Session 5aUW

Underwater Acoustics and Acoustical Oceanography: Geoacoustic Inversion

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Chair's Introduction—7:45

Contributed Papers

7:50

5aUW1. Notes on broadband seabed geoacoustic inversion in shallow water. Ji-Xun Zhou and Xue-Zhen Zhang (Georgia Inst. of Technol., Atlanta, GA 30332-0405 and Inst. of Acoust., Chinese Acad. of Sci., Beijing, 100080, China)

With increasing interest in shallow-water environments, where bottom interaction is a dominant effect, there is a need to acquire accurate information about seabed geoacoustic parameters. Due to the difficulties and high costs of directly measuring seabed parameters at low frequencies (LF) in shallow water (SW), seabed geoacoustic inversion from long-range propagation has become an active research area. Much progress on this subject, notably on inversion methods, has been made in the last two decades, mainly through the use of powerful numerical codes and data processing tools. Despite this, seabed geoacoustic inversion often fails to yield systematic LF seabed parameters in a broad band (such as speed/attenuation vs frequency) that are required for seabed geoacoustic modeling or for sonar performance prediction in the SW environment. This paper will discuss several basic concepts and technical issues related to SW geoacoustic inversion, including filter phase shifting, speed-attenuation coupling, hidden depth, and sea-surface effects. It shows that inverting the broadband seabed acoustic parameters is a delicate task that can often be subject to errors. These issues should be considered in designing experiments that test seabed geoacoustic inversion methods or in interpreting experimental results. [Work supported by ONR and NNSF of China.]

8:05

5aUW2. Efficient use of *a priori* data in sediment inversions through the use of null space. Gopu R. Potty, James H. Miller (Dept. of Ocean Eng., Univ. of Rhode Island, Narragansett, RI 02882), Ying-Tsong Lin, and James F. Lynch (Woods Hole Oceanogr. Inst., Woods Hole, MA)

We present improved inversions for sediment parameters by incorporating *a priori* information about the environment. This improvement is achieved by projecting a desirable solution into the null space of the inversion and including this null space contribution along with the standard non-null space contribution. We use singular value decomposition (SVD) to define the null space of the inversion and elucidate our projection method. The desirable solution, which is projected into the null space, is constructed based on previous data from cores, geophysical surveys, and historic data. This approach introduces user bias into the solution; the projection onto the null space supplies a safety net by showing which aspects of this bias are justified by the data. The user bias can be considered as additional data which, when incorporated, can lead to meaningful solutions. Effectiveness of probing the null space will be compared to the more conventional nonlinear inversion schemes. This approach will be tested using field data collected as part of the Shelfbreak Primer experiment. [Work supported by ONR.]

8:20

5aUW3. Robust source localization and geoacoustic inversion in the Haro Strait Primer. Rashi Jain, Zoi-Heleni Michalopoulou (Dept. of Mathematical Sci., New Jersey Inst. of Technol., Newark, NJ 07102), and Alex Tolstoy (A. Tolstoy Sci., McLean, VA 22101)

Gibbs sampling, a Markov chain Monte Carlo technique, has been shown to be apowerful tool for geoacoustic inversion and source localization. By providing estimates of posterior joint distributions, it offers a global optimization route for multidimensional estimation that reports uncertainty and covariance in addition to point estimates. In this work, Gibbs sampling is applied for extracting time delays from recorded time series during the Haro Strait primer experiment. Employing time delay estimates and using a linear approximation to the inverse problem and then regularization, estimates are obtained for source and receiver location and some environmental parameters. Simultaneously processing receptions at all three vertical line arrays for localization of each source reduces ambiguities in the estimation process. Similarly, using received signals corresponding to several sources, array element localization for a single array, a difficult problem for this particular data set, becomes more precise. Multiple data sets are used in the inversion and consistent results validate the robustness of the approach. Estimated bathymetry is in agreement with bathymetric maps for the region. [Work supported by ONR.]

