International Journal of Computational Acoustics, Vol. 8, No. 2 (2000)

INTERNATIONAL ASSOCIATION
FOR MATHEMATICS AND
COMPUTERS IN SIMULATION

OBJECTIVE FUNCTIONS FOR OCEAN ACOUSTIC INVERSION DERIVED BY LIKELIHOOD METHODS

CHRISTOPH F. MECKLENBRÄUKER

Forschungszentrum Telekommunikation Wien, A-1040 Vienna, Austria
cfm@ieee.org

PETER GERSTOFT

Marine Physical Laboratory,
Scripps Inst. Oceanography, San Diego CA 92093-0704, USA
gerstoft@mpl.ucsd.edu

Received 13 August 1999
Revised 14 January 2000

Selection of a suitable objective function is an integral part of the inverse problem, and poor selection can have a strong influence on the inverse result. Objective functions are here derived for many practical occasions such as for single frequency and broadband, with and without knowledge of source strength, and with and without the received signal phase. These objective functions are all derived from a unified approach based on maximum likelihood and additive Gaussian noise models. The assumptions for the objective function are thus clear and the resulting estimator has good properties. From a Bayesian point of view, the solution to the inverse problem is the *a posteriori* probability distribution of the unknown parameters, which can be found from the likelihood function. Thus using objective functions based on likelihood functions facilitates computing the *a posteriori* distributions.

International Journal of Computational Acoustics, Vol. 8, No. 2 (2000)

INTERNATIONAL ASSOCIATION
FOR MATHEMATICS AND
COMPUTERS IN SIMULATION

DEDUCTIVE MULTI-TONE INVERSION OF SEABED PARAMETERS

M. A. AINSLIE, R. M. HAMSON, G. D. HORSLEY, A. R. JAMES, and R. A. LAKER

CORDA Ltd, Apex Tower, 7 High Street, New Malden, Surrey, KT3 4LH, UK

M. A. LEE, D. A. MILES, and S. D. RICHARDS

DERA(W), Winfrith Technology Centre, Winfrith Newburgh, Dorset, DT2 8XJ, UK

Received 6 August 1999
Revised 22 February 2000

An iterative matched field processing scheme is described for efficient inversion of geoacoustic parameters in shallow water using a vertical receiving array at three frequencies in the range 50–500 Hz. The method relies on the assumption that the acoustic data are sensitive to different geoacoustic parameters at different frequencies. First an exhaustive 2D search is carried out at high frequency to determine initial estimates for density and sound speed. A second 2D search follows at an intermediate frequency to determine sediment attenuation and sound speed gradient. An iteration is carried out over these first two phases until these four parameters converge. In a third phase, the low frequency data are used to search for the remaining unknown parameters (primarily sediment thickness, substrate density and substrate sound speed) with a differential evolution algorithm. Finally all three phases are repeated iteratively, in principle until a complete converged solution (a self-consistent set of all inverted parameters) is found, although for practical reasons the search is terminated before convergence is demonstrated. Tests on synthetic data are reported demonstrating the accuracy and stability of the method. Initial results for measured data are also presented.

International Journal of Computational Acoustics, Vol. 8, No. 2 (2000)

INTERNATIONAL ASSOCIATION
FOR MATHEMATICS AND
COMPUTERS IN SIMULATION

TOMOGRAPHIC INVERSION FOR GEOACOUSTIC PARAMETERS IN SHALLOW WATER

A. TOLSTOY

ATolstoy Sciences, 8610 Battailles Court, Annandale VA 22003, USA
atolstoy@ieee.org

Received 6 August 1999
Revised 3 December 1999

This paper examines the *linearized* tomographic inversion of simulated data for a shallow water, multi-array, multi-source scenario. The environments represented include simulations of (1) highly idealized constant regions as well as (2) the Haro Strait Test of June 1996 which displays range, depth, and azimuthal variability, i.e., 3-D dependence on environmental parameters where these parameters can include water depths and multiple sediment sound-speed profiles, densities, depths, and attenuations. This tomographic inversion method is *independent* of the *number* of parameters to be determined. However, the method does assume that *some* inversion method (such as RIGS, simulated annealing, genetic algorithms, etc.) has already estimated range-independent *average* source-to-receiver environmental parameters. These *average* parameters are then input into the tomographic inversion which relies on a matrix of path-cell distances. The matrix condition number, Λ, is a determining feature for the inversion accuracy where Λ is a function of source and receiver distributions and their subsequent path distances through the region cells. Additionally, the accuracy of the input estimates for the *average* geoacoustic properties is also an important factor in the *final* 3-D tomographic inversion accuracy. Results using this (linearized) tomography inversion method show a potential for *excellent* error estimates (much less than 1%) for the environmental parameters assuming exact, idealized input values. Errors are still quite reasonable (well under 10%) if more realistic, i.e., erroneous, input values are assumed. This paper will conclude with a discussion of upcoming future directions.

