

Uncertainties and Interdisciplinary Transfers Through the End-to-End System (UNITES): Oceanographic Contributions to the Quantification of Uncertainty in Sonar Performance

James F. Lynch

MS #11, Woods Hole Oceanographic Institution, Woods Hole, MA 02543

Phone: (508) 289-2230 fax:(508) 457-2194 email: jlynch@whoi.edu

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Glen Gawarkiewicz

MS#xx, Woods Hole Oceanographic Institution, Woods Hole, MA 02543

Phone: (508) 289-2913 fax: (508) 457-2181 email: ggawarkiewicz@whoi.edu

Timothy Duda

MS #11, Woods Hole Oceanographic Institution, Woods Hole, MA 02543

Phone: (508) 289-2495 fax:(508) 457-2194 email: tduda@whoi.edu

LONG TERM GOALS

UNITES is a unique, interdisciplinary team with expertise spanning the environment (physical oceanography, bottom geology), ocean acoustics (propagation, ambient noise, reverberation and signal processing), and tactical sonar systems. The overall goals of the research are to enhance our understanding of the uncertainty in the ocean environment (including the sea bottom), characterize its impact on sonar system performance, and provide the Navy with guidance for understanding sonar system performance in littoral areas.

OBJECTIVES

Specific objectives of the UNITES team are: 1) Develop generic methods for simply and efficiently characterizing, parameterizing, and prioritizing sonar system variabilities and uncertainties arising from regional scales and processes, 2) Construct, calibrate, and evaluate uncertainty and variability models for sonar systems and their components, thus addressing the forward and backward transfer of uncertainty, and 3) transfer uncertainty from the acoustic environment to the sonar and its signal processing, in order to effectively characterize and understand sonar performance and predictions.

APPROACH

The WHOI component of the UNITES team is focused on physical oceanography and acoustics issues in the end-to-end system, specifically mesoscale oceanography, finescale oceanography, and the acoustic fluctuations due to mesoscale and finescale oceanography.

In the mesoscale oceanography portion of this work, we are initially pursuing the following specific tasks: 1) quantifying the amplitude and spatial structure of the variance of the soundspeed field using both PRIMER experiment data as well as existing historical data and 2) relating simple frontal

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parameters such as cross-frontal temperature difference and the baroclinic Rossby radius to the spatial structure of the variance of the soundspeed.

In the finescale oceanography portion of our work, we are initially concentrating on the effects of nonlinear internal waves on the coastal acoustic field. To represent the internal wave field, we are developing a 3-D numerical model based on the range-dependent Korteweg-deVries (KdV) equation, which also inputs PRIMER data from SAR imagery and moored temperature sensors to constrain the calculations.

In the third component of our study, acoustics, we are concentrating on three topics, 1) so called “rules of thumb” for acoustic variability, 2) the “ground truth” quantification of acoustic uncertainty from high resolution field experiments such as PRIMER and ASIAEX and 3) the uses of Kravtsov’s predictability theory to determine acoustic uncertainty given measurement error in key environmental variables.

All of the WHOI PI’s are also actively engaged in working with other members of the UNITES team on the “en-to-end” problems that were originally formulated.

WORK COMPLETED / RESULTS

In the brief time since this project was initiated, we have already made some progress towards our technical goals. Regarding the mesoscale oceanography, during the past six months, we have computed the spatial structure of the variance of the temperature, salinity, and soundspeed fields near the shelfbreak front in the Middle Atlantic Bight. The fields show significant seasonal variations. We have compared these variance fields with those of the high-resolution hydrography data taken during the shelfbreak PRIMER experiment. As one would expect, the peak variances in soundspeed and temperature occur near the front. There is a surprisingly good correspondence between the spatial structure of the variance computed using all historical hydrographic data available from the National Ocean Data Center (NODC) versus that of the short-term high-resolution Shelfbreak PRIMER observations (order 6 days). Additionally, we have done some analysis of the moored instruments in the region to examine the probability density functions of temperature as a function of distance from the front. Probability density functions taken from moored thermistors indicate that there are large differences in the probability density functions for temperature as one moves away from the front, with, e.g., slope water temperatures becoming less probable shoreward of the front, but equally probable with shelf water temperatures near the mean position of the front. Finally, we have also prepared a manuscript on the Summer Shelfbreak PRIMER oceanographic observations (Gawarkiewicz et al., 2001), which will be submitted shortly for publication. The manuscript focuses on the large-amplitude frontal meander which propagated through the study area and led to large changes in frontal position over short along-shelf scales.

Turning to the finescale oceanography, the KdV computer codes to generate the internal waves have been initially coded, and are now being tested. The PRIMER satellite SAR images and moored data are also being examined, to constrain the computer simulation fields generated.

