# Full Field 3-D Geoacoustic Inversion

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## LONG TERM GOAL

The full field 3-D geoacoustic inversion method is eventually intended for real-time estimation of range, depth, and azimuthally varying shallow water environmental properties by non-invasive, acoustic, remote sensing means via simple broadband sources such as SUS. The estimated environmental properties would then be available as input parameters to fleet acoustic propagation models used for the detection of targets, e.g., subs or mines.

## OBJECTIVES

The objective of this approach is to estimate those geoacoustic environmental parameters to which acoustic fields are sensitive. Such environmental parameters include: number of sediment layers, sediment thicknesses, attenuations, densities, and sound-speed profiles. The intention is to replace present requirements for extensive environmental sampling (which can be extremely time-consuming and expensive) with intense computational processing of array data (with limitations determined primarily by the nature of the array configuration and the computer system available for data processing).

## APPROACH

The full field approach involves using array data from broadband sources with good signal-to-noise levels at frequencies from 50 to 500Hz. The time domain measured fields are first converted via FFTs to complex fields at constant frequencies. Next, these CW fields are compared to complex modeled fields (at selected frequencies) where the model environmental inputs are varied in a systematic way. The inversion method finally converges to a set of values which optimize the correlation between data and model. The principle assumed is that high correlations for a high resolution processor and over numerous frequencies will indicate input values “closer” to the “true” environmental values, i.e., those which would be measured given sufficient resources. The “true” values would result in nearly perfect predictions for the observed acoustic fields over the broadband low (50 - 500 Hz) frequencies and over the selection of target ranges of interest (usually under 10 km). Unlike the focalization approach our method hopes to estimate the “true” geoacoustic parameters.

## WORK COMPLETED

Work completed over the past year (Oct 01 1997 to Sep 30 1998) includes:

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- Co-guest Editorship (along with N.R. Chapman) of a Special Issue of the Journal of Computational Acoustics (to be appear in Fall of 1998) containing the compilation of 14 geoacoustic inversion papers presented in last summer's workshop.
- Summary JCA article (for the Special Issue) discussing the workshop and presented results.
- Contributed JCA paper (for the Special Issue) discussing results of 10 workshop cases investigated via the RIGS (Refined Iterative Grid Search) method.
- Simulation of Haro Strait data for the inversion estimation of water depth over 3-D, i.e., varying as a function of range, depth, and azimuth.

## RESULTS

Over the past 12 months we have analyzed simulated data (both the benchmark workshop data and Haro Strait data) for geoacoustic inversion processing. This has been highly important for the understanding of inversion limitations and of potential accuracies and has resulted in major improvements in the 3-D tomographic inversion method under study. We are also finding successful ways to search the large solution spaces and to eliminate non-uniqueness difficulties in solution estimation. In particular, we have found that multiple frequency processing (but not necessarily coherent broadband processing) is critical for accurate and unique results. Additionally, it has become apparent that frequency subspacing (lower frequencies for deeper properties, higher frequencies for surface sediment properties) results in significantly improved efficiency in the method. We have also made important progress in understanding: the bottom and geometric properties affecting the acoustic fields, the relative importances of these properties, and the optimal processing frequencies. The simulated Haro Strait data has suggested that finer grid sampling of the region can lead to degraded results unless there are increased resources. That is, finer grids mean fewer paths sampling each cell unless more sources and/or arrays are used in the configurations. To date we have estimated the simulated water depths over the Haro Strait region (keeping all other idealized parameters fixed at their true values) to within better than 1.0 m on average (relative to depths 115 to 240 m). Thus, we have continued to advance the capabilities of the tomographic, high resolution MFP based inversion method (RIGS) which has been under development for this project. The RIGS method was applied to the workshop data with excellent results. Conclusions to date include: broadband processing is critical, the propagation model used is critical (KRAKEN was found to have significant difficulties but incorporating ORCA can overcome those), physical insight to efficiently organize parameter seaches can be very helpful, and some parameters are easily estimated with very high accuracy (such as source coordinates, water depth, sediment density and attenuation; results illustrated in Figs. 1,2). Additionally the method has been applied to simulated Haro Strait data for the estimation of bottom depth with excellent results achieved for the coarse grid (53 unknown bottom depths).

