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SEMICLASSICAL APPROXIMATIONS AND PREDICTABILITY IN OCEAN ACOUSTICS

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Category: Long-Range Propagation

LONG-TERM GOALS

Our long-term goal is to understand limitations on the predictability of underwater sound fields in the ocean, especially using semiclassical (ray-based) methods. 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 the limitations of the validity of semiclassical wavefield representations in realistic ocean environments. There are two primary causes for the breakdown of ray methods: 1) the accumulation of phase errors associated with the asymptotic validity of these methods; and 2) in range-dependent environments the chaotic motion of ray trajectories limits one's ability to predict. We seek to improve our understanding of these phenomena to the point that we may quantitatively estimate the semiclassical "predictability horizon."

APPROACH

To address these problems, semiclassical wavefield predictions are compared to normal mode and PE-based wavefield predictions, and, whenever possible, measured wavefields. Comparisons with measured wavefields has led to the development of a stochastic ray-theoretical treatment of internal wave scattering. Deterministic semiclassical wavefield predictions are made with the MaChl algorithm (Brown, 1994) which properly treats caustic of arbitrary complexity. Numerical work is complemented by theoretical advances whenever possible.

This work is being done in loose collaboration with the following individuals: F. Tappert (U. Miami; parabolic wave equations, waves in random media, ray chaos); M. Wolfson (Penn State U.; numerical modelling, waves in random media, ray chaos); G. Zaslavsky (Courant Institute; chaos in dynamical systems, stochastic methods, quantum chaos); S. Tomsovic (Washington State U.; quantum chaos and semiclassical breakdown); and J. Colosi (WHOI; internal waves, long-range propagation).

WORK COMPLETED

The principal accomplishments of the last year are: 1) the development and numerical implementation of stochastic ray theory to describe and model the scattering of sound by internal waves in deep ocean environments; 2) the development (with J. Colosi at WHOI) of a new efficient, accurate, and robust algorithm to compute internal-wave-induced sound speed perturbation fields; 3) demonstration that for a large class of problems involving boundary interactions, ray phase errors are inversely proportional to frequency and increase linearly with range; and 4) demonstration that, in the ray limit, islands of stability in phase space exist when the environment is almost stratified and has quasiperiodic range dependence.

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 wave propagation in environments with nontrivial range-dependence.

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 the sharing of 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 (PSU), J. Spiesberger (PSU), S. Tomsovic (WSU), G. Zaslavsky (CIMS) and F. Tappert (U. Miami). All of these projects are concerned with aspects of long-range propagation.

REFERENCES

Brown, M.G., 1994, A Maslov-Chapman wavefield representation for wide-angle one-way propagation, Geophys. J. Intl. 116, 513-526.

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