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Sound propagation in a current rip region ; From Tsugaru warm eddy side to Oyashio cold water mass

潮目領域における音波伝搬；津軽暖水渦側から親潮冷水塊へ

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1. Introduction

In the east of Tsugaru Straits, Tsugaru warm eddy (TuWE) is formed. TuWE is the overhang over Oyashio that is a cold water mass. the current rip is generated in the boundary region. In this region, the seawater temperature is changed rapidly on both vertical direction and horizontal direction. Therefore, the sound propagation is affected by the temperature change. Tsurugaya *et al.* has examined the sound propagation across the current rip region. Additionally, they reported that the propagation of sound is affected by the topography of the seabed, and the configuration of the propagation is changed[1-4]. In these studies, the direction of sound propagation is mainly considered toward TsWE side from Oyashio Cold Water Mass (OyCWm). And, in this case, the bottom depth is decreasing. Then, the direction on sound propagation is reversed and the propagation toward OyCWm from the TuWE side is examined. In this case, the bottom depth becomes deep.

2. Temperature structure in the current rip region

Temperature structure and Vertical sound speed profile in the current rip region are shown in Fig. 1. The upper figure is the temperature structure along the line of the north latitude 41°, and the lower figures are the vertical sound speed profiles in each point. The structure of TuWE floating on OyCWm can be seen in this figure. The depth of sound channel (SC) axis under TuWE is roughly 600 m, and that of OyCWm is about 160 m. The sound propagation is examined from the TuWE side toward OyCWm. It is the range shown by the arrow in the figure, and the distance is 120 km. The current rip region is between about 40 km and 70 km. FOR3D[5], PE model, is used to calculate sound propagation.

3. Comparison for sound propagation caused by the difference on the topography of seabed

3-1 Comparison on sound fields

Sound fields by the difference on the topography of seabed are shown in Fig. 2. The shape of seabed is designated by a white solid line. a) is the flat bottom (Flat-B; 4000 m in depth), b) is

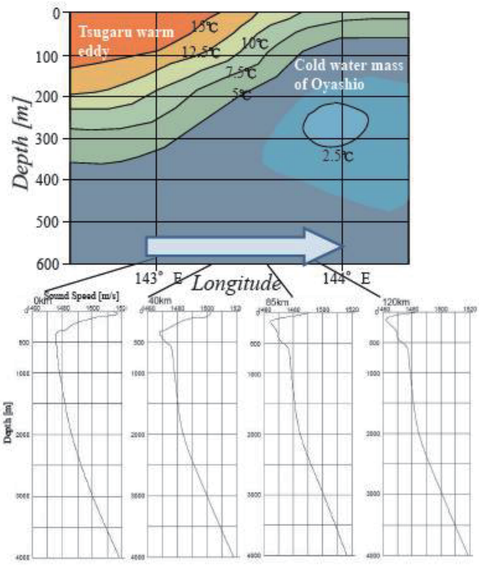

Fig. 1 Vertical temperature structure along 41° -N and Sound speed profiles

the monotonically inclined bottom (Inc-B; from 1230 m to 3200 m in depth), and c) is the actual bottom(Act-B). Source depth (SD) is 100 m. The propagation of sound consists of the following three forms because Sound Channel (SC)-axis under TuWE is 600 m; Surface Duct propagation, Convergence Zone (CZ) propagation, and Bottom Bounce (BB) propagation. The factor influenced by the topography of seabed to sound propagation is a depth and an inclination of bottom. SC propagation is predominated when source depth becomes deep.

3-2 Comparison on transmission loss

Transmission loss (TL) by the difference on the topography of seabed is shown in Fig. 3. The solid line is Flat-B, the broken line is Inc-B, and the dotted-broken line is Act-B. SD and the receiving depth (RD) is 100 m, respectively. In Flat-B, the sound radiated from source is refracted to downward and reached at the bottom. As a result, TL is increased from sound source to about 20km, and BB propagation is superimposed to sound field between 20km and 40km. A reduction of TL at 60km and 110km is due to 2nd CZ and 1st CZ. Concerning IncB and ActB, the shape of the bottom is the same up to 20km. Therefore, the difference of TL curve is very small. But, the difference in TL curve occurs from 30km being the different topography of seabed. TL is influenced by the

