SW06 Data Analysis and Slope/Canyon Experiment Planning

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LONG TERM GOALS

The long term goals of our shallow water acoustics work are to: 1) understand the nature of low frequency (10-1500 Hz) acoustic propagation, scattering and noise in shallow water when strong oceanic variability is present in the form of fronts, eddies, boundary layers, and internal waves (using the SW06 and QPE data, primarily) and 2) begin planning a 2014-15 bottom acoustics experiment off Texas and a 2016-17 field experiment to look at the complicated boundary between deep and shallow water, i.e. the slope/canyon region. (Dates for experiments are approximate.)

OBJECTIVES

Our primary objectives this year were: 1) to finish manuscripts on the QPE shallow water acoustics/Uncertainty work, and submit them to IEEE JOE, 2) begin 2014 (bottom acoustics) and 2016 (shelfbreak, slope and canyon) experimental planning, both on an individual basis, and in conjunction with the whole ocean acoustics community, 3) continue work on modeling scattering by coastal internal waves, and 4) begin work on developing simple "ocean feature model" based expressions for horizontal array coherence, transmission loss, and scintillation index.

APPROACH

We devoted a large effort this year towards finishing the manuscripts on the fall 2009 QPE Uncertainty experiment northeast of Taiwan. We have one manuscript on canyons accepted by IEEE JOE and one on the Dyer/Abbot PPD in review, and have three others in advanced preparation stage. The three in preparation are on: 1) the azimuthal dependence of TL, and how it compares at similar coastal sites worldwide, 2) a demonstration that the predictive probability of detection (PPD) formalism of Dyer and Abbot works well, using QPE field data, and 3) a paper on the noise field in the East China Sea, with the novelty being the competing low frequency effects of distant shipping versus large fishing fleets (like the squid fishing fleet encountered in QPE). We also have a UAM conference proceeding paper published on the QPE canyon propagation data.

The work on internal wave scattering of sound continues, and we have looked at mode coupling, ducting by curved waves, and high frequency energy fluctuations, among other topics. Three peer reviewed journal papers were published on these results.

Planning for the next two shallow water experiments was also part of our effort this year, though at a modest level due to the delays in the experiments.

Finally, a good deal of progress has been made on using coastal ocean feature models to generate simple estimates of important acoustic quantities like array coherence length, transmission loss, and scintillation index, and results have been presented in the Corfu UAM conference proceedings.

WORK COMPLETED/ACCOMPLISHMENTS

As discussed above, we have had five peer reviewed papers and four conference proceeding papers published this year in our various research directions. Also, work was completed on an MIT Open CourseWare site for the MIT 2.682 "Acoustical Oceanography" course, that can be accessed free online.

RESULTS

Two of our nicer results were: 1) that we were able to understand and model (to first order) the OMAS transmissions over the very complicated Mien-Hua Canyon area northeast of Taiwan, including 3-D effects (see Figure 1), and 2) we were able to form the "predictive probability of detection" (PPD) function from the QPE data, and successfully show that the formalism works for detection.

IMPACT/APPLICATIONS

The impact of our experiment should be: 1) an increased understanding of the propagation of sound through complicated coastal oceanography, 2) an eventual capability to model these effects for use in sonar performance prediction applications, and 3) showing that the PPD formalism for detection could be a useful extension of the usual sonar equation ROC curves.

TRANSITIONS

One eventual transition of our analyses will be to ONR's Uncertainty DRI program, where the interest is in "the error bars" in ocean acoustic field and system performance prediction. Another transition is the use of our SW06 internal wave data to verify a large "coastal oceanography plus internal wave" model being developed under a MURI that can eventually be used as a Navy standard model that works at all ocean scales down to the internal waves and finescale. Finally, the simple feature model expressions for coherence length, TL and SI that we are generating could be very useful in showing how accurate one needs to be with larger scale models and theories in order to predict these quantities at an acceptable level.

RELATED PROJECTS

The SWARM acoustics/internal wave study, the PRIMER acoustics/shelfbreak front study, and ASIAEX experiment were direct predecessors of SW06, and examined some of the same acoustic scientific issues, only with far fewer measurement resources. The "Non-linear internal waves initiative" (NLIWI) was strongly related to our SW06 effort via the environmental support that the oceanographic moorings (and other PO measurements) provided. The QPE experiment, stressing acoustic and environmental uncertainty in a coastal environment, is also related. Finally, the MURI for

full 3D modeling of coastal internal waves and acoustics will directly use our SW06 data for model verification.

