Angular Dependence of High-Frequency (>200 kHz) Seafloor Acoustic Backscatter

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LONG-TERM GOALS

The long-term objectives of the proposed research are to develop a physics-based model of high-frequency sound scattering from stratified heterogeneous sediments. Such a model is needed to interpret the ever-increasing amount of seafloor acoustic backscatter data collected by, or for the US Navy with high-frequency sonars (>200 kHz) mounted on autonomous underwater vehicles (AUVs) for rapid environmental assessments and reconnaissance missions in denied areas.

OBJECTIVES

The scientific goals of this work are to determine empirically the angular dependence of high-frequency seafloor acoustic backscatter over grazing angles spanning 25º to 90º, for which no reliable model exists (Jackson et al., 2007, Ch. 7-8).

APPROACH

Acoustic backscatter measurements were made with a RESON SeaBat 7125 SV^2 multibeam echo-sounder at 50 kHz increments between 150 kHz and 450 kHz. This was possible thanks to a non-standard sonar configuration made available for this project by RESON. The standard configuration allows operation at two frequencies: 200 kHz and 400 kHz. At 400 kHz, the sonar transmits continuous wave (CW) pulses in a beam 1º × 145º (fore-aft × across-track). It forms up to 512 contiguous receive beams covering a 128º across-track sector centered at nadir, with a nominal 0.5º across-track beam width at broadside. At 200 kHz, the transmit beam is 2º × 142º, and up to 256 contiguous receive beams are formed over a 128º across-track sector centered at nadir, with a nominal 1º across-track beam width at broadside.

RESON (PIs: G. Wendelboe, E. Maillard) plans to do a full acoustic calibration of this sonar (beam patterns, transmit voltage response, receive sensitivities, gains).

Data acquisition took place as an ancillary task during the ONR-sponsored GulfEx11 reconnaissance experiment (PIs: B. T. Hefner, DJ Tang, K. L. Williams). This involved (1) a reconnaissance survey with combined swath bathymetry (PI: C. de Moustier), chirp subbottom profiling and sediment core sampling (PI: J. A. Goff) offshore Panama City Beach, FL, and (2) work on station with the ship in a

4-point moor, coupled with in-situ measurements of sediment geoacoustic properties (sound speed, attenuation, surficial roughness).

WORK COMPLETED

In support of the GulfEx11 reconnaissance experiment, the SeaBat 7125 SV^2 sonar was hull-mounted on R/V H. Sharp and used for a seafloor survey offshore Panama City Beach, FL (Apr. 9-15, 2011). The survey tracks are shown in Fig. 1, including a detailed survey box (Fig. 2) within which the ship was subsequently moored for the GulfEx11 work.

