

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.

OBJECTIVES

Our primary objectives this year were: 1) to finish publishing our SW06 results in a JASA Special Issue, as well as in other JASA manuscripts, 2) to finish manuscripts on the QPE shallow water acoustics/Uncertainty work, and submit them by the end of 2012 to IEEE JOE for a Special Issue, and 3) 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.

APPROACH

In performing the SW06 data analyses, we concentrated on the effects of the SW06 coastal oceanography on acoustic propagation. We have published papers on: 1) the horizontal Lloyd's mirror, 2) the azimuthal variability of transmission loss in the coastal ocean, 3) acoustic back-propagation techniques, 4) marine mammal tracking, 5) the shallow water spice field, 6) horizontal array coherence, 7) waveguide invariant techniques, 8) 3-D ducting by bottom topography, 9) acoustic effects of crossing internal waves, and other topics. Several more manuscripts about SW06 are also in progress.

We also devoted a large effort this year towards finishing the manuscripts on the fall 2009 QPE Uncertainty experiment northeast of Taiwan. We have six to eight manuscripts which we expect to submit before the end of this year to an IEEE JOE Special Issue. These manuscripts were coordinated so that *in toto* they give a fairly complete view of the issue of sonar system uncertainty in an important coastal region.

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Planning for the next two shallow water experiments was also part of our effort this year. There have been a series of workshops at ONR/Mandex, some focused conference calls, and an upcoming meeting at the Kansas City ASA meeting devoted to planning the upcoming 2014-15 shallow water bottom acoustics experiment. There was a large 2011 meeting concerning the 2016-17 slope/ shelfbreak/ canyon experiment, but since that is further down the timeline, efforts there have been smaller since the workshop (mostly individual work on our own).

WORK COMPLETED/ACCOMPLISHMENTS

As mentioned, we have finished the publication process for the SW06 Special Issue, and are publishing even more on SW06 topics. The published papers are listed at the end of this report.

The QPE fall 2009 experiment manuscripts are nearing completion, and should be six to eight manuscripts submitted by the end of 2012, which is our deadline.

A final accomplishment is the write-up of Ph.D. work by Alexey Shmelev, which was done under ONR support. Alexey has produced two manuscripts on his work on internal wave scattering, which we are fine tuning for submission to JASA in the near future.

RESULTS

One of the more interesting preliminary results that we have obtained this year is from the 2009 QPE azimuthal dependence of TL data. In Figure 1, we see TL tracks that were created using the OMAS sound sources and sonobuoy receivers. Many of these tracks were circular, to be used for azimuthal TL dependence studies. In Figure 2, we see a rather strong azimuthal dependence of TL in the data, in fact much stronger (in amplitude) than what was observed in the SW06 experiment, under seemingly similar condition. However, scaling the data by the range, water depth, and strength of the internal wave field showed that one could go from one data set to the other, which would indicate that we can understand these fluctuations in a global sense, and not just on a local, “case by case” basis. We are currently testing these results with fully 3-D ocean and acoustics models.

IMPACT/APPLICATIONS

The impact of our experiment should be: 1) an increased understanding of the propagation of sound through complicated coastal oceanography and 2) an eventual capability to model these effects for use in sonar performance prediction applications.

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.

RELATED PROJECTS

The SWARM acoustics/internal wave study, the PRIMER acoustics/shelfbreak front study, and ASIAEX 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.

II. Accomplishments

A. Recent Publications (refereed)

- [1] Chiu, L.Y.S., Y.-Y. Chang, C.-F. Chen, D. B. Reeder, C.-S. Chiu, Y.-T. Lin, J.F. Lynch, and Y.-J. Yang, "Enhanced nonlinear acoustic mode coupling resulting from an internal solitary wave approaching a shelf break," accepted with revisions, *J. Acoust. Soc. Am.* (2011)
- [2] Ballard, M., Y.T. Lin, and J.F. Lynch, "Horizontal refraction of propagating sound on the New Jersey shelf: Effects of topography and range dependent bottom properties." *J. Acoust. Soc. Am.* Vol 131, pp 2587-2598 (2012)
- [3] Lin, Y.T, and J.F. Lynch, "Analytical study of the horizontal ducting of sound by an oceanic front over a slope." *JASA-EL*, vol 131, pp EL1-EL7 (2012).
- [4] 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." Accepted with revisions, *J. Acoust. Soc. Am.* (2012)
- [5] Lin, Y.-T., A.E. Newhall and J.F. Lynch, "Low-frequency broadband sound source localization using an adaptive normal mode back-propagation approach in a shallow-water ocean," *J. Acoust. Soc. Am.* Vol 131, pp 1798-1813 (2012)
- [6] Newhall, A.E., Y.-T. Lin, J.F. Lynch, M.F. Baumgartner, and G.G. Gawarkiewicz, "An acoustic normal mode approach for long distance passive localization of vocalizing sei whales on a continental shelf," *J. Acoust. Soc. Am.* Vol 131, pp 1814-1825 (2012)
- [7] Colosi, J.A., T.F. Duda, Y.-T. Lin, J.F. Lynch, A.E. Newhall, and B.D. Cornuelle, "Observations of sound-speed fluctuations on the New Jersey continental shelf in the summer of 2006," *J. Acoust. Soc. Am.* Vol 131, pp 1733-1748 (2012)
- [8] Duda, T.F., J.M. Collis, Y.-T. Lin, A.E. Newhall, J.F. Lynch, and H.A. DeFerrari, "Horizontal coherence of low-frequency fixed-path sound in a continental shelf region with internal-wave activity," *J. Acoust. Soc. Am.* Vol 131, pp 1782-1797 (2012)
- [9] Lynch, J.F., C. Emerson, P.A. Abbot, G.G. Gawarkiewicz, A.E. Newhall, Y.-T. Lin, T.F. Duda, "Are azimuthal isotropy and alongshelf translational invariance found in low-frequency acoustic propagation along the New Jersey shelfbreak?" *J. Acoust. Soc. Am.* Vol 131, pp 1762-1781 (2012)
- [10] McMahon, K., L.K. Reilly-Raska, J.F. Lynch, T.F. Duda, and W.L. Siegmann, "Horizontal Lloyd Mirror patterns from straight and curved nonlinear internal waves." *J. Acoust. Soc. Am.* Vol 131, pp 1698-1700 (2012)

