

Chemical absorption of acoustic energy due to an eddy in the western Bay of Bengal

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Acoustic energy losses due to chemical absorption, within the western Bay of Bengal, in the presence of a subsurface meso-scale cold core eddy has been analysed. These estimates, for two different frequencies - 400 Hz and 10 kHz, find applications in acoustic tomographic studies and SONAR operations. The results show that the eddy has been found to contribute to increased loss of acoustic energy due to chemical absorption. At 400 Hz the energy loss increases by 1.76×10^{-3} dB/km as against 1.0×10^{-1} dB/km for 10 kHz over the ambient value. The study also brings out the fact that the loss of acoustic energy due to chemical absorption even in the presence of a meso-scale eddy works out to a negligible percent (0.4) as compared to geometrical spreading for long ranges and at 400 Hz. For SONAR frequencies this loss amounts to 25%. Thus, in terms of range, the meso-scale features would limit the performance of SONAR.

Introduction

Acoustic monitoring of oceanic features is becoming more and more relevant with recent interest of oceanographers in understanding the energetics and dynamics of meso-scale phenomena. The existence of SOFAR channel in the ocean makes possible propagation of acoustic pulses over long ranges and an appropriate acoustic model can be utilised to obtain a snapshot of existing, large scale features in the form of eddies, fronts etc. However, the ability to model acoustic propagation effectively in the ocean depends on the accuracy of estimation of acoustic energy losses.

Acoustic signals propagating within the ocean volume lose their intensity due to processes such as scattering, reflection at the physical boundaries in addition to geometrical spreading and absorption within the medium. Chemical losses due to absorption of acoustic energy in sea water, caused by

viscosity and relaxation processes, however, depends on the frequency of the acoustic signal.

Some studies were made to understand the physical losses due to spreading in the Bay of Bengal¹⁻³. However, information as to the nature of losses due to chemical absorption does not exist.

In the present paper the authors attempt to study the acoustic energy losses of chemical nature associated with a cold core, subsurface eddy in the northwestern Bay of Bengal.

Data

In a recent study, Babu et. al.⁴ reported the presence of a cold core subsurface eddy in the northwestern Bay of Bengal during late July (Fig. 1a) based on the CTD data collected at 42 stations on board ORV Sagar Kanya during 21-29 July 1984. The

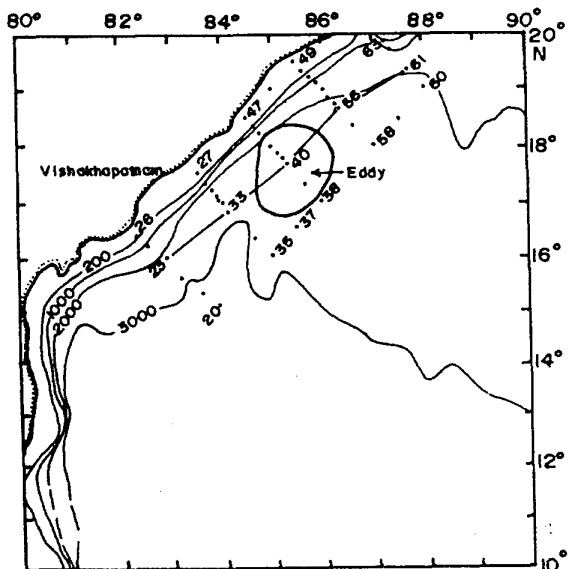


Fig. 1 (a) Area of study-CTD stations - the reported location of the eddy, (b) 3-D perspective of the temperature distribution at 150m surface presenting the eddy.

eddy, having a diameter of about 200 km, was located at sub-surface depths between 50 and 300 m. A temperature drop of about 5°C was observed at the center of the eddy (Fig. 1b). The surface dynamic topography relative to 500 dB showed that the eddy center was depressed by approximately 10 dyn cm as compared to the surrounding waters indicating cyclonic circulation.

CTD data from five stations (#23, #33, #40, #56 & #61) parallel to the western boundary out of 42 stations (Fig. 1) were chosen for the present study to understand the influence of the reported subsurface eddy.

