Three dimensional sound propagation in Mien Hua Canyon

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(Dated: November 19, 2009)

Abstract

In this paper, we report numerical results corresponding to the propagation of sound wave in the Mien Hua Canyon region northeast of Taiwan. The object is to demonstrate the 3D effect of sound wave propagation in this particular exercise during the Quantifying, Predicting and Exploiting Environmental and Acoustic Fields and Uncertainties(QPE) experiment in 2009. The numerical simulations are performed using a fully 3-D parabolic equation based model (FOR3D) coupled with a 4D ocean modeling based on primitive equation. The transmission loss (TL) comparisons between Nx2D and 3D calculations are shown to demonstrate the 3D effect due to azimuth coupling, which includes both horizontal refraction and net energy exchange between vertical planes.

PACS numbers: 43.30.Ft, 43.30.Re, 43.30.Ma

I. INTRODUCTION

Three-dimensional (3-D) propagation effects on underwater sound field still has been regarded as a very difficult and unresolved issue, due to both very limited ocean environmental information and expensive computational cost. Moreover, in most realistic sound propagation scenarios, the 3-D environmental variability is weak enough to allow two-dimensional (2-D) models to correctly predict sound propagation with assumption of there is no energy flux between two adjacent vertical plane. However, with recent emphasis on shallow water and on long range tomography, the significance of three-dimensional (3-D) propagation effects on underwater sound field has attracted more attentions lately, and it is easy to see how 3-D issue may now be essential to address. The 3D effect could be caused by both horizontal refraction and net energy exchange between vertical planes due to complex bathymetry or inhomogeneous of background sound speed. One example of later one is internal wave(nonlinear or linear) scattering of sound in an along-wavefront geometry, which is also known as internal wave ducting sound. It has been studied and observed at sea[Katsnelson, 2000, Lynch, 2006, Badiey, 2005; Lin, 2009]. For across slope propagation the bending of sound rays towards the downslope direction is an established phenomenon too, which is caused by the interaction of the sound waves with a sloping bottom, and it has been studied and observed at sea[Tolstoy, 1996; Sturm, 2008; Heaney, 2008]. In this paper, we will address the 3D effect of sound propagation in canyon region, which is seldom investigated before.

This letter is organized as follows. In section 2, the experimental and environmental information will be introduced. Section 3 presents the numerical investigation of 3D effects in Mien Hua Canyon based on 3D sound propagation simulation coupled with 4D ocean modeling output. The concluding remarks are stated in section 4.

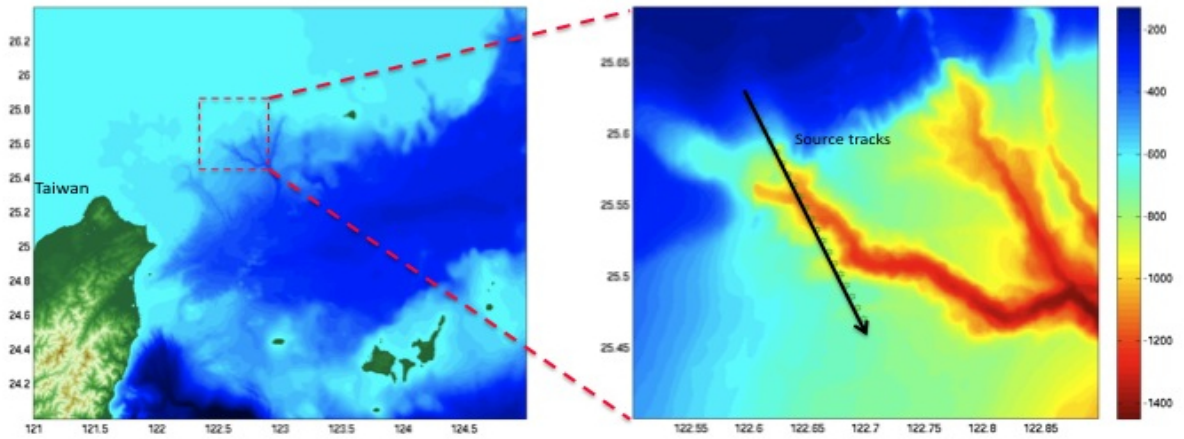

FIG. 1. The QPE experimental region (left panel); Mien Hua Canyon bathymetry and OMAS sound source track.

II. DESCRIPTION OF EXPERIMENT

Follow the QPE pilot experiment in 2008, QPE Intensive Observation Period 2009 was conducted in the almost same region as pilot cruise, i.e., on the continental shelf and slope of northeast Taiwan, as shown in Figure 1. As suggested by the name- intensive observation period, a large amount effort was carried on to collect ocean environmental data to provide initial condition and assimilation data for ocean forecast modeling. The acoustic experiments were also carried out intensively during the second leg of OR1 cruise in both shelf and slope region in the north east of Taiwan. In order to explore the acoustic propagation in Canyon region, one single day of cruise was also devoted to have the OMAS moving source run cross over the Mienhua Canyon. In support this testing, both Nx2D and 3D simulations were tested during the real time experiment.

III. NUMERICAL SIMULATIONS

A. Ocean simulations

B. 3D simulations with range independent sound speed profile

C. 3D simulations with range dependent sound speed profile

1.

IV. SUMMARY AND DISCUSSION OF RESULTS

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