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THE FLUCTUATION OF THE THERMAL FRONT IN THE SOUTHEASTERN AREA OFF KOREA

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ABSTRACT

The oceanographical condition of the southeastern area off Korea is investigated in the point of view of the fluctuation of the thermal front. Although the feature of the front is somewhat complicate, it can be classified into three types. The first type is elongated toward north with the narrow cold water belt inside the front. The second type is almost parallel with the latitude of 36°N and the third type is the irregular one in which the cyclonic cold water mass and the anti-cyclonic warm water mass develop equally. The north-south directed fronts are strengthened either by the supply of the warm Daema Current (Tsushima Current in Japanese) or by the appearance of the cold North Korean Water along the coast. In the first type the thermocline inclines up toward the coast when the southward component of the wind is weakened. On the other hand, in the second type the homogeneous and medium warm water spreads up to the coast and the latitude of 36°N, the second type front is formed.

INTRODUCTION

There are some interesting phenomena in the southwestern part of the Japan Sea; for examples, the seasonal variation of the water transportation through the Daema Straits(Tsushima Straits in Japanese) (Yi, 1966 and Miita, 1976), the cold water appearance along the Korean coast which is probably due to either the northward wind in summer season (An, 1974) or the current pattern induced by the Daema Current (Lee, 1978 and Huh, 1976), the branching of the Daema Warm Current (Suda and Hidaka, 1932; Uda, 1934; Tanioka 1968; Moriyasu, 1972; Yoon, 1982 and Kawabe, 1982) and the appearance of the stationary warm water mass around the Ulrung Island (Tanioka, 1968), etc. Obviously these various phenomena might not be independent ones, but are interrelated with each other. The characteristic features in this area are the frontal variation accompanied with the appearance of the warm Daema Current. The cold water mass is restrained westward near the coastal area and sometimes expands to the offshore (Tanioka, 1968 and Uda *et al*, 1977). This frontal structures seem to be affected also by the temperature variation on an oceanic scale and by the distribution of the wind blowing over this area. The front is the western most end of the polar frontal zone of the Japan Sea which is parallel almost along the latitude of 40°N. The overall structure of this front is comparatively well known by many studies (e.g., Akamatsu and Konaga, 1979). However, the western most end of this front is not well understood because the observational data are confined to the southern part of the latitude of 39° 12′ N.

In this study we will investigate the fluctuation of the frontal feature, by examining the correlation with the appearance of the cold water mass near the coast and the development of the warm water mass supplied by the Daema Current.

DATA

Data used in this study are as follows; The serial observation from the Fisheries Research and Development Agency has been used in studying the oceanographical conditions from 1971 to 1979. These observations which cover the southeastern area of the Korean Peninsula have been taken six times every year, that is, February, April, June, August, October, and December. However, the coverage is restricted to the small area from the inlet of the Daema Straits to the latitude of 38°12.6'N and from the Korean coast to the longitude of 131°15'E.

Although these measurements are not sufficient in studying the current and oceanographic conditions of all western part of the Japan Sea, they are worthwhile to investigate locally. The inconsistency between the Korean data and the Japanese as pointed out by Kawabe (1982) probably attributes to two reasons. One is the time difference at which the data were obtained. The other is the high variability of the oceanic conditions. Because if we use the long-term average values, they are continuously connected each other. The daily mean atmospheric pressure from 1973 to 1980 by the Korean Central Meteorological Agency are used for the pressure gradient instead of the geostrophic wind. The locations of the serial observation and the stations of the tidal observation and the atmospheric pressure measurement are shown in figure 1.

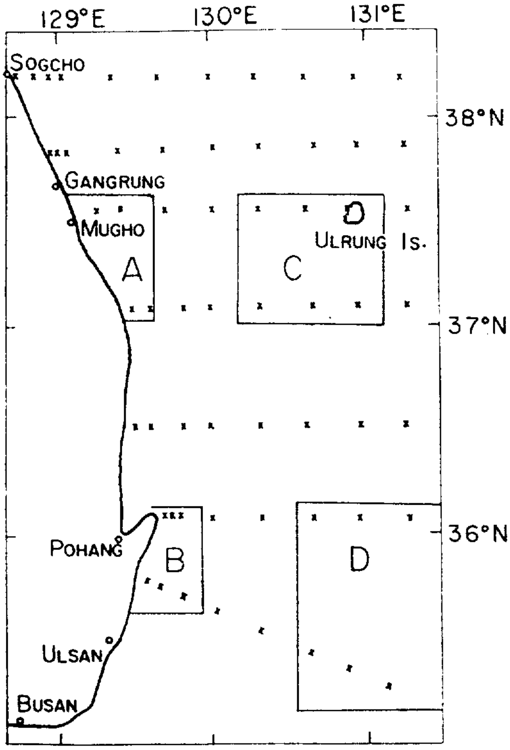

Figure 1. The locations of the serial observation and the stations of the tidal observation and the atmospheric pressure measurement.

