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Physical Structure of Eddies in the Southwestern East Sea

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東海南西海域 渦流의 物理的構造

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Eddies and surface current field in the southwestern part of the East Sea were investigated using satellite-tracked drifters, CTD, and ADCP from November 1992 to September 1993. Trajectories of surface drifters provided information for the first time on the meandering motion of the East Korean Warm Current in the Ullung Basin (referred as UB) and clearly indicated the existence of cyclonic and anticyclonic eddies of various scales. Anticyclonic eddies persisting for a relatively long period were observed in UB and the southwestern corner of the Northern (Japan) Basin (SNB), while a cyclonic eddy was found in the coastal area between Sokcho and Donghae during the summer. Analysis shows that the eddy in UB behaved as a stationary eddy at least during the observation period and the cyclonic eddy was closely related to the existence of a cold water mass. The anticyclonic eddy in SNB was larger than that in UB, but much elongated in shape. The eddy in UB is characteristic of major and minor axes of about 120 and 70 km, revolution period of 13.6 days, mean swirl velocity of about 24 cm/s, and mean eddy kinetic energy of 392 cm^2/s^2. The eddy in SNB is described as follows; major and minor axes of 168 and 86 km, period of 14.9 days, mean swirl velocity of 29 cm/s and mean eddy kinetic energy of 629 cm^2/s^2. The mean translational speed is about 3 cm/s for both eddies. The agreement of the surface current pattern in UB observed by ADCP with the geostrophic flow pattern may suggest that the eddy in UB was nearly in geostrophic balance. The eddy was found to be strongly bottom-controlled.

1992년 11월부터 1993년 9월사이 동해남서해역에서 조사한 인공위성 추적부이, CTD, ADCP 자료를 이용하여 와류와 표층해류의 물리적 구조를 분석하였다. 부이의 이동궤적으로부터 울릉분지내에서 동한난류의 사행과 연구해역에서 다양한 크기의 시계방향과 반시계방향의 와류가 존재하는 것을 처음으로 직접 해류조사로 밝힐 수 있었다. 비교적 오래 지속되는 시계방향의 와류가 울릉분지내와 북부(일본)분지의 남서쪽에서 관측된 반면에 반시계방향의 와류가 속초와 동해시 사이의 연안역에서 여름철에 관측되었다. 울릉분지의 와류는 적어도 관측기간 중에는 분지내에 머물러 있었으며, 반시계방향의 와류는 냉수의 존재와 밀접한 관련이 있는 것으로 나타났다. 북부분지의 시계방향 와류는 울릉분지의 것보다 크며 더 길쭉한 타원 형태를 지녔다. 울릉분지의 와류는 주축과 종축이 각각 120 km, 70 km이고, 회전주기는 13.6일, 평균회전속도는 24 cm/s, 평균 와동운동에너지는 392 cm^2/s^2이다. 북부분지의 와류는 주축과 종축이 각각 168 km, 86 km이고, 회전주기는 14.9일, 평균회전속도는 29 cm/s, 평균 와동운동에너지는 629 cm^2/s^2의 특성을 보였다. 와류의 평균이동속도는 두 경우 모두 약 3 cm/s이다. 울릉분지내에서 ADCP로 관측한 표층해류와 지형류의 상호일치는 울릉분지의 와류가 지형평형을 이루고 있음을 시사한다. 관측된 와류는 해저지형에 강하게 지배되어 있다.

INTRODUCTION

The surface circulation in the southwestern part of the East Sea has long been known to compose of a northward movement of the Tsushima Warm Current (TWC) water along the east coast of Korea after passing through the Korea Strait and a southward spreading of relatively fresh cold water formed in the northern part of the East Sea. The northward flow has been known as the East Korea Warm Current (hereafter EKWC), a branch of the TWC, while the southward flow along the Korean coast has been known as the North Korea Cold Current, a continuation of the Liman Current. The two different water masses meet together near 39°-40° N and form a front running west to east. Toba et al. (1984) have pointed out that mesoscale eddies are seen everywhere in the East Sea on NOAA infrared images, especially near the front.

The EKWC has been reported to flow southward around Ulleung-do (Tanioka, 1968). Kim et al. (1991) suggested a possibility of an anticyclonic circulation in the Ulleung Basin (hereafter UB) which is controlled by the shoaling bottom. Furthermore, a part of the EKWC continues to flow farther northward like a warm streamer (Sugimoto and Tameishi, 1992). Mesoscale warm eddies have been frequently detected in UB and northwest of Ulleung-do both in hydrographic data and on NOAA infrared images (Isoda and Saitoh, 1992; Kang and Kang, 1990; Min, 1993; Shin et al. 1995). Isoda and Saitoh (1993) claimed that the eddy formed in UB moves northward from spring to summer. Previous studies on eddies off the east coast of Korea were based mostly on sea surface temperature (SST) estimated from NOAA infrared images or on historical hydrographic data. Very recently, Lie et al. (1994) combined drifter data observed by Korea Ocean Research and Development Institute and Woods Hole Oceanographic Institution and reported the existence of mesoscale eddies in UB, the southwestern corner of the Northern (Japan) Basin (hereafter SNB), and the Yamato Basin and Oki Trough. However, the physical structure, formation and evolution in time of the eddies are poorly understood so far.

Eddies, even if they exist, are hardly identified on infrared images in warm seasons because SST becomes spatially uniform due to solar radiation. Recently, satellite-tracked surface drifters are widely employed because trajectories of drifter can provide information on the kinematical aspects of eddies such as swirl and translational velocity, and parameters of elliptical feature (e.g. Glenn et al. 1990; Kirwan et al. 1984). To investigate the EKWC and eddies in the East Sea, we deployed a few drifters in 1992-1993 and attempted to reveal their detailed physical structures by analyzing data of Conductivity, Temperature, Depth (CTD), Acoustic Doppler Current Profiler (ADCP), and satellite-tracked drifters.

EXPERIMENT AND DATA ANALYSIS

CTD measurements at 70 stations were performed three times (February, April, and September, 1993) by the Neil Brown Mark IIIb. Temperature and salinity data were resampled at one meter interval by averaging. Geostrophic flow was estimated by taking 700 dbar as the reference level of no motion. At stations where the bottom is shallower than 700 dbar, we assumed the same density profile as that of the neighboring deep station. The assumption may cause a large discrepancy between the true current field and the estimated geostrophic flow at coastal stations, but the geostrophic flow pattern was a better match with the pattern observed by ADCP than the flow estimated by taking the bottom as a reference level. Currents were measured at all CTD stations by ADCP with an acoustic frequency of 153.6 kHz and bin length of 8 m and twenty consecutive ensembles recorded during 10 minutes were averaged for vertical current profiles. The ADCP data is thought to properly represent the true current field since signals in the tidal and inertial frequency bands are sufficiently small compared to those in the subinertial frequency bands in the study area (Lie, 1988; Lie and Byun, 1985).

