Seabed Variability and its Influence on Acoustic Prediction Uncertainty

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LONG-TERM GOALS

A basic tenet of the Office of Naval Research's "Uncertainty in the Natural Environment" Defense Research Initiative (Uncertainty DRI) is that, in any strategic situation, environmental parameters will never be known in complete enough detail to enable a perfectly accurate acoustic detection. Our group has been funded address acoustic uncertainty associated with bottom and subbottom variability. In particular, we will (1) assess and characterize the seafloor variability, and (2) determine the impact of seafloor variability on acoustic prediction uncertainty.

OBJECTIVES

The primary scientific objective of my work for this project is to formulate a statistical model for bathymetric and geoacoustic variability for the seabed, and to generate from that model realizations that can be incorporated into acoustic modeling efforts.

APPROACH

Nearly 100 collocated grab samples and in situ 65 kHz acoustic measurements were collected on the New Jersey middle and outer shelf during the summer of 2001 as part of the Office of Naval Research's Geoclutter program. The effort was focused within an area that had previously been mapped with multibeam backscatter and bathymetry data, and more recently with chirp seismic reflection profiling. Eighteen short cores were also collected, and probed for resistivity-based porosity measurements. The combined data set provides a basis for empirically exploring the relationship among the remotely sensed data, such as backscatter and reflection coefficients, and directly measured seabed properties such as grain size distribution, velocity, attenuation and porosity. We also investigate the spatial variability of these properties through semi-variogram analysis to facilitate acoustic modeling of natural environmental variability.

WORK COMPLETED

Directly measured seafloor properties (grain size, *in situ* velocity and attenuation) in the Geoclutter natural laboratory have been compared against collocated remotely sensed data (backscatter and seafloor reflection coefficients) data to investigate the possible use of remotely sensed data as a proxy for measuring spatial variability in sedimentary properties. Statistical characterizations have been produced for bathymetry, velocity and grain size properties. Random realizations have been generated

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for bathymetry and velocity for use in acoustic modeling work by collaborators in the seabed variability group (Kevin LePage and Bob Odom).

RESULTS

Our combined analysis of grain size distribution, velocity, attenuation, porosity, backscatter and reflection coefficients demonstrate complex relationships among the physical properties, acoustic response and spatial variability of seafloor sediment on the New Jersey mid- and outer shelf. Seafloor sediments in the survey area commonly exhibit multi-modal grain size distributions, leading us to separate characterization of fine, medium (sand), and coarse contributions. The coarse % (> 4 mm) represents a primary control on the backscatter, but is spatially independent of the mean sand grain size and fine %. Where the coarse % is a significant factor, which includes most of the area considered here, interpretation of the backscatter map is limited by this relationship. Where coarse % is absent, particularly in the "high fine/low coarse" population of sediments, then a relationship can be discerned between backscatter and velocity and between backscatter and fine %. Porosity and density may also have an influence on backscatter, but our sampling of this parameter is thus far very limited. Mean sand grain size and fine % are partially correlated with each other and combined represent the primary control on velocity. The fine %, rather than mean grain size as a whole, appears to be the primary control on attenuation, although coarse % may increase attenuation through scattering.

The STRATAFORM backscatter map(Figure 1) is thus largely a characterization of variability in surface roughness, which locally is dominated by coarse material on the seafloor. We had hoped, based on theoretical expectations, that the backscatter map could be used as a proxy for physical parameters of importance to us: velocity, attenuation, density. However, that goal has proven unattainable as of yet. Nevertheless, we have demonstrated that where coarse material is not present in significant amounts, backscatter correlates with acoustic velocity and porosity, implying that backscatter can be used as a proxy for physical properties in those environments. In contrast to the backscatter, vertical-incidence reflection coefficients, when carefully culled of values considered unreliable and averaged to reduce variability (which also decreases resolution), did exhibit a strong correlation with in situ sediment velocity measurements. Although not nearly as cost effective as swath backscatter, high resolution seismic data may prove to be a more reliable as a remote sensing means of sediment characterization.

