A Study on the Fluctuation of Bottom Cold Water in the Western Channel of Korea Strait

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Abstract

We researched the mechanism on the fluctuation of Bottom Cold Water in the western channel of Korea Strait, using 13 years (1981~1993) oceanographic data of FRDA. The bottom cold water in the western channel appears more often in summer and fall than in winter and spring, and its year-to-year variation of temperature is very large. Such variation seems to be closely related with the variations of cold waters in the subsurface layer of the southwestern East Sea. According to the longitudinal temperature distribution along the korean southeastern coast, a density difference occurs all the time at the sill depth between the western channel and the southwestern East Sea. Thus, it is inferred that the cold waters would intrude into the western channel from the subsurface layer in the southwestern East Sea as a density-driven current, and its intensity depends upon the density difference.

1. Introduction

The Korea Strait is located between the southeastern coast of korean peninsula and the northern coast of Kyusu, Japan, and it is divided into the western and eastern channel by Tsushima Islands. These two channels show different characteristics in bottom topography, water masses and current. The western channel shows more complicated hydrographic conditions than the eastern channel, as various kinds of water masses such as Tsushima Warm Current Water, North Korean Cold Current Water, East Sea Proper Water, Coastal Water exist in this channel.

Besides these features, in the western channel, the cold waters of less than 10℃ have frequently been observed in the trough, whose depth is more

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than 200m (Fig. 1), in summer and autumn.

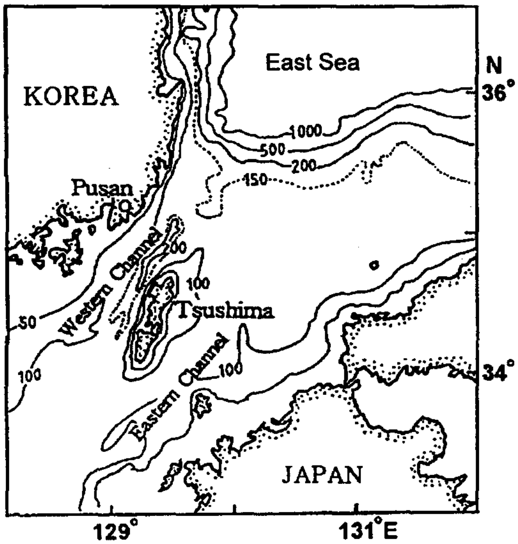

Fig. 1. Bottom topography in the studied areas.

These cold waters, however, never be found in theeastern channel. Many oceanographers have been studied these cold waters since the early 1900s, and they called this Bottom Cold Water (herinafter "BCW").

Among previous researches concerning origin and inflow path of BCW, Lim and Chang(1969), Yun et al.(1992) described that BCW was the cold water mass in the East Sea which flowed down into the western channel through the bottom layer of korean southeastern sea off Ulgi, mixing with Tsushima Warm Current Water above. On the other hand, Kim and Kim(1983), Kim and Chung(1984) and Kim et al.(1991) said that BCW was the East Sea Intermediate Water from East Sea which originated from North Korean Cold Water. In addition, Yi(1970) represented that BCW was the cold water mass which existed below the intermediate layer in East Sea and its fluctuation might be correlated with the strength of Tsushima Warm Current. Furthermore, Lim(1973) made an assumption that BCW was the cold water in the East Sea which flowed into the western channel with velocity of 0.2~0.3 knots through the bottom layer near Ulgi and the intensity of its southward flow might be correlated with the tidal cycle.

As stated above, considerable researches regarding origin and inflow path of BCW was carried out. However, few studies have been dealt with the mechanism of its fluctuation have been dealt with so far. Thus, we descriptively investigated and analyzed the oceanographic conditions in the western channel including its adjacent seas in order to find out the mechanism on the fluctuation of Bottom Cold Water in the western channel.