We deployed three satellite-tracked surface drifters with holey sock drogue. The drifters were equipped with a thermistor for SST. One drifter of

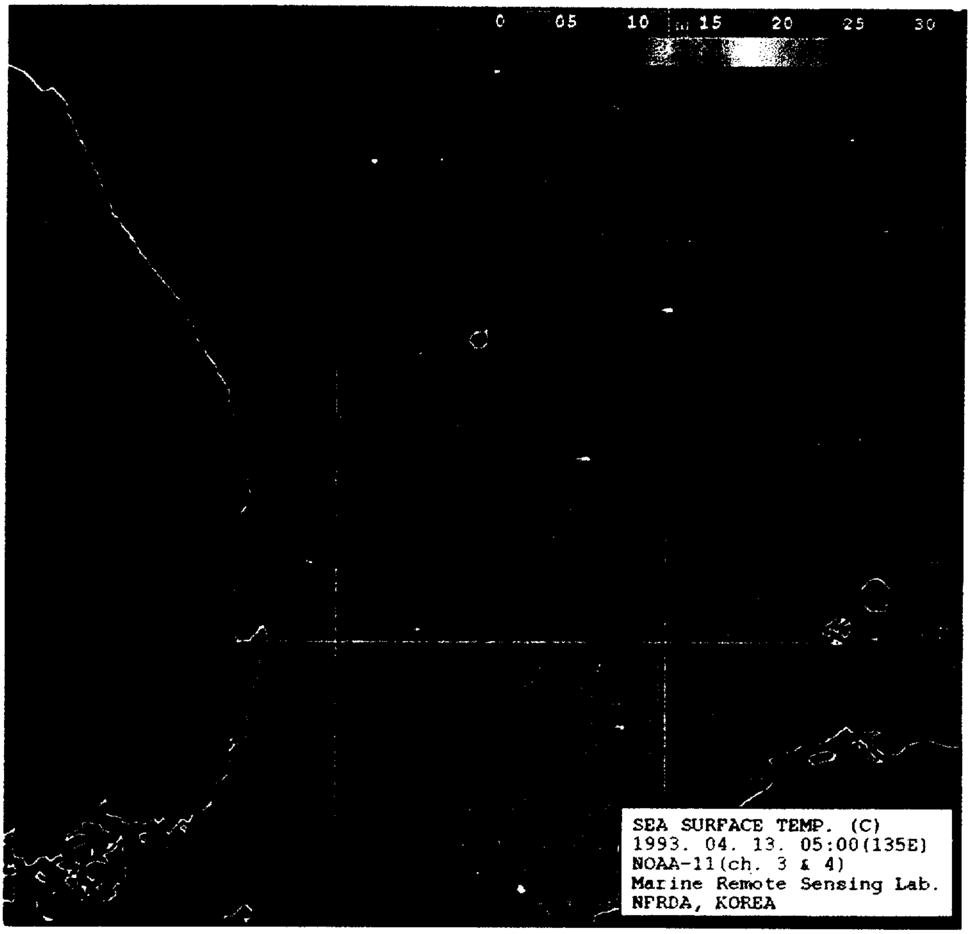


Fig. 1. NOAA infrared image taken on April 13, 1993 (courtesy of Fisheries Research Development Agency).

the World Ocean Circulation Experiment (WOCE) prototype (Sybrandy and Niiler, 1991) with drogue centered at 15 m below sea surface (identity number 9731) was released in November, 1992. An NOAA infrared image clearly indicated the existence of a clockwise warm eddy in UB in April 1993 (Fig. 1) and two drifters (3156 and 3157) of mushroom-type surface float with drogue centered at 35 m were released at the same point on April 21, 1993. Drifter 9731 transmitted data eight hours a day and the other two twenty four hours a day. The drag ratio of the WOCE standard drifter is 41.3 and the slip velocity is less than 2 cm/s at wind speed of 20 m/s (WOCE, 1991). The drag ratio of the mushroom-type drifter is estimated to be about 40. Thus, drifters may follow surface current field in the study area where the current speed is much stronger than the slip velocity. Detailed information on the drifter experiment is listed in Table 1.

Feature models are often used to study kinematic properties and physical shape of eddies. A buoy feature model, developed by Glenn et al. (1990), was applied to two eddies observed in UB and SNB. Drifter trajectories showing eddy motion were divided into a series of segments. Each segment was chosen to form approximately one closed loop and starting times of consecutive segments were separated by two days. We selected fourteen segments for the eddy in UB and nine for the eddy in SNB. By least square fitting of position data to an ellipse,

Table 1. Information on satellite-tracked surface drifters deployed in the East Sea.

ID number	Depth of Drogue (m)	Type	Date of deployment	Releasing position	
				Long. (E)	Lat. (N)
3156	35	mushroom	Apr., 21, 1993	129° 52'	36° 50'
3157	35	mushroom	Apr., 21, 1993	129° 52'	36° 50'
9731	15	WOCE standard	Nov., 22, 1992	129° 45'	35° 30'

parameters of ellipse such as center, semi-axes, and orientation are determined for each segment. The translation velocity of an eddy can be estimated from the change of center in time and the period is taken as duration time when a drifter forms a complete closed ellipse. Swirl velocity is computed from $(ab)^{1/2}\omega$, where a and b are the semi-major and minor axes, and ω is the rotation frequency.

GENERAL DESCRIPTION OF MESOSCALE EDDIES

Spaghetti diagrams of the three trajectories (Fig. 2) show that the drifters stayed a long time in a region connecting UB and SNB. The surface current field looks more complicated than the schematic pattern reported previously, though the number of drifters were not enough to derive a comprehensive surface circulation. The trajectories show clearly mesoscale eddies rotating clockwise in UB and SNB. It is noted that in late August a westward flow between 38° and 40° N is observed, which is opposite to an expected eastward current flowing along the polar front.

