Tomographic inversion for geoacoustic parameters

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LONG TERM GOAL

The tomographic geoacoustic inversion method is intended for the eventual real-time estimation of range, depth, and azimuthally varying shallow water bottom properties by means of simple, rapidly deployed, broadband sources plus a few rapidly deployed receiver arrays. The computed 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 efficiently and rapidly 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, as a function of 3-D *range, depth, and azimuth.* The intent is to replace present requirements for extensive environmental sampling (which can be extremely time-consuming and expensive) with intense computational processing of multiple array plus multiple broadband source data.

APPROACH

The present approach for tomographic inversion has evolved from deep ocean tomography (see Munk et al., '95; Tolstoy, '94) where for shallow water geoacoustic parameter estimation it now involves:

1. sensitivity analyses on individual source-to-receiver (SR) paths in order to optimize the non-linear inversion (via the RIGS method or some other selected inversion method) to find the *critical* geoacoustic parameters (which are scenario dependent); see Tolstoy, '98, '99a;

2. non-linear inversion (via RIGS or some other selected method) applied to individual SR paths to estimate the *average* critical geoacoustic parameters per path; see Tolstoy et al., '98;

3. a single matrix inversion incorporating *all* the SR paths (via their distances through the gridded region of interest; see Tolstoy, '92, '99b);

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4. a final combination of the matrix inversion result (step 3) with the average critical path parameter values (from step 2) via a *linear* equation to obtain the full 3-D tomographic global (range, depth, and azimuthally varying) parameter estimations;

5. special emphasis on the recently collected, multiple array, multiple broadband source, Haro Strait data.

Analysis to date has involved both *simulated* and *test* data. We note that the method is *independent* of the number of parameters to be estimated per SR path where this number will only affect the inversion method applied to obtain the *average* path parameters, e.g., via RIGS or another selected method. The tomographic method *does* depend on the number of resources, i.e.,the number of sources and receiving arrays and their relative geometries, and on the selected gridding of the region of interest, i.e., more cells offer more variablility in the 3-D dependence of the parameters but result in reduced accuracy for those values.

WORK COMPLETED

This past year has resulted in the examination of model selection on MFP (see Tolstoy, '99c) and in the application of this new linearized tomographic approach to simulated Haro Strait data and in estimates of its potential accuracy under a variety of conditons, e.g., as a function of errors in the estimation of the average parameter values and of the number of cells.

In Fig. 1 we see the simulated Haro Strait scenario (see Jaschke, '97, for full details) with 42 sources indicated by *'s, 3 arrays by •'s, and where the 53 cells into which the region has been gridded are perfectly square with water depth indicated by the shading (deeper is darker).

In Fig. 2 we see the effect on errors in the estimation of water depth (m) as a function of error in the average SR water depth estimates. That is, if a randomized error of 1% is introduced into the SR average water depth values (and this was done 10 times), then the resultant tomographic inversion will have rms errors of approximately 3m (out of the maximum depth of 240m) in the final 3-D estimates of water depth. In the case of perfect estimates of the average SR depths, a final rms error of 0.23m and a maximum depth error (over 51 cells) of 0.68m resulted.

ACCOMPLISHMENTS AND RESULTS

The linearized tomographic method has been shown to offer excellent potential accuracy in the final 3-D inversion over *any number* of candidate SR geoacoustic parameters. That is, its accuracy will *not* depend on the number of geoacoustic parameters to be determined in each cell, e.g., on the details of the bottom structure which can lead to *many* unknowns per SR path. The method's accuracy *does* depend on the resources of the problem, i.e., on the number of sources, receiving arrays, and their relative geometries, and on the user selected gridding of the region of interest.

