

SW06 Data Analysis, Slope-Canyon Experiment Planning, and Long-Range Sound Propagation with Applications to the Arctic

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Grant Number: N00014-11-1-0195

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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 and scattering in shallow water when strong oceanic variability is present in the form of fronts, eddies, boundary layers, and internal waves and 2) begin planning a 2016 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 continue the analysis of the vast data set collected by the SW06 experiment, model it with theory and numerical models, and publish the results in a JASA Special Issue. 3-D acoustics and oceanographic effects were of particular interest. 2) Begin 2016 experimental planning, both on an individual basis, and in conjunction with the whole ocean acoustics community.

APPROACH

In performing the data analyses, we concentrated on the effects of the real SW06 coastal oceanography on acoustic propagation. We have nearly finished (i.e. accepted or in press) publishing 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.

In planning the 2016 experiment, two approaches were utilized. The first was conducting (along with Kyle Becker) an ONR workshop at the Seattle ASA meeting discussing the scientific objectives, sites, and equipment available for such an experiment, and 2) making individual theory and computer models of the slope/canyon region, in order to identify the major acoustic effects one would expect to see in these regions.

Report Documentation Page			Form Approved OMB No. 0704-0188		
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE SEP 2011		2. REPORT TYPE		3. DATES COVERED 00-00-2011 to 00-00-2011	
4. TITLE AND SUBTITLE SW06 Data Analysis, Slope-Canyon Experiment Planning, and Long-Range Sound Propagation with Applications to the Arctic			5a. CONTRACT NUMBER		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S)			5d. PROJECT NUMBER		
			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Woods Hole Oceanographic Institution,MS 12,Woods Hole,MA,02543			8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSOR/MONITOR'S ACRONYM(S)		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 4	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

WORK COMPLETED/ACCOMPLISHMENTS

As mentioned, we have nearly finished (i.e. accepted or in press) publishing papers on: 1) the horizontal Lloyd's mirror, 2) the azimuthal variability of transmission loss (TL) 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. These are listed at the end of this report.

Regarding the workshop, Becker and Lynch completed a report on the workshop which was distributed to the ocean acoustics community for comments. Further discussions will be held with the ONR OA program managers to decide which steps will be taken next.

A final accomplishment was the successful completion of his Ph.D. work by Alexey Shmelev, mostly under ONR support. Alexey produced a fine thesis on the coastal 3-D acoustic effects that would be seen due to regular oceanography and topography in the coastal ocean. We look forward to publishing this work in the peer reviewed literature next year. Alexey will begin working for Schlumberger in Houston this fall.

RESULTS

Probably the most important result of our work over the last year was the explanation of how the azimuthal variability of TL is created in the coastal ocean. Working with data taken by OASIS, Inc. in SW06 (see Figures 1 and 2), we have developed theory that explains what to expect for the azimuthal fluctuations of TL. This can be used for both coherent peak TL and integrated TL.

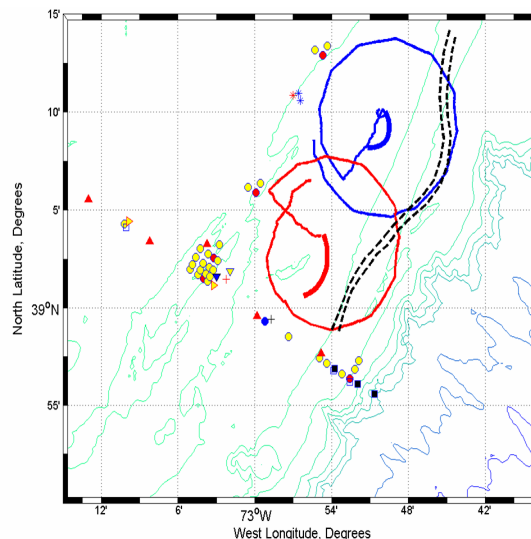


Figure 1. Geometry used to examine azimuthal variability of TL during SW06. Thin tracks are OMAS source vehicles, and thick tracks are sonobuoy receivers.

SW06, 9/08/06 OMAS Run, 900 Hz, OMAS 1 to DIFAR1, Lap 1 "Peak" TL vs Bearing
 With Mean and Distribution About the Mean, Range Corrected to 7.5km,
 Clock Drift Corrected and Triangulated positions

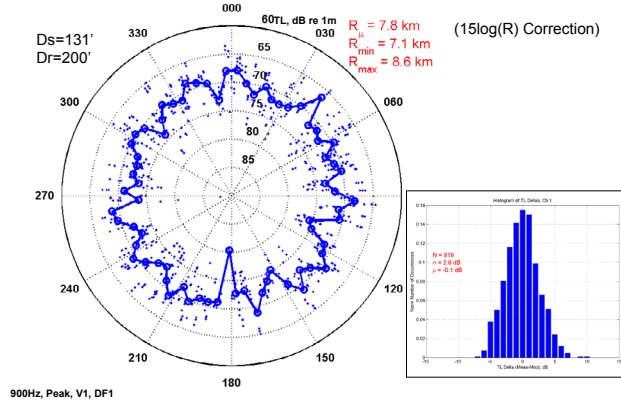


Figure 2. Example of azimuthal TL variability from SW06 OMAS data.

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.

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) is strongly related to our SW06 effort via the environmental support that the oceanographic moorings (and other PO measurements) provided. The recently QPE experiment, stressing acoustic and environmental uncertainty in a coastal environment, is also related.

PUBLICATIONS

A. Recent Publications (refereed)

- [1] 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," accepted with revisions, J. Acoust. Soc. Am. (2011)
- [2] 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," accepted with revisions, J. Acoust. Soc. Am. (2011)

- [3] 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," accepted with revisions *J. Acoust. Soc. Am.* (2011)
- [4] 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," in press *J. Acoust. Soc. Am.* (2011)
- [5] 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?" accepted with revisions, *J. Acoust. Soc. Am.* (2011)
- [6] 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," submitted to *J. Acoust. Soc. Am.* (2011)
- [7] 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." In press, *J. Acoust. Soc. Am.* (2011)
- [8] Kuzkin, V.M, Y.T. Lin, A.A. Lunkov, J.F. Lynch, and V.G. Petnikov, "Frequency shifts of the sound field interference pattern on the oceanic shelf in summer conditions." *Acoustical Physics*, 57(3), pp 381-390 (2011)
- [9] 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." Submitted to *J. Acoust. Soc. Am.* (2011)
- [10] Badiey, M., B.G. Katznelson, Y.T. Lin, and J.F. Lynch, "Horizontal Lloyd's mirror effect due to the interaction between acoustic waves and nonlinear internal waves." In press *JASA-EL*. (2010.)

B. Recent Publications (non-refereed)

- [1] Shemelev, A. and J.F. Lynch. "A theoretical and computational look at the physics of acoustic propagation through crossing ocean waves." *Proceedings of the ICTCA*. (2011)