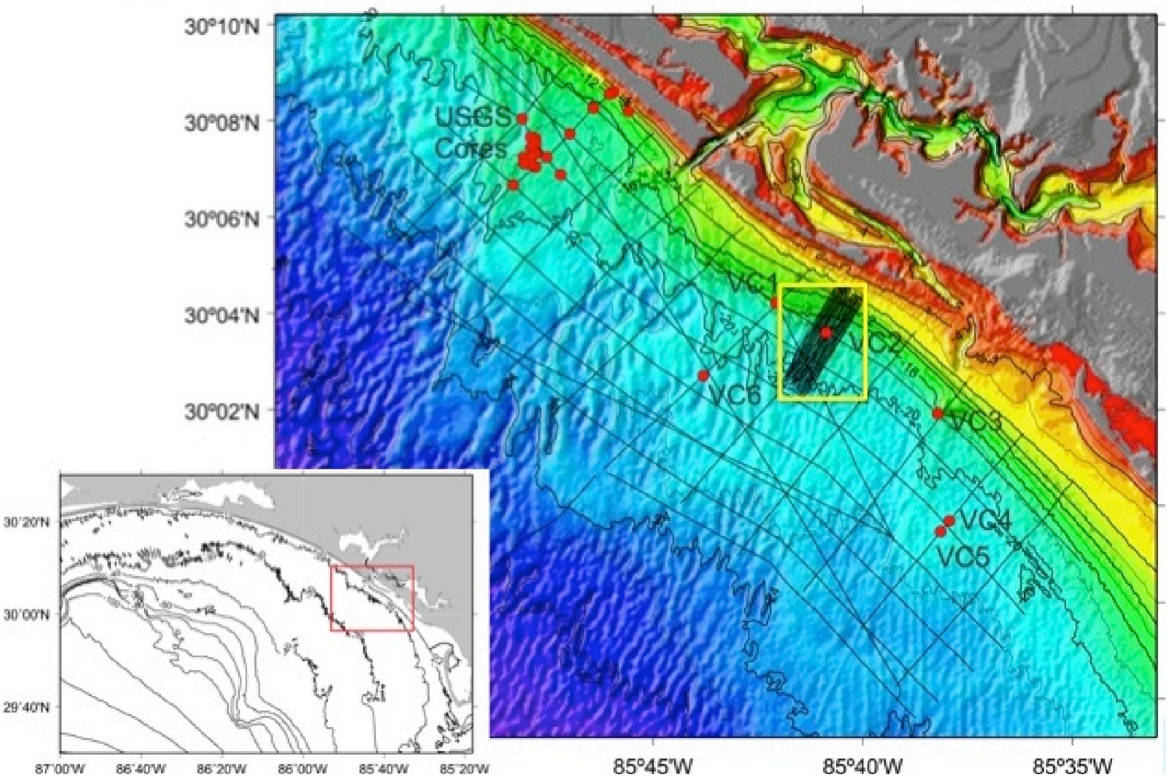

Figure 1. GulfEx11 Reconnaissance Survey Tracks of the Inner Shelf Offshore Panama City, FL. The yellow box delimits a higher resolution survey (results shown in Fig. 2) of an area selected to moor the R/V Sharp for the GulfEx11 work. Sediment core locations, including 6 vibracore (VC#) taken during the survey, are identified by red dots. Figure from J. A. Goff.

Raw SeaBat 7125 acoustic data, consisting of basebanded quadrature samples from each element in the receive arrays, were acquired by G. Wendelboe aboard R/V H. Sharp held in a 4-point moor in 17 m of water depth. The mooring constrained the ship's motion and allowed acoustic data acquisition at the 7 discrete frequencies over the same well defined seafloor patch. This provided thousands of independent samples of the angular dependence of seafloor acoustic backscatter for grazing angles ranging from 90º to about 25º at each frequency.

A dynamically focused beamforming method was implemented at all frequencies to obtain effective receive beam footprints with nearly constant fore-aft width across the swath (Fig. 3). Bottom detection, compensation for the ship's attitude (roll, pitch, yaw, heave), and correction for local bottom slope were then used to extract curves of acoustic backscatter vs. grazing angle. Such curves will be corrected for beam pattern effects at each frequency (calibration work in progress at RESON).

