Semiclassical Approximations and Predictability in Ocean Acoustics

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LONG-TERM GOALS

Our long-term goal is to improve our understanding of the physics of the forward scattering of underwater sound. Of particular interest is understanding limitations on the predictability of underwater sound fields. Improving our understanding of the mechanism(s) that contribute to the loss of predictability will lead to improved predictive models.

OBJECTIVES

The scientific objective of this work is to understand limitations on the predictability of acoustic wavefields in realistic (range-dependent) ocean environments. Both full wave and semiclassical (ray-based) predictive models are of interest. Both cw and broadband wavefields are of interest. We seek to both develop improved predictive acoustic models and to understand their limitations.

APPROACH

Using semiclassical methods, ideas relating to ray chaos provide a framework for studying predictability. Wavefield behavior in the ray limit is explored numerically and, whenever possible, analytically. The extent to which limitations on predictability carry over to finite frequency wavefields are then explored numerically, generally with parabolic-equation-based models. Both deterministic and stochastic models are of interest. Comparisons with data are made whenever possible.

Several tools have recently been developed and/or extended for use in our work: Tappert's c_o-insensitive PE model (Tappert et al., 1995); the MaCh1 algorithm (Brown, 1994) for finite frequency ray-based wavefield predictions; a stochastic ray model (Brown and Viechnicki, 1998) to model scattering by internal waves; and an efficient algotithm to generate realistic internal-wave-induced sound speed perturbation fields (Colosi and Brown, 1998).

This work is being done in loose collaboration with the following individuals: F. Tappert (Univ. Miami; parabolic wave equations, waves in random media, ray chaos); M. Wolfson (Washington State Univ.; numerical modelling, waves in random media, ray chaos); S. Tomsovic

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 1999		**00-00-1999 to 00-00-1999**

4. TITLE AND SUBTITLE
Semiclassical Approximations and Predictability in Ocean Acoustics

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)
University of Miami,Rosenstiel School of Marine and Atmospheric Science,4600 Rickenbacker Causeway,Miami,FL,33149

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	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT	b ABSTRACT	c THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**3**	

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

(Washington State Univ.; classical and quantum chaos, semiclassical breakdown); G. Zaslavsky (Courant Institute, NYU; chaos in dynamical systems, stochastic methods, quantum chaos); and J. Colosi (WHOI; ocean internal waves and long-range underwater sound propagation).

WORK COMPLETED

Recent accomplishments include: 1) development and numerical implementation of stochastic ray theory (Brown and Viechnicki, 1998) to describe and model the forward scattering of underwater sound by internal waves; 2) development of a new efficient, accurate and robust algorithm to compute internal-wave-induced sound speed perturbation fields (Colosi and Brown, 1998); 3) incorporation of this internal wave model into both ray and full wave propagation models; 4) demonstration (Brown, 1999) that, in the ray limit, islands of stability in phase space exist when the environment is almost stratified and has nonperiodic range-dependence; and 5) construction (Brown, 1999) of the solution, in the form of a Maslov integral, of a large class of problems involving wave motion in inhomogeneous moving media.

RESULTS

Stochastic ray theory and the new technique to compute internal-wave-induced sound speed perturbation fields are important new tools which can be used to address fundamental questions relating to the predictability of long-range sound propagation in deep ocean environments. The work relating to the structure of phase space provides critically important insight into – and a mathematical framework for the study of – sound propagation in environments with nontrivial range-dependence. Our (with M. Wolfson and S. Tomsovic) semiclassical breakdown studies show that, even in the presence of chaotic ray motion, semiclassical wavefield representations accurately predict many important features of underwater acoustic wavefields. Recent work on analysis of the AET long-range propagation data indicates that path stability is controlled to a large extent by the background sound speed structure.

IMPACT/APPLICATIONS

Our work gives insight into the limitations on the predictability of underwater sound fields. This is an important basic science issue which impacts all systems applications which require accurate predictions of underwater sound fields.

TRANSITIONS

The PI collaborates informally with the investigators listed above, ATOC investigators, and others. This includes sharing both ideas and software. It is not known whether any software produced by the PI has been used to address any applied Navy problems.

RELATED PROJECTS

This work is closely related to the ATOC project and the ONR-funded work being performed by P. Worcester (SIO), J. Colosi (WHOI), M. Wolfson (WSU), J. Spiesberger (UPenn), S.

Tomsovic (WSU), G. Zaslavsky (CIMS/NYU) and F. Tappert (UMiami). All of these projects are concerned with aspects of long-range propagation.

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