J. Korean Fish. Soc. 29(6), 862~875, 1996 한수지, 29(6), 862~875, 1996

Water Mass Distribution and Seasonal Circulation Northwest of Cheju Island in 1994

Ig-Chan PANG, Hong-Kil RHO* and Jae-Hak LEE, and Heung-Jae LIE****

Department of Oceanography, Cheju National University, Cheju-Do 690-756, Korea

** Department of Fishery, Cheju National University, Chju-Do 690-756, Korea*

***Korea Ocean Research and Development Institute, Ansan P.O.Box 29, Seoul 425-600, Korea*

The CTD data observed in the sea northwest of Cheju Island have been analyzed to figure out the seasonal circulation around Cheju Island. Warm and saline waters flow into the Yellow Sea through the middle region of the Yellow Sea in winter and along the west coast of Korean Peninsula in summer. On the other hand, cold and less saline waters flow out of the Yellow Sea through the middle region in summer and along the west coast of Korean Peninsula in winter. These flows make the seasonal circulation around Cheju Island. As dynamics, the monsoon wind and the variation of Kuroshio transport have been suggested. Comparing the observational result, the circulation driven by the variation of Kuroshio transport is strengthened by monsoon winds in the numerical model.

Key words : water mass distribution, seasonal circulation, cheju Islands

1. Introduction

Around Cheju Island, there are several flows. The flow of warm and saline waters from the East China Sea to the Tsushima Strait is dominant as a primary flow (Pang et al., 1992). In addition, there are secondary flows around Cheju Island: the southward expansion of Yellow Sea Bottom Cold Water (Asaoka & Moriyasu, 1966; Nakao, 1977; Lie, 1984; Park, 1985, 1986; Kim et al., 1991; Youn et al., 1991), the northward intrusion of Yellow Sea Warm Water (Uda, 1934; Byun & Chang, 1988; Pang et al., 1992), and the flow of Yangzee Coastal Water to Cheju Strait (Yu et al., 1983; Beardsley et al., 1983; Zhao et al., 1983; Kim 1986). In the past, researchers looked at these influencing factors as though they were independent of one another. Recently, Pang et al. (1992) suggest that there may be a unifying element among these factors.

As the influences of the Yellow Sea's bottom topography are well documented (Park, 1986; Pang, 1987; Pang et al., 1992). the alongshore winds in the Yellow Sea drive down-wind flows along the coasts and upwind flows along the middle trough. This flow structure is well matched to the secondary flows along the middle trough. This flow structure is well matched to the secondary flows mentioned above, but not to the reported flow along the west coast of the Korean Peninsula. According to the roports (Nakao, 1977; Lie, 1984, 1985; Kim et al., 1991), strong salinity fronts formed along the Cheju Strait in summer are believed to keep southern saline waters from flowing into the Yellow Sea along the coast. Contrary to this belief, we can find some biological and chemical evidences of alongshore flows (Sim et al., 1988). Such discrepancy may arise from interpretation of data. In summer, there is abundent fresh water input from river systems as well as the continued strong tidal mixing. Consequently, in-situ salinity is not so evident as a tracer.

In this study, we want to look at the ocean region which is between the northwest Cheju Island and the southwest tip of mainland Korea considering the

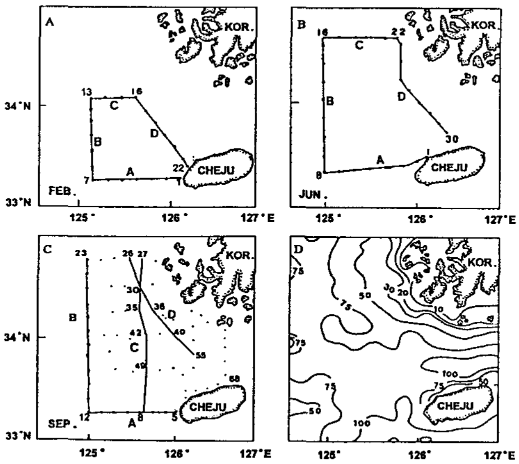

Fig. 1. **Observation stations in the northwestern sea of Cheju Island in (A) Feb. 17~18, (B) Jun. 20~22, and (C) Sep. 6~15, 1994, and (D) bathymetry in m.**

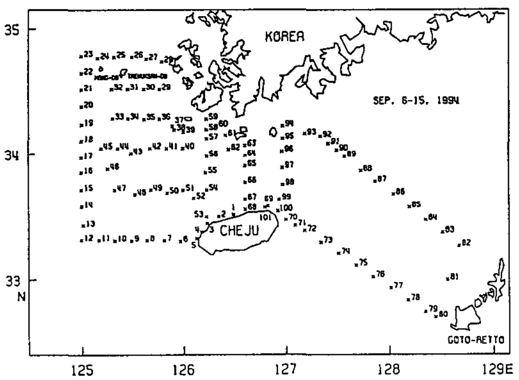

Fig. 2. **Observation stations in Sep. 6~15, 1994. Stations 1~68 are marked in Fig. 1.**

dynamics and to check the flow along the west coast of Korean Peninsula in summer.

2. Seasonal change of the characteristics of water masses

The sea northwest of Cheju Island was observed with (SBE-19) in Feb. 17~18, Jun. 20~22, and Sep. 6~15, 1994. The stations and the bottom topography are shown in Fig. 1. In Sep. 6~15, the sea east of Cheju Island was also observed as shown in Fig. 2.

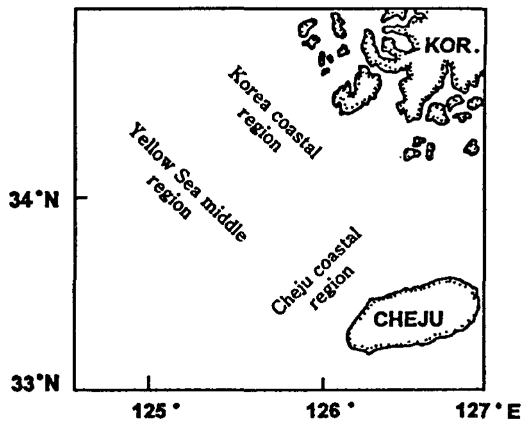

Fig. 3. **3 regions devided for explaining seasonal flows.**

The stations of Sep. 6~15 in Fig. 1 are the parts of those in Fig. 2. The study area is divided into 3 regions as shown in Fig. 3. More detailed explanation is given later in the section 3. The data are calculated in 1 m-spaced vertical distances and plotted on T-S diagrams (Fig. 4). The horizontal contours and vertical profiles in Feb., Jun., and Sep. are shown in Figs. 5 and 6, Figs. 7 and 8, and Figs. 9 and 10, respectively.