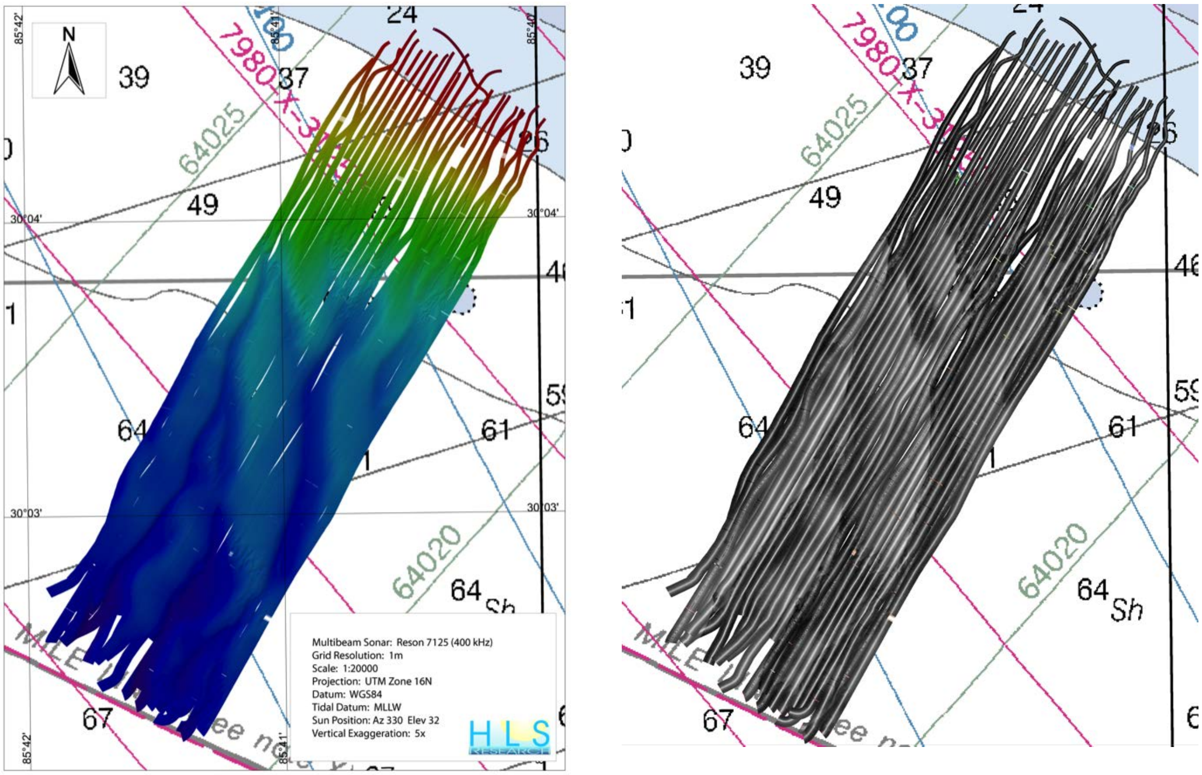

Figure 2. Gridded swath bathymetry (left) and seafloor acoustic backscatter (right) for the area delimited by the yellow box in Fig. 1. The bathymetry color scale ranges from 8 m (red) to 22 m (dark blue). Soundings in the underlying NOAA chart are in feet. The acoustic backscatter is displayed on a relative logarithmic scale (dB) with white representing high backscatter. These data were collected with the SeaBat 7125 operating in its standard mode at 400 kHz. Processing, gridding, and display by B. J. Kraft.

RESULTS

The most significant result obtained during the reporting period (01/07 – 09/30 2011) is the dynamic focusing effect achieved while beamforming in the time domain for ranges beyond the Fresnel focusing limit (about 4 m at 400 kHz). Such focusing yields improved target range and angle detection, hence better estimation of the acoustic backscatter level at each (range, angle) pair in the detected returns.

Preliminary acoustic results will be presented at the fall meeting of the Acoustical Society of America (de Moustier et al., 2011) and preliminary geomorphology and stratigraphy results will be presented at the fall meeting of the American Geophysical Union (Goff et al., 2011).

IMPACT/APPLICATIONS

We have collected a comprehensive multi-frequency data set over the same patch of seafloor and under relatively controlled conditions (vessel in a 4-point moor). Pending completion of the sonar's acoustic calibration by the manufacturer, the signal processing and modeling techniques (in collaboration with D. R. Jackson, B. T. Hefner, and A. Ivakin) resulting from this work should be integrated into the standard operation of the sonar and made available to all future users.