Both the in situ station measurements and chirp reflection coefficients provided important statistical information on spatial variability of acoustic properties (Figure 2a). These results, perhaps typical for sandy environments, can be compared to similar analysis of core data from the Northern California STRATAFORM natural laboratory (Goff et al., 2002), which is dominated by muddy sediments (Figure 2b). Through stochastic modeling, we are able to generate synthetic realizations, which conform to the statistical behavior as determined through semi-variogram analyses from both areas (Figure 3).

IMPACT/APPLICATIONS

Realizations of bathymetry and velocity statistical models are being used by LePage and Odom for use in acoustic modeling of the impact of seabed variability on acoustic prediction.

RELATED PROJECTS

The STRATAFORM and Geoclutter programs have provided critical data inputs for this project.

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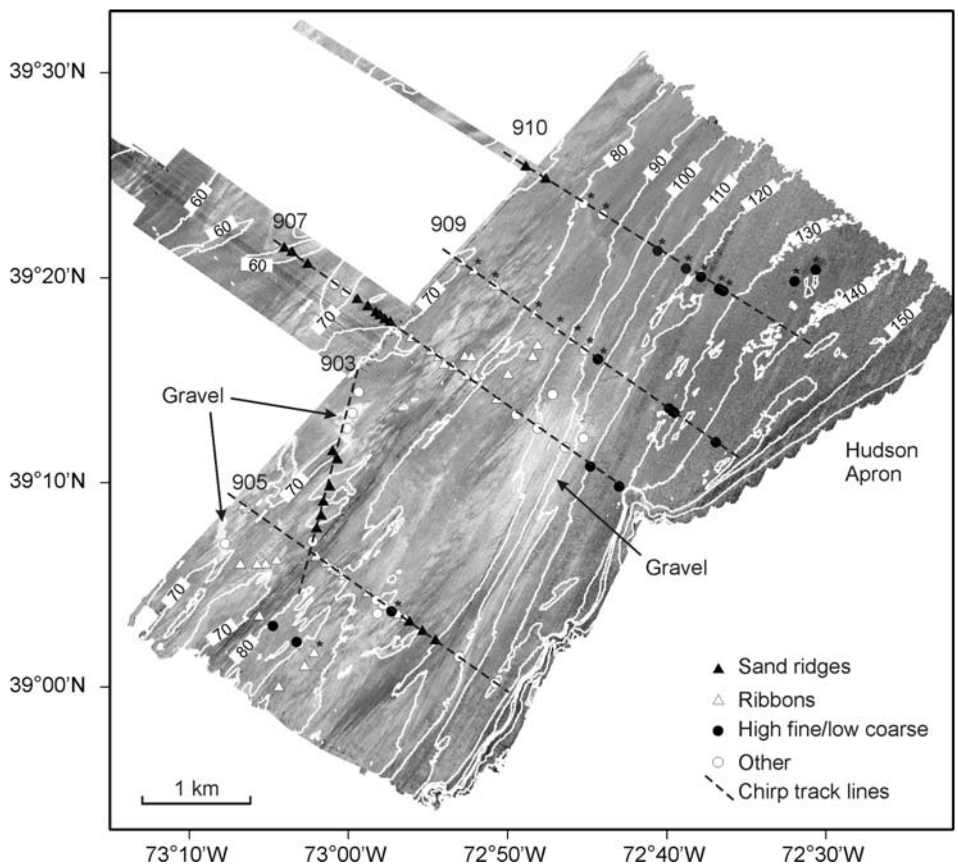

Figure 1. Multibeam backscatter from the 1996 STRATAFORM swath map survey. Lighter shades in indicate higher backscatter intensity. Contours are in meters. Symbols, categorized by morphological/sedimentological provinces, indicate station locations for grabs samples and* in situ *velocity and attenuation data. Short core stations are indicated by asterisks. Dashed lines indicate track lines of CHIRP seismic data used for reflection amplitude analysis.