2. Materials and Methods

In this paper, we mainly used 13 years (1981~1993) oceanographic data observed bimonthly by National Fisheries Research and Development Agencies(FRDA), along with the oceanographic data of Japanese Fisheries Agencies for analyzing the hydrographic conditions of the eastern channel. Fig. 2 shows the locations of oceanographic lines and stations in the studied areas.

We drew the horizontal distribution of mean bottom temperature for Febuary, April, August and October to investigate general oceanographic conditions at bottom per season in the studied areas. Likewise, we selected the years when the bottom temperature at St. 207-4 was colder and warmer than normal in summer, then made drawings of vertical sections of temperature at 3 lines (line-207, 208 and 209), and longitudinal sections of temperature along the korean southeastern coast in order to find differences in the hydrographic structures between warmer and colder occasions. The line connecting 6 stations (St. 206-4, 207-4, 208-3, 209-6 and 102-6) for the longitudinal section was marked in Fig. 2.

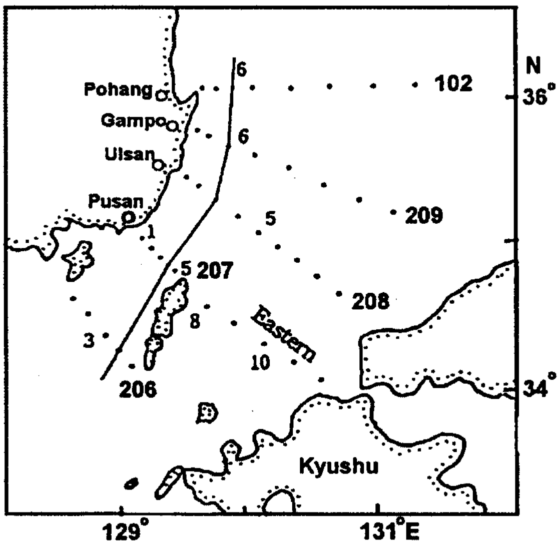

Fig. 2. Location of the oceanographic lines and stations for this study. Thick line denotes the oceanographic line for longitudinal section in chapter 3.

In addition, we prepared a vertical section of standard deviation of temperature (1981~1993) at line-209 and a graph with temperature at a depth of 200m of St. 207-4 against that at a depth of 100m at St. 209-6 in summer during 13 years(1981~1993). These were done to find the correlation between BCW in the western channel and the cold water masses in the subsurface layer in the East Sea.

In this paper, Bottom Cold Water (BCW) denotes the cold water masses of less than 10℃ present in the bottom layer in the western channel, unless otherwise stated.

3. Results

3.1 Mean bottom temperature per season

Fig. 3 shows the mean bottom temperature (1981~1993) in the studied areas for Febuary, April, August and October. In winter and spring, isotherms are crowded together near the continental slope (Fig. 1) off Pohang and the cold waters of less than 10℃ can be seen only in the north of continental slope. However, the tongue-shaped 10℃ isotherm is extended into the western channel along the korean southeastern coast from the southwestern East Sea in summer and fall. These cold water masses are distributed only at the korean southeastern coastal zone within about 50 km from Ulsan. In comparision with the western channel, the waters in the eastern channel are 2~3℃ warmer in summer and fall than in winter and spring. This feature is attributed to convection, which causes the upper and bottom water in this area to mix up and down as the air temperature gets colder in winter and spring.

It can be noted by Fig. 4, which shows the year-to-year variation of temperature at a depth of 200m at St. 207-4 during 13 years, that BCW is more often observed in summer and fall and its temperature is colder than other seasons, and BCW has a big fluctuation in temperature from year to year. Fig. 4 also shows that the cold water masses appear in winter and spring, though the BCW is not seen in the western channel in these seasons in Fig. 3.

3.2 Sections of temperature in summer

To find differences in the oceanographic structures between the years when BCW is colder than normal and the years when no BCW appears in the western channel in summer, we drew the vertical sections of temperature at line-207, 208 and 209 (Fig. 5) and the longitudinal section of temperature along the korean southeastern coast (Fig. 6).

