A progress report on the estimation of geoacoustic parameters from measured time series taken during the East China Sea component of ASIAEX

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#### 6. AUTHOR(S)

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Also See: M001452, The original document contains color images.
I. Modeling of forward transmission data
II. Comparisons to analyses of previous experiments
III. Summary and future work
Extract information on physics of low-frequency scattering from seabed

Use acoustic forward transmission data to establish average geoacoustic structure

Employ this information in the scattering equations to invert for the scattering potential of the seabed using reverberation data.

What features in the forward data allow for extraction of sound speed and attenuation structure?
ARL Analysis and Inversion Methodology

**Apriori information**
- SSP and variability
- Bathymetry
- Seabed representation
- Layering and geophysical information
- Source-receiver geometry

**Propagation models**
- Normal modes (NAUTILUS, ORCA)
- High angle PE (RAM 1.5)
- Ray theory (MEDUSA)

**Data inputs**
- Multi-frequency TL
- Time series from impulsive sources
- Broadband data from moving sources

**Simulated Annealing systematic decoupling**

**Parameter estimation and uncertainties**

**Cost functions**
- Narrow band and broadband
- Coherent over space, time, and frequency

**Validation with independent measurements**

**Agreement with ground truth**
Comparison of measured and modeled time series data on the APL/URI VLA. Range = 16.94 km, source depth = 55 m.
Comparison of measured and modeled magnitude of spectra for a single phone on VLA in East China Sea measurements. Source-receiver range = 16.94 km. Source depth 55 m. Source spectra from Chapman-Wakely model convolved with modeled frequency response in 50-350 Hz band. Modeled frequency response made with ORCA normal mode model.
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<th>Depth - m</th>
<th>Compressional Speed - m/s</th>
<th>Density - g/cc</th>
<th>Attenuation db/m-kHz</th>
<th>Frequency Exponent</th>
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Current Estimated Geoacoustic Profile in ECS basin from data analysis
Comparison of modeled TL using the ECS geoacoustic profile to measured TL taken at 29 05 N 126 43 E.
Estimated sound speed structure of upper 10 m of sediment describes relative arrival times of main multipath arrivals and general time spread characteristics as a function of range. Arrivals demonstrate critical angle effect at the water sediment interface.

A top sediment sound speed of 1640 m/s with a high sound speed depth gradient appears to be the key structure of the geoacoustic profile. Analysis, however, may have slightly overestimated sound speed because of incorrect water depth.

Very difficult to establish precise sediment thickness from time series data.
Comparisons of geoacoustic profiles in ECS region

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</tr>
</tbody>
</table>


* Rozenfeld et al IEEE JOE
** Knobles et al
An approximate geoacoustic description has been established for ECS Consistent with previous geophysical measurements.

Key characteristics of both forward time series and transmission loss measurements are reproduced by range-independent Geoacoustic model used in analysis of scattering data.

Uniqness of attenuation and layering structure in seabed difficult to es

Elastic description may be required for consistent picture of seabed acoustics.
Modeling of ASIAEX Reverberation

Research in progress
Sources of Reverberation

\[ z_{int} = H + \zeta (r,\theta) \]

\[ c_{\text{sed}} = c_s(z)[1+\mu(r,\theta,z)] \]

\[ \rho_{\text{sed}} = \rho_s(z)[1+\eta(r,\theta,z)] \]
Model Assumptions

- Density fluctuations proportional to sound speed fluctuations: \( \eta(r) = 2\gamma\mu(r) \)
  
  - Sound speed fluctuations small: \( |\mu(r)| \ll 1 \)

- Water sediment interface nearly flat, slightly rough:
  \[
  |k_0\zeta(r)| \ll 1 \quad |\nabla_{\parallel}\zeta(r)| \ll 1
  \]

- Perturbation approximation: keep only first order terms in above small quantities
Equation for Scattered Field

\[ p_{\text{scat}}(\mathbf{r}) = -\frac{1}{4\pi} \left\{ \int_{V} (2\gamma + 2) \mu(\mathbf{r}') k_0^2(z') [G_0(\mathbf{r}; \mathbf{r}') G(\mathbf{r}'; \mathbf{r}_0)] dV' \right. \\
- \left. \int_{V} (2\gamma) \mu(\mathbf{r}') [\nabla G_0(\mathbf{r}; \mathbf{r}') \cdot \nabla G(\mathbf{r}'; \mathbf{r}_0)] dV' \right\} \\
+ \int_{S} (2\gamma) \mu(\mathbf{r}') \left[ G_0(\mathbf{r}; \mathbf{r}_0') \frac{\partial G}{\partial z'} (\mathbf{r}_+'; \mathbf{r}_0) \right] dA' \\
+ \int_{S} \zeta(\mathbf{r}') \left( 1 - \frac{\rho_w}{\rho_s} \right) [\nabla G_0(\mathbf{r}; \mathbf{r}_+') \cdot \nabla G(\mathbf{r}_+'; \mathbf{r}_0)] dA' \\
- \int_{S} \zeta(\mathbf{r}') \omega^2 \left( \frac{1}{c_w^2} - \frac{\rho_w}{\rho_s c_s^2} \right) [G_0(\mathbf{r}; \mathbf{r}_+') G(\mathbf{r}_+'; \mathbf{r}_0)] dA' \]
Described by radially isotropic, power-law, power spectra:

- Interface deviations:
  \[ W(k_r) = \frac{4\pi \nu \sigma^2 l_r^2}{(1 + l_r^2 k_r^2)^{\nu + 1}} \]

- Sound Speed Fluctuations:
  \[ W(k_r) = \frac{8\pi^{3/2} \sigma^2 l_r^2 l_z \Gamma(\nu + 3/2)}{\Gamma(\nu)(1 + l_r^2 k_r^2 + l_z^2 k_z^2)^{\nu + 1}} \]
Simulation Details

- Single-scattering: Use Born Approximation (i.e. $G(r_1; r_2) = G_0(r_1; r_2)$)
- Monostatic scattering geometry
- Compute unperturbed Green’s function by normal mode decomposition
- Narrow (30 Hz) band processing
- Fit ensemble-averaged simulated time series to band-filtered time series via power spectrum parameters
References


• Li, D. et al., “Modeling of bottom backscattering from three-dimensional volume inhomogeneities and comparisons with experimental data,” *JASA* 109, 1384-1397 (2001)