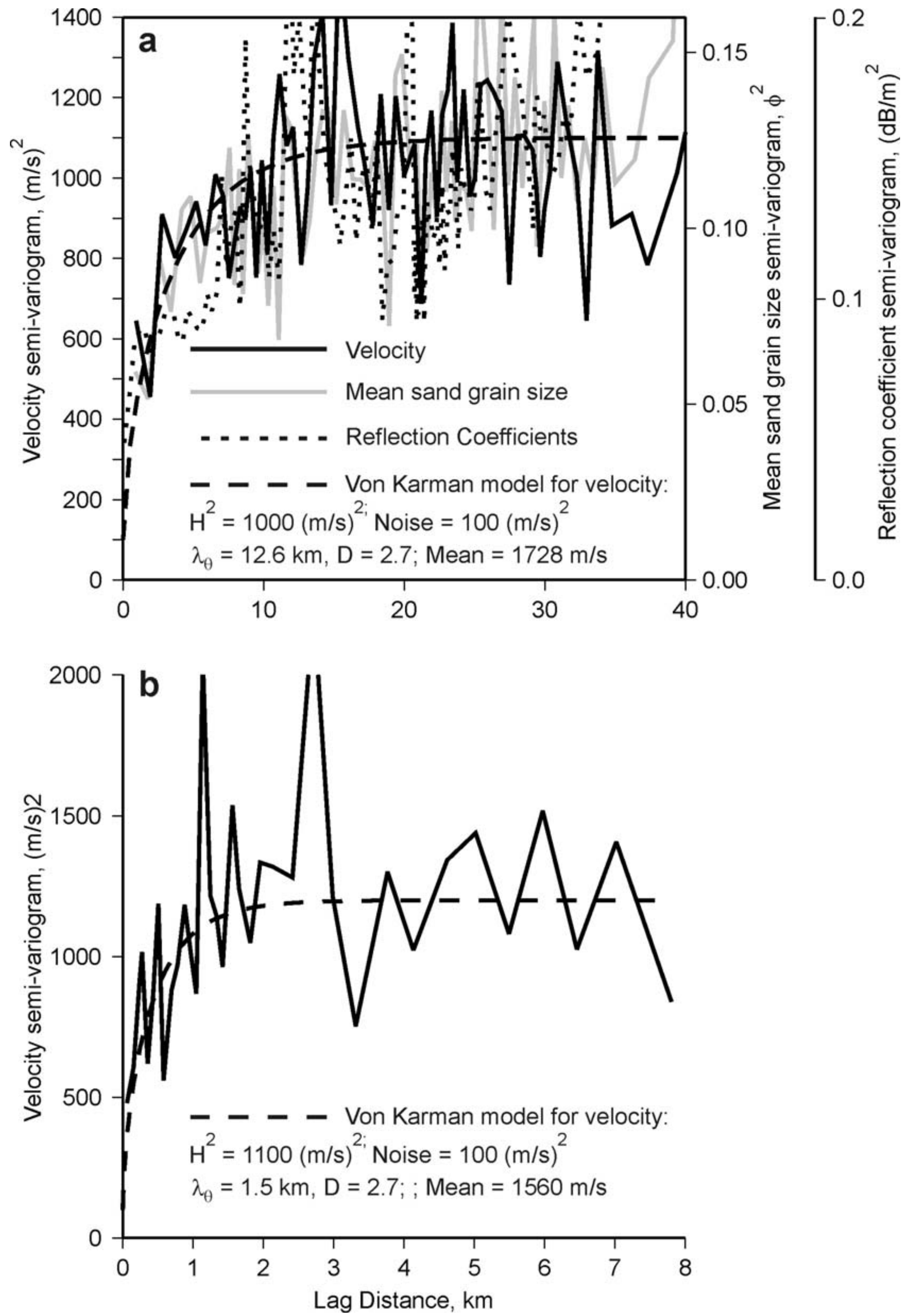

Figure 2. Semi-variograms derived from station (in situ compressional velocity, mean sand grain size) and seismic line (reflection coefficient) sources within the New Jersey shelf (a) and Eel River shelf (b) STRATAFORM natural laboratories. The New Jersey shelf is primarily sandy, while the Eel River shelf is primarily muddy.

