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STUDY ON THE COASTAL COLD WATER NEAR ULSAN

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ABSTRACT

The coastal cold water near Ulsan, Korea, almost always appears in summer. From the results of some data analysis, it is found that this cold water has an important relation to the anticlockwise circulation appearing near the coast where the anticlockwise circulation turns its current direction from south to east.

INTRODUCTION

It has been reported that a cold water mass appears off the east coast of Korea(Nagamuna, 1972; Ogawa 1971). Recently, Ann (1974) concluded that the appearance of this cold water mass is attributed to the upwelling induced by the strong Tsushima warm current and a great northeasterly component wind blowing along the coast. Upwelling induced by the wind stress will be probably a main factor of the appearance of this cold water mass. But this phenomenon seems to have an important relation to the Tsushima warm current and the anticlockwise circulation appearing near the east coast of Korea during the summer. It also has some interesting characteristics: the water near the shore is colder than that offshore and the coldest water appears near Ulsan.

Figure 1 shows the monthly averaged profiles of the surface water temperature which were observed at some fixed observation sites situated along the east coast of Korea. In Figure 1 the surface water temperature of the southern coast is higher than that of the northern coast in winter, but the situation reverses in summer. In Figure 2 the coastal (N35°29′, E29°27′) surface water temperature of Ulsan, with the running mean over 10 days, is compared with that of Sogcho coast (N38°12′, E128°36′) during the period from 1968 to 1973. The

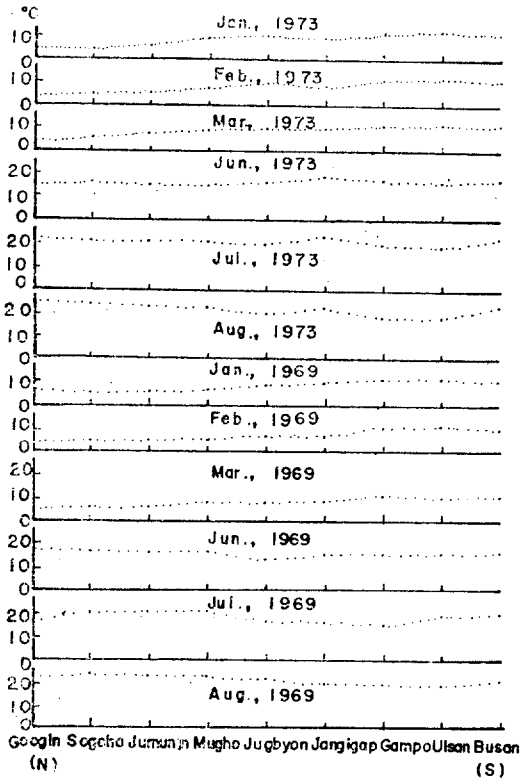

Fig. 1. The monthly averaged profiles of the surface water temperature which were observed at some fixed observation sites situated along the east coast of Korea.

Ulsan coastal surface water temperature was higher than that of the Sogcho coastal water during the period from the fall to the spring every year, but it inversed in July of 1968, August of 1969, July of 1971, June and August of 1972, and in August and September of 1973, as can be seen from Figure 2. These two figures show that the remarkably cold water appears almost always at the coast of Ulsan in summer.

In order to know the reasons for the appearance and the source of the Ulsan coastal cold water, some data analysis was performed. This study will show that the coastal cold water has an important relation to the anticlockwise circulation appearing near Ulsan in summer and to the upwelling induced by the strong Tsushima warm current.

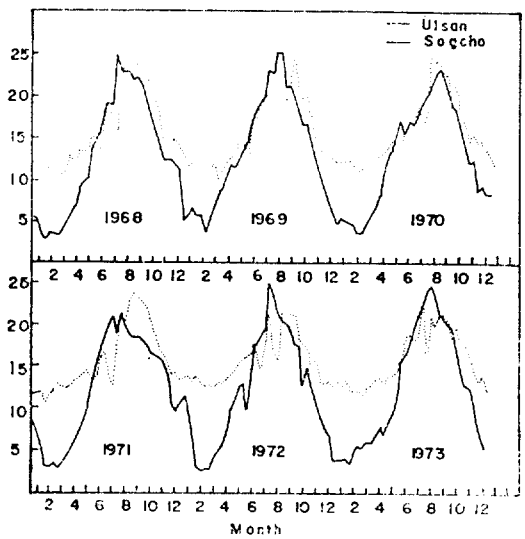

Fig. 2. The surface water temperature off Ulsan (dotted line), and that off Sogcho(solid line), which are averaged over 10 days.