## IMPACT/APPLICATION

If this technique proves to be successful, it could influence array technology and the selection of propagation models used by the fleet for target detection and localization. It could also affect fleet strategy for the calibration of a region's environmental parameters with subsequent target searches prior to committment of fleet resources. The estimation of true geoacoustic properties will be extremely important for the detection and localization of targets such as subs as well as of buried targets such as mines.

## TRANSITIONS

The Workshop97 and RIGS results are influencing a host of methods for geoacoustic inversion (see next section). Other researchers are also investigating the Haro Strait data.

## RELATED PROJECTS

Many inverse techniques are currently being pursued to determine bottom properties, and the newest involve the use of MFP for a signal measured along an array of receivers. The MFP techniques often involve simple least squares fits of model predictions to data which are subsequently combined with computationally intense, random number based methods such as simulated annealing (Chapman, Dosso, et al.) or genetic algorithms (Gerstoft). The full field 3-D geoacoustic inversion approach being developed in this work is not a least squares fit nor is it random-number based. It is based on the high resolution, non-linear minimum-variance (MV) processor plus a global, user directed search through parameter space. Other investigations in the area of geoacoustic inversions are being conducted by the Canadians (Chapman et al. who are also investigating the Haro Strait data; Heard et al., Zala and Ozard), Europeans (Hamson and Ainslie of Great Britain; Jesus of Portugal; Siderius and Gerstoft of SACLANT Centre; Simons and Snellen of The Netherlands; Stephan et al. of France; Taroudakis and Markaki of Greece; Westerlin of Sweden), and Asians (Ratilal et al. of Singapore; Zhang et al. of China).

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## FY 98 PUBLICATIONS


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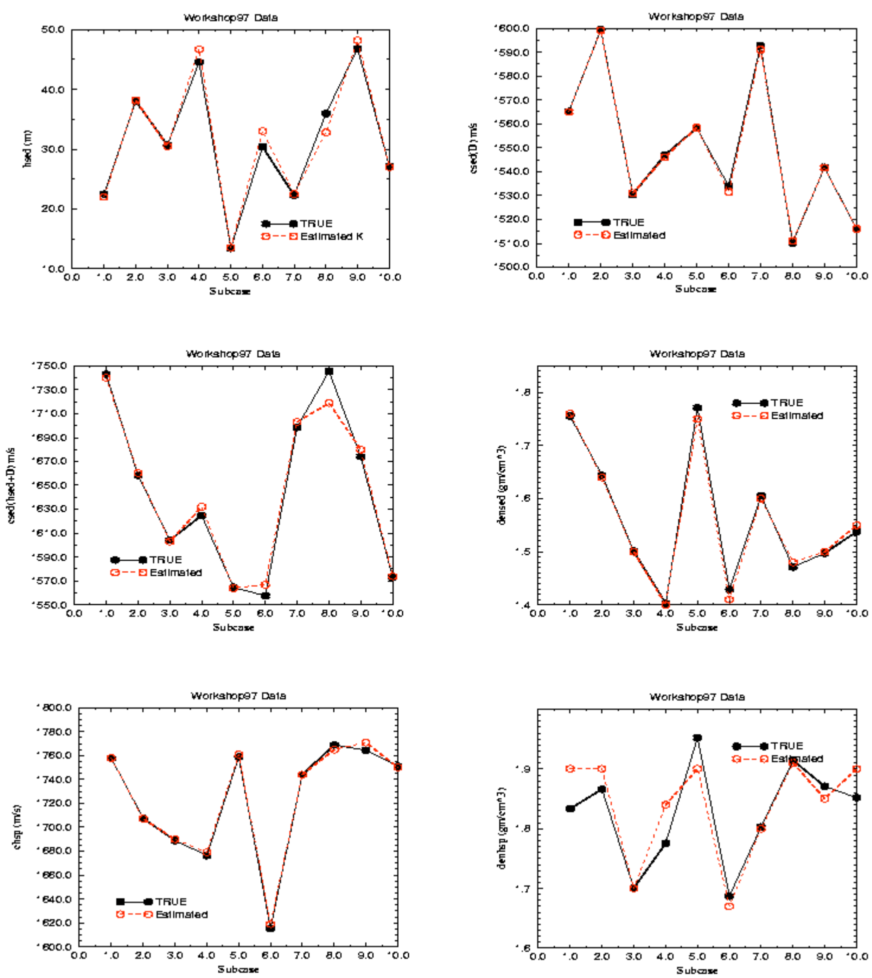