In winter, the waters form a line on T-S diagram. Since the waters are not grouped, it is hard to define the boundary values between water masses. However, we know that there are 3 water masses: Tsushima Warm Water (TWW) which is warm and saline, Yellow Sea Cold Water (YSCW) which is cold and less saline, and Yellow Sea Warm Water (YSWW) between them. YSWW is located between TWW and YSCW in T-S diagram and also in the horizontal distributions (Fig. 5). This means that YSWW is the mixture of the other two water masses. Most water columns are vertically homogeneous in winter (Fig. 6).

In summer, the water columns are stratified (Figs. 8 and 10) because the upper layer waters are differently characterized by atmospheric influences. In the lower layer, the winter water characteristics are basically maintained. So, the summer water masses are spreaded in T-S diagram toward high temperature

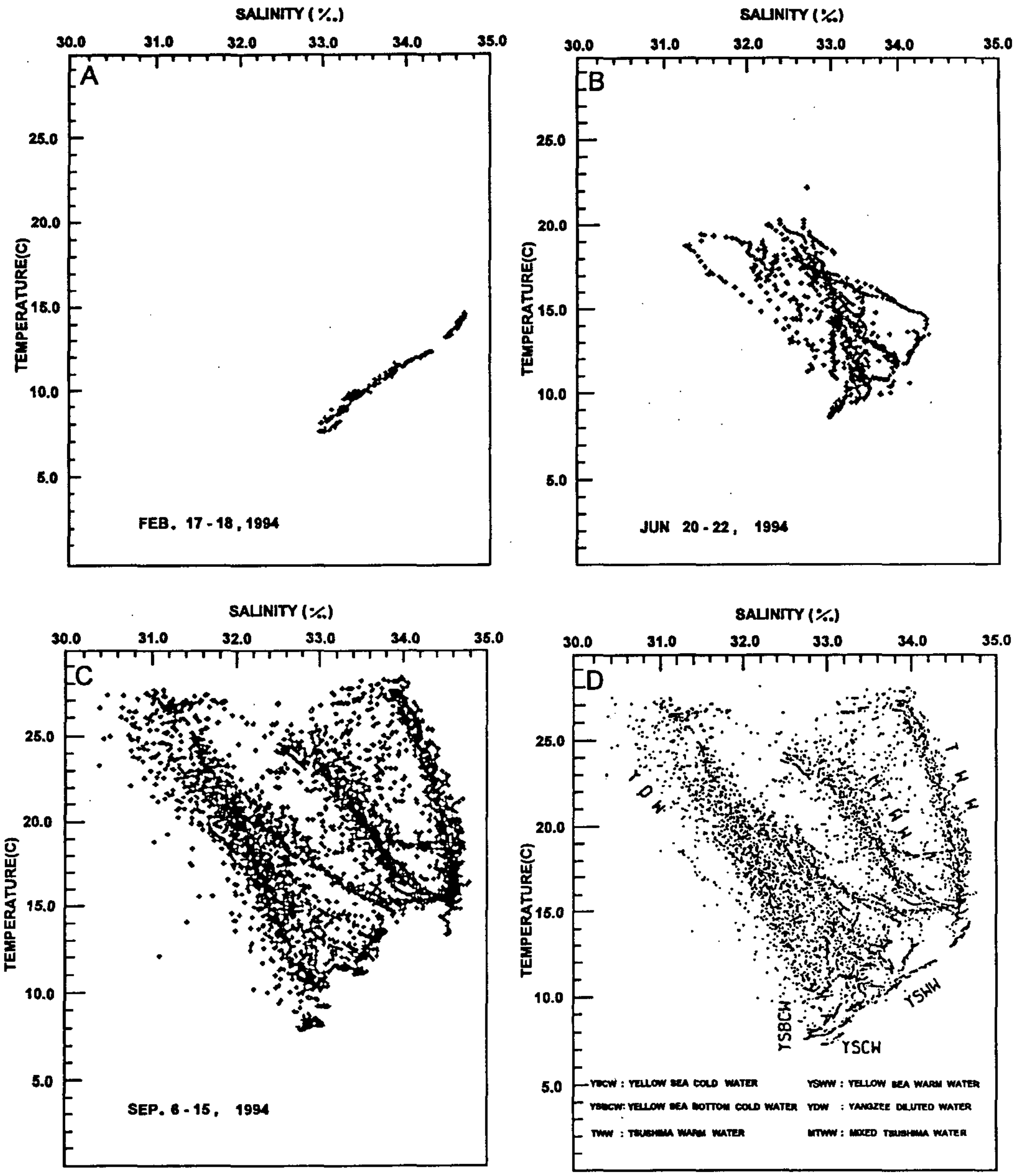

Fig. 4. T-S diagrams of (A) Feb. 17~18, (B) Jun. 20~22, (C) Sep. 6~15, 1994, and (D) all data.

and low salinity. In September, the water masses specially form 3 separate groups in T-S diagram. In the T-S diagram of September (Fig. 4), the group on the right is TWW. The group on the middle is mostly separated from TWW, but linked to TWW in the deeper layer. It suggests that the waters of this group originate from TWW, but have been differently mixed while separatly flowing north over the East China Sea. So, we call it Mixed Tsushima Warm Water (MTWW) in this paper. While TWW distributes only near Japan, MTWW appears in the sea southeast of Cheju Island in summer (not shown in Fig. 9). The group on the left is formed with the cold bottom waters and the diluted upper warm waters. YSCW in winter gets war-