DATA ANALYSIS

1. Data Sources

Data sources in the present study are as follows. The first is the surface water temperature observed once a day at some observation sites in the east coast of Korea, such as Busan, Ulsan, Gampo, Jangigap and others. The second is the water temperature, salinity and dissolved oxygen concentration observed five to six times a year in the CSK Project by Fisheries Research and Development Agency (FRDA) of Korea along the survey lines 102, 209 and 208 as shown in Figure 3.

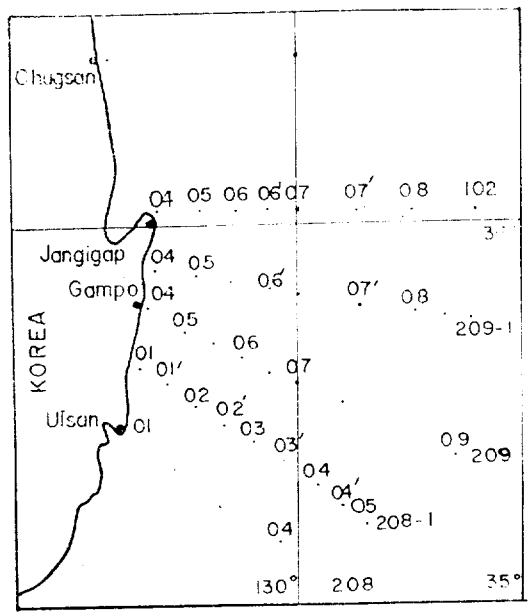

Fig. 3. Observation field

The third are those observed by FRDA of Korea as a special observation project along the survey lines 208, 208-1, 209, 209-1 and 102 on June 24, July 26-30 and August 31, 1973. These data were obtained at the ordinary standard depth of oceanographic observation.

2. The Geostrophic Flow Patterns and the Distribution of Surface Water Temperature

In order to find the relation between the coastal cold water and the pattern of the geostrophic flow, especially the Tsushima warm current, dynamic calculations were performed using the oceanographic data by the FRDA of Korea.

In this calculation the motionless level was

adopted to be 100m depth, because the depth of the Tsushima Strait(located between Tsushima Island and Korea) is about 100m. Figures 4(a) and (b) show the resultant surface topography.

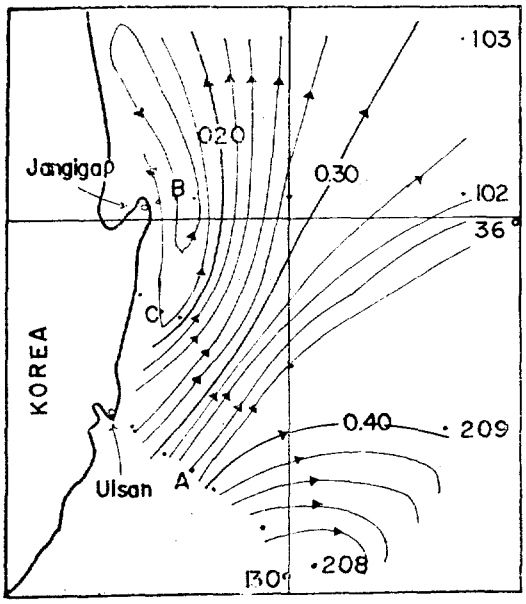

Fig. 4 (a). The surface dynamic topographies over 100db surface in August, 1969.

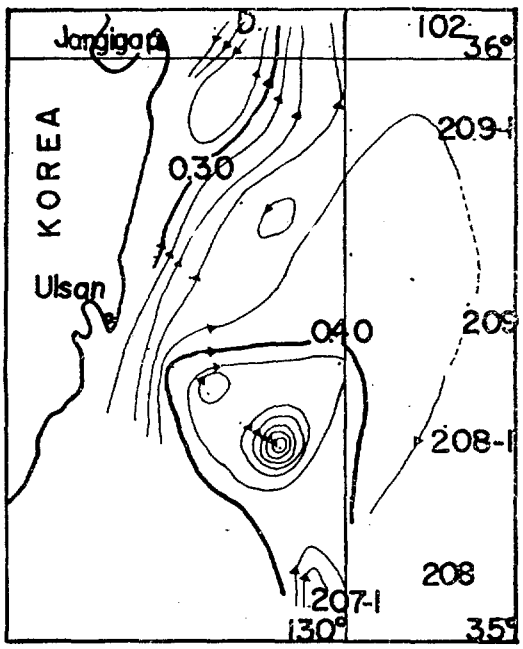

Fig. 4 (b). The surface dynamic topographies over 100db surface in July, 1973.

