Modeling and Analyzing the Propagation from Environmental Through Sonar Performance Prediction

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LONG-TERM GOALS

Central to the long term goals of this joint project is to understand the physics of the propagation of uncertainty through the interfaces between oceanography, acoustics, array processing and performance prediction. We will develop an efficient overall simulation platform that combines all of the components of the baseline (mean) and uncertainty problem: Oceanography through 4-D acoustic field prediction. The development of a methodology to distill the complexity and uncertainty of the ocean acoustic environment and the system level sensitivities to relevant situational awareness for the operator is an important goal of this research.

OBJECTIVES

The objective of this research program is develop a systematic approach to addressing the catastrophic deficiencies in sonar performance prediction in the littoral environment. Sorting out the issues of uncertainty, bias and variability is critical. A process is sought which incorporates ocean measurement and modeling, acoustic modeling, tactical sonar data collection and geo-acoustic inversion. Updating the geo-acoustic databases with in-situ, through the sensor inversion techniques provides the opportunity to reduce the error (bias) in TL and communicate the uncertainty to the operator.

APPROACH

Work at ORINCON for the past year has focused on two related areas. The first involves analysis of the system issues associated with acoustic modeling and sensitivity to the environmental uncertainty in the sonar performance prediction system. The second area of research has been in the use of rapid geo-acoustic characterization and the development of an approach to estimate the environment as well as determine sonar performance sensitivity to the uncertainties in our environmental knowledge.

System Issues:

Tactical Decision Aids (TDAs) are computer applications that perform acoustic model-based performance predictions based on available inputs and data bases, manipulate the sonar equation, display the results usually in very attractive (and convincing) color graphics, and provide advice or information to the operators. They are becoming increasingly sophisticated. Is the advice provided good ? Are results presented correct in some absolute sense? To what extent would an expert believe the TDAs? Trust them? How should operators use them?

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14. ABSTRACT
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The importance of input errors can be understood by examining the sensitivity of the output to those errors. A SENSITIVITY measure is needed. There are two types of concerns about inputs: BIAS and VARIABILITY. By BIAS I mean that the inputs such as bottom properties for a given area are wrong in some average sense. There are a growing number of examples in which shallow water predictions differ from measurements by many dB. The data bases themselves need some quality assessment. E.G. Very few measurements, user beware. Lots of measurements. models and data agree to within XX dB over the frequency range YY to ZZ. This is a goodness of fit criterion. The user needs to be told whether there is low or high confidence in the prediction. This involves both quality of the inputs and sensitivity to those inputs.

With regard to TDAs, we need to ask how they convey uncertainty, sensitivity and confidence to the user. We also need to be warned when tactical advice is very sensitive to parameters about which there is uncertainty. We need to face up to the reality of faulty inputs and uncertainty, rather than proceeding with an idealized problem as if the inputs were perfect. The target source level, aspect dependence, depth etc are well within the realm of the operator to deal with. Acoustic propagation on the other hand is something for which he needs help from the technical community. We should not opt out by saying, for example, that environmental uncertainty is not important because we do not know the target source level.

Estimating Uncertainty:

In order to estimate uncertainty, sensitivity and bias in a relevant manor for the sonar operator, we need to develop a set of observables with which to pass on this uncertainty. We believe that single-frequency TL vs. range and depth is not the correct metric, due to the extreme sensitivity (not chaotic) to the environment. We have developed a set of basic acoustic Observables (BOA) that summarize the relevant acoustic propagation physics. By using the TL slope (or TL level at a set of ranges), the time-spread and the slope of striations observed in passing surface ship data in shallow water, as our observables, we have a mechanism for quantifying and communicating the uncertainty in acoustic variables in a manor that is relevant to the operator. These observables are also used in the Rapid Geo-acoustic Characterization (RGC) algorithm, being developed by ORINCON and SPAWAR, which performs geo-acoustic characterization in real time. Data drive characterization should eliminate the BIAS due to incorrect geo-acoustic information and make the UNCERTAINTY problem relevant.