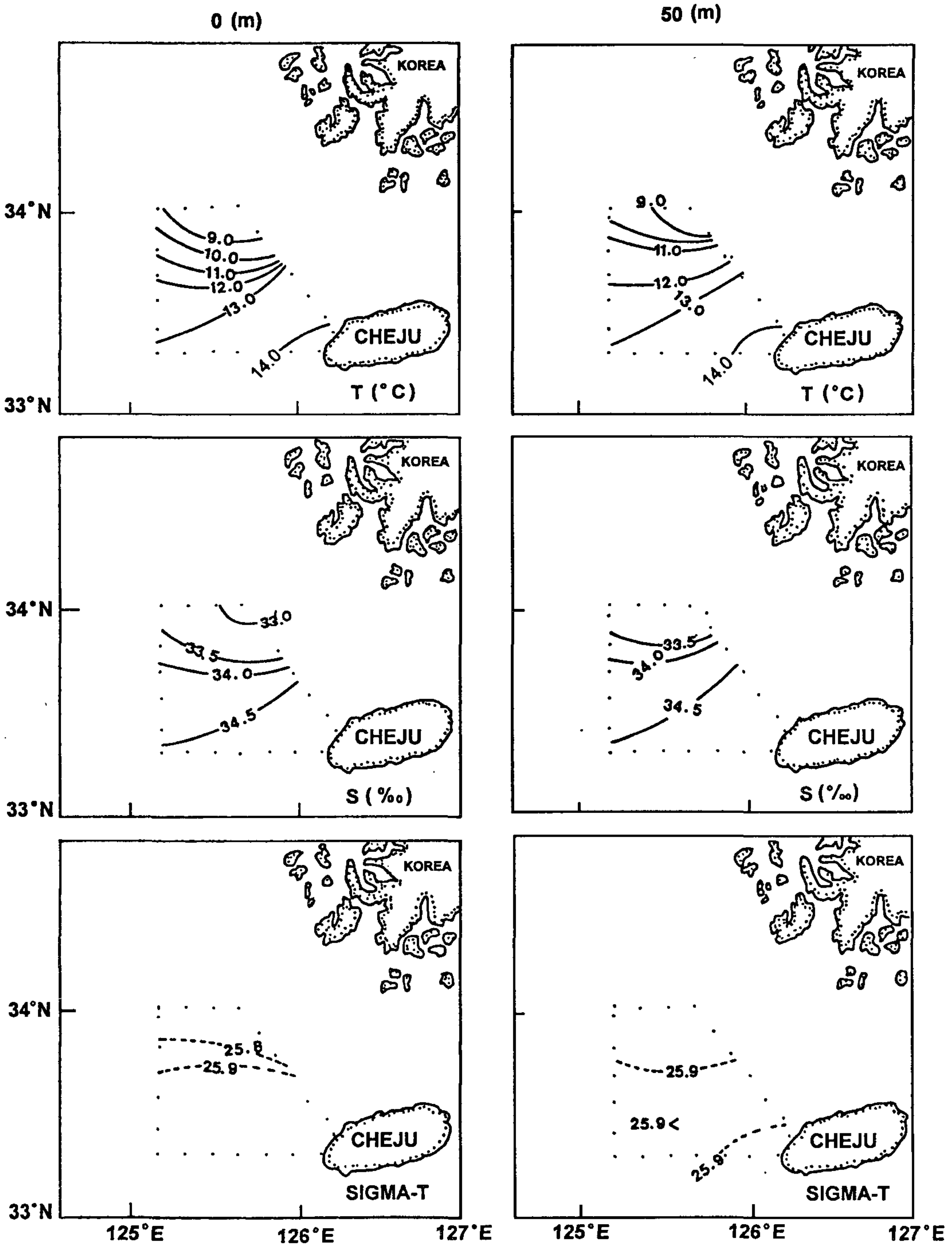

Fig. 5. Horizontal distributions of temperature, salinity, and sigma-t on the depth of 0 m and 50 m in Feb. 17~18, 1994.

mer in the upper layer, but still keeps cold in the bottom layer, which is called Yellow Sea Bottom Cold Water (YSBCW). The lowest saline upper waters are formed by the influence of Yangzee River Water, which is called Yangzee Diluted Water (YDW). This waters distributes widely in the sea northwest of

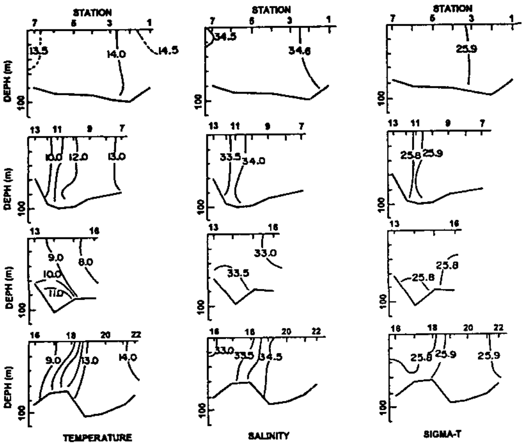

Fig. 6. Vertical distributions of temperature, salinity, and sigma-t along A, B, C, and D Lines shown in Fig. 1 in Feb. 17~18, 1994.

Cheju Island (Figs. 7 and 9) and some part of them flows into the Yellow Sea (see later). So, we will call the part YSWW in summer.

Although the water masses are clearly grouped in T-S diagram, it is hard to define their characteristic ranges. Because their ranges are overlapped or some water masses are still not separated as YSCW (YSBCW in summer) and YSWW. Therefore, in this paper, we will distinguish the water masses directly in T-S diagram, instead of comparing with their separately defined ranges of temperature and salinity.

3. Seasonal change of water mass distributions

Since the water properties in the Yellow Sea are strongly influenced by various processes such as diluting and tidal mixing in summer, it is not simple to figure out the seasonal change of water mass distributions. A relatively simple way is to focus on the movement of YSWW, because YSWW distributes in the boundary region between the offshore waters in the East China Sea and the coastal waters in the Yellow Sea. In describing them, the study area can be divided into 3 regions as shown in Fig. 3. One is the coastal region of Cheju Island (Cheju coastal region), in which the principal flow is dominant. The principal flow is the flow of warm and saline waters from the East China Sea to the Tsushima Strait (Pang et al., 1992). The waters coming into the study area from the south flow over this region and out to Cheju Strait, circulating clockwisely around Cheju Island. Another is the coastal region of Korea (Korea coastal region), which covers the region of down-wind flow (Park, 1986; Pang et al., 1992). The last is the middle region of Yellow Sea (Yellow Sea middle region), which covers the region of up-wind flows (Park, 1986; Pang et al., 1992).

Let's compare the distributions of the 50 m depth in winter and summer. In winter (Fig. 5), cold waters are distributed in Korea oastal region, while warm waters are distributed in Cheju coastal region. The cold waters are less saline and correspond to YSCW, and the warm waters are more saline and correspond to TWW (see Fig. 4). YSWW between them is connected to the Yellow Sea middle region. On the other hand, in summer (Figs. 7 and 9), cold waters occupy Yellow Sea middle region while warm waters are distributed in Cheju coastal region and Korea coastal region. The cold waters are less saline and correspond to YSBCW (see Fig. 4). The warm waters in Cheju coastal region are relatively more saline, but the warm waters in Korea coastal region are not so saline. Both of them are not TWW. TWW, which is the right group in the T-S diagram of September in Fig. 4, is distributed only near Japan in summer and YSWW fills Cheju coastal region where TWW stays in winter.