Methodology

The general equation for the absorption of sound⁵⁻⁶ in sea water obtained through theoretical formulations accounting for the contributions due to boric acid, magnesium sulphate and pure water are given by :

$$\alpha = \frac{A_1 P_1 F_1 f^2}{F_1 + f^2} + \frac{A_2 P_2 F_2 f^2}{F_2 + f^2} + A_3 P_3 f^2$$

where 'f' is the frequency in kHz and coefficients are given by

$$A_1 = (8.86/C) \times 10^{(0.78 \text{ pH}-5)}$$

$$A_2 = 21.44 (1+0.025 T) S/C$$

$$A_3 = 4.937 \times 10^{-4} - 2.59 \times 10^{-5} T (T < 20^\circ\text{C}) \\ = 3.964 \times 10^{-4} - 1.146 \times 10^{-5} T + 1.45 \times 10^{-7} T^2 \\ - 6.5 \times 10^{-10} T^3 (T > 20^\circ\text{C})$$

$$P_1 = 1$$

$$P_2 = 1 - 1.37 \times 10^{-4} D + 6.2 \times 10^{-9} D^2$$

$$P_3 = 1 - 3.83 \times 10^{-5} D + 4.9 \times 10^{-10} D^2$$

$$F_1 = 2.8 (S/35)^{0.5} \times 10^{(4-1245/\theta)}$$

$$F_2 = [8.17 \times 10^{(8-1990/\theta)}] / [1 + 0.0018 (S-35)]$$

where T is temperature (°C), $\theta = 273 + T$ is the absolute temperature, S is salinity (pss), D is depth (m) and C is sound speed (m/s). This equation holds good for all oceanic conditions and to frequencies varying from 0.2 kHz to 1.0 MHz. Following Chen and Millero⁷, C was computed for all the five CTD station data.

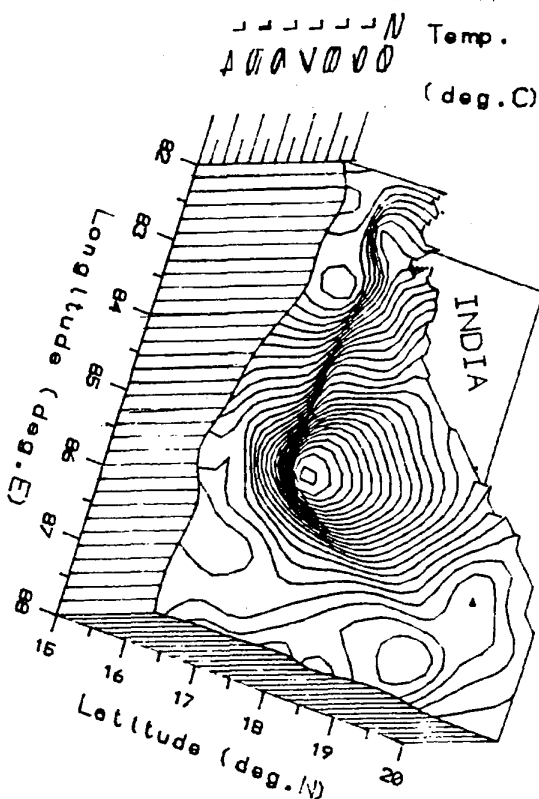


Fig. 2 Mean pH profile in the Bay of Bengal.