THE FLUCTUATION OF THE THERMAL FRONT NEAR THE EASTERN COAST OF THE KOREAN PENINSULA

The general pattern of the temperature distributions in the western part of the Japan Sea are shown by Uda *et al.* (1977) and also by Tanioka (1968). According to their studies a great anticyclonic warm water mass is steadily placed near the Ulrung Island and some cyclonic cold eddy surrounds this warm water mass. Especially, cyclonic cold water mass is formed between the East Korean Warm Current and the coast and intrudes intermittently toward the east so that the cold water region surrounded by the sharp temperature gradient diverges in this area. In another case the front formed between the North Korean Cold Current and the East Korean Warm Current is straightened in the northward direction or in the eastward direction. These two cases are the extreme ones which depend upon whether the north cold water mass develops extraordinarily or the south warm water mass supplied by the Daema Current develops. However, the actual fluctuation of this front seems more complicate. Figure 2 shows the maps of the isothermal lines of 10°C on the 100 meters depth level which approximately traces the thermal front. Although the traces of six times in the interval of two months in each year from 1971 to 1979 are shown, no identities among the same month appear. The simple pattern which the isothermal lines of 10°C are running toward the east is shown in February and April, 1971, in February, August, October and December, 1974 and in April and June, 1977. The fronts parallel with the latitude of 36°N may represent the development of the second branch of the warm Daema Current. In the years of 1973, 1976 and 1979, the narrow north-south cold water belt develops along the coastal line and the anticyclonic warm water mass forms around the Ulrung Island. On the other hand, very irregular patterns of the fluctuation of this line are appeared in the years of 1972, 1975 and 1978. This irregularities might be due to the intrusion of the cold water masses from the coastal North Korean Cold Current or the weakening of the Daema Warm Current.