As is seen in these Figures, Tsushima warm current flows along the east coast of Korea to the north-east and there is an anticlockwise circulation to the left side of the Tsushima warm current (between the Korean east coast and the Tsushima warm current) and a clockwise circulation to its right side. These current patterns appear every summer in this area, though the position of the anticlockwise circulation near the coast moves along the east coast of Korea. Figures 4(a) and 4(b) show two typical examples of these patterns. Figure 4(a) shows the case in which the anticlockwise circulation stretches off the Ulsan shore in August 1969. Figure 4(b) shows the case in which the anticlockwise circulation stayed in the northern area. Figures 5(a) and (b) show the distribution of surface temperature corresponding to the Figures 4(a) and (b), respectively.

As is evident in Figures 4 and 5, the lowest surface water temperature, i.e. the coastal cold water, appears near the coast where anticlockwise circulation turns its current direction from south to east. This phenomenon is the most

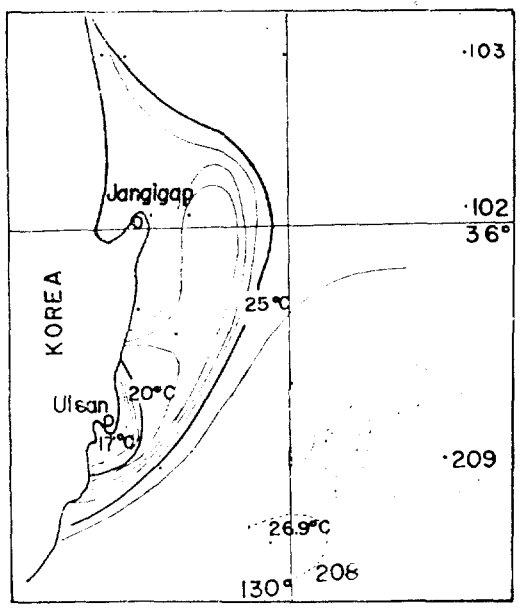

Fig. 5(a), The distributions of surface temperature in August, 1969.

remarkable characteristics of the coastal cold water of Korea. This indicates that the appearance of the coastal cold water near Ulsan has an important relation to the offshore current pattern, especially to the anticlockwise circulation near the coast and to the Tsushima warm current.

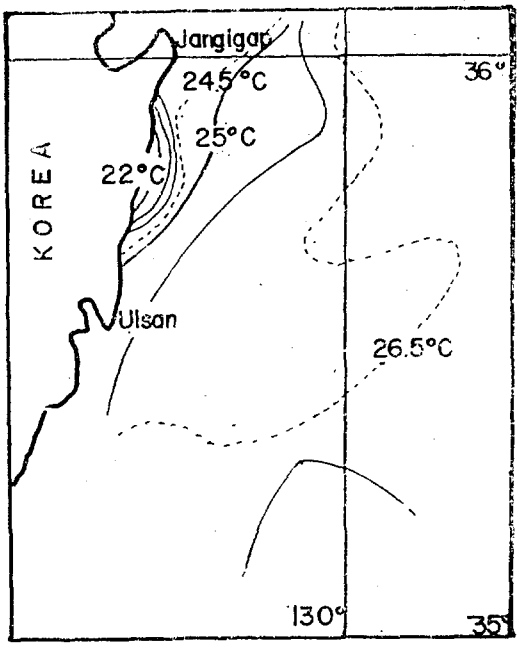

Fig. 5(b). The distributions of surface temperature in July, 1973.

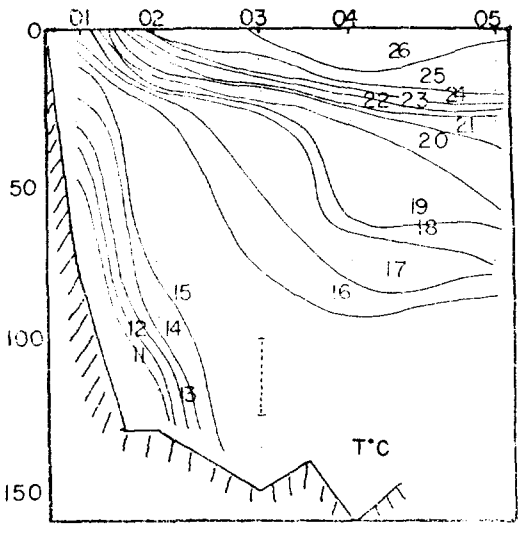

Fig. 6. The vertical distribution of temperature along observation line 208 in August, 1969.

3. The vertical distribution of temperature and salinity

Figures 6 and 7 show the vertical distribution of temperature and that of salinity, respectively, along the observation line 208 from Ulsan towards the offshore in August 1969. The seasonal thermocline and the main thermocline steeply incline and rise towards the coast, and the distribution of salinity is similar to that of temperature.