Fig. 3 presents detailed trajectories of the three drifters. The drifter 9731 (Fig. 3a), released in mid November 1992 in the western channel of Korea Strait, drew a small clockwise loop at the southwestern corner of UB and started moving swiftly to the north on December 5 with a daily mean speed faster than 20 cm/s (maximum speed of 34 cm/s) up to Ulleung-do and gradually changed its direction to the east. Near Ulleung-do it moved to the southeast and then flowed southward with a speed greater than 20 cm/s along 131.3° E between 36° and 37° N. The loop trajectory in the shape of 'Ω' followed by the drifter points out clearly a meander motion of EKWC in UB.

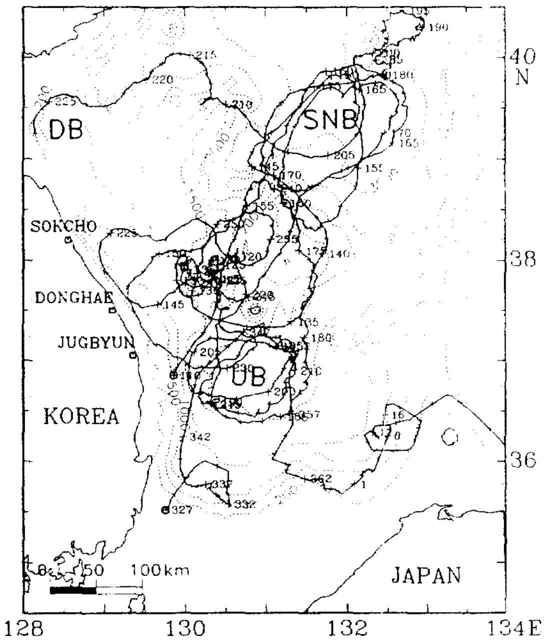


Fig. 2. Study area and composite trajectories of three satellite-tracked surface drifters from November 1992 to September 1993. Isobaths in meters are marked by dashed lines. Numbers at cross symbol aside trajectory are Julian days. UB, SNB, and DB indicate, respectively, the Ulleung Basin, the southwestern corner of Northern (Japan) Basin, and Donghan Bay.

Drifters 3156 and 3157 (Fig. 3b and 3c) drogued at 35 m were deployed at the same point off Jugbyun in mid April inside the EKWC water of high temperature and salinity. The drifters followed the same route during the first twenty days and then separated from each other in early May near 38° N, 130° E, probably due to a strong current shear. After separation, drifter 3156 moved to the east toward Ulleung-do and to the north along 131.5° E. On arrival at SNB in late May, it rotated clockwise twice during late May-late June. Meanwhile, drifter 3157

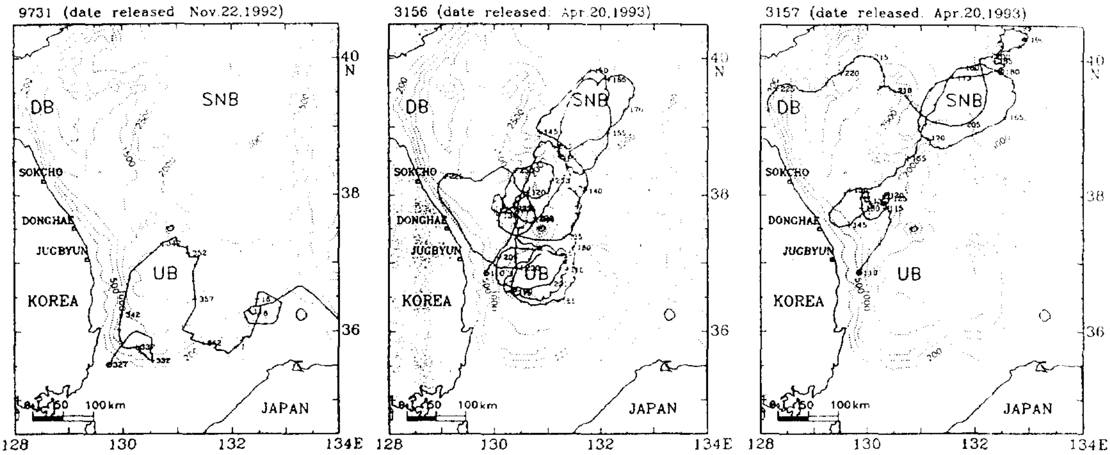


Fig. 3. Detailed trajectories of the three drifters. (a) drifter 9731 with drogue centered at 15 m, (b) drifter 3156 with drogue centered at 35 m, and (c) drifter 3157 with drogue centered at 35 m. Numbers at cross symbol aside trajectory are Julian days.

moved to the west, changed its direction to the northeast on May 27, and arrived at SNB 15 days later. Drifter 3157 stayed in SNB during the period of early June to late July, forming an ellipse rotating clockwise and a smaller ellipse rotating counterclockwise with a larger fluctuation north of 40° N.

Drifters 3156 and 3157 left SNB in late June and July, respectively. Drifter 3156 moved to the south toward UB, following the same route along which it had moved up to the SNB. This implies a drastic change of surface current in time between UB and SNB over a period of about 40 days. Drifter 3157 moved to the west toward the Donghan Bay during late July-mid August after leaving SNB, turned its direction to the south along the coast and then stopped transmitting signals due to an unknown cause. Meanwhile, drifter 3156 arrived at UB, rotated clockwise almost three times inside UB from late June to mid August and then drew a closed, larger loop in the counterclockwise sense during August 10-23 in the coastal area between the east coast of Korea and 131° E, and then rotated clockwise off Sokcho, north of UB (referred as the Korea Plateau) during late August-September. The clockwise elliptical loops on the Korea Plateau became more and more circular in shape and smaller in size from the first loop to the third one. This may suggest that the eddy motion on the Korea Plateau lost its energy more rapidly than those in UB and SNB.

TEMPERATURE STRUCTURE

The trajectories clearly demonstrated the existence of mesoscale eddies of various scales off the east coast of Korea; clockwise rotating eddies in UB, SNB, and the Korea Plateau and a counterclockwise rotating eddy in the coastal area off Sokcho-Donghae. Surface drifters only provide information on the surface current field, so that CTD and ADCP data collected in 1993 were analyzed to see the physical structure of eddies. Though the survey area did not cover the whole UB and SNB, our data are useful to see general hydrographic and dynamical aspects of eddies detected in UB.