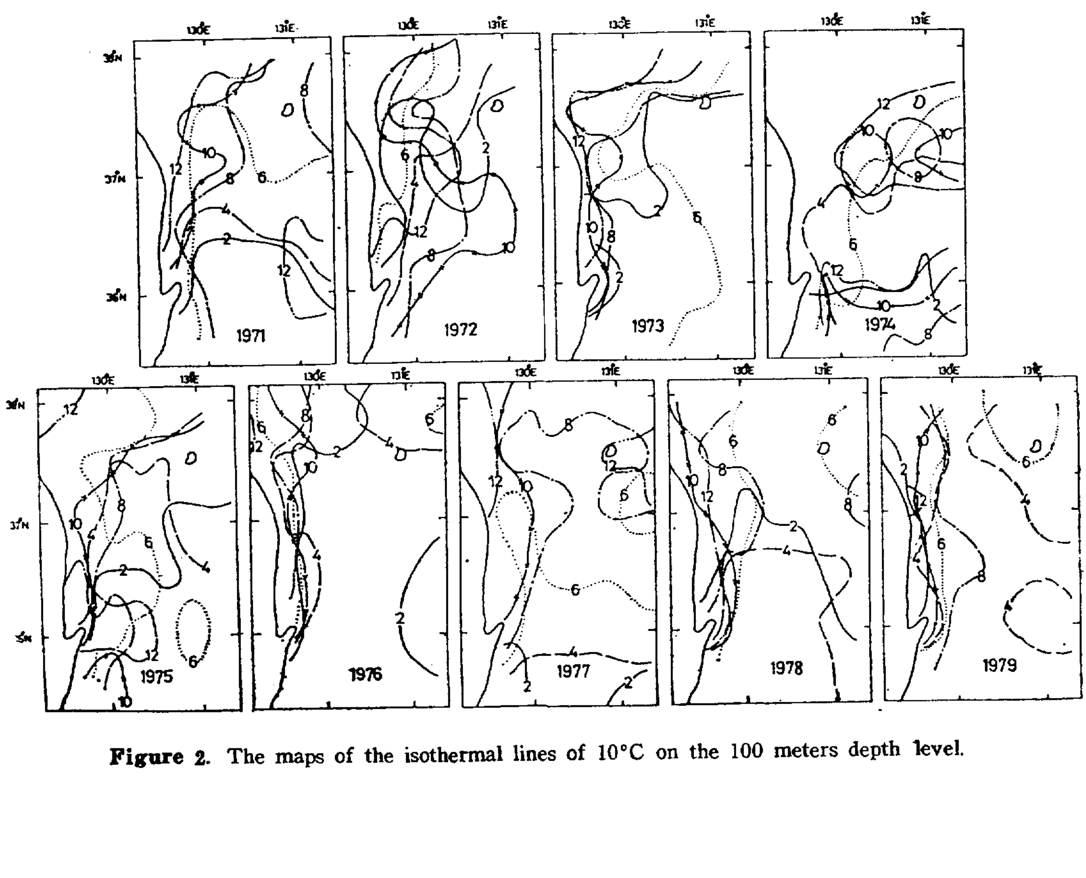

Figure 2. The maps of the isothermal lines of 10°C on the 100 meters depth level.

THE CORRELATION BETWEEN THE WATER MASSES AND THE POSITION OF THE FRONT

In order to consider the relation of the strength of the northward current with the water masses, several regions were carefully selected, which represent the typical water temperature on the surface of 100 meter depth as seen in figure 1. The region A which consists of four stations near the northern coast represents the cold water flowing southward from the north and the region B which consists of six stations represents the cold water region offshore of Pohang and Ulsan. The region C which also consists of six stations represents the warm water region around the Ulrung Island. The warm water mass is always located in this region so that it is often called as a steady or stationary warm water mass(Uda *et al.* 1977). The region D which also consists of six stations represents the warm water region located around the southwestern part of the Japan Sea. The figure 3 shows the time variation of the average temperature of the regions A, B, C and D are 6.0°C, 11.1°C, 11.3°C and 13.0°C, respectively. The higher temperature appears in December or February in the region A and in October or December in the regions C and D. In the region B, more irregular variation appears.

The irregularities of the region B might come from the alternative effect of the Daema Warm Current and the coastal cold water. The high correlation between the region C and the region D is seen because both of them represent the properties of the Daema Warm Current.

It is interesting to compare the temperature difference among each region. Figure 4 shows the time variation of the temperature difference between the region A and the region C and between the region C and the region D. The temperature differences may correlate with the development of the front which passes through between them.

The temperature difference between the region A and the region C reaches the highest value in August or October and the lowest or negative value on December or February. This temperature difference is related not only with the development of the warm water

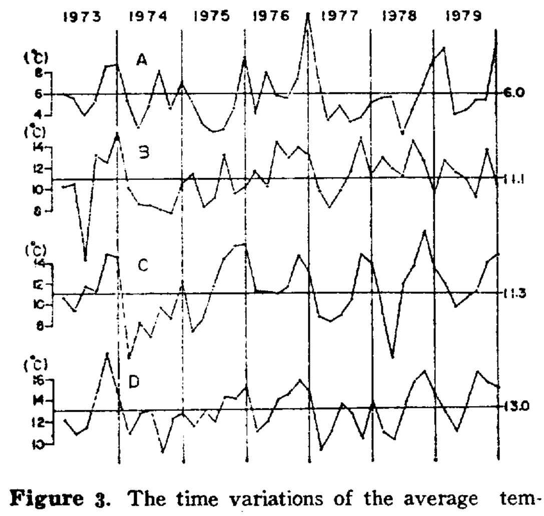

Figure 3. The time variations of the average temperature of the regions of A, B, C and D from 1973 to 1979.

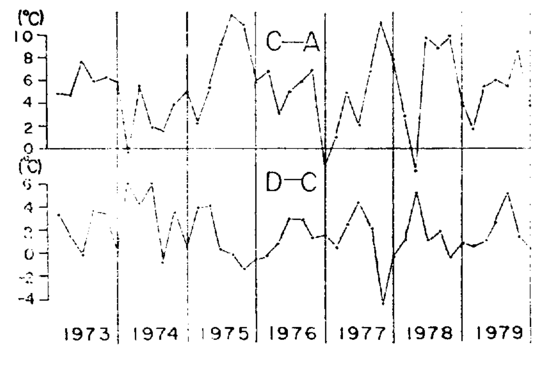

Figure 4. The time variation of the temperature difference between the regions A and C and between the regions C and D.

mass near the Ulrung Island(region C) but also with the occurrance of the cold water of the region A. The temperature difference is correlated with the temperature of the region C with the correlation coefficient of 0.40. However, it is inversely correlated with the temperature of the region A with the coefficient of −0.53. This means that the strength of the front perpendicular to the east-west temperature gradient would be fortified either by the growth of the warm water mass near the Ulrung Island or only by the cold water appearance near the coast.