Some different features in the temperature

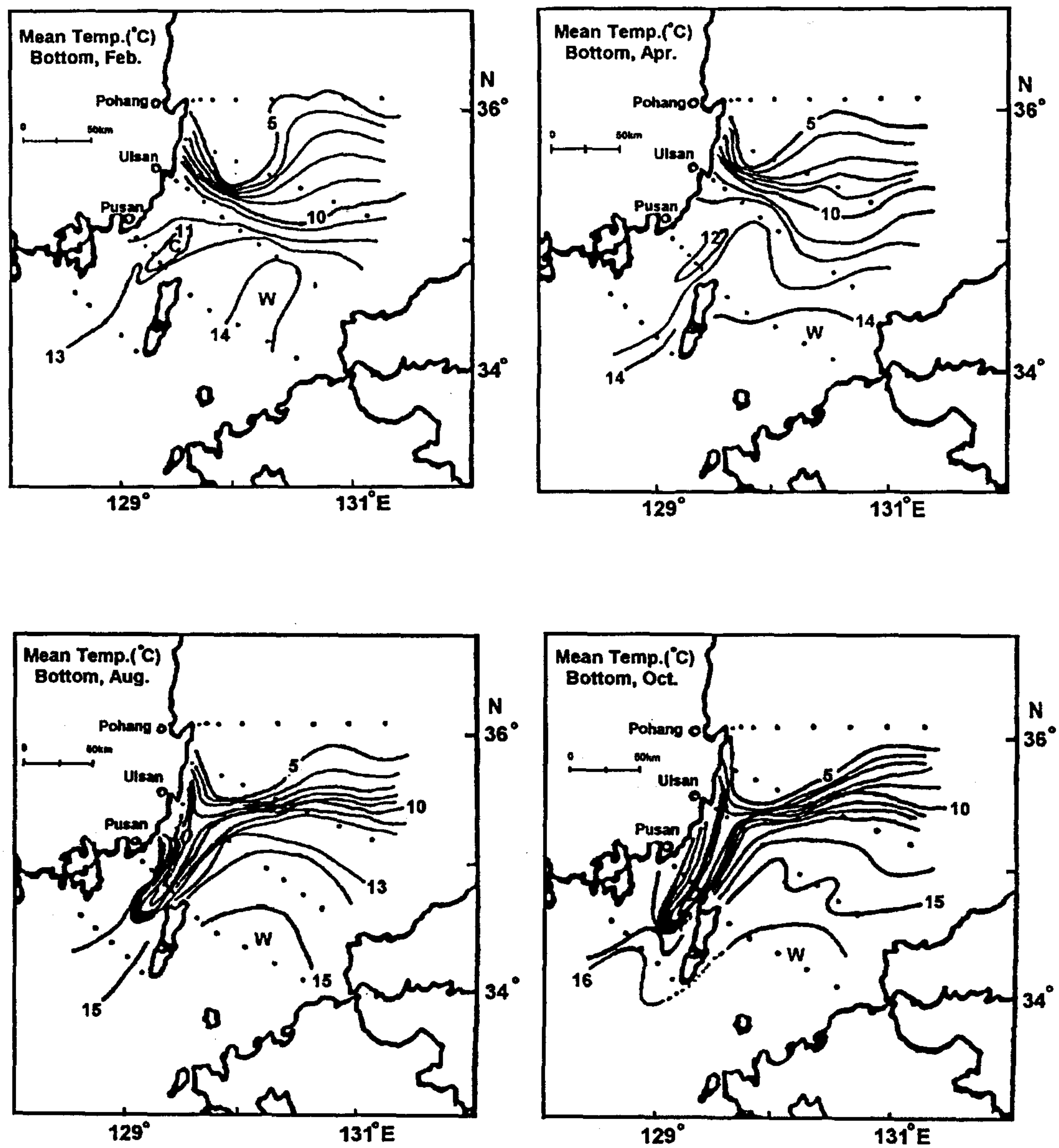

Fig. 3. Mean bottom temperature(1981～1993) per season.