Although warm waters are distributed over Korea coastal region in summer, they seems to be disconnected to the Korea coastal region in salinity. It is a important question to understanding the Yellow Sea circulation how we should interprete the connection in temperature and disconnection in salinity. We will talk about the question in the next section.

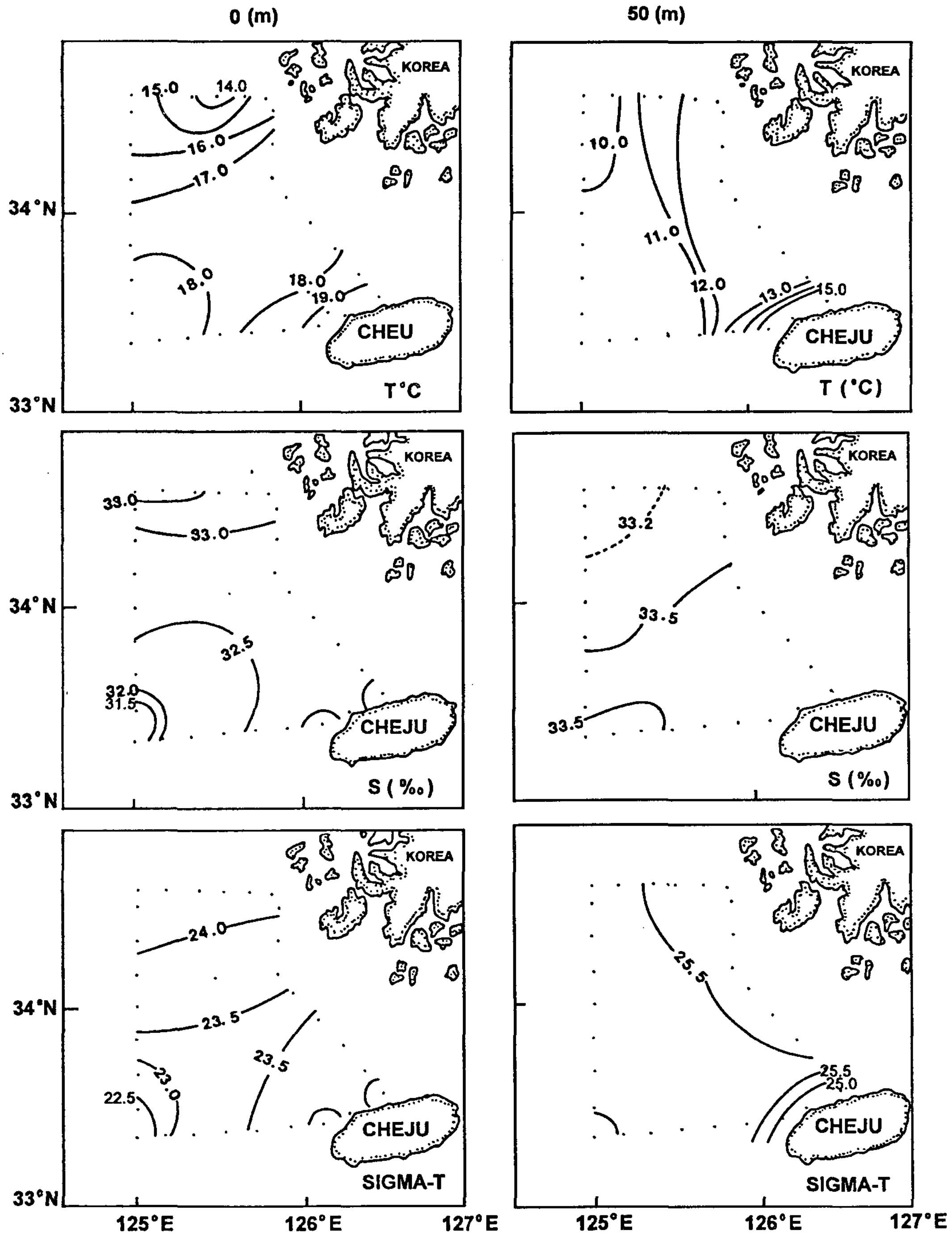

Fig. 7. Horizontal distributions of temperature, salinity, and sigma-t on the depth of 0 m and 50 m in Jun. 20~22, 1994.

4. Effect of tidal mixing off the southwest tip of Korean Peninsula

As shown in the previous section, the water mass distributions are different in temperature and sal-

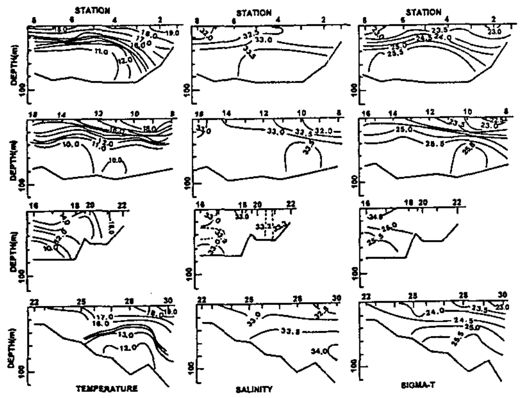

Fig. 8. Vertical distributions of temperature, salinity, and sigma-t along A, B, C, and D lines shown in Fig. 1 in Jun. 20~22, 1994

inity in summer (Figs. 7 and 9). In the depth of 50 m, the waters in Korea coastal region are linked in temperature with the waters in Cheju coastal region, but not in salinity. In such a case, salinity has been usually chosen to be reliable, and the salinity front fromed along the Cheju Strait has been interpreted to show that saline waters do not flow into the Yellow Sea along the west coast of Korean Peninsula in summer (Lie, 1984, 1985; Nakao, 1977; Kim et al., 1991). However, the real phenomenon does not seem to be so simple due to the effect of abundunt river water input and the strong tidal mixing. The area off the southwest tip of Korean Peninsula is famous for the surface cold water in summer due to tidal mixing (Lie et al., 1986).