International Journal of Computational Acoustics, Vol. 8, No. 2 (2000)

INTERNATIONAL ASSOCIATION
FOR MATHEMATICS AND
COMPUTERS IN SIMULATION

MATCHED FIELD TOMOGRAPHIC INVERSION TO DETERMINE RANGE DEPENDENT GEOACOUSTIC PROPERTIES

V. CORRE, N. R. CHAPMAN, and M. J. WILMUT

School of Earth and Ocean Sciences, University of Victoria, P.O. Box 3055, Victoria B.C., V8W 3P6, Canada

Received 5 August 1999
Revised 29 November 1999

The paper describes a new broadband tomographic matched field method for estimating the geoacoustic properties of a range-dependent shallow water environment. This method is designed for a multiple acoustic element configuration (several sources and vertical arrays deployed in an ocean region) in order to estimate the range and cross-range properties of the sediment over the region. The synthetic pressure fields (replicas) for the tomographic inversion are computed using a ray model. A linear processor operating in the frequency domain is used to quantify the match between replica and measured fields. This processor is based on coherent summations over frequencies and receiver pairs. The method is demonstrated for a geoacoustic ocean model simulating the environment of the Haro Strait experiment. The area is divided into cells in which the geoacoustic properties are range independent but can vary from one cell to another. The layer thickness can vary within a cell. Results are presented for the estimation of the compressional velocity and sediment layer thickness in the ideal case of a noise free synthetic data set.

International Journal of Computational Acoustics, Vol. 8, No. 2 (2000)

INTERNATIONAL ASSOCIATION
FOR MATHEMATICS AND
COMPUTERS IN SIMULATION

IDENTIFYING MODAL ARRIVALS IN SHALLOW WATER FOR BOTTOM GEOACOUSTIC INVERSIONS

MICHAEL I. TAROUDAKIS

Institute of Applied and Computational Mathematics,
Foundation for Research and Technology-Hellas,
P.O. Box 1527, GR-711 10, Heraklion, Crete, Greece

Department of Mathematics, University of Crete,
714 09 Heraklion, Crete, Greece
taroud@iacm.forth.gr

Received 24 August 1999
Revised 4 January 2000

A mode identification process that can be applied to broadband acoustic transmissions in the ocean is presented. The process is associated with a modal travel time inversion scheme for geoacoustic or tomographic inversions. The process is based on the assumption that a reference (background) environment is known and the identification process is based on information on the group (modal) velocities of the reference environment only. Using two characteristic examples corresponding to shallow water environments it is shown that the identification process works well at least for the lower order modes.

International Journal of Computational Acoustics, Vol. 8, No. 2 (2000)

INTERNATIONAL ASSOCIATION
FOR MATHEMATICS AND
COMPUTERS IN SIMULATION

GEOACOUSTIC TOMOGRAPHY: RANGE DEPENDENT INVERSIONS ON A SINGLE SLICE

GOPU R. POTTY and JAMES H. MILLER

Department of Ocean Engineering,
University of Rhode Island, Narragansett, RI 02882, USA

Received 24 June 1999
Revised 21 February 2000

A hybrid inversion scheme is used for the inversion of bottom geoacoustic properties using synthetic data as well as broadband signals from explosive sources. This technique is shown to be effective for range dependent inversion on a single slice using synthetic and experimental data. The experimental data was acquired during the Shelf Break Primer Experiment. Time-frequency analysis was performed using wavelets. Group speeds obtained from the time-frequency scalograms were used as data for the inversion. The hybrid method consists of a Genetic Algorithm, which performs the global search, and a Levenberg-Marquardt method, which hastens the descent to the global minimum. Error estimates based on Hessians and *a posteriori* variances are also provided. Resolution is estimated using an *a posteriori* analysis.