structures between the above years can be identified in Fig. 5. In 1989, the seasonal thermocline is formed near a depth of 50m and only warm waters of 14～17℃ is present below seasonal thermocline at line-207 and 208. Two thermoclines are seen at line-209, one is the seasonal thermocline formed at depth of 10～30m and the other is the permanent thermocline formed

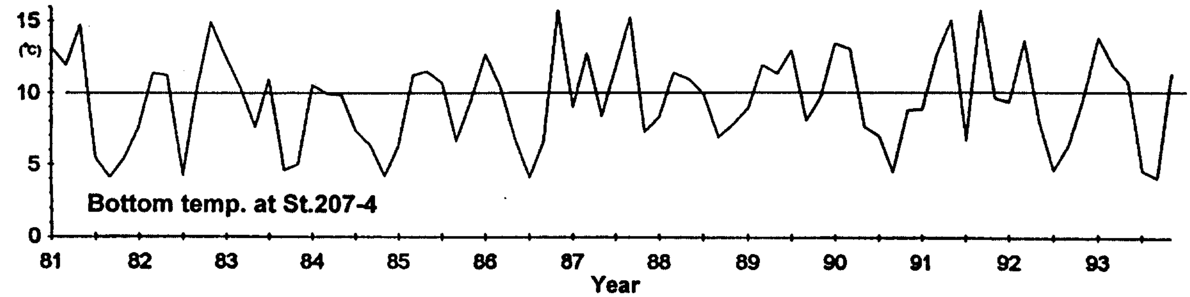

Fig. 4. Year-to-year variation of bimonthly bottom temperature at St. 207-4. Straight line indicates temperature of 10℃.