We are examining a structured approach to validating TDA’s through a combination of taking tactical data, performing predictions using TDAs and performing acoustic measurements to examine errors, sensitivities and variability – leading us to a measure of confidence in the TDA as well as a data drive bound on the UNCERTAINTY.

WORK COMPLETED

Work this year consisted of interaction with Navy Sponsors at various levels to ascertain the nature of the system and systematic problem. Analysis of these issues led to the presentation by Dr. Cox at the Uncertainty yearly review meeting. Dr. Heaney explored the utility of using the Rapid Geoacoustic Characterization to greatly reduce the BIAS of the prediction and as a basis for quantifying uncertainty in sonar operator relevant terms.

RESULTS

By using in-situ, through the sensor approaches to environmental characterization, the inversion is most likely to be driven by propagation physics that is directly relevant to sonar performance prediction. By measuring the striation slope, the frequency spacing and band averaged TL vs. range of a passing surface ship, it is possible to perform a real-time geoacoustic characterization of the environment. (These Acoustic Observables are compared with a forward model prediction from a set of simplified geo-acoustic parameter sets to find the optimal match.) The results of this inversion are shown in figure 1.

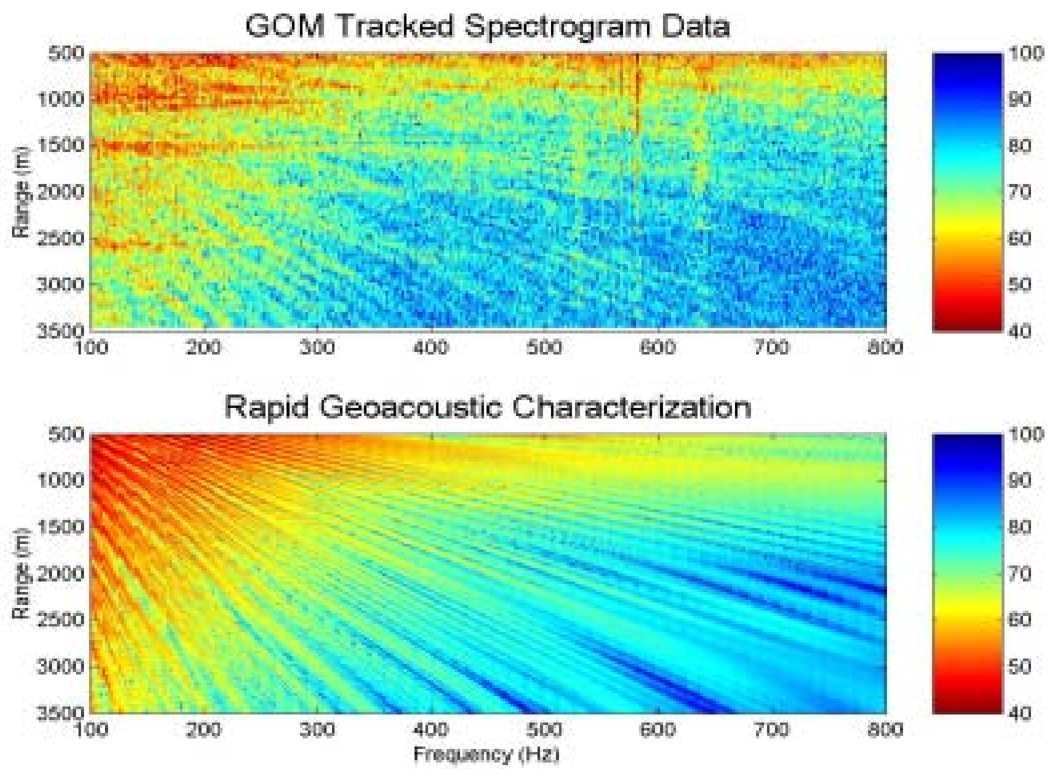

Figure #1. RGC Inversion from Passing Surface Ship

Using a set of realizations for the sound speed field generated by Dr. Bruce Cornuelle (SIO) using the ROMS ocean model, we can compute the effect of sound speed variability on the Basic Acoustic Observables that drive sonar performance prediction. The variability of the sound speed fields are computed, and multiplied by the sensitivity of the acoustic