View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by CiteSeerX

A New Scheme for Acoustical Tomography of the Ocean

Alexander G. Voronovich
NOAA/ERL/ETL, R/E/ET1, 325 Broadway, Boulder, CO 80303
phone: (303)-497-6464 fax: (303)-497-3577 email: agv@etl.noaa.gov
E.C. Shang
NOAA/ERL/ETL, R/E/ET1 325 Broadway, Boulder, CO 80303
phone: (303)-497-6363 fax: (303)-497-3577 email: eshang@etl.noaa.gov
Award #: N00014-95-F-0046
http://www.etl.noaa.gov

LONG-TERM GOAL

The long-term purpose is to develop a new scheme of the acoustical tomography of the ocean of meso- to global scales which is based on measurements of horizontal-refraction angle (HRA) related to different acoustic modes rather than travel time along different rays.

OBJECTIVES

To develop robust inversion scheme for retrieving 3-D ocean inner structure based on measurements of HRA. In spite of its small value HRA angle can be easily measured with the help of pair of mode-resolving line vertical arrays situated about 10 km apart (ocean interferometer). As a first approximation adiabaticity of mode propagation should be assumed. Then the scheme should be generalized to the case of non-adiabatic propagation with mode interaction taken into account in a "N 2-D" approximation, and appropriate computer simulations should be performed. Scattering of acoustic signals from internal waves should be also considered, and its effect on the accuracy of sound speed field retrieval should be estimated.

APPROACH

A low frequency tonal sound source (F = 30-100 Hz) is assumed to be towed by a vessel around the area of interest with typical horizontal scale of the order of 1000 km. The transmitted signal is received by acoustic interferometers located inside or outside the area. Thus, the area is exposed from different directions, and HRA is known as a function of source position. Those data are then used for tomography inversion.

In the general case, acoustic mode interaction due to water mass inhomogeneity should be taken into account. This is accomplished with the help of iterations. In the first approximation mode interaction is neglected, and HRA are inverted into sound speed profiles assuming adiabatic propagation. The inversion proceeds in two stages: 1) 2-D tomography which retrieves propagation constants of different modes at the nodes of horizontal rectangular grid covering the area. 2) 1-D tomography which retrieves sound speed profile (in terms of expansion with respect to a set of empirical orthogonal functions) at each node of horizontal grid based on already determined values of propagation constants. Then the contribution to horizontal refraction due to mode interaction are calculated with respect to retrieved inhomogeneous medium using propagation code which takes into account mode interactions in N

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 **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**
4. TITLE AND SUBTITLE **A New Scheme for Acoustical Tomography of the Ocean**		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) **National Oceanic and Atmospheric Administration (NOAA),Environmental Technology Laboratory,325 Broadway,Boulder,CO,80308**		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 **See also ADM002252.**		
14. ABSTRACT		
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)**	**3**	

2D approximation. These corrections are subtracted from the data on HRA (one can say, that propagation is thus made “more adiabatic”), and the procedure of “adiabatic” inversion is repeated with the corrected set of data. When converges, this procedure provides sound speed field which is consistent with the acoustical HRA data.

WORK COMPLETED

The inversion scheme described above was formed. The inversion in the “adiabatic” case was developed at the previous stage of this project (see ref. [1],[2]). Now we extended this inversion scheme to the “non-adiabatic” case in the way described above. Mention, that it requires extensive solution of the direct propagation problem with accurate enough calculation of the modal phases. To achieve this, we used non-parabolic marching algorithm developed previously with the support from ONR within another project. This allowed us to perform all calculations on a standard PC. The approach described above was realized as a software package, and appropriate numerical simulations were performed.