Let's look at the vertical sections in Jun (Fig. 8). On the stations 20~22 which correspond to the surface cold water region, we can clearly see vertically homogeneous water columns, while water columns on the other regions are stratified. It tells us that stratified water columns come into the region and are vertically mixed. So, we should look at the whole columns. Comparing with the mixed water columns in the tidal mixing region, the waters in the Yellow Sea are colder and less saline in the whole column, while the waters in the Cheju Strait are warmer and less saline in the upper layer and colder and more saline in the lower layer. Table 1 shows the vertical mean temperatures and salinities of the water columns in the 3 regions: Yellow Sea region, tidal mixing region, and Cheju Strait region. As their representative stations, stations 17, 21, and 27 are respectively chosen. In calculating mean values, the vertically 1 m spaced data are used from surface to bottom and from surface to the depth of 50 m, which is the depth of tidal mixing region. In any case, the mean values in Yellow Sea region are quite lower than those in tidal mixing region. It shows that the water columns in the Yellow Sea can not make the values shown in the tidal mixing region by vertical mixing. However, the mean values in Cheju Strait region show that they can make the values in the tidal mixing region by vertical mixing from surface to some depth over 50 m. It means that the mixed waters in the tidal mixing region come from the Cheju Strait.

By vertical mixing, the upper layer becomes col-

Table 1. Vertical mean temperatures and salinities from surface to 50 m depth and from surface to bottom in the stations of the Yellow Sea (St. 17). tidal mixing region (St. 21), and Cheju Strait (St. 27)

		Yellow Sea region (Station 17)	tidal mixing region (Station 21)	Cheju Strait region (Station 27)
mean temperature	surface to 50 m	13.362℃	14.778℃	15.383℃
	surface to bottom	11.950℃		14.153℃
mean salinity	surface to 50 m	33.089‰	33.355‰	33.230‰
	surface to bottom	33.060‰		33.422‰

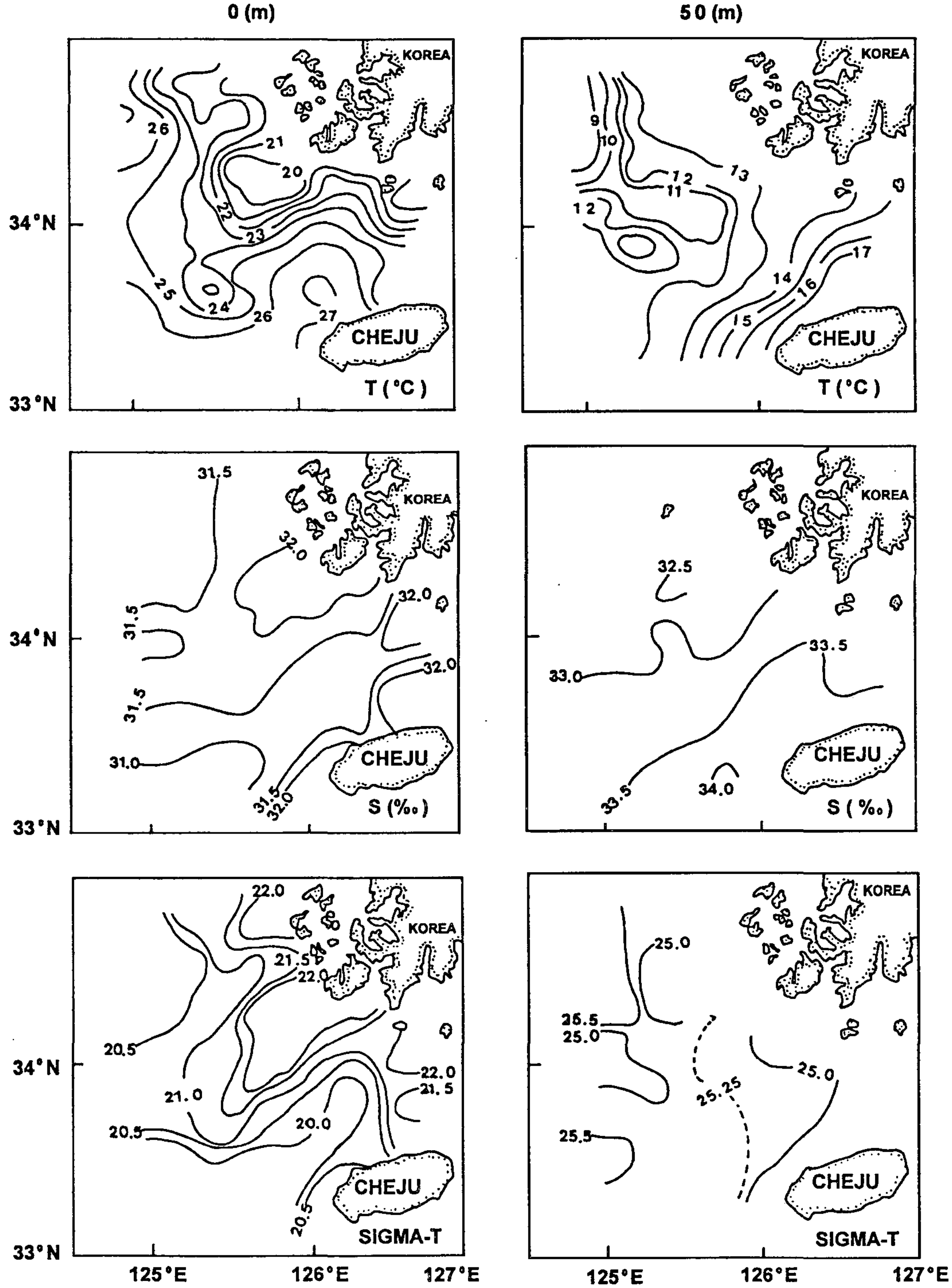

Fig. 9. Horizontal distributions of temperature, salinity, and sigma-t on the depth of 0 m and 50 m in Sep. 6~15, 1994.

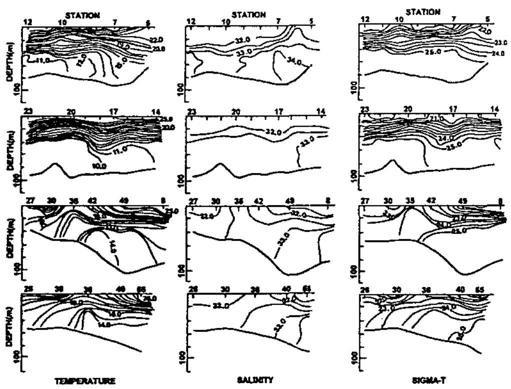

Fig. 10. Vertical distributions of temperature, salinity, and sigma-t along A, B, C, and D lines shown in Fig. 1 in Sep. 6~15, 1994.

der and more saline and the lower layer becomes warmer and less saline. This is the reason why the tidal mixing region has surface cold waters and is linked in the depth of 50 m with the southern region in temperature but not in salinity. So, the water mass distributions on some particular layer may mislead us in understanding the connection of water masses. In this case, the vertical mean values seem to be more reliable to figure out where the waters in the tidal mixing region come from.