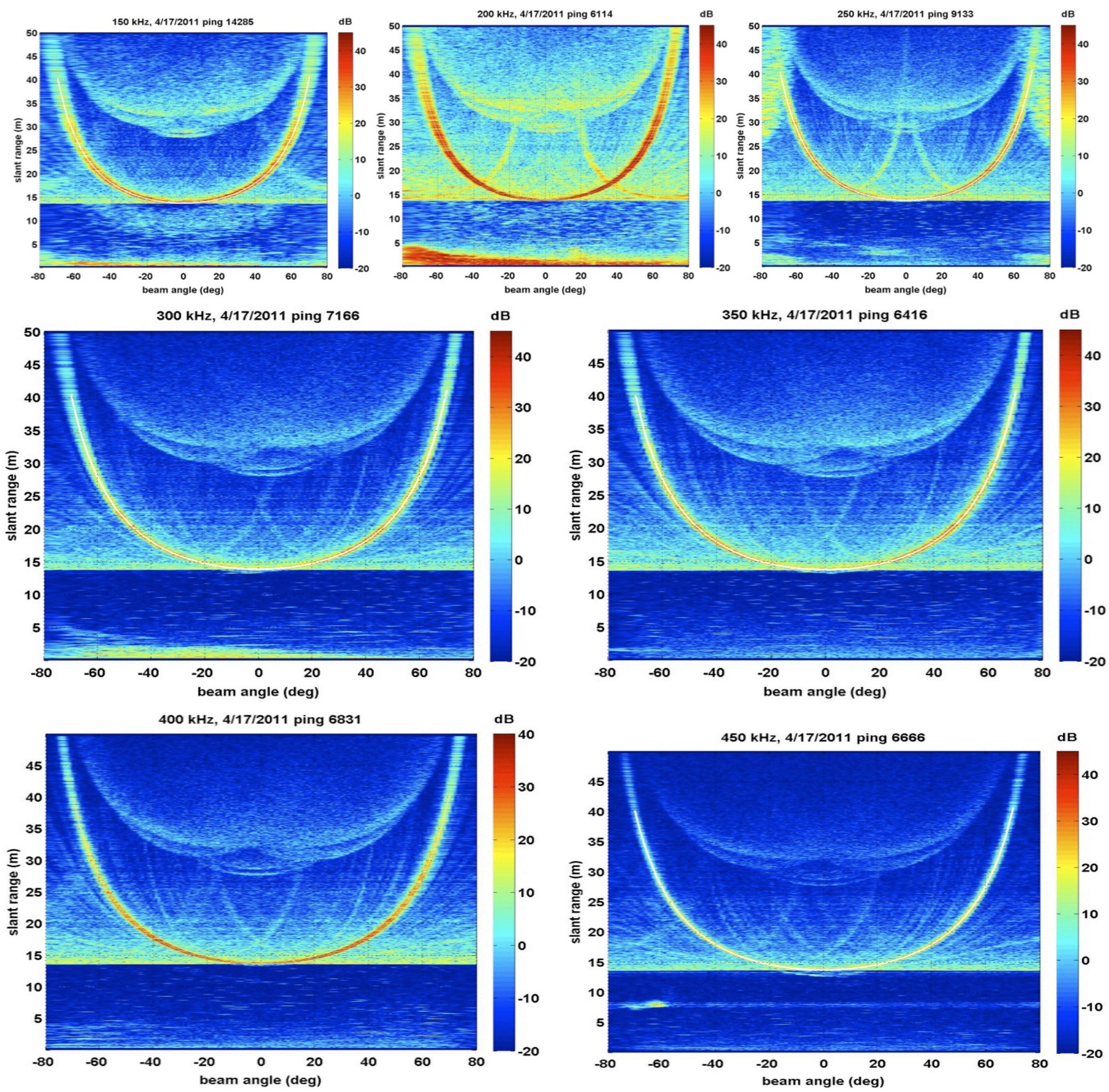

Figure 3. Dynamically focused beamforming results at the seven frequencies (150 – 450 kHz). Each panel represents the ouput of one ping, with the same seafloor in all panels. The 200 kHz transmit and receive arrays are used at 150 – 250 kHz (top row), whereas the 400 kHz transmit and receive arrays are used at 300 – 450 kHz (middle and bottom rows). The bottom is about 14 m below the sonar. Slant ranges from 0 to 14 m correspond to the water column below the transducer, which is about 3 m below the sea surface. Bottom echoes appear along the redish parabola (20 – 35 dB relative intensity) in each plot. The thin white line inside each parabola is the across-track sequence of (range, angle) pairs obtained from bottom detection.

TRANSITIONS

The gridded swath bathymetry and seafloor acoustic backscatter data have been provided to other GulfEx11 investigators (J. A. Goff, U. Texas Austin; K. L. Williams, DJ Tang, APL U. Washington).

RELATED PROJECTS

This work is closely coupled with that of other PIs who participated in the GulfEx11 sea tests:

- J. A. Goff, geomorphology and stratigraphy of the inner shelf offshore Panama City, FL;
- D. R. Jackson and B. T. Hefner, physics-based inversion of high-frequency multibeam sonar data;
- DJ Tang and K. L. Williams, acoustic reverberation modeling.

REFERENCES

D. R. Jackson and M. D. Richardson, "High-frequency seafloor acoustics", Springer, 2007.

PUBLICATIONS

Published abstracts of presentations at scientific meetings:

J. A. Goff, C. de Moustier, B. Kraft, "Multibeam and CHIRP sonar imaging of sand ridge morphology and basal stratigraphy on the inner shelf offshore Panama City, Florida", Am. Geophys. Union Fall 2011 meeting, OS24A-01.

C. de Moustier, G. Wendelboe, E. Maillard, B. Kraft, "Angular dependence of high-frequency seafloor acoustic backscatter (200-400 kHz)", J. Acoust. Soc. Am., 130(4-2), 2349, 2011 (A)