B. Recent Publications (non-refereed)

- [1] Shemelev, A., J.F. Lynch, Y.T. Lin, J. Colosi, and T.Duda, “Effects of focused and strongly refracted scattering in shallow water on the scintillation index”, Proceedings of the ECUA. (2012)
- [2] Badiey, M. and J. Lynch. “Recent studies of acoustic wave propagation in shallow water waveguides with variable water column properties.” Proceedings of the Beijing Acoustics Meeting (2012)

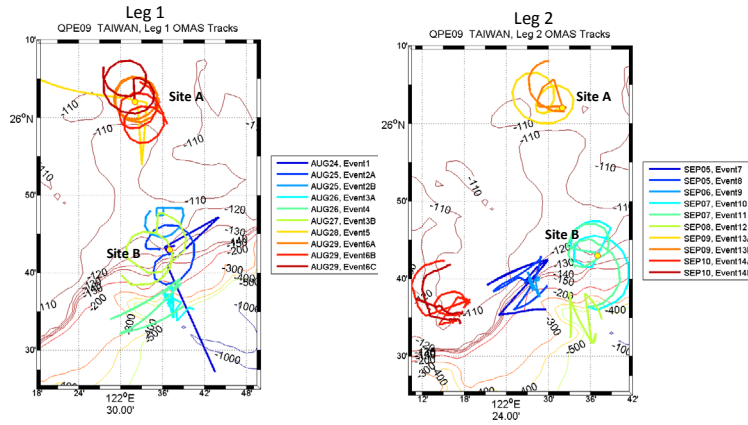


Figure 1. TL tracks used to study azimuthal TL dependence in the QPE experiment than in the SW06 experiment. However, by scaling the range, water depth, and oceanographic IW strengths, we found that the fluctuations seemed to scale with the SW06 data. If this can be made rigorous, it would show that we could understand azimuthal TL variations on a global basis simply by using scaling arguments from regions which are well measured and understood.

QPE09 TAIWAN, August 29, Event 6A OMAS # 15557,
Circle 2 900 Hz DIFAR1 TL vs. Bearing, $ds=90\text{ft}$, $dr = 90\text{ft}$

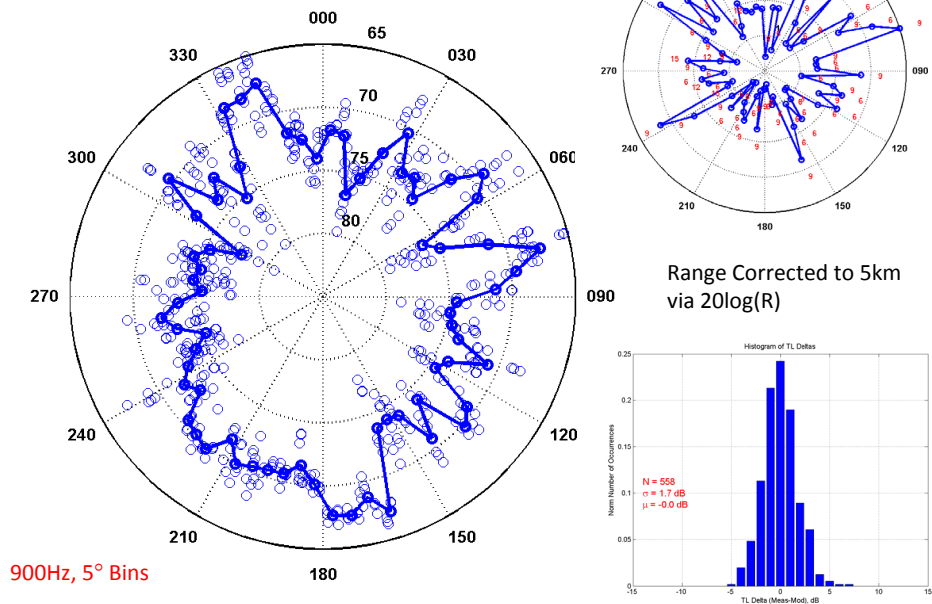


Figure 2. Azimuthal TL variations seen in the QPE experiment.