The data in September is better to make horizontal contours because of widely spreaded data stations. The mean temperatures and salinities from suffuce to bottom or the layer of 70 m in the case that water depth is greater than 70 m are calculated and their horizontal isotherms and isohlines are shown in Fig. 11. The figure shows the possibile connection of water masses. In the temperature contours, the tidal mixing region are linked with the Chju Strait. Although the salinity contours do not show such a connection, it shows the feature that the southern saline waters intrude into the tidal mixing region.

The difference in the temperature and salinity contours in Fig. 11 come from the different influences by input fresh waters. The salinity of the input fresh waters is much different from that of the surface sea waters, while the temperature is not. Therefore, the influence of input fresh waters is strong in salinity and weak in temperature. The disconnection in salinity contours means that the amount of input fresh water is significant. In this circumstance, the intrusion feature in salinity suggests that saline waters in Cheju Strait are supplied to the north. And the connection in temperature supports that the waters in the tidal mixing region mainly come from the Cheju Strait in spite of significant input fresh waters.

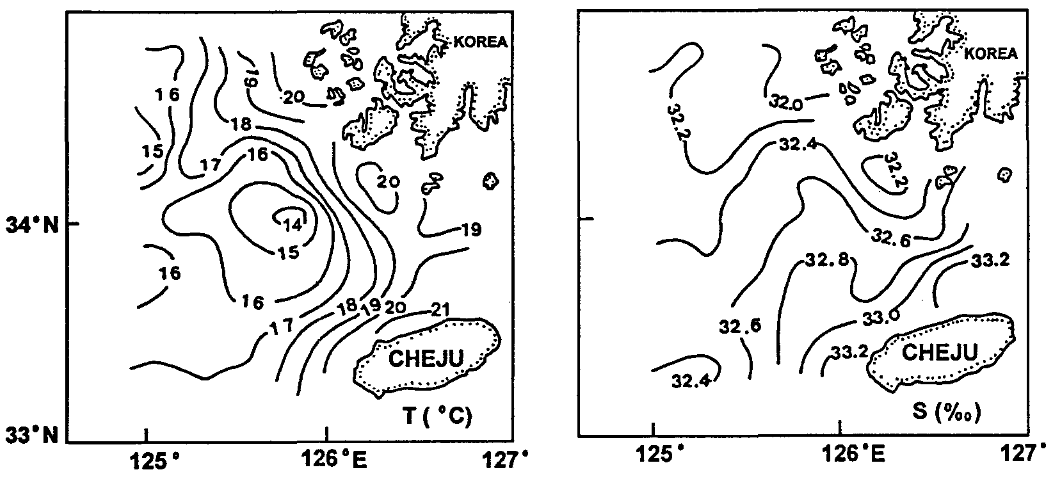

Fig. 11. Horizontal distributions of vertically mean temperature and salinity from surface to the depth of 70 m (or bottom) in Sep. 6~15, 1994.

5. Seasonal Circulation

The distributions of the warm waters (YSWW) and the cold waters (YSCW or YSBCW) are reversely changed in season. By the change, the warm waters in the Cheju Strait are connected to Yellow Sea middle region in winter and to Korea coastal region in summer, while the cold waters occupy Yellow Sea middle region in summer and Korea coastal region in winter. Such a seasonal change of water mass distribution makes it possible to deduce seasonally changed circulations in this area.

Before talking about circulation, we have two things to be mentioned. One thing is that although the seasonal change of salinity distributions is not explicitly clear in summer, the warm waters in Korea coastal region are more saline than the cold waters in Yellow Sea middle region in the lower layer. It means that there is a supply of saline water. If the waters get warmer by solar radiation without the supply of saline water, such a reverse salinity distribution to winter's is impossible. The other thing is that the salinity distribution along the Korean Peninsula in summer seems as if it is formed by diffusion. If it is true, the vertical salinity structure should have a similarity between the Cheju strait and the Yellow Sea. However, the 2 regions have different vertical salinity structures. The bottom layer has the most saline waters in the Cheju Strait, but less saline waters in the Yellow Sea. It means that diffusion is not a dominant factor. Moreover, diffusion cam not explain the seasonal change of water mass distribntion.

In Cheju coastal region and Yellow Sea middle region, the distribution of warm waters moves into the Yellow Sea from summer to winter and out of the Yellow Sea from winter to summer. The movement is reverse to nataral expectation. Since the waters in the Yellow Sea get colder from summer to winter, the cold waters expectedly move out of the Yellow Sea in winter. Therefore, there must an advection, which is reverse to natural tendency. The advection should be into the Yellow Sea in winter and out of the Yellow Sea in summer. As a result, TWW is widely distributed in Cheju coastal region and YSWW is connected to the Yellow Sea middle region in winter. In summer, YSWW fills Cheju coastal region but is disconnected to the Yellow Sea middle region (YSBCW occupies the region instead).

In Korea coastal region, the distribution of warm waters move southerly from summer to winter and northerly from winter to summer. While the southerly expansion of cold waters in winter is clear, the northerly expansion of warm waters in summer is not so clear. The northerly expansion supplies salt to maintain the salinity against fresh water input, but is too weak to make isohalines to be linked with the Cheju Strait. Anyway the seasonal advection is opposite to that in Yellow Sea middle region.

A seasonal circulation deduced from the seasonal change of water mass distributions is as follows: The inflow of warm and saline waters is along Yellow Sea middle region in winter and along Korea coastal region in summer. The outflow of cold and less saline waters is along Korea coastal region in winter and along Yellow Sea middle region in summer.

6. Possible dynamics of seasonal circuation

Pang et al. (1992) suggests that the prevailing monsoon winds drive the seasonal circulation in this area. Since the directions of monsoon winds are majorly alongshore, they drive down-wind flows along the coasts and up-wind flows along the middle trough (Csanady, 1982). In winter, the northerly winds are strong so that winter circulation is prominant. Since the southerly winds are weak and more irregular, we expected that the summer circulation is much weaker. It seemed to be one of the reason why the northward flows in Korea coastal region is not clear.

