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PROBABILISTIC ESTIMATION OF MERCHANT SHIP SOURCE LEVELS AND SEABED GEOACOUSTIC PROFILES IN A SHALLOW-WATER ENVIRONMENT

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ABSTRACT

The estimation of ship source levels (SSL) in shallow-water environments is affected by sound interaction with the seabed. Uncertainty in seabed properties influence SSL estimates, and it is of interest to mitigate and quantify such effects. This paper applies a probabilistic approach to ship radiated noise recorded on hydrophone line arrays to infer SSLs and properties of a mud-sand seabed in shallow waters (depths ~80 m) on the New England Shelf. The approach, trans-dimensional Bayesian marginalization, samples probabilistically over source strengths, source depths/ranges, number of seabed layers and geoacoustic parameters of each layer. Radiated noise due to three large merchant ships passing at 2−4 km range from hydrophone arrays is considered. The estimated SSL spectra agree well with reference spectra. The average SSL uncertainty is 3.2 dB/Hz for narrowband (20−120 Hz) noise and 1.8 dB/Hz for broadband noise (190−590 Hz). Seabed layering and geoacoustic parameter estimates agree reasonably well with mud-over-sand seabed models from other inversions in the experiment area.

Keywords: *seabed parameters, inverse methods, ship.*

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1. INTRODUCTION

Merchant ships are a major contributor to ocean noise in coastal marine environments, especially near shipping lanes leading to and from commercial ports, and it is of interest to obtain information on ship source levels (spectra) from measurements in such settings. Measurements of SSL typically require a deep-water site and controlled test geometries to minimize environmental effects. Numerical acoustic propagation models can be used to mitigate seabed and multipath effects but require knowledge of often unknown seabed structure and parameters. This paper applies a statistical inference approach (non-linear Bayesian marginalization) to infer SSLs and seabed properties in shallow waters, with application to ship-noise data collected during the 2017 Seabed Characterization Experiment [1].

2. DATA AND PROCESSING

Shallow-water acoustic data were collected during the 2017 Seabed Characterization experiment on the New England Mud Patch [1]. The experiment area was located between shipping lanes leading to/from the Port of New York and New Jersey. Instruments included a 20-element horizontal line array (HLA) of length 480 m deployed by FFI at water depth 68.7 m in the northern part of the experiment area within 2−3 km of the northern shipping lane, and a 16-element vertical line array (VLA) of length 56 m deployed by the Scripps Institution of Oceanography at water depth 76.2 m in the southern part of the experiment area within 3−4 km of the southern shipping lane. Radiated noise from three merchant ships are considered in this work: the cargo ship *M/V Ever Living* on the HLA [2], and the cargo ship *MSC Kalamata* and the vehicle carrier *Tombarra* on the

VLA [3]. Fig. 1 shows a spectrogram of noise due to the *MSC Kalamata* received on one of the VLA hydrophones.

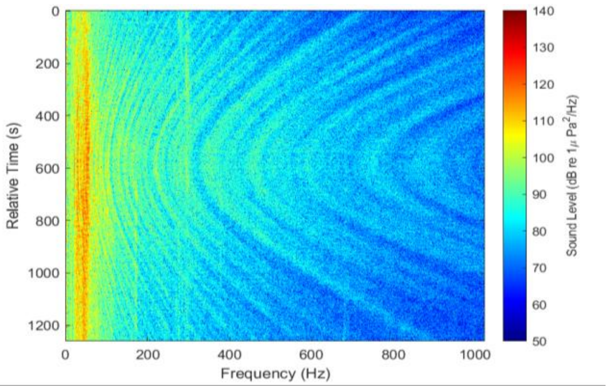

Figure 1. Spectrogram of received noise due to the container ship *MSC Kalamata*.

3. RESULTS

This work applied a non-linear Bayesian marginalization approach to infer SSLs and seabed properties from hydrophone array data [2,3]. The posterior probability density comprised a likelihood function assuming uncorrelated Gaussian errors and uniform priors. The approach samples probabilistically over source amplitude/phase at each frequency, source depths/ranges (via Metropolis-Hastings sampling), and number of seabed layers and geoacoustic parameters of each layer (via reversible jump Markov-chain Monte Carlo sampling). SSL estimates are inferred from source amplitude distributions. The estimated geoacoustic marginal probability profiles indicated a low-speed/low-density iso-speed upper layer, an interface/transition at 7−10 m depth, and a higher-speed/higher-density layer below. Table 1 provides the mean and mean deviation values for the seabed parameters, at depths of 0 m (at the top of the mud layers) and at 12 m (beneath the mud layers) from inversions of *MSC Kalamata* ship noise. The profiles are overall consistent with the layered mud-over-sand sediment model from other inversions in the area [1]. Fig. 2 shows the SSL estimates and uncertainties from inversion of data due to the *MSC Kalamata*. There is reasonable agreement with reference spectra from the literature (solid and dashed curves in Fig. 2), based on ensembles of deep-water SSL measurements.

Table 1. Seabed parameters and units, and parameter mean and mean-deviation uncertainty estimates from inversions of *MSC Kalamata* ship noise on a VLA.

Parameters and units	Depth [m]	*MSC Kalamata*
Sound speed (m/s)	0 12	1473.1±0.5 1785±58
Density (g/cm^3)	0 12	1.36±0.06 1.99±0.10
Attenuation (dB/λ)	0 12	0.04±0.02 0.27±0.12

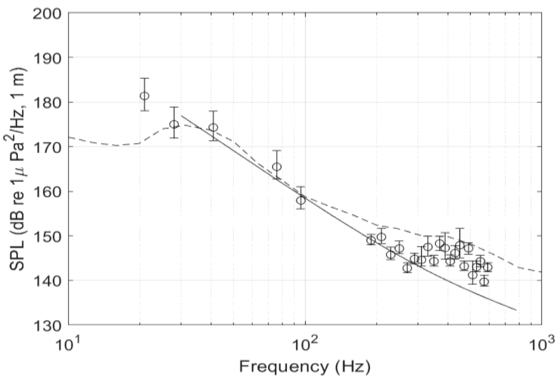

Figure 2. Median SSL estimates (circles) with inter-quartile range uncertainty intervals (bars), from inversion of noise due to the container ship *MSC Kalamata*. The curves are reference spectra.

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