

SW06 Shallow Water Acoustics Experiment

James F. Lynch

MS #12, Woods Hole Oceanographic Institution, Woods Hole, MA 02543

phone: (508) 289-2230 fax: (508) 457-2194 e-mail: jlynch@whoi.edu

Grant Number: N00014-04-1-0146

<http://acoustics.whoi.edu/sw06/>

LONG TERM GOALS

The long term goal of our shallow water acoustics work is to understand the nature of low frequency (10-1500 Hz) acoustic propagation and scattering in shallow water when strong oceanic variability in the form of fronts, eddies, boundary layers, and internal waves is present. To achieve this goal, we participated in a scientifically sound and Navy relevant basic research experiment in shallow water acoustics, concentrating on both low and medium frequencies.

OBJECTIVES

Our primary objective this year was to perform analysis of the vast data set collected by the experiment. A secondary objective was to continue some of our other ongoing analyses in shallow water acoustics, both in data analysis and theory.

APPROACH

In performing the data analysis, we have concentrated in the past year in calibrating the data, doing positioning and timing of acoustic source/receiver systems, reducing the data to a useful form (e.g. performing cross correlations on m-sequence transmissions), documenting the large amount of work done in this “preparatory phase” of the analysis, disseminating the data to various investigators, maintaining a web site for the project, and coordinating efforts to analyze and publish the data.

WORK COMPLETED/ACCOMPLISHMENTS

Given the very successful execution of the SW06 experiment, we were then faced with the large but pleasant task of analyzing ~10 TByte of data of various sorts. We put a large amount of effort into turning raw data, like the SHRU data shown in Figure 1, into processed data like the modal arrival time structures shown in Figure 2. The results of this data processing have been reported in a WHOI Technical Report, which should be a very useful document for all the PI's (inside and outside WHOI) who will be working with the SW06 data set. We have already produced some beginning papers on the data analyses (see below), and are aiming to have a series of 7-10 papers additional submitted to a JASA-EL Special Issue at the end of 2007.

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 2007		2. REPORT TYPE Annual		3. DATES COVERED 00-00-2007 to 00-00-2007		
4. TITLE AND SUBTITLE SW06 Shallow Water Acoustics Experiment				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 code 1 only						
14. ABSTRACT The long term goal of our shallow water acoustics work is to understand the nature of low frequency (10-1500 Hz) acoustic propagation and scattering in shallow water when strong oceanic variability in the form of fronts, eddies, boundary layers, and internal waves is present. To achieve this goal, we participated in a scientifically sound and Navy relevant basic research experiment in shallow water acoustics, concentrating on both low and medium frequencies.						
15. SUBJECT TERMS						
16. SECURITY CLASSIFICATION OF:				17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 5	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified				

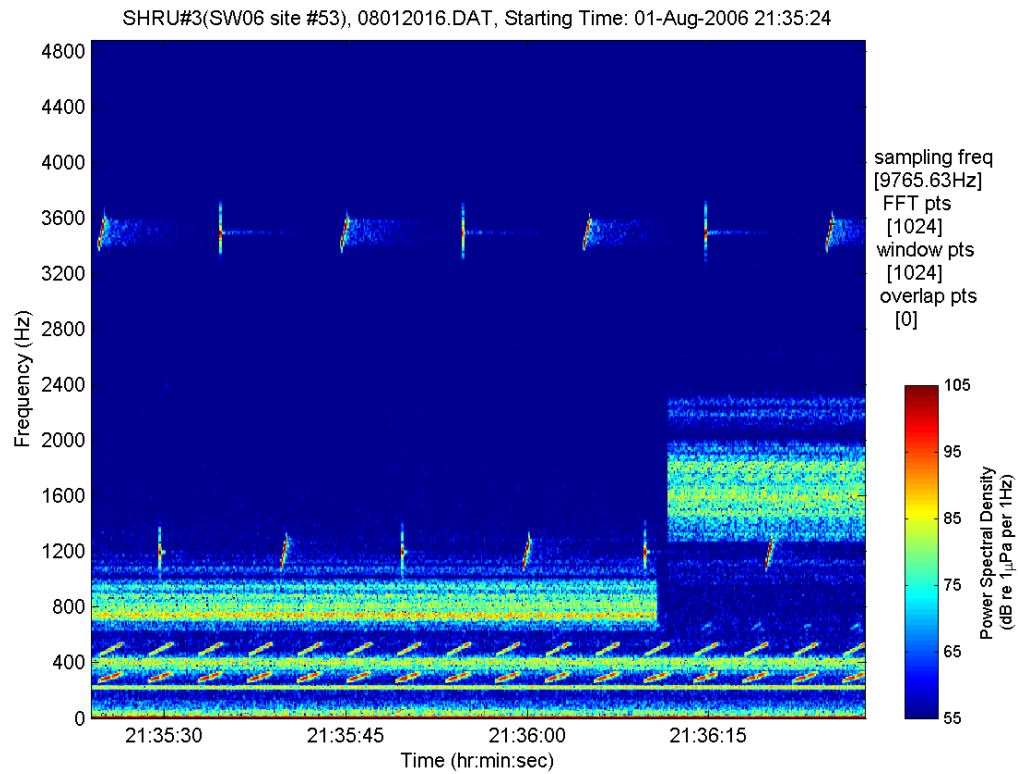


Figure 1. SHRU data from SW06, showing receptions from 224 Hz, 300 Hz, 400 Hz, 500 Hz, 800 Hz, and 1600 Hz moored sources, and 1200 Hz and 3600 Hz A-Comms signals sent from a shipboard source.