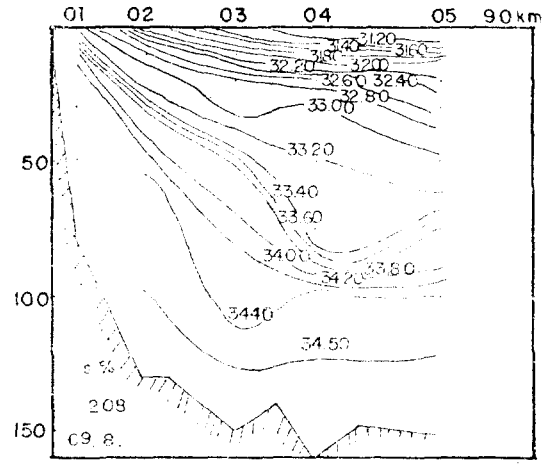

Fig. 7. The vertical distribution of salinity along observation line 208 in August, 1969.

Therefore, sea water near the coast has low temperature and high salinity. The vertical distributions of temperature and salinity, as shown in Figures 6 and 7, suggest that the coastal cold water moves up from the offshore deeper regions by upwelling. Figure 8 shows the vertical T-S diagram of observation line 208 taken in August 1969 and this corresponds to the Figures 6 and 7. The idea seems to be supported by this diagram.

It is found from Figure 8 that the character of the surface water at the point 01 near the coast (17.93°C and 33.10°C ‰) is almost the same as that about 15m deep from the point 02, that at about 30m deep from the point 03 and that at about 75m deep from the point 04. The sea

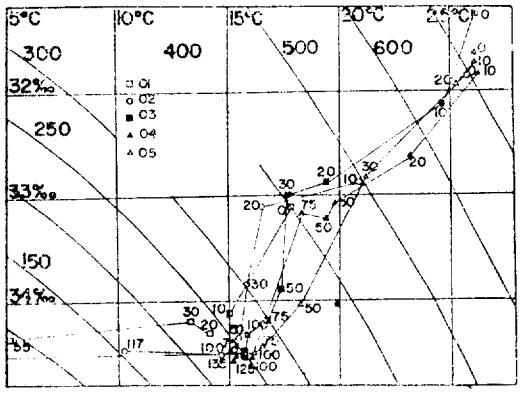

Fig. 8. The vertical T-S diagram of observation line 208 in August, 1969.

water with the same temperature as the surface water near the survey line 208 appears at about 10m deep from the points 209-05 and 102-07. These facts and the temperature inversion, as will be mentioned in the following, seem to support upwelling occurred in this area. Figure 9 shows the vertical profile of temperature along the observation line 208-1 in the vicinity of Ulsan in August of 1973, when a special observation was made. The general pattern of the distribution of isotherms is similar to that of Figure 6. Surface temperature of the coastal water is about 16°C and the temperature inversion between 14°C and 16°C occurs between 50m and 120m depth at the observation site 208-02, as seen in Figure 9. The water temperature inverson occurs at the observation sites 102-05, 102-06 and 209-05.

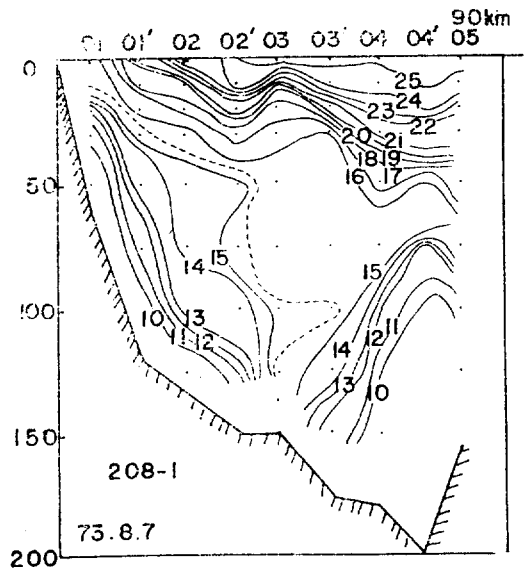

Fig. 9. The vertical distribution of temperature along observation line 208-1 in August, 1973.

Such temperature inversion was observed near the Oregon coast during the upwelling period. Hasong Pak and et al. (1970) concluded that it has an important relation to upwelling and occurs in the sinking area.

CONCLUDING REMARKS

The coastal surface water in the southern area of the tip of the anticlockwise circulation is remarkably cold. Specially, when the anticlockwise circulation approaches near Ulsan, it seems that the strong upwelling takes place near the Ulsan coast. A great northeasterly component wind will surely strengthen the upwelling as mentioned by Ann (1974), but the surface cold water on the east coast of Korea appears to be influenced by the current pattern induced by the Tsushima warm current even though the behavior of wind stress on the sea surface was not treated in this paper.

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