The most significant problem remaining is taking into account in an accurate way such an important factor as scattering of acoustic signals at internal waves. For sufficiently low frequencies applied in our tomography scheme an adequate analytical approach to the description of this process was developed (see publ. [4],[5]). Another problem in the practical case could be bottom-interaction. Towards this effect we tried to generalize appropriately mentioned above non-parabolic propagation code (see publ. [6])

RESULTS

To check numerically the suggested inversion scheme we have chosen the case of Atlantic “meddy” which was measured experimentally in 1991 to the west of Gibraltar. The sound speed profiles included double-channel situation which often gives rise to strong mode coupling. We found, however, that even when the correction to the phases of the acoustic modes is significant, mode interaction weakly affects the HRA, because the corrections cancel out upon subtracting phases at two vertical arrays composing the acoustic interferometer. However, for some propagation paths interaction-induced HRA correction was appreciable. Nevertheless, the inversion according to the iterative scheme performed successfully. In the error-free situation the solution required three iterations. The first iteration corresponded to the maximum error in the sound speed retrieval of about 0.5 m/s, the second iteration produced an error of 0.1 m/s, and the third iteration converged to the exact solution.

This inversion scheme was also tried for different situations including the case of frontal zone and internal waves solitons. The results regarding tomographic inversion of the frontal parameters and transverse current were obtained (see publ. [1],[2].)

IMPACT/APPLICATIONS

The main conclusion is that the suggested acoustic tomography inversion scheme is feasible and can be practically used. Potential applications of the HRT for acoustic tomographic inversion of ocean frontal structure and solitons in coastal area are also promising. This scheme is simpler and cheaper than "traditional" time-of-flight based tomography, because: 1) it uses only simple low-power tonal signals; 2) there is no need in exact positioning of the source and exact time keeping; 3) interpretation of data and inversion technique is greatly simplified; 4) inversion is not subjected to "non-linear biases"; 5) duration of the tomography measurements is reduced significantly.

RELATED PROJECTS

An exact non-parabolic algorithm developed within the project "Non-parabolic marching algorithm for sound field calculations in the inhomogeneous ocean waveguide" was used for numerical simulations taking into account mode interactions.

REFERENCES

1. A.G. Voronovich and E.C. Shang (1995): "A note on horizontal-refraction-modal tomography," J. Acoust. Soc. Am., v.98, 2708-2716.

2. A.G. Voronovich and E.C. Shang (1997): "Numerical simulations with horizontal-refraction-modal tomography. Part I. Adiabatic Propagation", J. Acoust. Soc. Am., v. 101, 2636-2643.

3. E.C. Shang (1997): "Ocean acoustic thermometry and tomography", J. Ocean Univ. Qingdao, v. 27, No. 1, 1-15.

4. E.C. Shang, Y.Y. Wang and A.G. Voronovich (1997): "Nonlinear tomographic inversion by using WKB modal condition", J. Acoust. Soc. Am., v.102, 3425-3432.

PUBLICATIONS

1. E.C. Shang, A.G. Voronovich, Y.Y. Wang, and L.A. Ostrovsky, "Application of modal horizontal-refraction tomography and modal phase tomography for ocean remote sensing." Proc. of PORSEC'98, pp. 698-702, 1998.

2. E.C. Shang, Y.Y. Wang, "The frontal effects on long-range acoustic propagation in the North Pacific Ocean", (JASA, in press).

3. A.G. Voronovich and E.C. Shang, "Horizontal-refraction modal tomography of the ocean with mode interactions", submitted to the special issue of IEEE, ser. Ocean Eng.

4. A.G. Voronovich, "Low-frequency sound propagation through random internal waves with application to measurements of internal wave spectra by acoustic means," Proc. of the Fourth European Conf. on Underwater Acoustics, Ed. By A. Alippi and G.B. Cannelli, v. II, 751-756, Rome, 1998.

5. A.G. Voronovich, "A statistical theory of low-frequency sound propagation through internal waves," Proc. 16th Int. Congress on Acoustics and 135th Meeting of the Acoust. Soc. Am., v. I, 379-380, 1998.

6. A.G. Voronovich, "Numerical model for low-frequency sound propagation in inhomogeneous waveguides," Proc. 16th Int. Congress on Acoustics and 135th Meeting of the Acoust. Soc. Am., v. II, 975-976, 1998.