GEOACOUSTIC INVERSION IN A RANGE-DEPENDENT ENVIRONMENT UNDER THE ASSUMPTION OF RANGE-INDEPENDENCE

Michael G. Morley, Stan E. Dosso, and N. Ross Chapman
School of Earth and Ocean Sciences, University of Victoria, Victoria, B.C., Canada, V8W 3P6

1. INTRODUCTION

A significant amount of research has been devoted to estimating the geoacoustic properties of the seabed by matched-field inversion (MFI) in recent years. The assumption of range independence reduces the number of parameters in the problem and significantly improves the computational efficiency of MFI; however, neglecting spatial variability in the properties of the real environment degrades the accuracy in modelling the acoustic field. This may lead to large theory errors and produce unacceptable inversion results. The aim of this paper is to investigate the effect that ignoring random variability of individual model parameters has on the accuracy of the inversion results for a simple, shallow-water model. In Ref. 1 the authors investigated how well a range-independent inversion could recover average values for the parameters of a range-dependent environment. Their results suggested that ignoring range dependence leads to large biases in the recovered parameters but their conclusions were based mostly on single frequency inversions for a hard-bottom environment. This study re-examines the issue addressed in Ref. 1; however, a much faster forward model is used making it practicable to use multiple frequencies in the inversion – a more common practice in the ocean acoustics community. The study is extended to consider a soft-bottom environment as well. The degree of random, range-dependent variability in water depth and seabed sound speed that can be tolerated is examined by inverting synthetic data sets generated from many unique, random realizations of the environment. Comparisons are made between inversion results using single and multiple frequencies for the two environments. The results indicate that the biases in the recovered parameters are much smaller than previously suggested, although in some cases significant biases can occur.

2. METHOD

The general form of the geoacoustic model considered in this study consisted of an 80 m deep ocean of sound speed 1460 m/s over a semi-infinite sediment layer. Two different sediment regimes were considered: a hard-bottom case similar to the one in Ref. 1 with sound speed 1677 m/s, density 2.06 g/cm^3, and attenuation 0.436 dB/λ, and a soft-bottom case with sound speed 1500 m/s, density 1.5 g/cm^3, and attenuation 0.2 dB/λ. The experimental geometry consisted of a source at 35 m depth and 4 km away from a 70 m long vertical array with hydrophones spaced at 1 m intervals from 5 m to 75 m in the water column. For each case in the study, one hundred unique realizations of a range-dependent environment were generated by adding scaled random perturbations to either the sediment sound speed or water depth at regular intervals so as to achieve a desired mean and variance [1]. Data for each realization were generated at 50 Hz intervals over the 100-800 Hz band using a range-dependent, parabolic equation acoustic propagation model. Several data sets were generated for different degrees of range dependence ranked by the standard deviation of the random fluctuations in sound speed, σ_{cp}, or water depth, σ_H. Spatially white, Gaussian noise was added and an inversion was performed for each data set using the adaptive simplex simulated annealing (ASSA) hybrid inversion algorithm [2] with a normal mode acoustic propagation model. The inversions solved for the water depth, sound speed, density and attenuation parameters assuming the environment was range independent. Separate inversions were performed using a single frequency of 100 Hz and for all 15 frequencies within the band.

3. RESULTS

The distributions of the best-fit model parameters from all of the inversions are used as an indicator of how well the range-dependent environment can be approximated by a range-independent model. These distributions are described by the standard deviation about the true mean parameter value, the standard deviation about the distribution mean, and the bias of the distribution. Figure 1 shows a plot of these values for multiple and single frequency inversions at 100 Hz for the case of variable sound speed in a hard bottom. The multiple frequency inversion results from all the data sets in this case are distributed tightly about the true mean model values even when there is considerable deviation in sound speed in the bottom. The single frequency inversion results are broadly distributed with large biases. This indicates that in this environment significant fluctuations of sound speed in the seabed can be effectively averaged over by including multiple frequencies in the inversion.

For the soft-bottom case shown in Fig. 2 the inversion results are more dependent on each realization of the range-dependent environment. Beyond σ_{cp}= 20 m/s the

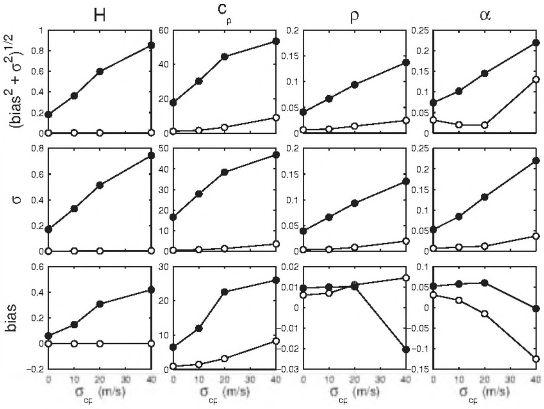

Fig. 1. Summary of the distributions of results for variable sound speed in the hard bottom model. Multiple frequency (open circles) and single frequency results at 100 Hz (closed circles) are shown.

distributions of the best-fit model parameters are wider with larger biases than for the hard-bottom case; however, reasonable average sound speed and water depth values are still found.