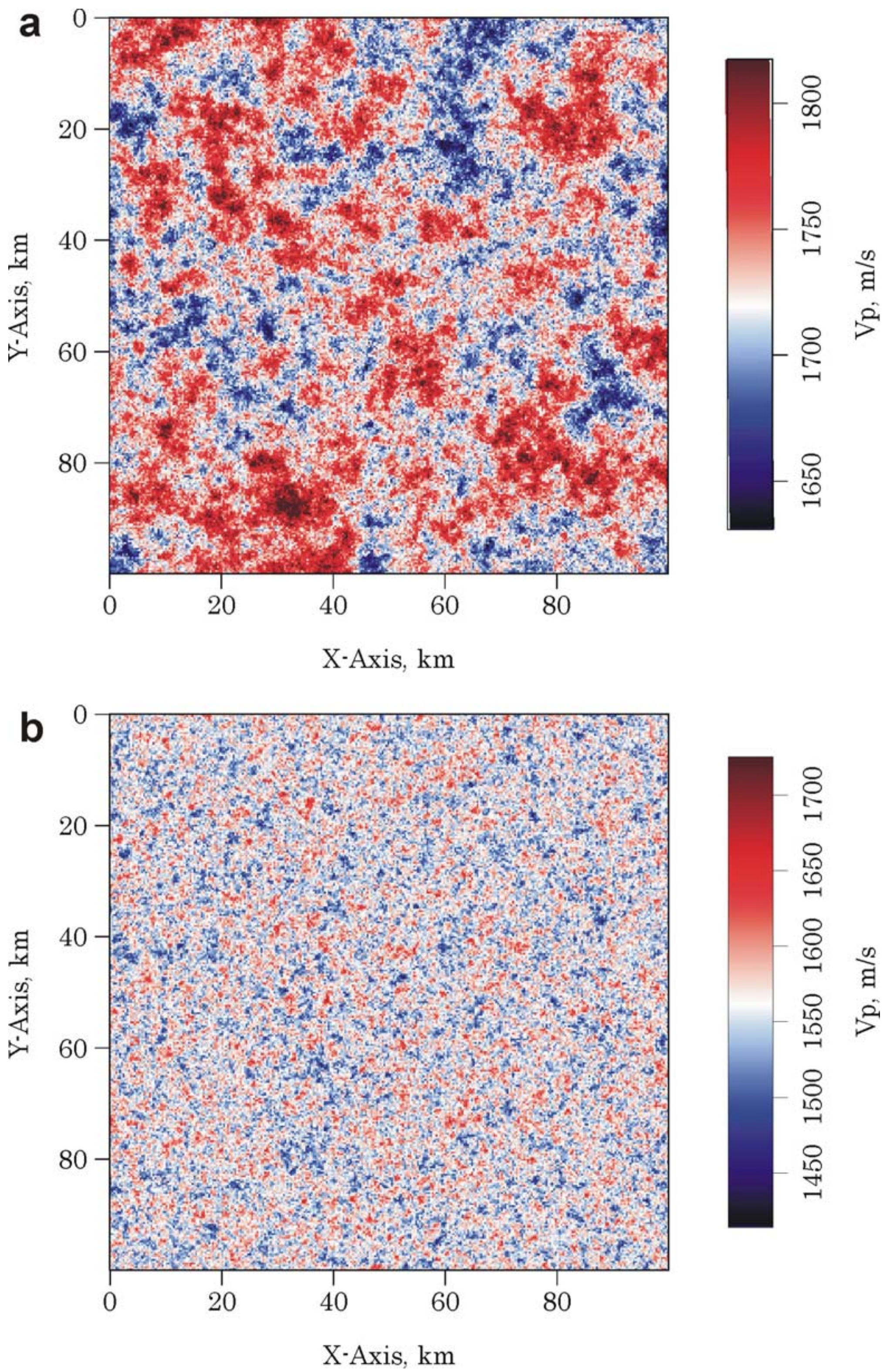

Figure 3. Synthetic realizations based on the New Jersey (a) and Eel River (b) seafloor velocity models shown in Figure 2, generated using a Fourier method (Goff and Jennings, 1999)