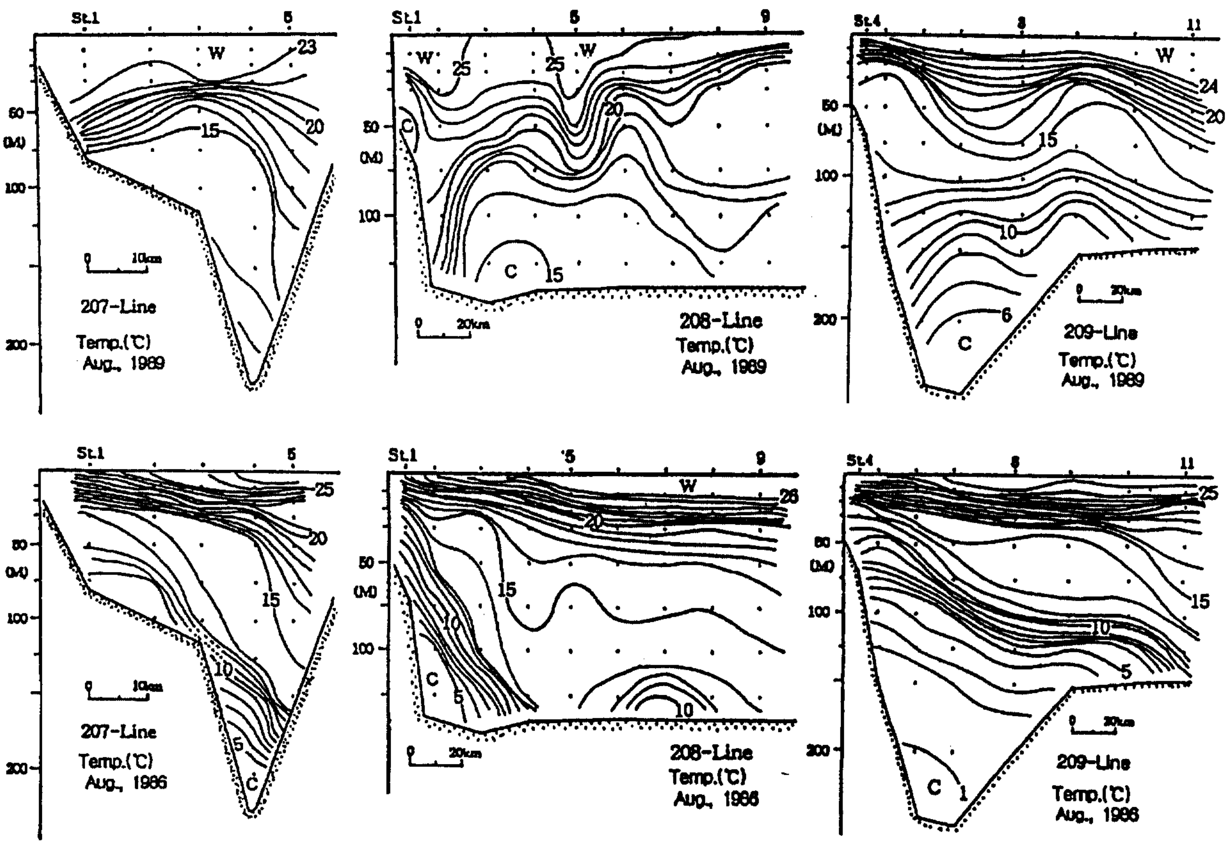

Fig. 5. Temperature for line-207, 208 and 209 in summer of the year when no BCW exists in the western channel(upper) and BCW is much colder than normal(lower).

at a depth of 150m. Likewise, the cold waters of less than 10℃ are present below the lower thermocline at this line. On the other hand, all sections are well stratified into three layers by the formation of two thermoclines in 1986. The seasonal thermocline is strongly formed near the