International Journal of Computational Acoustics, Vol. 8, No. 2 (2000)

INTERNATIONAL ASSOCIATION FOR MATHEMATICS AND COMPUTERS IN SIMULATION

NONLINEAR SOLITON INTERACTION WITH ACOUSTIC SIGNALS: FOCUSING EFFECTS

O. C. RODRÍGUEZ and S. JESUS

UCEH-Universidade do Algarve, Campus de Gambelas, 8000, Faro, Portugal

Y. STEPHAN and X. DEMOULIN

EPSHOM/CMO, BP426, F-29275, Brest, France

M. PORTER

Science Applications International Corp., San Diego, USA

E. COELHO

Instituto Hidrográfico, 1296, Lisboa, Portugal

Received 6 August 1999
Revised 11 January 2000

The problem of nonlinear interaction of solitary wave packets with acoustic signals has been intensively studied in recent years. A key goal is to explain the observed transmission loss of shallow-water propagating signals, which has been found to be strongly time-dependent, anisotropic, and sometimes exhibited unexpected attenuation versus frequency. Much of the existing literature considers the problem of signal attenuation in a static environment, without considering additional effects arising from groups of solitons evolving both in range and time. Hydrographic and acoustic data from the INTIMATE'96 experiment clearly exhibit the effects of soliton packets. However, in contrast with reported observations of signal attenuation, the observed transmission loss shows a pronounced signal enhancement that behaves like a focusing effect. This focusing is correlated with peaks in current, temperature, and surface tide. That correlation suggests that the nonlinear interaction of solitary wave packets with acoustic signals can lead to a focusing of the signal. To clarify this issue, hydrographic data was used to generate physically consistent distributions of "soliton-like" fields of temperature and sound velocity. These distributions were then used as input for a range-dependent normal-mode model. The results strongly support the hypothesis that the soliton field causes the observed signal enhancement.

International Journal of Computational Acoustics, Vol. 8, No. 2 (2000)

INTERNATIONAL ASSOCIATION
FOR MATHEMATICS AND
COMPUTERS IN SIMULATION

SEAFLOOR PROPERTIES DETERMINATION FROM ACOUSTIC BACKSCATTERING AT NORMAL INCIDENCE WITH A PARAMETRIC SOURCE

ANDREA CAITI

ISME — Interuniversity Centre of Integrated Systems for the Marine Environment & DII — Dip. Ing. Informazione, University of Siena
ISME — c/o DSEA, Dept. Electrical Systems & Automation, University of Pisa, via Diotisalvi 2, 56100 Pisa, Italy

Received 28 July 1999
Revised 9 December 1999

An inversion technique is proposed for the determination of the geoacoustic and morphological properties of the uppermost sediment layer. The methodology is based on the use of the backscattering acoustic return when the source is a parametric instrument steered at normal incidence with respect to the seafloor. The peculiarity of the parametric sonar (i.e., its narrow beam and the absence of sidelobes) allows for discriminating between the scattering effects due to surface roughness and those due to volume perturbations. The inversion procedure is based on the minimization of a discrepancy measure between data and model predictions. Model predictions are obtained as time series realization of a stochastic process, modeling the backscattering process with the Kirchoff approximation for surface scattering and the small perturbation theory for volume scattering. The BoRIS code is used to generate the time series predictions. It is important to note that the model is stochastic, i.e., the model predicted time series with the same nominal parameters may differ from one realization to another. However, by use of wavelet transform of the signals involved, and measuring the data-model discrepancy in a generalized time-frequency domain, the stochasticity of the problem is greatly reduced. In particular, the wavelet transform is insensitive to different model realizations obtained with the same set of parameters, and sensitive to changes in the parameters. By appropriately weighing the discrepancy in the wavelet domain, and exploiting the properties of the parametric source, it is possible to separately recover the parameters influencing the surface backscattering (acoustic impedance and surface roughness) and those influencing the volume backscattering (P-wave attenuation and volume inhomogeneity), avoiding ambiguities and nonuniqueness problems. The approach proposed requires, however, a precise calibration of the parametric sonar, in terms of source level and beam pattern. Comparison of inversion results with independently measured ground truth at three different sites in the Mediterranean Sea are reported.