Temperature at 200 m in February, April and September 1993 (Fig. 4) shows that warm water with temperature higher than 5°C appeared only in UB. In September, the temperature decreased by a few degrees as compared with that in February and April, but isotherms in UB maintained a semi-elliptical shape. According to CTD data collected in April and September 1993 over a larger area covering UB (KORDI, 1994), the center of closed, elliptical isotherms was located near 130° 30' E, 36° 54' N and the size of ellipse in September became smaller. Thus the clockwise eddy in UB is closely

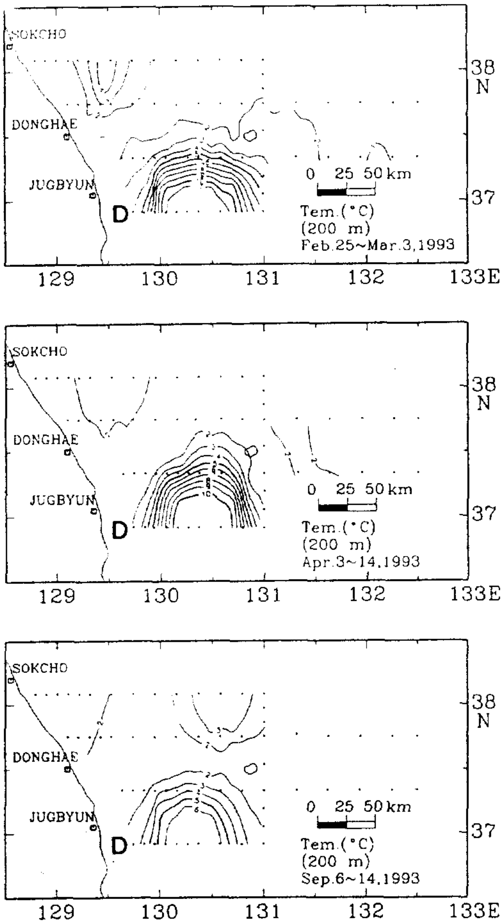


Fig. 4. Temperature at 200 m in February, April, and September 1993.

connected to the warm water confined to UB and the eddy remained stationary at least during February-September, not leaving UB.

The vertical structure of the eddy can be inferred from a temperature section on the line of 36° 54' N (referred as line D, Fig. 5) since the center of the eddy was located just near St. D10 of the line. The isotherm of temperature equal to and higher than 10°C was in the form of a convex lens. The isotherm of 10°C at the center of eddy was 250 m deep in early March, 230 m in early April, and 160 m in mid-September. In March and April, the water column above the isotherm of 10°C was vertically uniform and had a temperature range of 10-12°C, but in September when the eddy shrank in size, the column was strongly stratified and uniform water of 10-12°C occupied the layer between depths of 80-160 m below the warmer surface layer. Eddies are hardly recognized on SST in warm season when the surface layer is well formed due to the solar insolation. Convex isotherms of temperature below 10°C at deeper depths may reflect that the eddy motion influence significantly hydrographic structure of the whole water column.

Temperature at 50 and 100 m in early September (not presented here) shows a wide spreading of cold water mass of temperature lower than 10°C in the area between Sokcho and Donghae. The drifter 3156 turned counterclockwise there around the cold water mass. The cold water in the surface layer may reflect either a southward penetration of the cold water mass from the north or upwelling of cold water existing in the lower layer.

DYNAMIC FEATURES

Warm Eddy in the Ulleung Basin

Drifter 3156 (Fig. 3b) shows an orbital trajectory in the area between 130-131° 30' E, 36° 28'-37° 24' N in UB ('Eddy UB' hereafter for convenience). The orbit was nearly parallel to the periphery of 2,000 m isobath. The drifter rotated clockwise almost three times during a period of about 40 days from June 28 to August 6, 1993. The first circular trajectory was formed between June 29-July 15, the second one between July 16-27, and the third one between July 27-August 6. The third path was not completely closed. The first and second orbital paths are elliptic with their major axis almost parallel to the west-east direction. Its major and minor axes are 120 km and 70 km long, respectively.

The approximate swirl velocity during the orbital motion from June 28 to August 6 was 25 cm/s. The maximum daily mean velocity was 48.8 cm/s on day 194, with east (u) and north (v) components of 47.9 cm/s and 9.0 cm/s. Eddy kinetic energy, computed from the daily mean velocity, is 392 cm^2/s^2. SST recorded on the drifter maintained 20-22°C along the eddy trajectory, but it dropped sharply

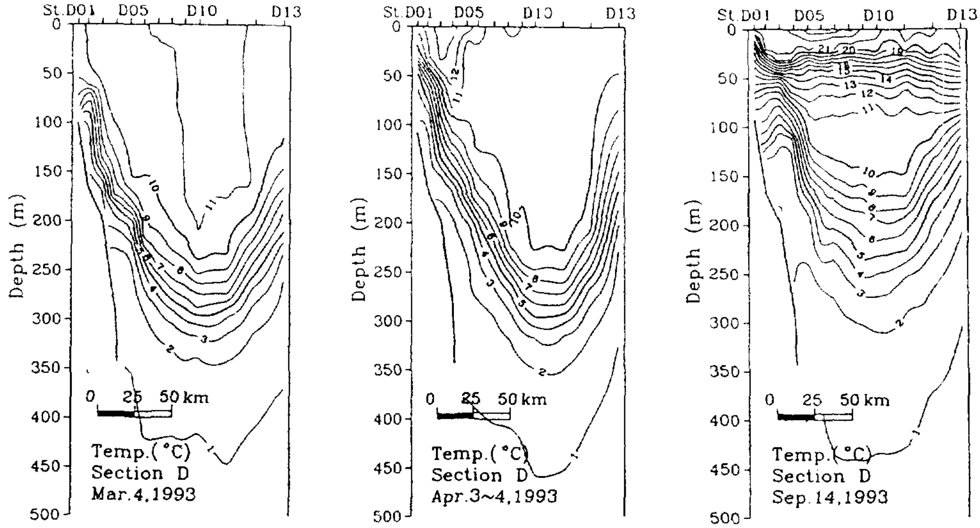


Fig. 5. Sections of temperature along line D marked in Fig. 4. (a) March, (b) April, and (c) September 1993.