8:35

5aUW4. Coherent noise processing and geoacoustic inversion. Peter Gerstoft, Chen-Fen Huang, and William S. Hodgkiss (Marine Physical Lab., Univ. of California San Diego, San Diego, CA 92093-0238)

Ocean acoustic noise can efficiently be processed to extract Green function information from noise [Roux *et al.*, J. Acoust. Soc. Am. (2004), Siderius *et al.*, *ibid.* (2006)]. By cross-correlating the ambient noise field from two sensors, it is possible to extract the impulse response between the two sensors including bottom and subbottom bounces. When this noise processing is used on a vertical array, it can give valuable information about the subbottom near the array. This information will be then be used to constrain a classical geoacoustic inversion procedure where we use a distant towed source to obtain the geoacoustic bottom parameters.

8:50

5aUW5. Geoacoustic inversion based on both acoustic pressure and particle velocity. A. Vincent van Leijen (NLDA, P.O. Box 10.000, 1780 CA, Den Helder, The Netherlands, av.vanleijen@kim.nl), Jean-Pierre Hermand (ULB, B-1050 Bruxelles, Belgium), and Kevin B. Smith (NPS, Monterey, CA 93943)

Conventional inversion schemes for environmental assessment depend on an objective function that exploits amplitude or phase information of acoustic pressure data alone. This work investigates the potential of vector sensors for geoacoustic inversion by defining an objective function that

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also takes into account acoustic particle motion. Calculations are performed on synthetic broadband data for a shallow water environment (South Elba) with an optimization scheme based on different metaheuristics. Differences in the inversion process, including sensitivity of the cost function to environmental parameters and convergence speed of the optimization algorithm, are presented by comparing inversion results for a sparse pressure-only array and a vector sensor array.

9:05

5aUW6. Geophysical parameter inversion in a range-dependent environment. Woojae Seong, Keunhwa Lee, Kyungsup Kim (Dept. of Ocean Eng., Seoul Natl. Univ., Seoul, 151-742, Korea), and Seongil Kim (Agency for Defense Development, Jinhae, Korea)

Matched-field inversion technique is applied for estimation of geophysical parameters of the ocean bottom in a range-dependent shallow water. In the experiment (MAPLE-4), conducted off the coast of the East Sea during May 2005, narrow-band multitone cw acoustic data were obtained from the towed moving source along a weakly range-dependent track, from 2 to 18 km apart from the L-shaped receiver array. In the inversion, complex density model based on Biot model is used to invert for parameters including porosity and permeability. Inversion results are compared with existing geological survey data. In addition, the effect of range dependency resulting from the seafloor slope and the existing bottom intrusion is examined.

9:20

5aUW7. Bayesian inversion of propagation and reverberation data. Peter L. Nielsen (NATO Undersea Res. Ctr., Viale S. Bartolomeo 400, 19138 La Spezia, Italy) and Stan E. Dosso (Univ. of Victoria, Victoria, BC, Canada V8W 3P6)

A Bayesian matched-field inversion approach to infer geoacoustic and scattering properties of the seabed is applied to simulated propagation and reverberation data received on a towed horizontal array. The approach is based on the method of fast Gibbs sampling (FGS) of the posterior probability density to estimate uncertainties in both geoacoustic and scattering parameters for broadband acoustic data in realistic shallow-water environments. The FGS is linked to an acoustic propagation model that simultaneously provides complex acoustic pressure at short propagation ranges and long-range reverberation intensity. The inversion algorithm is initially applied to long-range reverberation data alone to assess the geoacoustic information content of reverberation in terms of marginal posteriori probability densities for the environmental parameters. A reduction in uncertainty for the extracted geoacoustic and scattering parameters is demonstrated by a simultaneous inversion of the propagation and reverberation horizontal array data.

9:35

5aUW8. On the use of acoustic particle velocity fields in adjoint-based inversion. Matthias Meyer, Jean-Pierre Hermand (Université libre de Bruxelles, Belgium & Royal Netherlands Naval College, The Netherlands), and Kevin B. Smith (Naval Postgraduate School, Monterey, CA)

Following the recent interest in the use of combined pressure and particle motion sensors in underwater acoustics and signal processing, some general aspects regarding the modeling and multipath phenomenology of acoustic particle velocity fields in shallow water environments have been studied. In this paper we will address a number of issues associated with the incorporation of vector sensor data (pressure and particle velocity) into adjoint-based inversion schemes. Specifically, we will discuss the ability of a semi-automatic adjoint approach to compute the necessary gradient information without the need for an analytic model of the adjoint particle velocity field. Solutions to the forward propagation of acoustic pressure are computed using an implicit finite-difference parabolic equation solver while the particle velocity is calculated locally at each grid point. Some numerical examples of vector sensor inversion results are provided. [Work supported by Royal Netherlands Navy.]