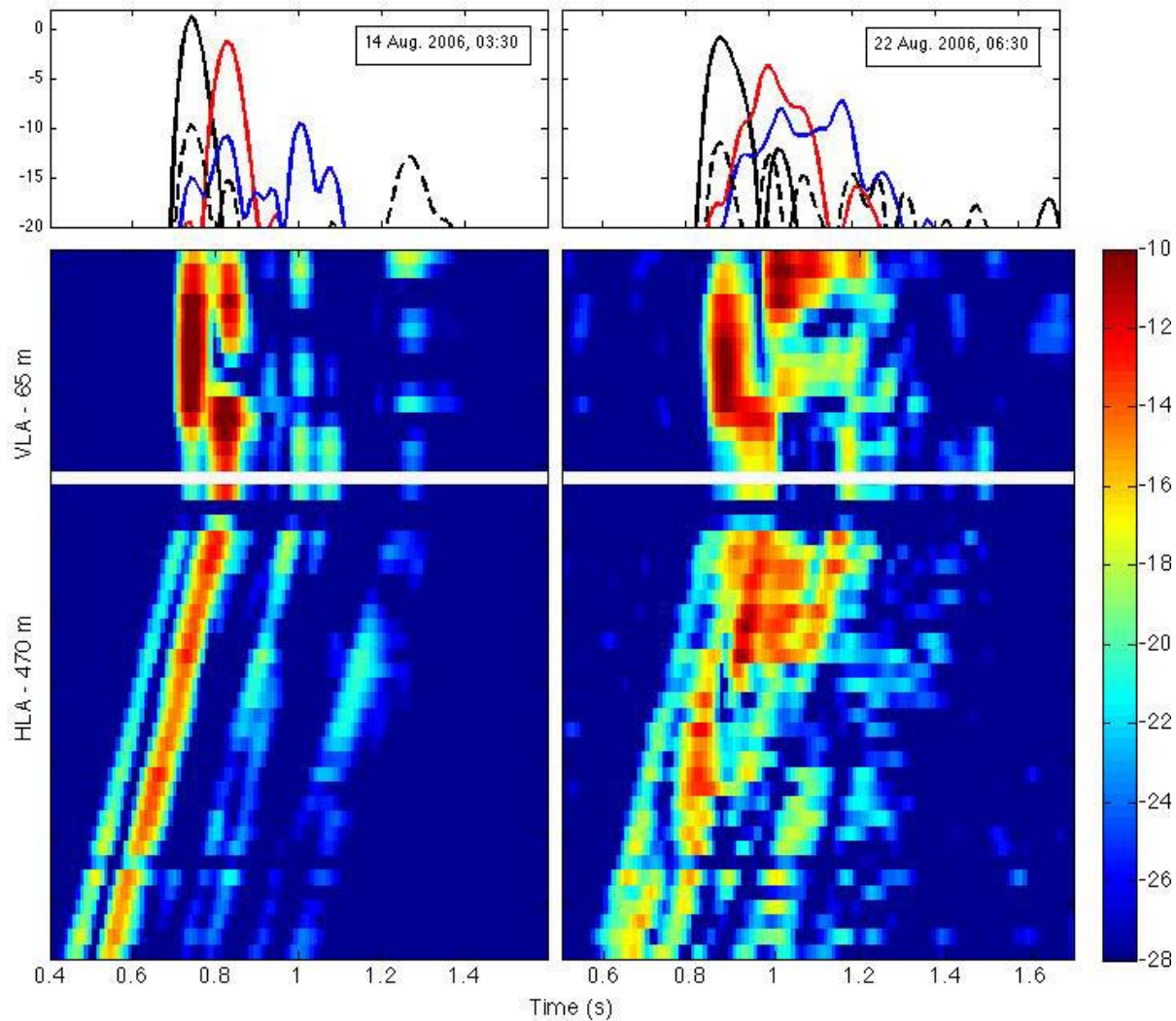


Figure 2. Processed data from the WHOI HLA/VLA showing normal mode arrivals during two periods – one without high internal wave activity present (left panels) and one with high internal wave activity (right panels). The scattering of the higher mode acoustic arrivals by the internal waves is clearly evident.

