MODELLING OF SEAFLOOR REVERBERATION IN NORTHERN GULF OF MEXICO SANDY SEDIMENT

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1 Introduction

Underwater acoustics is an important tool for detecting and classifying targets such as submarines, mines, and fauna. Backscatter from the seafloor degrades the acoustic signal received from targets and thus modelling seafloor backscatter is an important component of active sonar. In this paper seabed roughness and cone pentrometer data taken during the TREX2013 sea trial will be used to produce a model of backscatter from sediment. The TREX sea trial was conducted in the Northern Gulf of Mexico, just off the coast of Panama City, Florida. The data was collected along two different tracks known as the main track(Figure 1) and the clutter track, which runs approximately perpendicular to the to the main track. The study area is composed of fine to medium grained quartz sand with a low carbonate content and patches of fine-grained sediment(mud and silt) [1, 2]. The bathymetry of the TREX study area is characterized by large-scale north-south-trending sand ripples with amplitudes ranging from 1–3 m and wavelengths between 0.1 to 0.5 km [1, 3]. At high resolutions the acoustic scattering is considered nearly isotropic, however, on a broad scale it appears to show both gradual and abrupt changes in backscatter strength [4]. At high frequencies backscatter in the study area is mainly controlled by roughness spectra, however, at low and medium frequencies it is expected that volume scattering will also play a role in sediment backscatter. The most prominent volume scatterers in the study area are likely to be shell hash, hard packed sand, and other carbonate scatterers [5].

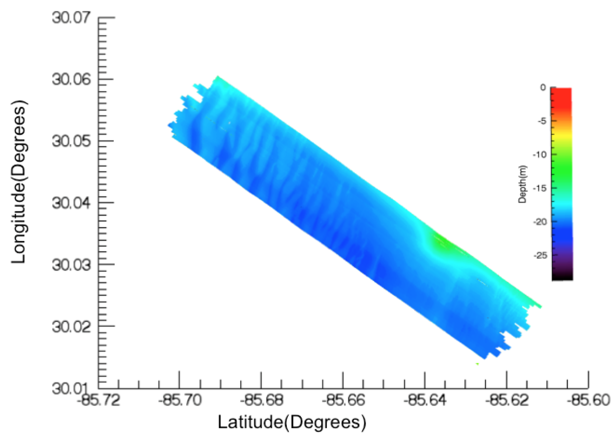

Figure 1: Image of main track bathymetry at 1m resolution

2 Methods

2.1 Roughness Spectra

The one dimensional roughness spectra for the multiple different sources of bathymetry collected during TREX were calculated in both the along track and across track directions. For each line a peridogram was calculated and then in each direction the peridograms were averaged. To test for isotropy a 2D FFT was also calculated.Two important parameters for inputs into backscattering models are spectral strength(ω_2) and spectral slope($-\gamma_2$).This can be modelled by the power law, which can be expressed as $W(\vec{k}) = \omega_2 k^{-\gamma_2}$ [6]. Since, in this study, the roughness was found to be roughly isotropic the spectral strength and slope can be determined from the 1D spectra, which is modelled as a power law of spectral strength (ω_1) and slope($-\gamma_1$). It was assumed that the measured roughness scaling continued to scales that affect the scattering.

2.2 Scattering Model

The two-dimensional roughness spectra and geoacoustic parameters measured by the cone pentrometer were used to model acoustic backscatter as a function of Grazing Angle. Methods described in [7] were used to empirically estimate sound speed ratio(υ), density ratio(ρ), loss parameter(δ), and volume scattering parameter(σ_2) based on the grain sizes determined by the cone penetrometer. A composite roughness approximation (CRA) model [6, 7] was used to determine the backscattering strength. In the CRA backscattering strength is defined as the product of roughness scattering and volume scattering.

3 Results

3.1 Roughness Spectra

For all sources of bathymetry the 2D FFTs show roughly isotropic spectral characteristics at the scale of 75m or less, and thus in terms of high to mid frequency acoustics the sediment can be considered isotropic. Shown in Figure 2 is the average one dimensional spectra across the north/south lines, east/west lines, and across all lines. The power law fit obtained from the 1D spectra is $\omega_1 = 5.716^{-8} m^{3-\gamma_1}$ and $\gamma_1 = 1.454$. The 2D spectral parameters were calculated to be $\omega_2 = 4.464^{-7} m^{4-\gamma_2}$ and $\gamma_2 = 2.454$.