observables to sound speed fluctuations to produce an accurate statistical estimate of the variance of a particular observable. The results are shown in figure 2 for four different BOA's and for 6 particular bottoms. It should be noted that in this example we are assuming that we have removed the uncertainty due to the sediment type, and that this uncertainty is clearly the strongest influence.

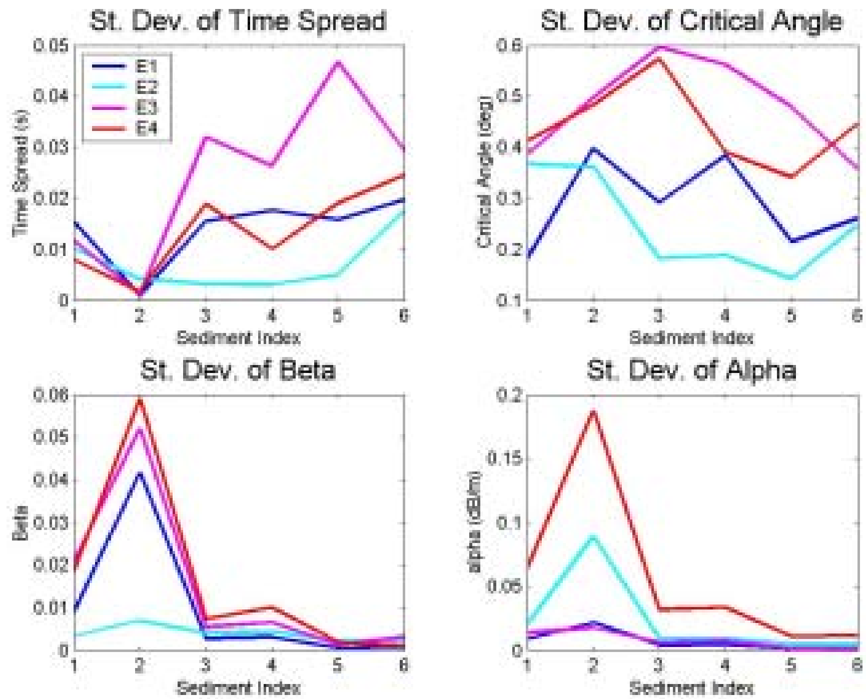

Figure 2. Standard Deviation of Basic Acoustic Observables in the presence of Oceanographic Variability for 6 sediments.

Each of the four colors are for a different location in the California Bight region. The sediment indexes go from softer bottoms to harder bottoms. In particular, sediment index 2 is a soft deep bottom, which shows that in this environment there is strong sensitivity to oceanographic variability in the TL slope (ALPHA) and the Striation Slope (BETA), but very little in the time-spread.

We are in the process of developing an approach where these Acoustic Observables are used to communicate the level of uncertainty to the operator.

IMPACT / APPLICATIONS

This expected impact of this project is to provide a methodology to provide a reliability measure to the operator of at-sea performance prediction models.

TRANSITIONS

Ideas, algorithms and approaches from this work are expected to transition in ’03 through the SPAWAR/PMW-155 Geo-Acoustic Inversion Toolbox (GAIT) program.

RELATED PROJECTS

This is one of the programs in the ONR UNCERTAINTY DRI.

PUBLICATIONS

K. Heaney and H. Cox, “Rapid geoacoustic characterization for limiting environmental uncertainty for sonar system performance prediction,” in *Impact of Littoral Environmental Variability on Acoustic Predictions and Sonar Performance* Eds: Nicholas Pace and Finn Jensen, Boston: Kluwer Academic Publishers, 2002. [ISBN 0-4020-0816-3].