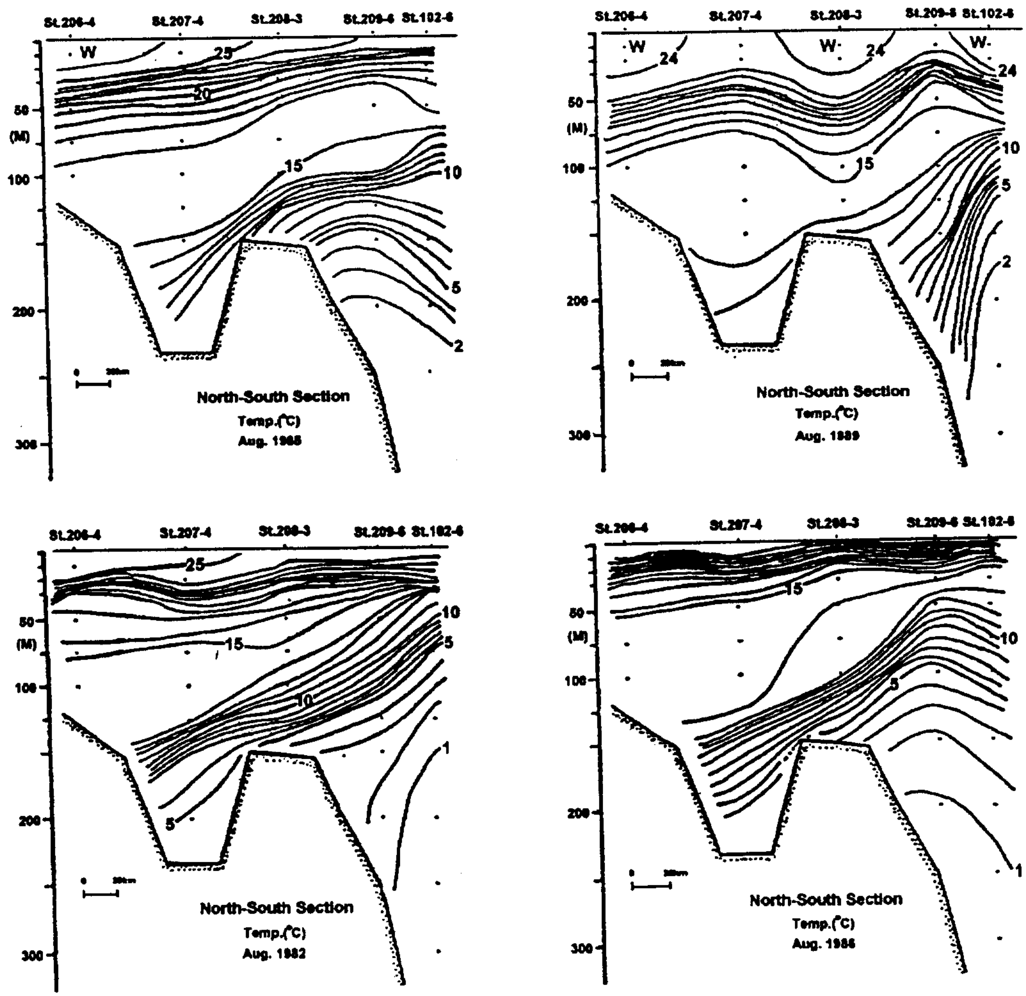

Fig. 6. Temperature along the korean southeastern coast in summer of the years when no BCW exists in the western channel(upper) and when BCW is much colder than normal(lower).

sea surface moving significantly upward at all lines compared with that in 1989, also the lower permanent thermocline at line-209 is intensified.

Other marked different features in the temperature structures between the above years can be found in Fig. 6. In 1985 and 1989, the warm water masses of above 14℃ are present from the surface to a depth of 150m in the western channel. These warm waters are also seen from the surface to a depth of about 125m in the southwestern East Sea (St. 209-6). This causes only a small density difference at the sill depth of 125~150m along the korean southeastern coast. In 1982 and 1986, the warm water masses of above

14℃ are present from surface to a depth of 125m in the western channel as well. But, these warm waters are present only from the surface to a depth of about 50m in the southwestern East Sea. This temperature structure indicates that the Tsushima Warm Current Water in the western channel tends to rise up the cold water masses in bottom layer, due to buoyancy effect when it enters into the East Sea. This type of structure looks very similar to a salt wedge estuarine type such as the Mississippi or Fraser River (Pickard and Emery, 1982). Consequently, there is a large temperature difference of 5~10℃ at the sill depth along the korean southeastern coast which may result in density current in this areas.

4. Discussions and Concluding Remarks

In this paper, we investigated and analyzed 13 years(1981~1993) oceanographic data of FRDA in order to find the mechanism on the fluctuation of BCW in the western channel. According to the seasonal distribution of mean bottom temperature, the cold water masses of less than 10℃ intrude into the western channel from the southwestern East Sea in summer and fall. They flow down through the korean southeastern coastal zone within about 50km from the coast. In addition, it is noted by year-to-year variation of BCW temperature at a depth of 200m of St. 207-4 that BCW appears more often in the western channel in summer and fall and its temperature is colder than other seasons. Likewise, we note that BCW is also present in winter and spring.

In the western channel, a marked feature is that the Tushima Warm Current Water is present in a thick layer from the surface down to about 125m all year round without significant year-to-year variation. Whereas, in the southwestern East Sea adjoining to the western channel, the Tushima Warm Current Water is present in a relatively thin layer from the surface down to about 100m. Below this layer, the cold water masses are present. The development of this cold waters in the subsurface layer varies from year to year and tends to be more developed in summer and fall than in winter and spring(Yun, 1996). Such variation can be seen in Fig. 7 which shows a standard deviation (SD) distribution of temperature (1981~1993) at line-209. It is shown that standard deviation is minimun at the surface and bottom, and maximum at a depth of 75~125m. This means that the waters in minimum SD layer have almost the same properties every year and those in maximum SD layer greatly vary year by year which may be due to the large year-to-year variation of the thermocline in this layer.