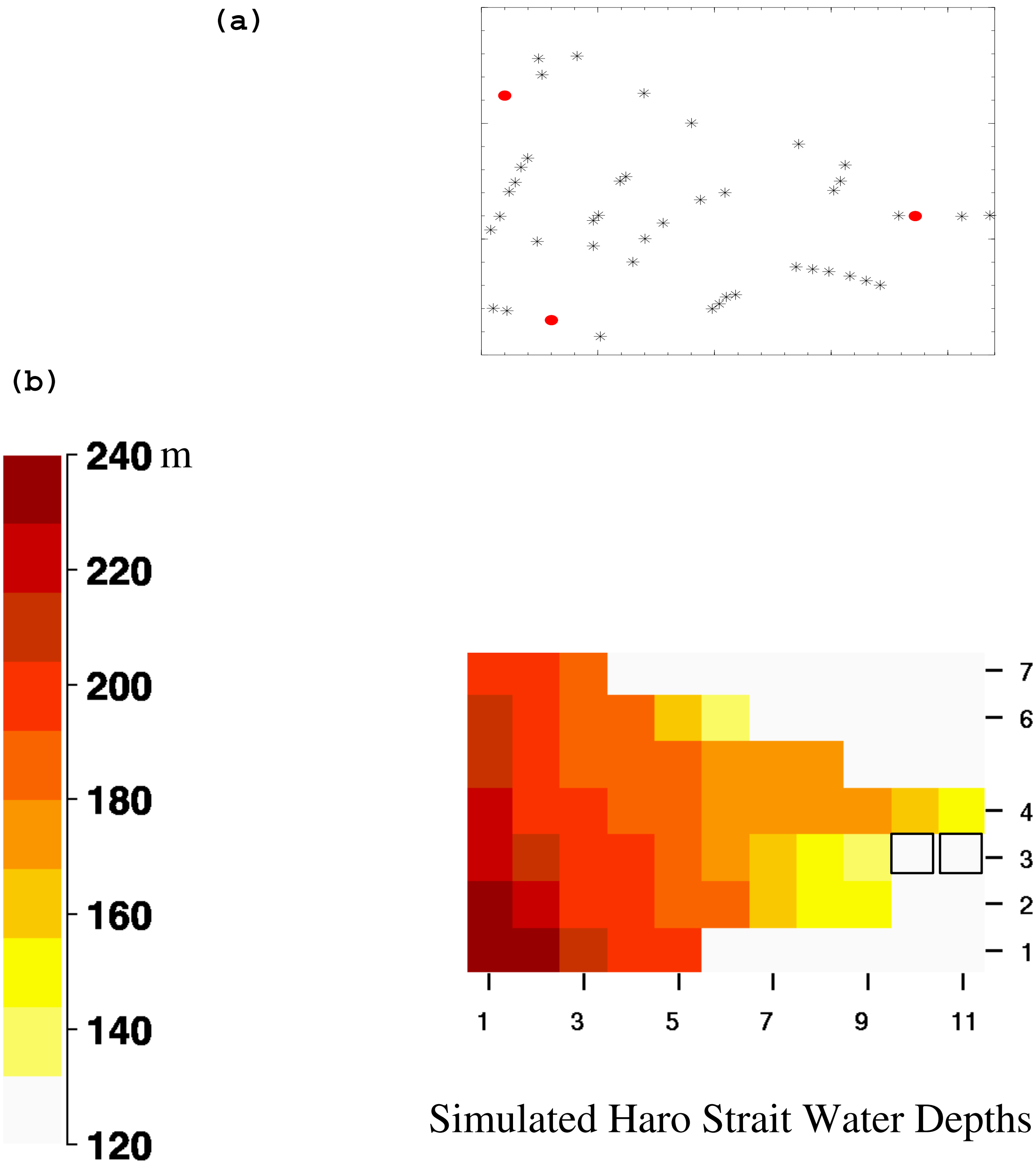

Figure 1: Simulation of Haro Strait resources (upper diagram) and water depths (lower diagram).