It is also worthwhile that the temperature variation of the region A is hardly correlated with that of the region B (with the low coefficient of 0.2). The temperature difference of the regions A and C is inversely correlated with that of the regions C and D with the coefficient of −0.3. This means that if the temperature gradient of one section become strong, then that of the other section would be weakend. Briefly speaking, when the warm water mass near the Ulrung Island develops, the front parallel along the latitude of 36°N would disappear and the longitudinal front along the coastal line strengthens. However, this north-south directed front can be fortified only by the appearance of the North Korean Cold Water along the coast.

THE RELATION BETWEEN THE FRONT AND THE E-W ATMOSPHERIC PRESSURE GRADIENT

There seems to be some correlation between the wind direction and the location or the strength of the front.

Figure 5 shows the distributions of the monthly mean differences of the atmospheric pressure at the sea level between Gangrung and

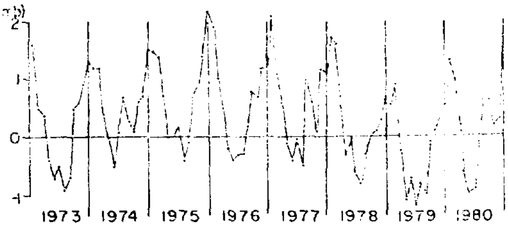

Figure 5. The time variation of the difference of the monthly mean atmospheric pressure at the sea level between Gangrung and Ulrung Island.

Ulrung Island from 1973 to 1980. According to the balance of the geostrophic wind, the positive values correspond to the southward component wind and the negative value to the northward component wind. Every year the southward component of the wind blows predominently around the year except the short summer season. Especially the year of 1974 and 1975 have only one or two months with the northward component wind and on the contrary, 1979 has seven months of northward component wind from March to September.

Figure 6 shows the vertical section of the temperature distribution along the line of 104

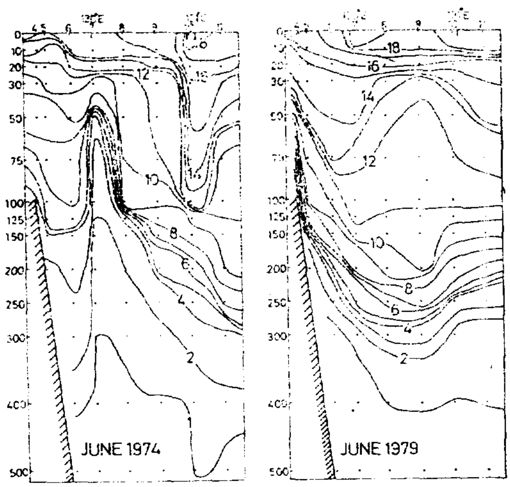

Figure 6. The vertical sections of the temperature distribution along the line of 104 in June, 1974 and 1979.