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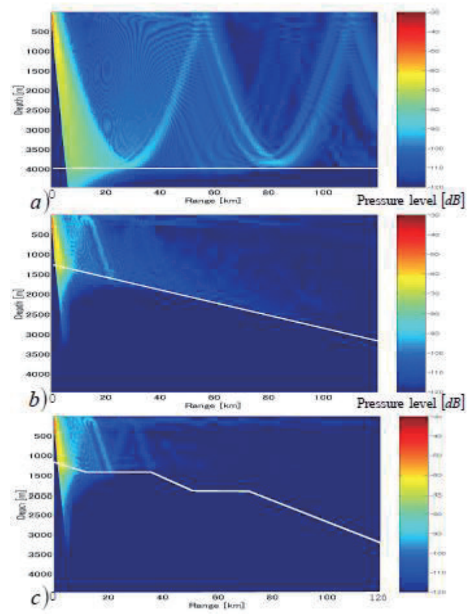

Fig. 2 Comparison on sound fields caused by the topography of seabed a) Flat-B b) Inc-B c) Act-B SD; 100 m

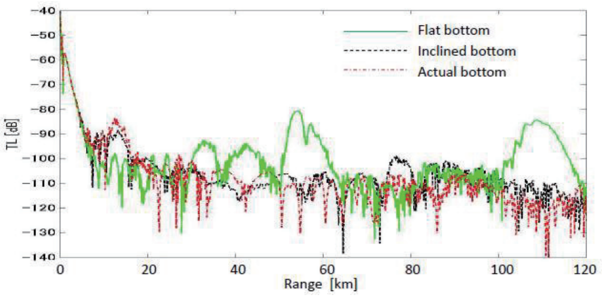

Fig. 3 Comparison on TL caused by the topography of seabed solid line; Flat-B broken line; Inc-B dotted-broken line; Act-B SD and RD is both 100 m.

bottom depth and the bottom slope. TL is also different depending on RD.

4. Comparison for TL caused by sound source approaching from OyCWm from TuWE

When the source moves from the TuWE side to OyCWm, TL received in OyCWm is shown in Fig. 5. ◆,▲, and■ is denoted to Flat-B, Inc-B, and Act-B, respectively. In the figure *a*), SD is 10 m, and RD is 50m. In the figure *b*), SD and RD is the same depth in 450 m. In the case of shallow SD and RD, decreasing TL by 2ndCZ and 1stCZ is appeared by Flat-B. In Inc-B and Act-B, the formation of CZ is prevented by the bottom. And, TL is large at shallow receiving depth because the reflection direction is changed by the bottom slope. Moreover, the formation of sound fields is not clear in shallow depth because the source approaching to 120km become a downward refraction. SC propagation is superimposed to the above mentioned propagation configuration when RD becomes deep. When both SD and RD are deep, the

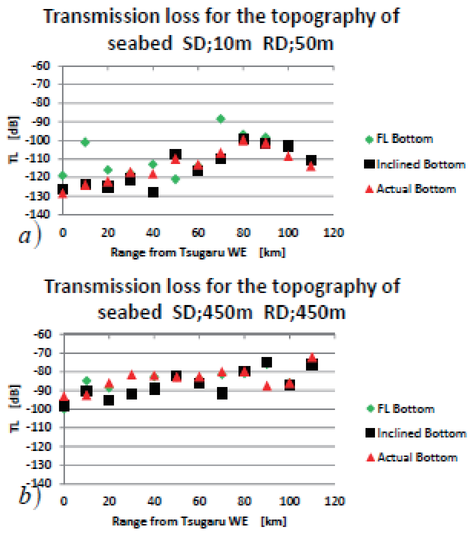

Fig. 4 Comparison for TL caused by the topography of seabed ◆;Flat-B ■; Inc-B ▲; Act-B

SC propagation is predominated. As a result, the dispersion on TL in the three configurations of bottoms becomes small , and the value of TL becomes small. In the middle SD, the difference by each configuration of bottom becomes large because TL is changed by the superposition of SC propagation.

5. Summary

In the current rip region, the sound propagation from the TuWE side toward the OyCWm side are compared for FlatB, IncB, and ActB, and is examined. When SD in FlatB is shallow, sound field is formed with CZ and BB propagation. When the source depth becomes deep, SC propagation is generated in addition to CZ and BB propagation. The formation of CZ propagation is obstructed by the bottoms, and BB propagation is controlled by the inclination of bottoms. When SD becomes deep, SC propagation is formed, and TL becomes small. The bottom obstructs the formation of CZ propagation, and the inclination of the bottom contributes to the change in the reflection direction.

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