3.2 Backscatter Model

The following geoacoustic parameters were obtained from the cone penetrometer data, and used as inputs into the scattering model : υ=1.23, ρ=1.46, σ_2=0.002, and δ=0.016. The CRA backscatter model has been plotted as a function of grazing angle along with Lambert's Law and a Lambert's Law fit for sandy sediment (μ=-20.2) for comparison. Between 30° and 90° the model appears to be most predominantly controlled by volume scattering. At grazing angles below approximately 18° roughness scattering is the dominant control on scattering strength. In between 18° and 30° both types of scattering appear to contribute equally to the scattering strength. Near the critical angle (35.7°) the CRA demonstrates a steep slope, causing the backscattering strength to be much lower than what is predicted by Lambert's Law. Below 15° the CRA plot has a much smaller slope than predicted by Lambert's Law. The CRA predicts significantly lower backscatter than the sandy sediment value fit with μ=-20.2 measured previously at other sites.

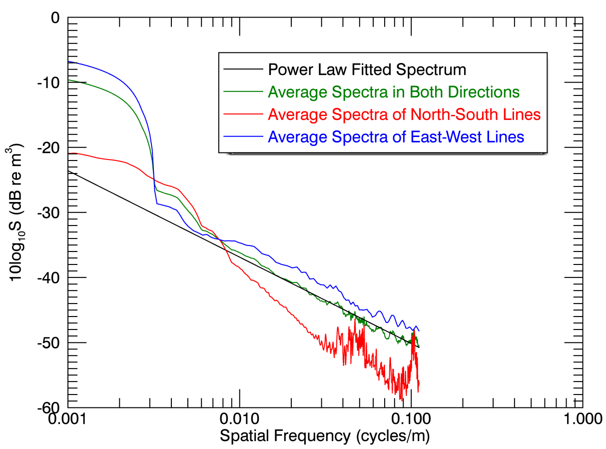

Figure 2: Average spectra and Power-Law fitted spectrum to average Spectra from both directions

4 Discussion

In the CRA the volume scattering coefficient is determined either empirically based on measured backscattering data or by estimation based on mean grain size. In this study, the volume parameter was determined based on mean grain size, however in many cases sediment grain size is not an accurate predictor of volume scattering [6, 7].In addition to this, the model also fails to consider volume scattering due to heterogeneity with depth as well as the presence of discrete scatterers [7]. Therefore it is possible that the CRA model predicts significantly lower backscattering strength than expected because volume scattering is not being fully accounted for.

5 Conclusions

The CRA model predicts that the sediment in the study area is not an ideal diffusely reflecting surface. Below the critical angle the CRA model predicts grazing angle dependency that is far different than what would be predicted by Lambert's Law. The significant difference in scattering strength predicted by the CRA model and the Lambert's law fit to sandy sediment indicates that predicting volume scattering with sediment grain size may not always be an effective way to mo-

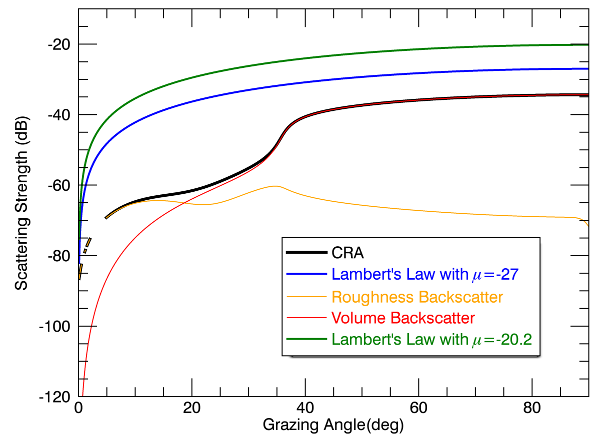

Figure 3: Plot comparing scattering strength as function of grazing angle for : the CRA model of TREX study area, Lambert's Law(μ=-27) and Lambert's Law fit for sandy sediment(μ=-20.2). Also shown is the seabed roughness scattering strength computed for the CRA and the volume scattering strength computed for the CRA

del backscattering. Thus more research needs to be conducted to test and further develop models that account for volume heterogeneity (both at and below the sediment water interface) and discreet scatterers. In future work sub-bottom profiler data collected during TREX2013 will be used in order to quantify volume scattering.

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