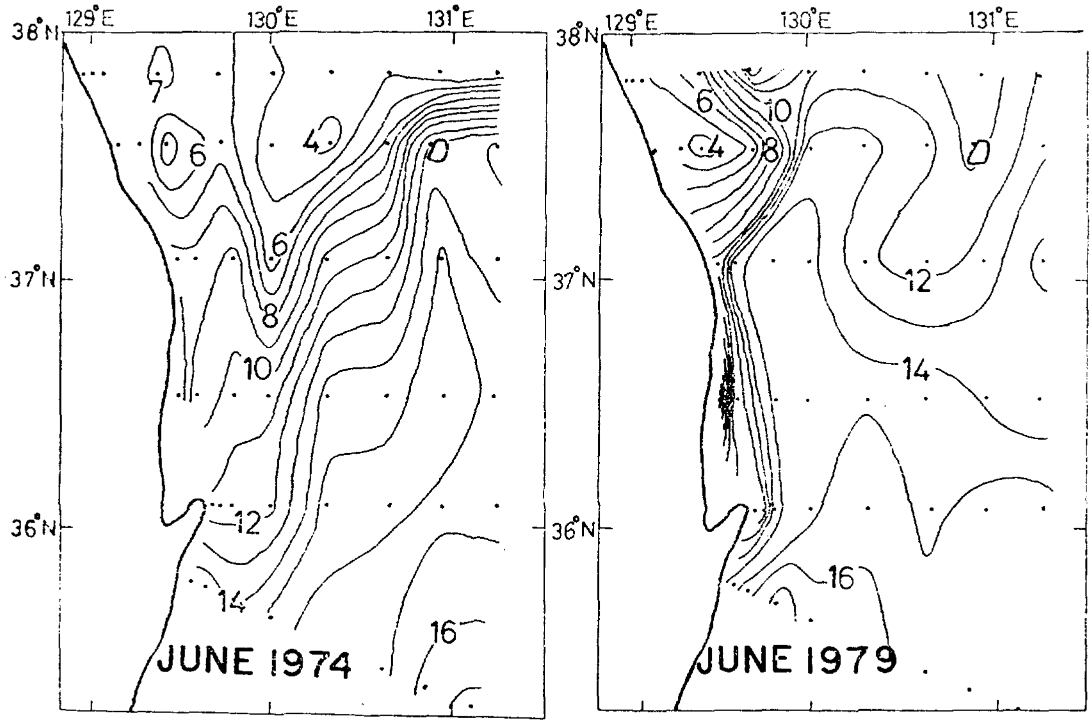

Figure 7. The horizontal distributions of the temperature on the 50 meters surface in June, 1974 and 1979.

in June, 1974 and 1979. In the section of 1979 all of the isothermal lines inclined up toward the coast, but in 1974 the lines were depressed downward near the coast, for somewhat higher temperature water has been found at the nearest two stations of 4 and 5 of the line of 104. In winter seasons or particular summer seasons (for example summer 1974 and 1975) when the southward component of the wind are predominent, the isotherms are almost horizontal or depressed toward the coast. Almost homogeneous water temperature as seen in the section of 104 line in June, 1974 is the common feature in the winter season when the strong north or northwest component of the wind blows. On the other hand, in the summer of 1979, a sharp upward inclination of the thermocline is observed in the cross section.

The horizontal distributions of the temperature on the 50 meter surface in June, 1974 are shown in figure 7. In 1974, the front directs northeastward and the broad cold water region spreads in the northern side of the front. The isothermal lines of the front are gathered around the Ulrung Island, but in the coastal side they are spread broadly and rather parallel to the latitude line. On the other hand, in 1979, a sharp front approaches near the coast and the narrow cold water is bounded inside the front.

CONCLUSION

There are three types of the thermal front in the eastern offshore of the Korean Peninsula. The first type is elongated toward north with the narrow cold water belt inside the front. The second type is almost parallel with the latitude of 36°N. In this case the northern area of this front is occupied with the colder water so that the stationary anticyclonic warm water mass is weakened. The third type is the irregular ones in which the coastally confined cold water mass diverges toward the offshore so that both of the cyclonic cold water mass and the anticyclonic warm water mass develops equally.

In the first type the thermocline inclines up toward the coast as seen in June, 1979. On the other hand in the second type the homogeneous and medium warm waters spread up to the coast and the latitude of 36°N, the second front (the second branch of the Daema Current) is formed.

It is concluded that the north-south directed fronts are strengthened either by the supply of the warm Daema Current or by the appearance of the colder North Korean Cold Water along the coast.

ACKNOWLEDGEMENT

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한국 남동 해역에 있어서 수온전선의 변동에 관한 연구

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요약 : 한반도 남동해역의 해황조건을 수온전선의 변동이라는 관점에서 조사연구하였다. 수온전선의 변동형태는 대단히 복잡하지만 크게 3개형으로 나누어진다. 제 1 형은 동해안과 평행하게 북쪽으로 연장된 형으로 연안쪽에 좁은 냉수대를 끼고 있으며 제 2 형은 대략 36°N 위도선에 나란하게 동서방향으로 연장되어 있고, 제 3 형은 불규칙하게 분포하는 형으로 저기압성 냉수괴와 고기압성 난수괴가 거의 비슷하게 여기저기 분포하기 때문에 나타난 형이다. 제 1 형은 대마난류와 북한한류 등 두 해류가 모두 발달한 때나 또는 어느 한쪽만의 발달에 의해서도 강화될 수 있다. 한편 이들 전선의 형태는 바람의 분포와도 밀접한 관련이 있는 것 같다. 겨울철 북풍성분의 바람이 강해지면 제 1 형은 약해지고 제 2 형이 뚜렷해지며 여름철 남풍성분의 바람이 강해지면 제 1 형이 강화되는 경향이 있다.