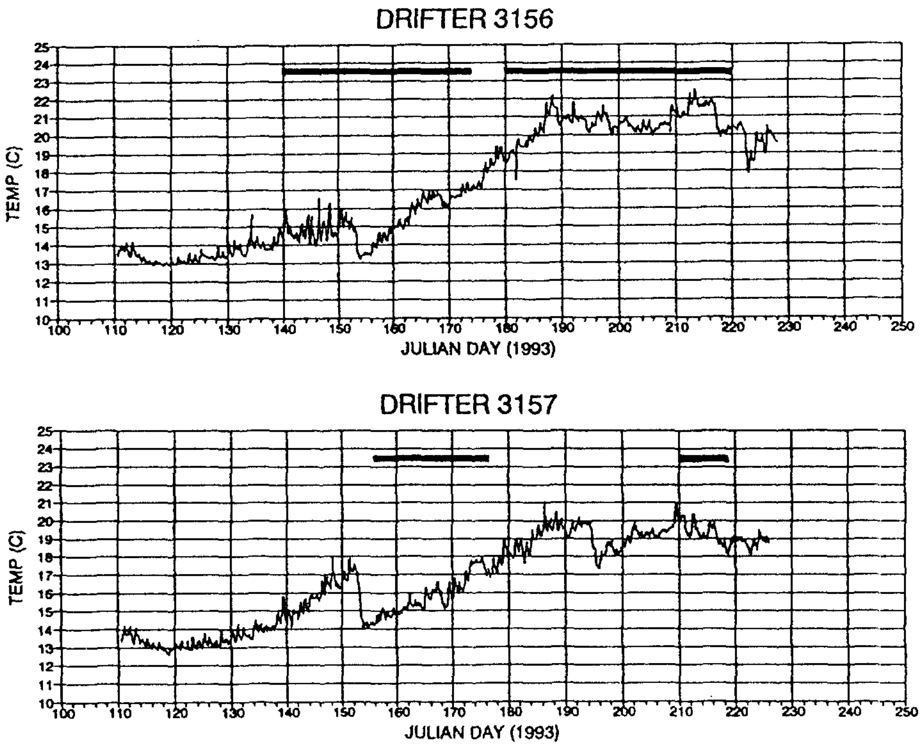
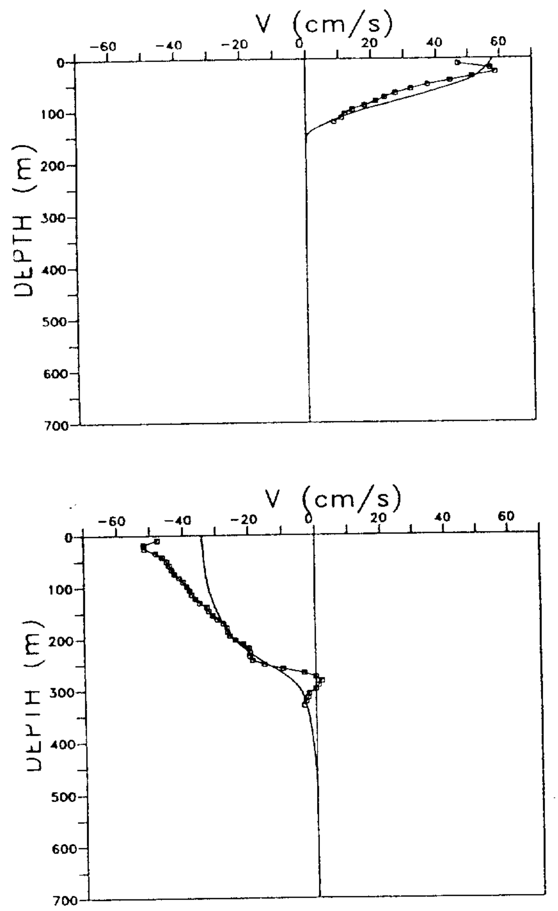


Fig. 6. Time series of SST observed on the surface float of drifters 3156 and 3157. Thick lines indicate period when drifters drew loop-trajectories.

from 22°C to 20°C when the drifter left UB (Fig. 6). The drifter, though it was drogued at 35 m, turned around the warm water mass located at depths of 80-160 m.

Fig. 7 shows profiles of velocities measured directly by ADCP and calculated by the dynamic method at two stations where the strongest northward and southward currents were recorded. Though the geostrophic current was calculated with the reference level at 700 dbar, general pattern of the two profiles matches well for both northward and southward flows. This may suggest that the eddy is approximately in geostrophic balance. Fig. 8 is the dynamic topography of the sea surface relative to 700 dbar and the current vector at 10 m depth measured by ADCP in April 1993. Flow pattern, deduced from the dynamic topography, agrees



ig. 7. Velocity profiles measured directly by ADCP (line with rectangular) and estimated by dynamic method at two different places of strong current. 36° 54' N, 129° 36' E for the upper panel and 36° 54' N, 130° 42' E for the lower panel.

with ADCP measurements. In 37°-37' 30' N, the flow direction is opposite around a north-south line parallel to 130° 30' E: northward on the western side, but southward on the right side. Although only the northern part of the eddy was observed, the eddy is about 80 km wide in the west-east direction and centered near 130° 30' E. Fig. 8 also indicates a counterclockwise rotating flow in the area of coast-130° E, 37° 15'-37° 30' N, northwest of Eddy UB.

Dynamic topography of the sea surface and the surface current at 10 m depth in September 1993 are given in Fig. 9. The current patterns are very similar each other as in April (Fig. 8). An anticyclonic eddy in UB, observed in April, existed there and its center was located almost at the same position. However, the swirl velocity was much reduced to a half of that in April. A minimum in dynamic topography off Sokcho-Donghae is closely related to the cold water mass occupying the surface layer below the thin surface mixed layer (KORDI, 1994). Drifter 3156 rotated counterclockwise during August 10-23 around the cold water mass (Fig. 3b).

Application of a simple feature model to fourteen segments of trajectory provides details of physical feature and dynamical aspects of Eddy UB (Fig. 10). The period ranges from 10.5 days to 18.0 days, with its mean of 13.6 days. The period is longer than 15 days for the first three segments and then becomes stable with values of 10.5-14.5 days. Lengths of semimajor and minor axes are 49-61 km and 24-42 km, respectively, with corresponding means of 57 and 35 km. The minor axis fluctuates more than the major axis. Swirl velocity has a range of 18.8-28.3 cm/s, with its mean of about 23.9 cm/s. An increase in swirl velocity can be noticed over the whole period except for the first two segments and it may be related to an increase of the rotation frequency. The eddy moved northwest for 18 days from day 186 to day 204, and then turned its direction to the southwest for the remaining period. Net and mean translation speeds are 0.7 cm/s and 3.0 cm/s over the whole 26 days, respectively.

