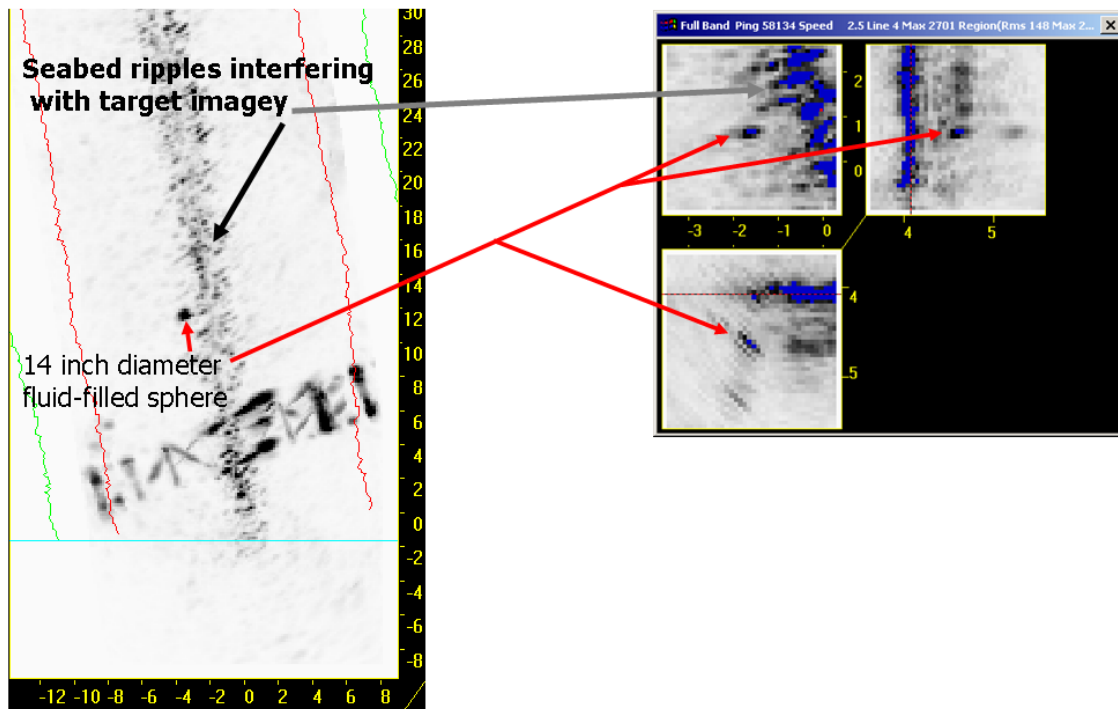


Figure 5 BOSS multi-aspect plan view image of seabed and APL-UW SAS rail(left). Image projections (right) of a flush-buried fluid-filled focusing sphere buried near APL-UW tower. The lower projection shows that the echo from the sphere appears to originate at a subsurface depth of 50 to 55 cm (based on 1500 m/s) or 57 to 62 cm (based on 1700 m/s). The image also shows that ripples generate scattering levels on the same order as the echo level and that the position of the sonar.

IMPACT/APPLICATIONS

Instrumentation and sediment classification procedures have been developed to predict the acoustic and physical properties of the seabed using normal incidence reflection data collected by FM subbottom profilers. This development provides a cost effective method of surveying seabed sediments and obtaining remote estimates of the bulk density, grain size, porosity, attenuation, acoustic impedance, volume scattering and sound speed of ocean sediments.

RELATED PROJECTS

The November 2004 surveys using BOSS and the chirp sonar were funded under the ONR grant “Buried Object Scanning Technology” (N00014-05-1-0072).

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