The Influence of the Shallow Water Internal Tide on the Properties of Acoustic Signals

Marshall H. Orr
Naval Research Laboratory
Att. Code 7120
4555 Overlook Ave, S.W.
Washington, D.C. 20375-5320
Tel: 202 767-3359 FAX: 202 404-7813 E-mail: Orr@wave.nrl.navy.mil

Award Number: N0001401WX20166

LONG-TERM GOAL

Quantitatively relate the temporal and spatial properties of shallow water acoustic signals to the physical processes that cause the temporal and spatial variability of the propagation channel sound speed field. Address internal waves, internal tides, surface gravity wavefields and the heterogeneous ocean bottom/subbottom.

SCIENTIFIC OBJECTIVES

Increase the understanding of the physics of broadband acoustic signal propagation through the random shallow water waveguide. Develop an ability to predict or estimate complex acoustic signal properties in the littoral.

APPROACH

Simultaneous measurement of acoustic signal properties and sound speed variability introduced by a variety of tidally driven fluid processes. Numerical simulation of the fluid processes that perturb the sound speed field and the temporal variability of the complex acoustic signal properties. The FY01 year was devoted primarily to the planning and execution of the NRL component of the ONR FY01 ASIAEX experiment. In addition, further analysis of SWARM95 data was undertaken and a environmental data set was acquired on the New Jersey Shelf during the SWAT experiment. The SWAT data set allows differences between fall and summer time propagation conditions to be studied.

WORK COMPLETED

ASIAEX

NRL participated in the ONR FY01 ASIAEX experiment. This experiment's purpose was to measure the phase and amplitude variability of acoustic signal propagation along shelf and downshelf in the vicinity of the continental shelf break and relate that variability to the fluid dynamic processes that controlled the sound speed field along the acoustic propagation paths. The experiment was performed at the South China Sea Continental Shelf Break in the vicinity of 21.85 N, 117.27 E. The following NRL equipment was brought to the experiment: a 128 channel (a 100m 32 channel vertical array, a 96 channel 465 m horizontal array) acoustic data acquisition system, 300 Hz and 500 Hz acoustic sources,

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**
4. TITLE AND SUBTITLE **The Influence of the Shallow Water Internal Tide on the Properties of Acoustic Signals**		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) **Naval Research Laboratory,,Att. Code 7120,4555 Overlook Ave, S.W.,,Washington,,DC, 20375**		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

Quantitatively relate the temporal and spatial properties of shallow water acoustic signals to the physical processes that cause the temporal and spatial variability of the propagation channel sound speed field. Address internal waves, internal tides, surface gravity wavefields and the heterogeneous ocean bottom/subbottom.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

a two frequency acoustic backscattering system for flow visualization of the fluid processes controlling the sound speed field along the acoustic propagation paths, a CTD installed in a borrowed WHOI (Tim Duda) tow body for tow-yo measurement of the range dependent sound speed profile, a number of temperature pods and a X-Band radar to detect the surface expression of the internal wave fields propagating in the vicinity of the acoustic propagation paths. The 128 channel system failed prior to deployment. Fortunately the WHOI 48 channel acoustic data acquisition system functioned properly and WHOI (James Lynch) has shared the acoustic data with NRL. The NRL moored sources functioned properly and provided 18 days of signal projection (along shelf path) at a 50 % duty cycle. All other NRL equipment was installed on the Taiwanese research vessel Ocean Researcher – III and functioned nominally during each of the three research legs. An excellent environmental data set was taken in the vicinity of the along shelf and downshelf acoustic propagation paths.

SWAT

Participated in the ONR/NRL SWAT experiment from September 28 – October 4, 2001. Acquired an environmental data set similar to the above ASIAEX data using the R/V Endeavor. Similar fluid processes to those described above were observed. A time dependent sound speed field was measured along a 10-20 km propagation path.