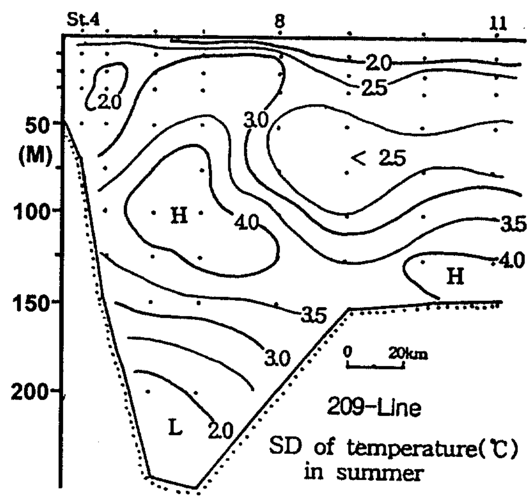

Fig. 7. Standard deviation of temperature(1981~1993) at line-209 in summer.

As can be seen from above, there is a major difference in hydrographic conditions along the path of Tsushima Current between adjacent seas, the western channel and the southwestern East Sea. Consequently, the Tsushima Warm Current Water looks like rising up the cold water masses

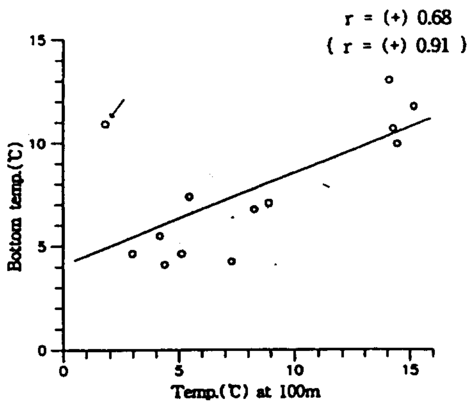

Fig. 8. Bottom temperature at St. 207-4 plotted against temperature at a depth of 100m at St. 209-6 in summer. Bracketed correlation coefficient is computed with 1983's data excluding arrow mark data.

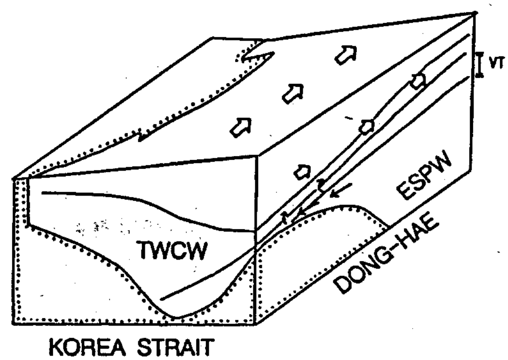

Fig. 9. Schematic representation of oceanographic structure and current system in the western channel and korean southeastern seas. TWCW and ESPW stand for Tsushima Warm Current Water and East Sea Proper Water respectively. VT on the right margin means the variation of permanent thermocline.

in bottom layer, and thinning in its vertical extent when it enters East Sea after passing the western channel. Likewise, the cold water masses intrude southward as a wedge below Tsushima Warm Current Water. Since this kind of pattern seems quite similar to that in weakly mixed estuaries (Dietrich et al., 1980; Yoo, 1989), we can assume that the density-driven current occurs at the sill depth along the korean southeastern coast due to density difference between two adjacent seas.

Fig. 8, in which bottom temperature at St. 207-4 was plotted against temperature at a depth of 100m at St. 209-6 in summer during 13 years(1981~1993), shows correlation between two temperatures. It is noted that there is a significant correlation between two temperatures, indeed a very close correlation if we exclude 1983's observation data which might be abnormal(Yun, 1996). This indicates that the growths and decays of BCW in the western channel seem to be affected by the variation of cold water masses in the subsurface layer of the southwestern East Sea.

In conclusion, it is assumed that the increased development of cold water masses in the subsurface layer of the southwestern East Sea causes a larger density difference at the sill depth along the korean southeastern coast. Thus, the southward intrusion of cold water into the western channel from the East Sea is more intensified as shown in the schematic diagram of Figure 9.

Complex surroundings in the western channel make it necessary to undertake more extensive studies not only of the oceanographic conditions in the East Sea but also the transport and path of Tsushima Current to reveal the mechanism on the fluctuation of BCW in the western channel.

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