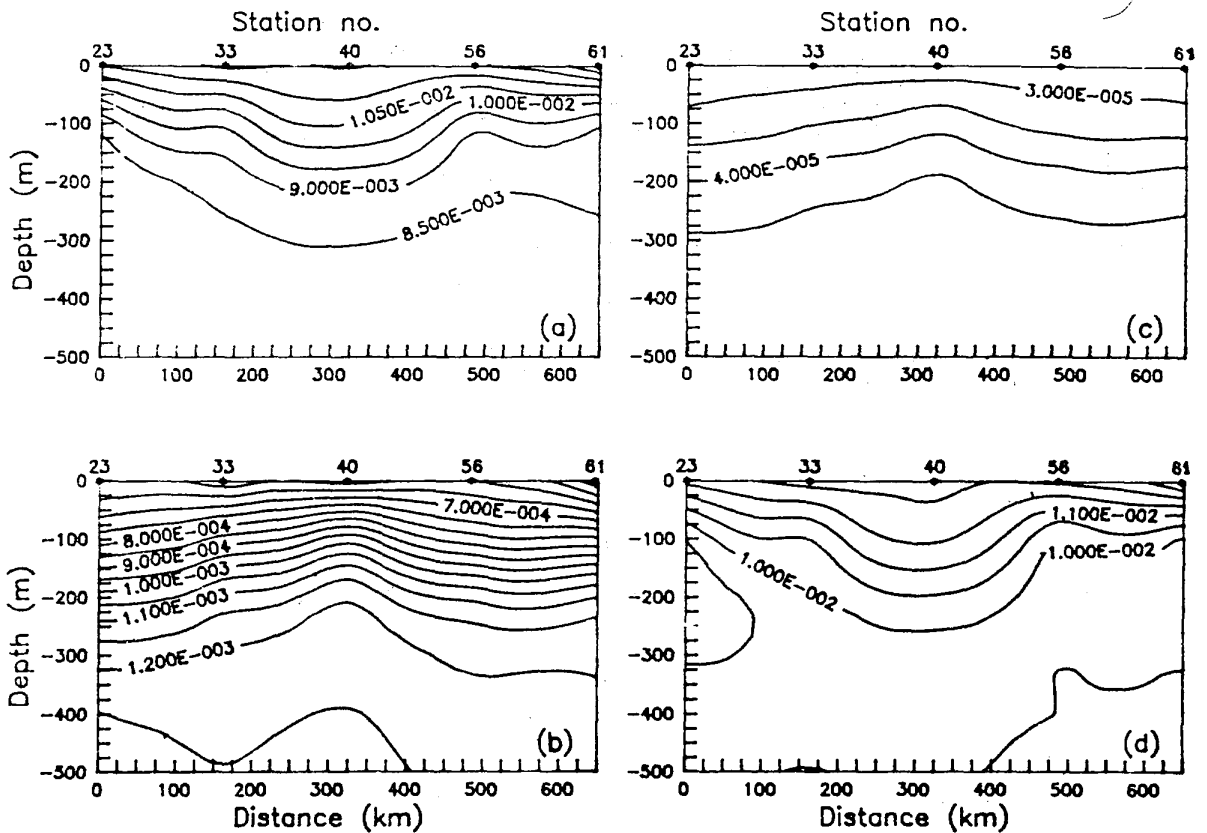


Fig. 3 Acoustic energy loss at 400 Hz due to (a) Boric acid, (b) Magnesium sulphate, (c) pure water and (d) total absorption.

Results and discussion

Chemical Losses are computed for two different frequencies - 400 Hz for application in ocean acoustic tomography and 10 kHz used for SONAR operations - considering the mean pH profile for Bay of Bengal (Fig. 2). Contributions due to boric acid, magnesium sulphate, pure water and total absorption are presented separately. At 400 Hz, the absorption due to boric acid is dominant (Fig. 3a) and shows a decrease with depth. This feature reverses for magnesium sulphate (Fig. 3b). It is interesting to note

that in the presence of cold core eddy the acoustic absorption at 400 Hz frequency due to boric acid and magnesium sulphate exhibit an increase by 1.5×10^{-3} dB/km and 3×10^{-4} dB/km (the ambient absorption being 8.95×10^{-3} dB/km and 7.56×10^{-4} dB/km) respectively. Absorption by pure water (Fig. 3c), however, shows a marginal increase of 0.75×10^{-5} dB/km. In a way, the eddy induces an overall increase in absorption up to 1.76×10^{-3} dB/km (Fig.3d).

