Numerical Modeling of Acoustic Propagation in a Variable Shallow Water Waveguide

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LONG-TERM GOALS

Random variability in shallow water will induce variability in a propagating acoustic field. The general long-term goal of this research is to quantify how random variability in the ocean environment translates into random variability in the acoustic field and the associated signal processing algorithms. The specific long-term goal for the current funding cycle is to develop a predictive capability for the ambient noise notch in the presence of random ocean internal waves.

OBJECTIVES

The scientific objective of current effort is to understand the effect of internal waves on the ambient noise notch. The ambient noise notch is a trough in the noise directivity pattern that is observed under certain circumstances.

APPROACH

The technical approach to modeling the ambient noise notch is to combine sub models for acoustic propagation, shallow water internal waves, and ambient noise generation. The acoustic propagation sub model is based on the transport theory developed by Dozier and Tappert [1978] augmented to include bottom loss, an important consideration in shallow water. The internal wave sub model is based on a shallow water version of the Garrett-Munk spectrum developed by Henyey et al. [1997]. The validity of the combined model is tested by comparison to data from field experiments. In this testing, we are working with Dajun Tang of APL-UW and using data from the 2001 ASIAEX experiment.

WORK COMPLETED

Sub models for acoustic propagation, shallow water internal waves, and ambient noise generation were combined to develop a model for the ambient noise notch. In the present funding cycle, a more detailed testing of the model was completed. Model predictions agreed with experimental observations made over extended periods.

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We gave an invited talk on our work in a special session on High Frequency Ambient Noise at the Spring 2006 meeting of the Acoustical Society of America [Rouseff and Tang, 2006a]. The work was also documented in a refereed journal paper [Rouseff and Tang, 2006b].

RESULTS

Figure 1 shows results from the 2001 East China Sea experiment. The left panel shows the vertical directivity pattern observed as a function of frequency between 500 Hz and 5 kHz. The notch in the noise field in the horizontal, i.e. 0 deg, is clearly visible. The depth of the noise notch is the noise level at 0 deg compared to the noise level at the local maxima on either side of the notch. The right panel in Fig. 1 shows the depth of the noise notch plotted as a function of time for 2, 3, and 4 kHz. In general, the three time series track one another and the noise notch is deepest at 4 kHz.

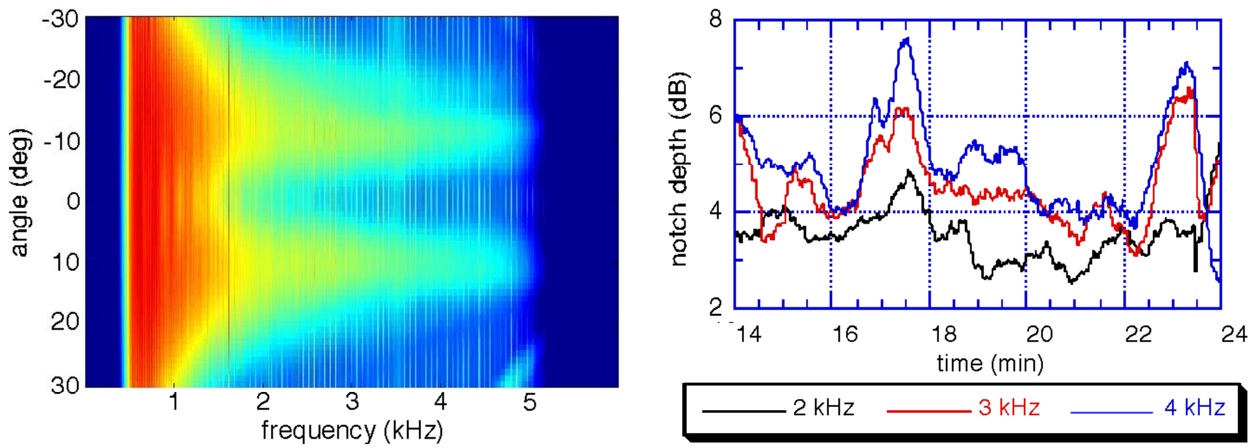

Figure 1: Left: Example of ambient noise beam pattern observed in East China Sea. Result is average over 140 consecutive time windows each of 0.5 s duration. 50 dB dynamic range. Right: Depth of ambient noise notch evolving over 10 minutes at 2, 3 and 4 kHz.

Table 1 shows the average depth and width of the ambient noise notch for East China Sea data collected on two different days at three different frequencies. Also shown are the predictions from our model. The agreement between model and data is good. The model predicts the correct trends as the noise notch gets narrower and deeper with increasing frequency. The model typically predicts the depth of the noise notch within about 1 dB and the width within a few degrees.

Table 1: East China Sea model/data comparison. Width and depth of ambient noise notch as observed on two days compared to model prediction. Model assumes internal wave field of moderate strength.

	June 6 data		**June 7 data**		**Model**	
	Notch width	Notch depth	Notch width	Notch depth	Notch width	Notch depth
2 kHz	20.6 ± 1.4º	3.6 dB	23.2 ± 1.7º	4.4 dB	18.0º	5.1 dB
3 kHz	17.9 ± 0.8º	4.7 dB	19.7 ± 1.8º	6.3 dB	17.2º	5.6 dB
4 kHz	15.8 ± 0.8º	5.2 dB	19.3 ± 2.6º	6.1 dB	16.8º	6.0 dB

IMPACT/APPLICATIONS

When present, the ambient noise notch may have significant impact on passive detection schemes; in effect, it creates a window to look through the noise for targets of interest. Being able to predict the extent to which a noise notch will exist at different locations under different oceanographic conditions is highly desirable. As implemented, the model uses minimal oceanographic information: the buoyancy profile is estimated from the sound speed profile and the internal wave energy level is estimated from other experiments. The significance of this result is that this implies a new capability to predict the characteristics of the noise notch with minimal environmental input.

TRANSITIONS

Partial support to apply the ambient noise notch model to East China Sea data was provided by SPAWAR.

RELATED PROJECTS

Additional ambient noise data was collected in the SW06 experiment. Synoptic measurement of the internal wave field were part of the experiment. Ideally, these data could be used to further test and refine our noise notch model.

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