In addition to monsoon winds, the variation of

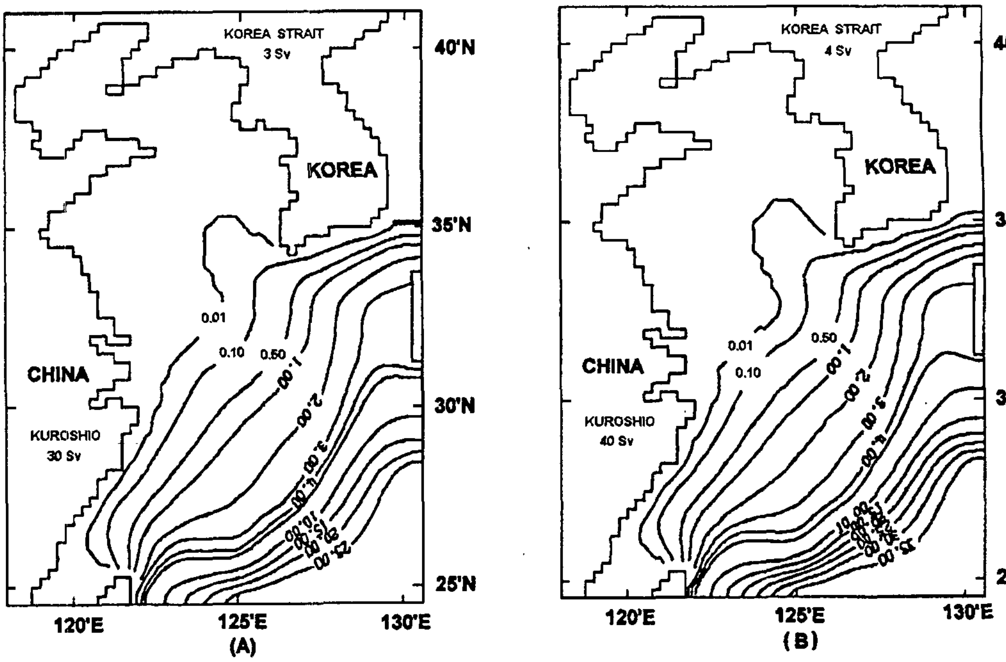

Fig. 12. Stream lines in Sv unit for the input waters of (A) 30 Sv and (B) 40 Sv through a 300 km-width section east of Taiwan. Waters freely flow out through the eastern boundaries. (from Pang et al., 1993)

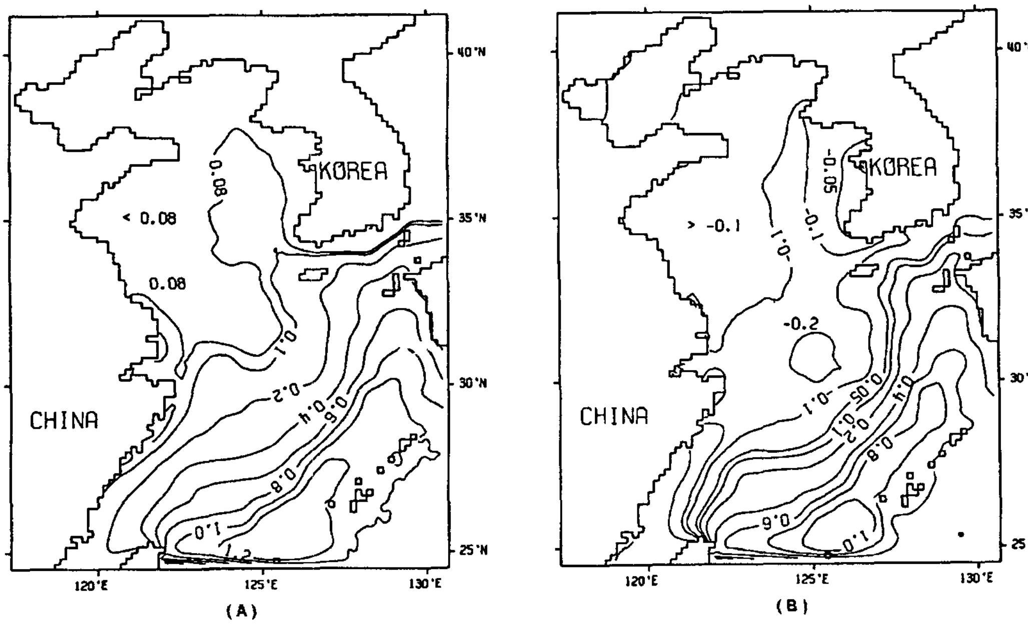

Fig. 13. Sea level heights (m) driven by the variation of Kuroshio volume transport and monsoon winds. It shows 2 snap shots which correspond to (A) winter and (B) summer circulations. (from Pang et al., 1995)

Kuroshio volume transport can drive seasonal change. When it was numerically studied by GCM model using the rigid-lid approximation, it does not generate any change of flow pattern except the volume transport in the East China Sea (Pang et al., 1993). Fig. 12 shows the model results for the Kuroshio transports of 30 Sv and 40 Sv. The volume transport of the Tshushima current is changed but the flow pattern is the same. However, when sea levels are allowed to fluctuate, the circulation in the Yellow Sea is changed by the variation of the Kuroshio transport (Pang and Oh, 1995), Fig. 13 shows the model results for the case with a one-year-period variation of Kuroshio transport and seasonal winds. By allowing sea level fluctuation, the Kuroshio transport variation generates a long-period wave to disturb the flow system in the Yellow Sea. Fig 13. shows two snap shots of sea level height representing winter and summer circulations. The winter wind strengthens the flows (the inflow in the middle and the outflow along the Korea coast) and generates a outflow along the China coast, but the summer wind gives only a minor effect. The numerical results show that the seasonal circulation could be driven by the variation of Kuroshio transport.

Besides the above two. there could be some effects from the coastal water transport of Yangzee River and the sea level change by solar heating. However, the major dynamics seems to be the variation of Kuroshio transport and the summer monsoon winds. In the real ocean, the flow seems to be strengthened by winds more than in the numerical model result. The pattern of isotherms in Fig. 11 shows closer connection between Cheju coastal region and Korea coastal region than that of the summer pattern of stream function in Fig. 13.