Warm Eddy in the Southwestern Corner of the Northern Basin

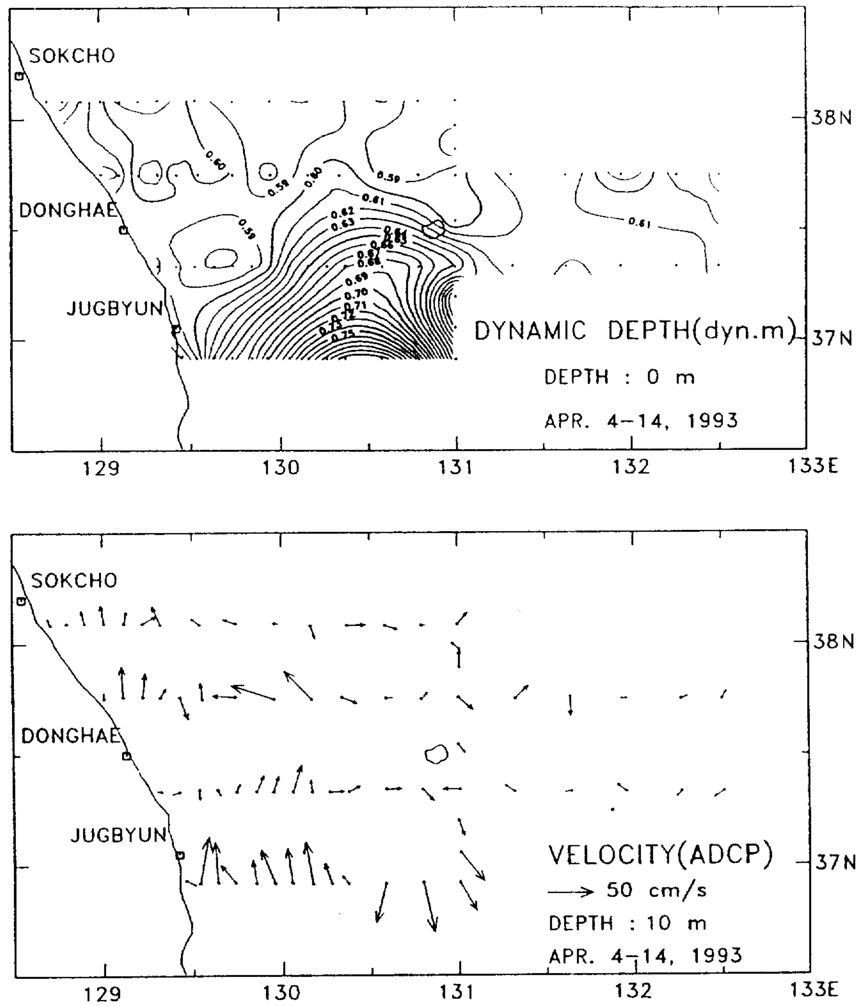


Fig. 8. Surface current field in April 1993. Dynamic depth anomaly of the sea surface relative to 700 dbar (upper panel) and velocity at 10 m measured by ADCP (lower panel).

Drifter 3156 entered SNB in late May after following the northern periphery of Eddy UB (Fig. 3b). There it turned around twice clockwise from May 21 to June 23 (called 'Eddy SNB'). The first loop during May 21-June 4 is in a triangular shape and the period of the eddy is estimated to be about 15 days. The second elliptical loop with its major axis along the northeast-southwest direction was completed between June 7-22. Drifter 3157 (Fig. 3c) moved into SNB 16 days after the arrival of drifter 3156 at SNB and made an elliptical trajectory during June 5-15 when drifter 3156 was in the second looping. After that it followed the same trajectory along the northwestern periphery of the first loop and then drew a smaller counterclockwise elliptical loop between June 25 and July 21 northeast of the first loop. Thus two drifters drew a closed loop three times, which reveals the existence of an anticyclonic eddy.

Mean swirl velocity of drifter 3156 over a period of 32 days (May 21-June 22) was estimated to be 32.3 cm/s, stronger than that of Eddy UB. Drifter 3157 rotated with the same speed as that of drifter 3156 during June 4-25. Maximum daily mean swirl velo-

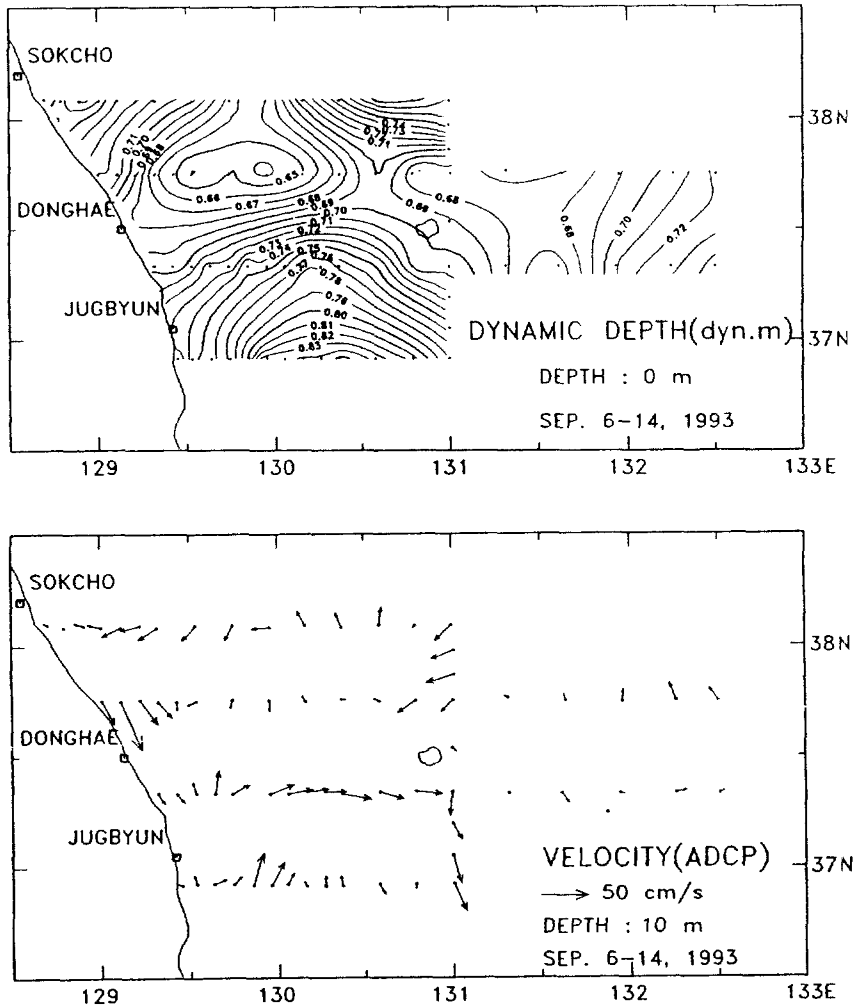


Fig. 9. Surface current field in September 1993. Dynamic depth anomaly of the sea surface relative to 700 dbar (upper panel) and velocity at 10 m measured by ADCP (lower panel).