SWARM

A SWARM related paper was prepared and submitted describing research started in the previous performance periods. Range dependent sound speed profiles estimated for slack flow and measured during ebb flow (SWARM95) were used to show that matched field signal processing gain differences on the order of 3-9 dB may occur as tidally driven stratified flow accelerates from slack flow to ebb flow. The work, using a fixed replica field, shows that matched field processor replica fields in the shelf/slope propagation environment will need to be updated regularly at time scales smaller than tidal frequencies in order to achieve maximum gain. The calculations over 9.3 km ranges show that the relative difference between acoustic signal amplitudes calculated at slack and ebb flow were negligible. The signal phase changes, however, were significant and the primary cause of the 3-9 dB of degradation in the coherent matched-field processing output for a full water column vertical array. The calculations indicate that acoustic signals propagating in the littoral will change continuously over a tidal cycle. Because the tidal flow is cyclic it is expected that acoustic signal propagating in the littoral may display repeatable and predictable changes in their phase coherent properties. The use of non-hydrostatic hydrodynamic models to predict the temporal evolution of the sound speed field and generate a time varying replica acoustic field is suggested. An article was submitted to JASA, reviewed, altered to meet some referee recommendations and resubmitted.

RESULTS

ASIAEX

The environmental data set taken aboard the Ocean Research III has been evaluated. The acoustic propagation paths were dominated by at least 3 internal wave families. One family resulted from the up slope propagation of the nonlinear internal wave field (solitons) that propagate from east to west across the Luzon Basin. The other internal wave families appeared to be generated locally. The internal wave displacement of the sound speed fields ranged from a few meters to ~ 100 m. The internal waves were observed to undergo a variety of dissipation processes including: shear instabilities with amplitudes of nearly 40 m, breaking of the internal waves and depression to elevation wave conversion as the Luzon Basin internal waves propagated upslope. The impact of these fluid processes on the complex properties of acoustic signals is being evaluated. Figure 1 is an illustration of an elevation wave that was generated from an upslope propagation of a Luzon Basin depression wave.

SWAT

An extensive time dependent sound speed field was repeatedly measured along a 10-20 km propagation path. The data was taken along the acoustic propagation path every 1-3 hrs for 2-3 days. The time dependence of the output of a matched field processor operating in the vicinity of the shelf slope break has been calculated for a variety of frequencies. Internal wave impact has not been included in the calculations yet.

SWARM

Range dependent sound speed profiles estimated for slack flow and measured during ebb flow were used to show that matched field signal processing gain differences on the order of 3-9 dB may occur as tidally driven stratified flow accelerates from slack flow to ebb flow. The calculations over 9.3 km ranges show that the relative difference between acoustic signal amplitudes calculated at slack and ebb flow were negligible. The signal phase changes, however, were significant and the primary cause of the 3-9 dB of degradation in the coherent matched-field processing output for a full water column vertical array.

IMPACT/APPLICATIONS

In the long term the results of this work will permit the prediction of ASW system performance in a shallow water propagation channels that have sound speed fields properties controlled by tidally related fluid processes.

TRANSITIONS

SWAT data has been used to calculate expected temporal variability of a matched field processor for the DARPA Robust Passive Sonar Project. A short report has been written and submitted to the DARPA RPS program manager (Dr. Thomas Green).

RELATED PROJECTS

The ASIAEX and SWAT efforts are interdisciplinary and included a number of ONR supported scientists including members of the Woods Hole Oceanographic Institution, the Naval Postgraduate School, The University of Miami and the University of Maine.

PUBLICATIONS

Referred Articles

Orr, M.H., Haury, L.A., Wiebe, P.H., and Briscoe, M.G., 2000, Backscatter of high frequency (200 KHz) acoustic wavefields from ocean turbulence, J. Acoust. Soc. Am., 108, 1595-1601.

Orr, M. H. and Mignerey, P., 2001, Nonlinear internal waves in the South China Sea observation of the conversion of depression internal waves to elevation internal waves, submitted to The Journal of Geophysical Research, 2001.