When the range-dependent water depth data were inverted the results are highly sensitive to the particular realization of the environment for the hard bottom but not for the soft bottom. A summary of the distributions of best-fit model parameters are shown in Fig. 3 for the hard bottom. A significant improvement is observed when using multiple frequencies in the inversion; however, beyond $\sigma_H = 0.25$ m the biases and standard deviations of the distributions of the geoacoustic parameters become significant. For the soft-bottom case in Fig. 4 the biases and standard deviations remain quite small even when there are significant random fluctuations in the water depth.

There is significant improvement in the consistency of the inversion results when multiple frequencies are used.

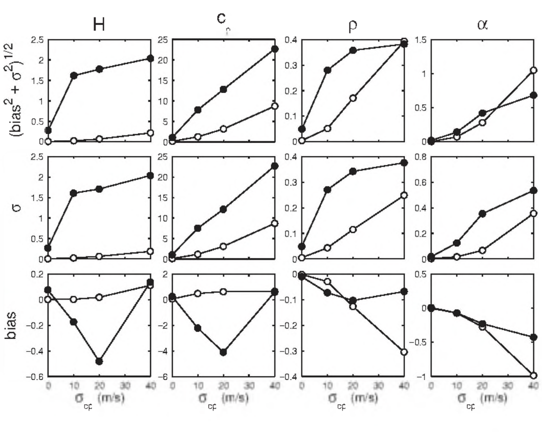

Fig. 2. Summary of the distributions of results for variable sound speed in the soft bottom model.

Inversions performed for the hard-bottom environment are sensitive to fluctuations in water depth but relatively insensitive to changes in sound speed. The opposite is true for the soft bottom. These sensitivities result in biased values for sound speed, density and attenuation. In the range-dependent data the fluctuations in seabed sound speed or water depth increase the amount of acoustic energy loss. To account for this loss in the range-independent approximation the inversion results are biased toward smaller average values for sound speed and density and larger values for attenuation.

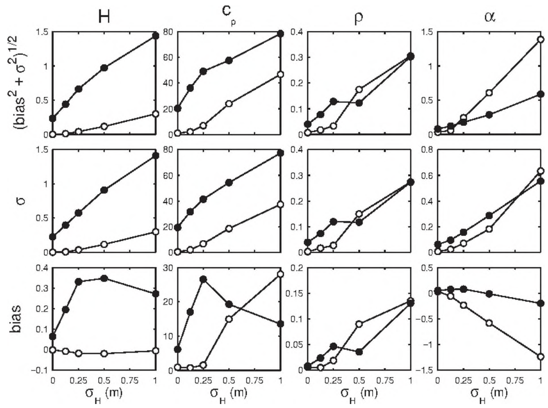

Fig. 3. Summary of the distributions of results for variable water depth for the hard bottom model.

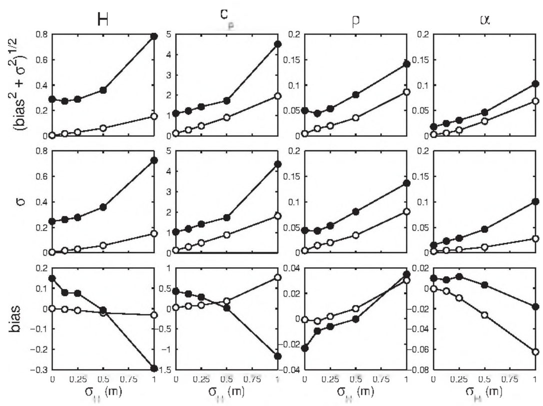

Fig. 4. Summary of the distributions of results for variable water depth for the soft bottom model.

REFERENCES

[1] Lapinski, A. -L. S., Chapman, D. M. F. "The effects of ignored seabed variability in geoacoustic inversion," *J. Acoust. Soc. Am.*, **117**(6), 3524-3538 (2005).

[2] Dosso, S. E., Wilmut, M. J., and Lapinski, A. -L. S. "An adaptive-hybrid algorithm for geoacoustic inversion", *IEEE J. Oceanic Eng.*, **26**, 324-336 (2001).

ACKNOWLEDGEMENTS

The authors would like to thank Anna-Liesa Lapinski and Dave Chapman of DRDC-Atlantic for providing some of the computer codes used in this work.