Regarding the acoustics efforts, we have also made progress in several areas. Together with Phil Abbot of OASIS, Inc., we have begun interacting with the operational Navy on the “rules of thumb” we have constructed, and are both refining and disseminating those simple rules. To look at the broadband generalization of the “5.6 dB” narrowband fluctuation rule-of-thumb, we have developed an in-house

capability to simulate broadband transmissions via parabolic equation acoustic models, and will connect this code to our ocean environmental simulations and data. Additionally, we have been working on quantifying the acoustic fluctuations seen in the summer PRIMER data. An example of these fluctuation analyses is seen in Figure 1, where we show the vertically and temporally integrated received acoustic field, denoted “energy”. It is seen that the total integrated field shows comparatively little variability ($\sim 3\text{dB}$) compared to instantaneous, single phone receptions, indicating that the instantaneous intensity variability seen by a single hydrophone is primarily due to the temporal and spatial movement of the acoustic field pattern, but is not due to increases or decreases in the energy lost to the bottom or to other loss mechanisms.

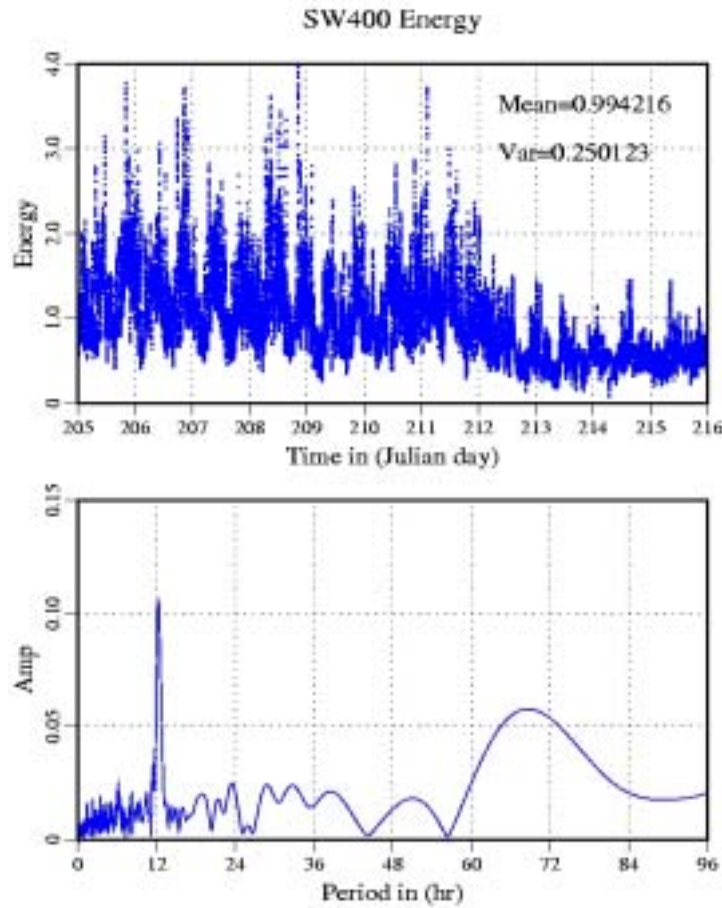


Figure 1. The top panel shows fluctuations in the total acoustic energy seen by the northeastern vertical line array in the summer 1996 PRIMER experiment. It is noted that the fluctuations of the temporally and spatially integrated signal are rather small ($\sim 3\text{dB}$), indicating that the variability in instantaneous levels due to varying bottom loss (or other loss mechanisms) is relatively small. The lower panel shows the amplitude spectrum of the fluctuations in the top panel. It is readily seen that M2 tide and lower frequency (mesoscale) variations dominate the signal. Figure courtesy A. Fredericks, WHOI.

IMPACT/IMPLICATIONS

The primary application of our work is to assist the sonar “prediction community” by quantifying what the expected environmental variability will be in various coastal environments. By using our highest quality basic research measurements of ocean variability, we can thus use a detailed understanding of the environmental processes affecting uncertainty to contribute to the transfer of uncertainty from the environment to systems performance.

TRANSITIONS

We see our work being transitioned to the Navy community by two principal means. First, there are the “rules-of-thumb” that are being developed, that should be easily presented to the operational Navy via briefs and, eventually, via Tactical Memos. Second, there are the research results on coastal phenomena that will be included into probabilistic models of sonar performance, such as the one being developed under this DRI by Phil Abbot and Ira Dyer of the UNITES team.

RELATED PROJECTS

The work being done under the auspices of the Uncertainty DRI relates closely to our work in three other ONR projects, specifically: 1) the shelfbreak PRIMER experiments, 2) the ASIAEX experiments, and 3) the ESME initiative.

PUBLICATIONS

Gawarkiewicz, G., F. Bahr, K. Brink, R. Beardsley, M. Caruso, J. Lynch, and C.-S. Chiu, “A Large-Amplitude Meander of the Shelfbreak Front during Summer in the Middle Atlantic Bight.” Manuscript to be submitted to J. Geophys. Res., 2001.

J. Lynch, A. Newhall, B. Sperry, G. Gawarkiewicz, P. Tyack, and C.S.Chiu, “Spatial and Temporal Variations in Acoustic Propagation Characteristics at the New England Shelfbreak Front.” Submitted to IEEE. J. Oceanic Eng’g., 2001