PUBLICATIONS

[1] Y.T. Lin, K.G. McMahon, J.F. Lynch, and W.L. Siegmann, "Horizontal ducting of sound by curved nonlinear internal gravity waves in continental shelf areas." *J. Acoust. Soc. Am*., vol. 133, pp. 37-49 (2013). [published, refereed]

[2] A.A. Shmelev, J.F. Lynch, Y.-T. Lin and H. Schmidt, "3D coupled mode analysis of internal-wave acoustic ducts," submitted (accepted subject to revisions) to J. Acoust. Soc. Am. (2013). [submitted, refereed]

[3] C. Emerson, J.F. Lynch, P. Abbot, Y.-T. Lin, T.F. Duda, G.G. Gawarkiewicz and C.-F. Chen, "Acoustic Propagation Uncertainty and Probabilistic Prediction of Sonar System Performance in the Southern East China Sea Continental Shelf and Shelfbreak Environments," submitted to IEEE J. Ocean. Eng. (2013). [submitted, refereed]

[4] Y.-T. Lin, T.F. Duda, C. Emerson, G.G. Gawarkiewicz, A.E. Newhall, B. Calder, J.F. Lynch, P. Abbot, Y.-J. Yang and S. Jan, "Experimental and numerical studies of sound propagation over a submarine canyon northeast of Taiwan," accepted, IEEE J. Ocean. Eng. (2013). [published, refereed]

[5] V. A. Grigor'ev**,** B. G. Katsnel'son**,** and J. F. Lynch. "Energy Fluctuations of High Frequency Sound Signals in a Shallow Water in the Presence of Nonlinear Internal Waves." Acoustical Physics, Vol. 59, No. 4, pp. 431–438 (2013) [published, refereed]

[6] A. E. Newhall, J. F. Lynch, Y.-T. Lin, T. Grothues, and G.G. Gawarkiewicz, "Scattering and reverberation from fish schools in the 500–1500 Hertz band," *POMA*, vol. 19, pp. 005028. (2013) (8 pages)

[7] M. E. G. D. Colin, T. F. Duda, L. A. te Raa, T. van Zon, P. J. Haley Jr., P. F. J. Lermusiaux, W. G. Leslie, C. Mirabito, F. P. A. Lam, A. E. Newhall, Y.-T. Lin, and J. F. Lynch, "Time-Evolving Acoustic Propagation Modeling in a Complex Ocean Environment," in *Oceans 2013 Bergen Conference Proceedings*, IEEE/MTS, June. 2013. (9 pages)

[8] J. F. Lynch, Y.-T. Lin, T. F. Duda, and A. E. Newhall, "Characteristics of acoustic propagation and scattering in marine canyons," in *Proceedings of the 1st International Conference and Exhibition on Underwater Acoustics*, June 23-28, 2013, Corfu, Greece. (9 pages)

[9] J.F. Lynch, T.Duda, W.Siegmann, J. Holmes, and A.Newhall, "The Carey number in shallow water acoustics." in *Proceedings of the 1st International Conference and Exhibition on Underwater Acoustics*, June 23-28, 2013, Corfu, Greece. (10 pages)

[10] J.F. Lynch, MIT Open Courseware Course 2.682 "Acoustical Oceanography. Full version just put on Sept. 23, 2013. (See ocw.mit.edu to get to site).

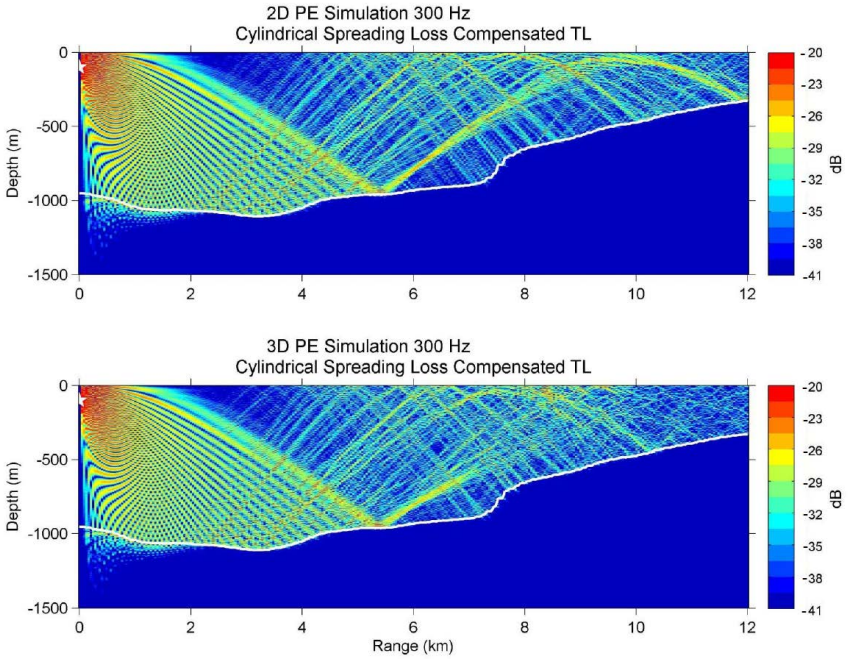

Figure 1. Comparison of 2-D and 3-D PE solutions forunderwater sound propagation in the North Mien-Hua Canyon.