We also worked on a number of other shallow water acoustics topics this past year, in addition to SW06. These were: 1) ducting of acoustic energy between internal waves in shallow water, 2) a book chapter on geoacoustic inversion techniques, 3) studies of the uncertainty in bottom inversions due to water column uncertainty, 4) a book chapter on nonlinear internal waves and acoustics, and 5) our book on shallow water acoustics. This work has resulted in a number of publications as cited below.

RESULTS

There are a large number of results that are coming out from our work, both on SW06 and other shallow water projects. Two of the most intriguing to us are: 1) developing a formalism (data nullspace projection) that allows us to project “noisy” data out of a data set, and thus use cleaner data for inversions, source localization, etc. and 2) obtaining and beginning the analysis of two data sets that

will allow us to see directly the azimuthal dependence of propagation (i.e. TL) in a shallow water environment.

IMPACT/APPLICATIONS

The impact of our experiment should be: 1) an increased understanding of the propagation of sound through complicated coastal oceanography, 2) a better understanding of how to incorporate “uncertainty” in the ocean state into sonar performance measures, and 3) an improved use of AUV’s in doing acoustic missions in coastal regions, eventually giving the Navy a “robotic forward area presence.”

TRANSITIONS

One eventual transition of our data will be to ONR’s Uncertainty DRI program, where the interest is in “the error bars” in ocean acoustic field and system performance prediction. We also hope to have our REMUS acoustic towed array technology transitioned to operational use in the future.

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 LEAR effort via the environmental support that the oceanographic moorings (and other PO measurements) provided. The SW06 experiment also had an AWACS component, stressing the use of acoustics on AUV’s and gliders, and also adaptive sampling. The upcoming QPE experiment, stressing acoustic and environmental Uncertainty in a coastal environment, is also related.

PUBLICATIONS

[1] B. Katznelson, V. Petnikov, and J. Lynch, “Shallow water acoustics”, ONR series book submitted to Springer Verlag editorial board, 630 pages. (2007)

[2] J. Lynch and B. Katznelson, “Low frequency acoustic propagation through shallow water internal waves.” Book chapter submitted to Cambridge University Press. (2007).

[3] M. Badiey, B. Katznelson, J. Lynch, S. Pereselkov, and W. Siegmann, “Frequency dependence and intensity fluctuations due to shallow water internal waves,” *J. Acoust. Soc. Am.*, 122(2), pp. 747-760 (2007).

[4] S.D. Rajan, G.V. Frisk, K.M. Becker, J.F. Lynch, G.Potty, and J.H. Miller, “Modal inverse techniques for inferring geo-acoustic properties in shallow water.” Book chapter, submitted to book on bottom inversions, A. Tolstoy, Ed.(2007).

[5] Poole, T.L., Frisk, G.V., Lynch, J.F. and Pierce, A.D. “Geoacoustic inversion by mode amplitude perturbation.” Accepted with revisions, *J. Acoust. Soc. Am.* (2007)

- [6] Y.T. Lin and J.F. Lynch, “Data nullspace projection method to reduce geoacoustic inversion uncertainties caused by water column fluctuations.” Submitted to *J. Acoust. Soc. Am.*(2007)
- [7] B.G. Katznelson, M. Badiey, and J.F. Lynch, “Horizontal refraction of sound in shallow water and its experimental observation”, *Acoustical Physics*, 53(3), pp. 313-325 (2007)
- [8] B.G. Katznelson, M. Badiey, and J.F. Lynch, “Sound field fluctuations due to mode coupling by internal waves in shallow water”, submitted to *JASA-EL* (2007).
- [9] D.J. Tang, J. Moum, J. Lynch, P. Abbot, R. Chapman, P. Dahl, G. Gawarkiewicz, S. Glenn, J. Goff, H. Graber, J. Kemp, A. Maffei, J. Nash, A. Newhall, “Shallow water ’06 – a joint acoustic propagation/nonlinear internal wave physics experiment”, accepted with revisions in *Oceanography* (2007).

PUBLICATIONS (non-refereed)

- [1] Newhall, A.E., Duda, T.F., Von der Heydt, K., Irish, J.D., Kemp, J.N., Lerner, S., Liberatore, S.P, Lin, Y.T., Lynch, J.F., Maffei, A., Morozov, A.K., Shmelev, A., Sellers, C., and Witzell, W. “Acoustic and oceanographic observations and configuration information for the WHOI moorings from the SW06 experiment,” Woods Hole. Oceanog. Inst. Tech Report, WHOI-2007-04, June 2007.
- [2] Irish, J.D., Lynch, J.F., Kemp, J.N., Duda, T.D., and Newhall, A.E. “Moored array for measuring internal solitary waves during Shallow Water ’06”, *IEEE/MTS Oceans ’07 meeting proceedings*, Vancouver, B.C., October 2007.
- [3] Maffei, A.R., Lerner, S., Lynch, J.F., Newhall, A.E., Sellers, C., and Glenn, S. “ExView: A real-time collaboration environment for multi-ship experiments.” *IEEE/MTS Oceans ’07 meeting proceedings*, Vancouver, B.C., October 2007.