city was 65.5 cm/s for 3156 and 62.8 cm/s for 3157. Eddy kinetic energy, estimated from the trajectories, is 629 cm^2/s^2 for 3156 and 709 cm^2/s^2 for 3157, much larger than that of Eddy UB. Mean SST was about 15°C with fluctuation less than 1.5°C , but it dropped by 2°C just before the beginning of the second loop. SST during the second loop increased gradually from 13.5°C to 17°C . SST of drifter 3157 increased from 14°C to 17.7°C with the same trend as that of drifter 3156 (Fig. 6). The gradual increase in temperature may represent how fast the surface water is warming up during the summer.

The physical feature of Eddy SNB is obtained by applying the feature model to nine segmented trajectories (Fig. 11). The period ranges from 12.3 to 18.3 days, with a mean of 14.9 days, a little longer than that of Eddy UB. Semi major and minor axes are 78-91 km and 38-51 km long, respectively, with corresponding means of 84 and 43 km. As seen in the trajectories, Eddy SNB is much larger in dimension than Eddy UB, with elongated shape. The swirl velocity has a range of 25.6-32.9 cm/s and its mean is 29.4 cm/s for a period of 18 days, faster than that of Eddy UB. The center of the eddy moved

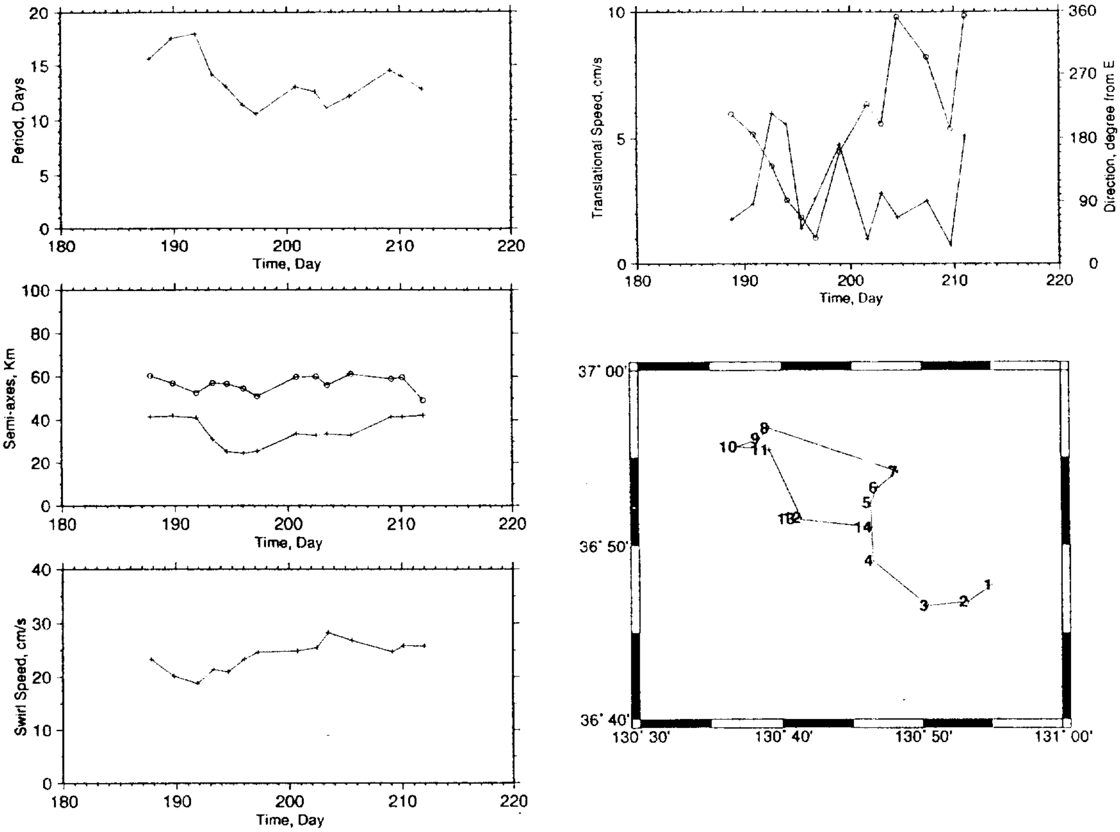


Fig. 10. Time series of elliptical parameters, swirl and translational velocities for the eddy in UB. Period, semi-axes, swirl velocity, translation velocity, and position of eddy center.

southeast for 10 days and then northeast. The net and mean translation speed during 18 days is about 1.8 cm/s and 3.1 cm/s, respectively, which are of the same magnitude as Eddy UB.

DISCUSSIONS AND CONCLUSIONS

The warm core in UB is seen in the monthly mean temperature at 100 m (Japan Maritime Safety Agency, 1992) and the rms temperature in the core is higher than that of the surrounding water (KORDI, 1990). This may indicate a high possibility that anticyclonic eddy is formed frequently in UB. In our study, an anticyclonic eddy in UB was detected by surface drifters. Meander motion of EKWC in UB in December 1992 was expected from the Ω-shaped trajectory, but the closed isotherms inside the meandering trajectory suggests that an anticyclonic eddy already existed there in UB (KORDI, 1994). From CTD data in 1993 the eddy was found to persist at least for 10 months and the convex isotherms deepening downward to 400 m may reflect a strong influence of the eddy on the water properties at the deep layer. The shrinking of the eddy in September seems to be closely related to the surface heating in summer. Isoda and Saitoh (1993) claimed that the eddy formed in UB moves northward from spring to summer. However, our observations showed that the eddy was always inside UB and rather it behaved as a stationary one, though its shape and size were gradually modified from December 1992 to September 1993.