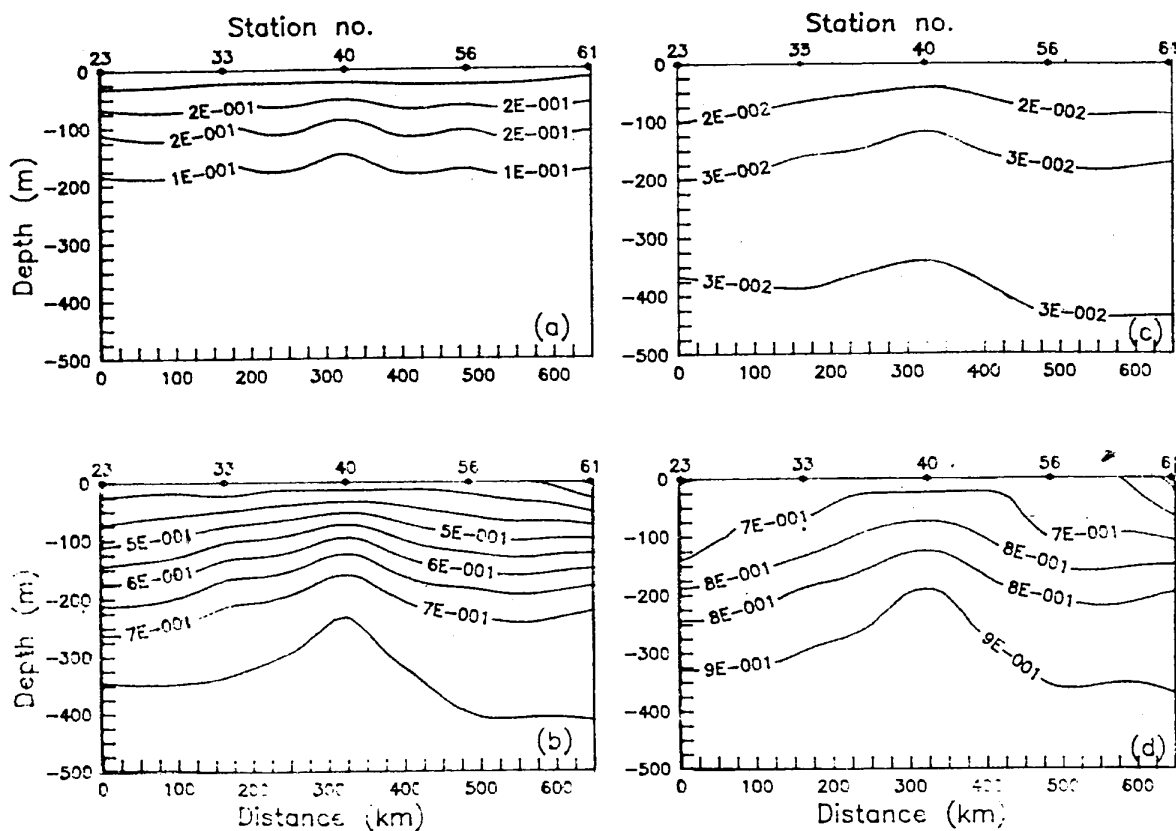


Fig. 4 Acoustic energy loss at 10 Hz due to (a) Boric acid, (b) Magnesium sulphate, (c) pure water and (d) total absorption.

For 10 kHz frequency, the absorption due to boric acid (Fig. 4a) within the eddy decreases by 0.6×10^{-1} dB/km while that due to magnesium sulphate (Fig. 4b) and pure water (Fig. 4c) increases by about 1.0×10^{-1} dB/km and 0.3×10^{-2} respectively. The total absorption (Fig. 4d) in the presence of eddy (at the higher frequency), amounts to 1.0×10^{-1} dB/km. In essence, the observed meso-scale feature (eddy) has been found to enhance the chemical absorption of acoustic energy irrespective of the frequency.

The study brings out the fact that for long range propagation using low frequency, as for the ocean

acoustic tomography studies, the loss of acoustic energy due to chemical absorption even in the presence of meso-scale (eddy) feature works out to a negligible percent (0.4) as compared to geometrical spreading. For SONAR frequencies the loss due to chemical absorption reaches to about 25%. Thus meso-scale features would impair the SONAR performance in terms of range.

Acknowledgements

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