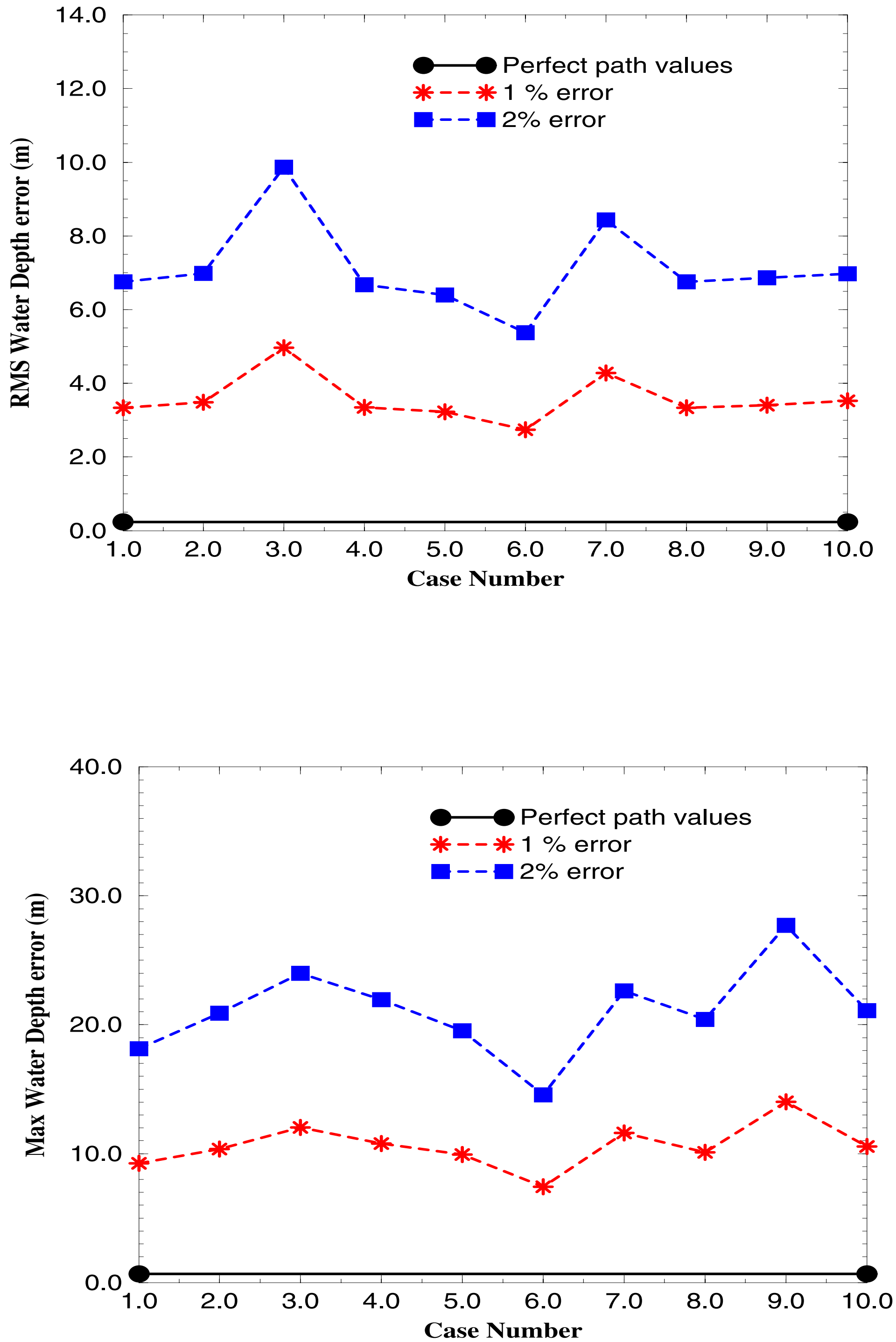

Figure 2: Results for 10 randomizations (of each *average* SR water depth error). (a) RMS errors; (b) Maximum Depth errors.

Accomplishments for FY99 also include:

- JCA paper on the subject of propagation model selection in MFP performance (accepted for publication).
- book article on MFP as applied to environmental inverse problems.
- book article on tomographic inversion for geoacoustic parameters in shallow water.
- co-author of Guest Editorial for IEEE J. Oceanic Acoust. Special Issue on Long Range Propagation which appeared in April '99.
- Four talks (2 invited) presented on the subject of inversion or MFP propagation modeling.
- Co-chair of 2 sessions at meetings.
- Co-chair and Co-organizer of SWAM99 Workshop, Monterey, 9/99.
- Member of organizing committee for ICTCA Beijing '01 meeting
- Member of Editorial Board of JCA
- Co-editor of IEEE Oceans Special Issue, 4/99.
- Member of SIAM Visiting Lecturers Program
- Member of AIP Visiting Lecturers Program
- ASA Committee Work:
  - Acoustical Oceanography Technical Committee
  - Underwater Acoustics Technical Committee
  - Committee on the Status of Women
  - Tutorials Committee
  - Book Committee.

IMPACT/APPLICATION

This technique is likely to influence array technology and the selection of propagation models used by the fleet for target detection and localization. It will also affect fleet strategy for the estimation of a region's environmental parameters. 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.

RELATED PROJECTS

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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