Figure 1: Plots in the style of Simons and Snellen of true and RIGS estimated parameter values. The parameters are indicated on the ordinate axes while the corresponding subcases are indicated on the abscissae. Subcases 1-3 correspond to SDa-c, 4-6 to ATa-c, 7-9 to SOa-c, and 10 to WAa. Note that subcases 1, 2, 5, 7, 10 were estimated with the new modified RIGS approach.

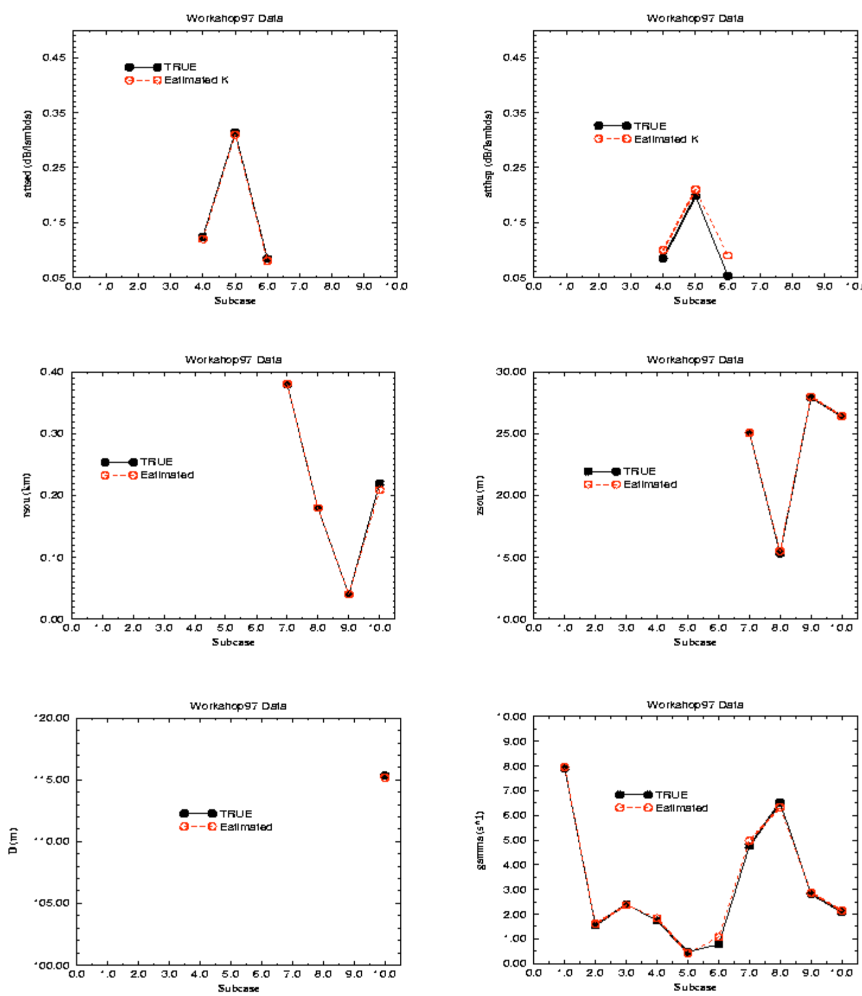


Figure 2: Continuation of Fig. 1 with additional parameters.