Generally, the mean current flows along the contour of f/H, where f is the Coriolis parameter and H

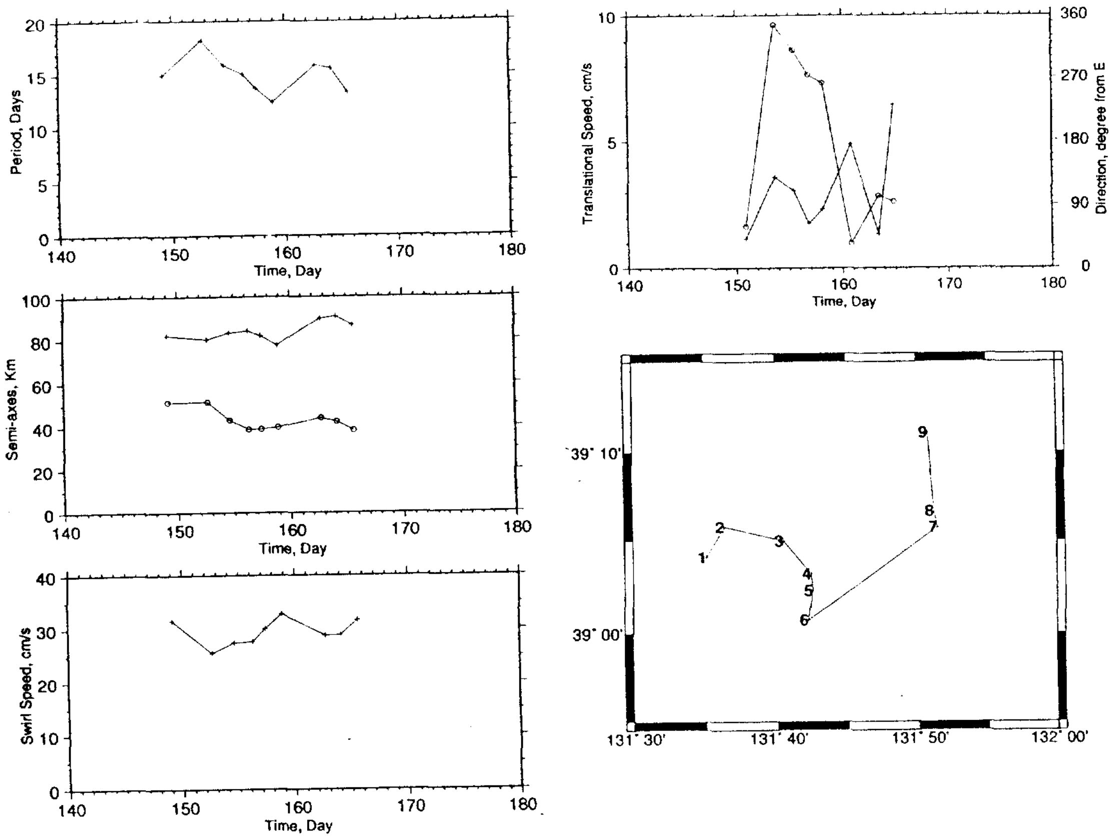


Fig. 11. Time series of elliptical parameters, swirl and translational velocities for the eddy in SNB. Period, semi-axes, swirl velocity, translation velocity, and position of eddy center.

the water depth. However, this need not to be true for eddy-type motions when their relative vorticity may be large. The bottom topography in the southwestern part of the East Sea has a very narrow shelf near the Korean coast and a vast shelf zone in the northern part of the Korea Strait. The UB and SNB are deep basins with a large variation in depth. The eddies observed in the two areas might be constrained by the shoaling topography. The topographic effect may be considered with the concept of conservation of potential vorticity. For an homogeneous ocean,

$$\frac{d}{dt}\left(\frac{\xi+f}{H}\right)=0$$

where ξ is the relative vorticity.

The order of ξ is estimated to be 10^{-6} from the trajectories of drifters, so that ξ is much smaller than f. The contour lines of f/H (Fig. 12) are nearly parallel to isobaths and the drifters rotated clockwise along the line with values of log (f/H) of -7.3 to -7.4. Thus the eddies in UB and SNB satisfy in general the conservation of potential vorticity. The stationary eddy in UB is assumed to be formed in connection with the meander motion of EKWC. The EKWC, transporting warm and saline water, tends to flow along isobaths to satisfy the potential vorticity conservation, which may cause a meander motion in the Ω shape. The meander motion supplies warm and saline water to the inward direction of the meandering, eventually forming a warm eddy. The eddy motion is maintained by this supply of warm water. In case where the supply decreases, an eddy in UB may weaken and finally disappears.

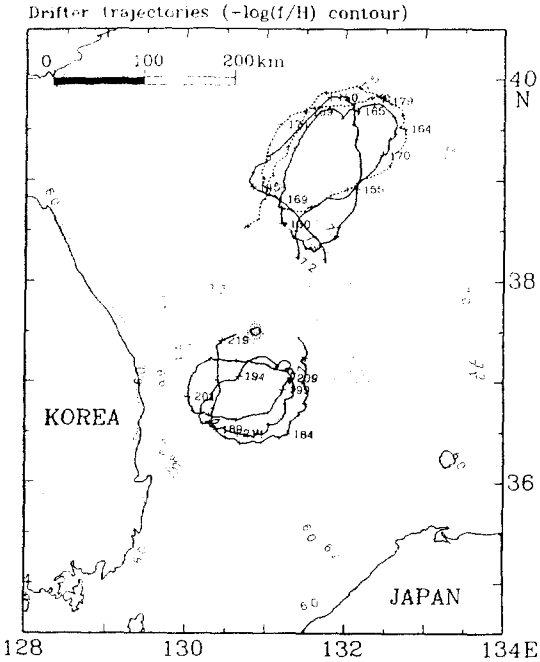


Fig. 12. Distribution of -log (f/H) with trajectories showing two eddies in the Ulleung Basin and southwestern corner of the Northern Basin, where f is the Coriolis parameter and H the depth.

Because of the lack of the available hydrographic data in SNB, a detailed structure of the anticyclonic eddy could not described. The formation of the eddy seems to be related to a smaller branch separated from the EKWC. The trajectories of the two drifters in Fig. 3 suggest a splitting of the EKWC into two parts; the main stream which meanders around UB and a branch flowing northeast toward SNB. The narrow branch transporting the EKWC water might play a role of a warm streamer circumvolving isobaths clockwise, though more observational information on the eddy is required.

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