7. Conclusion

Even if the water masses are clearly grouped in T-S diagram as in September of 1994, it is meaningless to define their characteristic ranges because their ranges are overlapped. Moreover, some water masses are not separated. Therefore, in this paper, we have distinguished water masses directly in T-S diagram, instead of separately defining their ranges of temperature and salinity.

With this method, water mass distributions in the 50 m depth have been compared between winter and summer. In winter, warm water (TWW) and cold water (YSCW) are distributed in Cheju and Korea coastal regions, respectiverly. YSWW between them is connected with Yellow Sea middle region. In summer, warm water (YSWW) and cold water (YSBCW) are distributed in Cheju coastal region and Yellow Sea middle region, respectively. YSWW is connected with Korea coastal region in temperature but not in salinity. The disconnection in salinity is due to strong tidal mixing and abundent input of fresh water.

Comparing with surrounding water columns, we can clearly see both in temperature and salinity that water columns in tidal mixing region come from Cheju coastal region in June when fresh water input is not so serious. However, in September when fresh water input is significant, vertical mean salinities only show an intrusion feature of saline waters into Korea coastal region, while vertical mean temperatures show a cleal connection feature between Cheju and Korea coastal regions. The two features are probably oposite extremes and the real flow might be between them. We do not know what the real flow be like, but we know that there is at least northward flows into Korea coastal region from Cheju coastal region in summer.

With the flow, we can deduce the seasonal circularion from the seasonal change of water mass distributions. The outflow of cold and less saline waters is along Korea cosatal region in winter and along Yellow Sea middle region in summer. The inflow of warm and saline waters is along Yellow Wea middle region in winter and along Korea coastal region in summer. The inflow should be called Yellow Sea Warm Current (YSWC). As the dynamics, the monsoon wind and the variation of Kuroshio transport have been suggested. Comparing the summer observations with the model results, the summer circulation driven by the variation of Kuroshio transport is strengthened by summer monsoon wind. Therefore, the major dynamics of the seasonal flows seem to be the sum of the monsoon winds and the variation of Kuroshio transport.

8. Acknowledgement

This paper is supported by the Ministry of Science and Technology (BSPN 00246-711-1 and PN00336-3).

References

Asaoka, O. and S. Moriyasu. 1996. On the Circulation in the East China Sea and the Yellow Sea in Winter (Preliminary Report). Oceanogr. Mag., 18 (1~2), 73~81.

Beardsley R. C. and R. Limeburner. 1983. Structure of the Changjiang River Plume in the East Chnia Sea during June 1980: Sedimentation on the Continental Shelf with Special Reference to the East China Sea. Acta, editor, Oceanologica. Sinica. China Ocean Oress, Beijing, 243~260.

Byun, S. K. and K. I. Chang. 1988. Tsushima Current Water at Entrance of the Korea Strait in Autumn. Prog. Oceanog., 21, 295~296.

Casnady, C. T. 1982. Circulation in the Coastal Ocean. D. Reidal Pub. Co., 279 pp.

Kim I. O. 1986. A Study on Coastal Waters of the China Continent appeared in the neighbouring Seas of Cheju Island. MS thesis, Cheju National Univ., 46 pp.

Kim K., H. K. Rho and S. H. Lee. 1991. Water Masses and Circulation around Cheju-Do in Summer. J. Oceanog. Soc. Korea, 26(3), 262~277.

Lie. H. J. 1984. A Note on Water Masses and General Circulation in the Yellow Sea (Hwanghae). J. Oceanog. Soc., Korea, 19, 187~194.

Lie. H. J. 1985. Wintertime Temperature and Salinity Characteristics in the south-westem Hwanghae (Yello Sea). J. Oceanog. Soc. Japan, 41, 281~291.

Lie. H. J., I. K. Bang. anf Y. Q. Kang. 1986. Empirical orthogonal function analysis of seawater temperature in the southeastem Hwanghae. J. Oceanog. Soc. Korea, 21(4), 193~202.

Nakao, T. 1977. Oceanic Variability in relation to Fisheries in the East China Sea and the Yellow Sea. J. Fac. Mar. Sci. Technol., Tokai Univ. Spec., No. Nov. pp. 199~366.

Pang, I. C. 1987. Theory of coastally trapped waves and its application to the Yellow Sea. Ph. D. Dissertation. Florida State University, 128 pp.

Pang, I. C., H. K. Rho and T. H. Kim. 1992, Seasonal Variations of Water Mass Distributions and their Cause in the Yellow Sea, the East Cina Sea and the adjacent Seas of Cheju Island, Bull. Korean fish. Soc., 25 (2), 151~163.

Pang, I. C., T. H. Kim, T. Matsuno. and H. K. Rho, 1993. On the origin of the Tsushima Current (I) : Borotropic case. Bull. Korean fish. Soc., 26 (6), 677~697.

Park, Y. H. 1985. Some Important Summer Oceanographic Phenomena in the East China Sea. J. Oceanog. Soc. Korea, 20, 12~21.

Park, Y. H. 1986. A Simple Theoretical Model for the Up-wind flow in the southem Yellow Sea. J. Oceanog. Soc. Korea, 21, 203~210.

Sim, M. B., J. K. Choi and D. Y. Kim. 1988. The distribution of zooplankton in the mid-eastem part of the Yellow Sea. Yellow Sea Research, 1, 1~10.

Uda M. 1934. The Results of Simultaneous Oceanographical Investigations in the Japan Sea and its adjacent Waters in May and June, 1932. J. Imp. Fisher. Exp. St., 5, 57~190.

Youn, Y. H., Y. H. Park and J. H. Bong. 1991. Enlightment of the Characteristics of the Yellow Sea Bottom Cold Water and its southward Extension. J. Korean Earth Science Society, Vol. 12 (1), 25~37.

Yu, H., D. Zheng and J. Jiang. 1983. Basic Hydrographic Characteristics of the Studied Area. Sedimenttion on the Continental Shelf with Special Reference to the East China Sea. Acta, editor, Oceanologica. Sinica. China Ocean Press, Beijing, pp. 270~279.

Zhao, J., R. Qiao, R. Dong, J. Zhang and S. Yu. 1983. An Analysis of Current Conditions in the Investigation Area of the East China Sea : Sedimentation on the Continental Shelf with Special Reference to the East China Sea. Acta, editor, Oceanologica. Sinica. China Ocean Press, Beijing, pp. 288~301.

Received October 4, 1996
Accepted November 9, 1996