9:50

5aUW9. Sensitivity analysis of a geoacoustic parametrized model and its application to inversion of seabed properties. Jin-Yuan Liu and Chung-Ray Chu (No. 70 Lien-hai Rd. Kaohsiung 804, Taiwan)

The work first aims to analyze the parametrized geoacoustic model proposed by Robins [J. Acoust. Soc. Am. **89**, 1686–1696 (1991)], in which the density and sound speed distributions vary with respect to depth as a generalized-exponential and an inverse-square function, respectively. The model contains a set of parameters that, by appropriate selection, may fit well the realistic geoacoustic variations [E. L. Hamilton, J. Acoust. Soc. Am. **68**, 1313–1340 (1990)]. By choosing the plane-wave reflection field as an objective function, each model parameter is carefully analyzed to determine its range and sensitivity. Then, numerical simulation is employed to establish an inversion procedure, in conjunction with the application of acoustic wave reflection from a nonuniform seabed. Finally, a field experiment is designed and implemented to estimate the seabed acoustic properties based upon the model parameter inversion.

10:05–10:20 Break

10:20

5aUW10. Characterization of sediment dynamics in an estuary environment using acoustic techniques. Jean-Pierre Hermand, Laura Perichon (Environ. Hydroacoustics Lab., Optics and Acoust. Dept., ULB-CP 194/05, 50 AV. F.D. Roosevelt, B-1050 Brussels, Belgium), and Michel Verbanck (Univ. Libre de Bruxelles, B-1050 Brussels, Belgium)

In recent years, acoustic-based methods have been developed to characterize the dynamical behavior of loose sediments and bed deposits in very shallow water environments. In this paper, we present preliminary results on the estimation of the dynamic changes in an estuarine environment using data from dual-frequency echosounding at high resolution and contemporaneous hydrological measurements including suspended matter concentration, density subbottom profiling, and data assimilation based on a sediment transport model. Those measurements are being conducted in the lower estuary of the Scheldt (Belgium) at the Sint Anna site where strong tide and season-dependent phenomena can be observed. This allows us to construct a ground-truthed, time-dependent geoacoustic model of the environment, i.e., a characterization of sound speed, density, and attenuation in function of time and depth. Synthetic acoustic data generated by that model will then be used to test inversion methods for monitoring sediment dynamics in real time.

10:35

5aUW11. Geoacoustic model for the New Jersey Shelf by inverting airgun data. Yong-Min Jiang, N. Ross Chapman (School of Earth and Ocean Sci., Univ. of Victoria, P.O. Box 3055, Victoria, BC V8W 3P6, Canada), and Mohsen Badiey (Univ. of Delaware, Newark, NJ 19716)

This paper describes geoacoustic inversion of airgun data acquired during the SWARM95 experiment. Hybrid optimization and Bayesian inversion techniques were applied to three airgun data sets recorded by a vertical line array. Optimization results are used to show the consistency of the estimates from all of the shots in terms of histograms and standard deviations of the inverted geoacoustic model parameters. The inversion results from the Bayesian approach are used to show the uncertainties of the estimates in terms of marginal distributions, MAP estimates, and credibility intervals. In the Bayesian inversion, full data error covariance matrices were estimated by ensemble averaging the covariance of the residuals of the measured and modeled data of inversions from many shots. The numbers of shots in the ensemble averages were determined by checking the temporal coherence of the signal. Statistical tests were used to test the validity of the assumptions in the Bayesian approach after incorporating full data error covariance matrices. With these inversion techniques, equivalent geoacoustic models with/without shear wave estimates are extracted for this experimental site. The frequency dependence of the p-wave attenuation, and the correlation between the geoacoustic parameters are obtained from the inversion results. [Work supported by ONR.]

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