Orr, M. H. and Mignerey, P., 2001, Matched-field processing gain degradation caused by tidal flow over continental shelf bathymetry, submitted to The Journal of the Acoustical Society of America, accepted with revision, revisions completed and the manuscript has been returned to the editor.

Report

Mignerey, P. and Orr, Marshall H., Matched-field processing gain degradation of large vertical arrays caused by large scale (>~500 m) variability in the SWAT-00 environment, Submitted to Thomas Green, DARPA Robust Passive Sonar Program Manager, in September 2001.

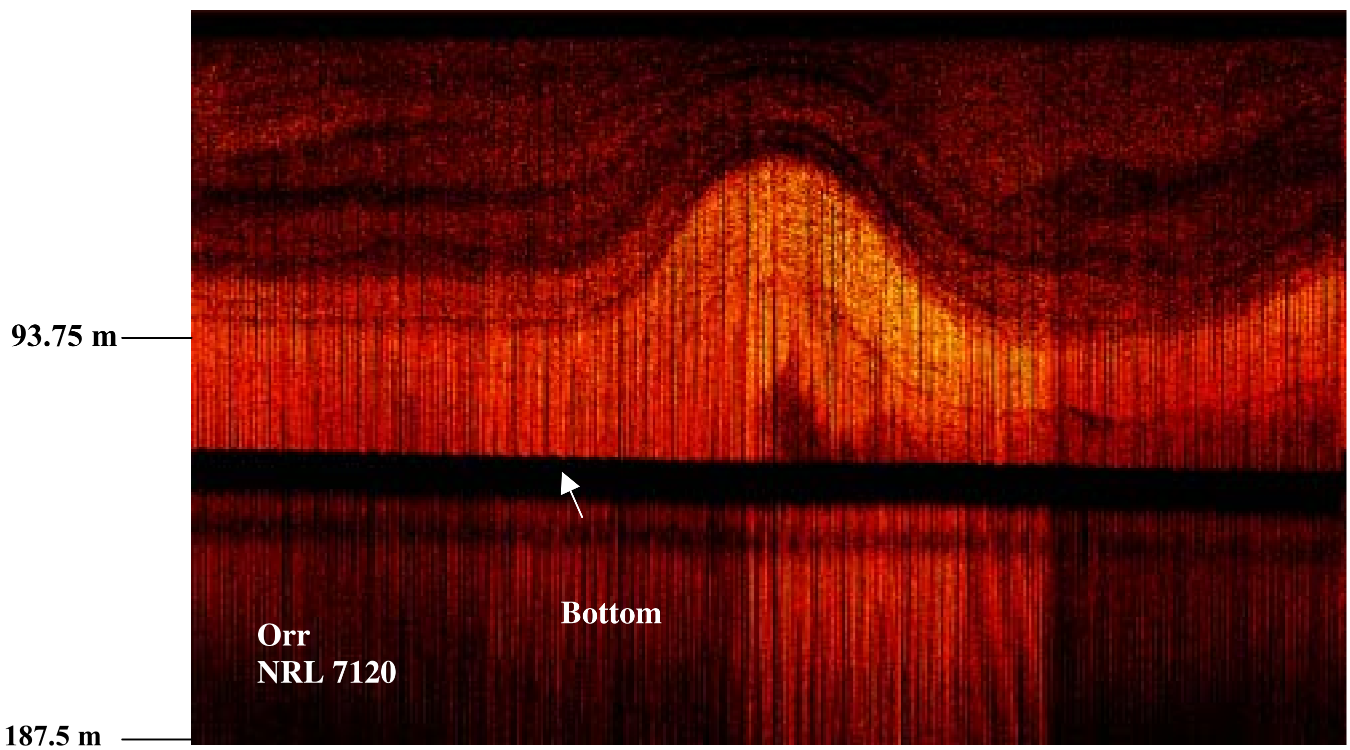

Figure 1. An elevation wave detected at the ONR ASIAEX Experiment Site. During a 5.5 hour period an depression internal soliton was repeatedly imaged as it propagated up the South China Sea slope. The depression wave converted into several elevation waves one of which is shown.