

Investigation of Parametric Acoustic Response of a Fluctuating Ocean

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LONG-TERM GOALS

The long-term goals are: 1) to take advantage of the ever-changing ocean environment's effects in order to provide a more complete understanding of long-range acoustic pulse propagation, 2) understanding the extent of fundamental limitations on ray-based acoustic tomography; of particular interest is the breakdown range of semiclassical methods, and 3) to address important basic physics issues that arise in the ocean problem, but within a more general context.

OBJECTIVES

There are two primary scientific objectives of this work: 1) to begin developing a geometric acoustics theory that addresses parametrically varying ocean environments in the presence of ray chaos, determines what information survives under such conditions, and determines how to extract it, and 2) to determine the sensitivity of acoustic wavefields to relevant ocean environment parameters thereby connecting the scale of changes in the ocean to range scales of wavefield correlation decay.

APPROACH

We consider acoustic propagation problems that allow for parabolic equation description. Advantage is taken of new semiclassical approaches to approximate time-evolving wavefields in systems possessing classically chaotic analogs. The methods rely on wave packets, heteroclinic orbit summations, and have been shown to be remarkably accurate in spite of relying on highly unstable chaotic trajectories. The approach is similar in spirit to the van Vleck approximate propagator, and the Gutzwiller trace formula. From this starting point, we consider systems whose governing equations can be expressed as varying with respect to a parameter; this can model, for example, a time-changing internal wave configuration. To study response and sensitivity, it is fruitful to apply perturbation theory to describe the changes arising in ensembles of classical trajectories underlying the wavefields. We compare semiclassical predictions with 'exact' numerical wavefield calculations.

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WORK COMPLETED

The work completed this year falls into two projects, one in collaboration with M. Wolfson, and the other with a visiting scientist, A. Lakshminarayanan, and a WSU Ph. D. graduate student, Nicholas Cerruti. Dr. Wolfson and I are nearing completion of a paper on the stability of rays propagating through mesoscale structure in the ocean. The model is simplified, possessing a single scale of weak random structure, involves only the horizontal plane, and is isotropic. Nevertheless, it has some key features of rays propagating in random media similar to ocean acoustic rays. It has the advantage that Wolfson and Tappert have worked out some previous analytic results helpful for our current study. Preliminary results were presented at the ASA Berlin meeting. The second project was an investigation of how chaotic wave systems respond to changing a parameter in their governing equations. We used abstract maps as dynamical models, but we have in mind eventually making connections to changing mesoscale and internal wave field fluctuations. This work was published in Phys. Rev. E this year.

RESULTS

Dr. Wolfson and I have found that the stability of rays discussed above fluctuate as log normal random variables. Our results also predict the scaling of the width of the distribution, how it collapses in the infinite range limit, and gives us a prediction for the number of remaining nearly stable or intermittent rays as a function of the range. The same stability measures appear in ray theories for the amplitudes of various contributions to the wave fields. The remaining stable rays may be important for helping tomographic techniques where mostly chaotic rays exist, and the log normal distribution may have ramifications for the wave field statistics at finite range. In the second project, we found that correlation decay functions based on ensembles of rays in the chaotic maps we were considering could be analytically linked to the strength of response of the corresponding wave equation solutions.

IMPACT/APPLICATION

The work is aimed at understanding the predictability and/or other limitations of ray methods in the presence of unstable dynamics. In addition, parametric variation, once understood, is often found to be one of the only successful ways of deducing otherwise difficult-to-asertain information about complex systems such as the ocean environment. It may lead to new ocean acoustic tomography techniques.

TRANSITIONS

It is too early to discuss how these results will eventually be used by others.

RELATED PROJECTS

Additional work currently underway, but not described in this report, involves collaborations with the following individuals: M. Wolfson (WSU) and M. Brown (RSMAS-AMP).

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