WARM CORE IN THE EAST KOREAN BAY IN WINTER

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Introduction

The Japan/East Sea (JES) is a marginal sea of the North Pacific. The bottom of the JES may be divided approximately into two parts by 40°N parallel (Fig. 1). The northern half, the Japan Basin, is comparatively flat and deep. The southern part of the JES has two basins. One is Ulleung Basin which is located in western side and the other is Yamato Basin. The East Korean Bay (EKB) or Tong Han Man is located off mid eastern part of Korea. The EKB has continental shelf wider than other coast of Korea and the deepest part is connected with the Japan Basin which is deeper than 3000 m. The southern and eastern part of the EKB is the Korea Plateau. Therefore, the bottom topography of the EKB is like a basin which has the center around 39°N, 129°E.

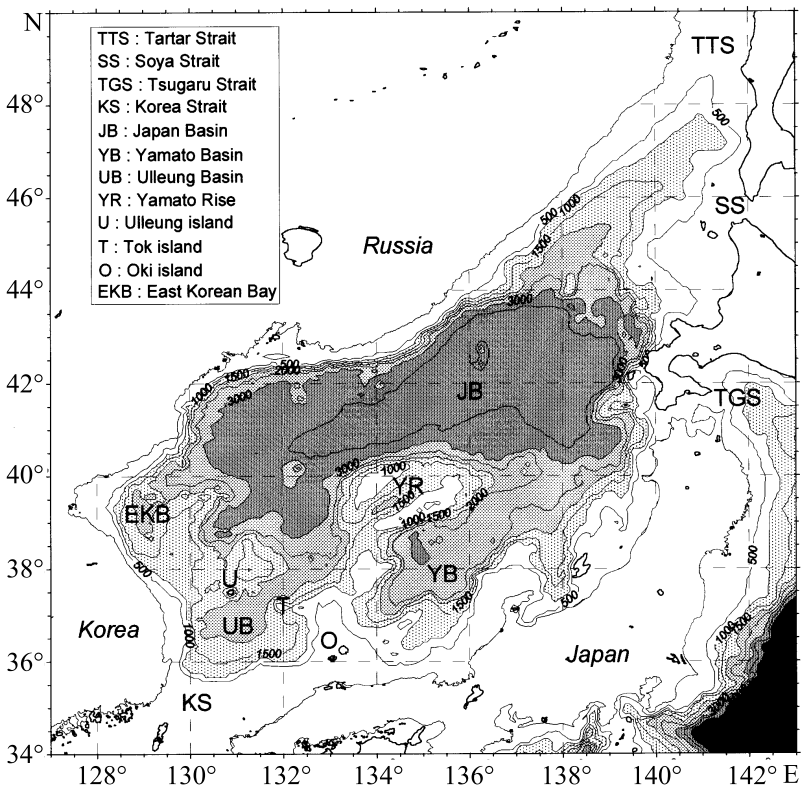

Fig. 1. Bottom topography of the JES. Depth in meters. The EKB located in mid eastern part of Korea

The southern part of the JES is affected by Tsushima Warm Current (TWC), which carries warm and saline water. The TWC pass the Korea Strait and branch out in a few directions. One of the branch currents is East Korean Warm Current (EKWC) that flows to the north along the eastern coast of Korea. The EKWC is separated from the coast at 38-40°N and flows to the northeast. The EKWC meet North Korean Cold Current (NKCC) at the separation latitude and forms a subpolar front. Infrared images of the NOAA satellites show many mesoscale eddies along the subpolar front.

A warm eddy in the EKB was shown in wintertime infrared images. By watching the images during 4 years form 1997 to 2000, we know that the warm eddy always exist in wintertime. To describe characteristics of the warm eddy, we use hydrographic data observed in the EKB and the vicinity in February 1934.

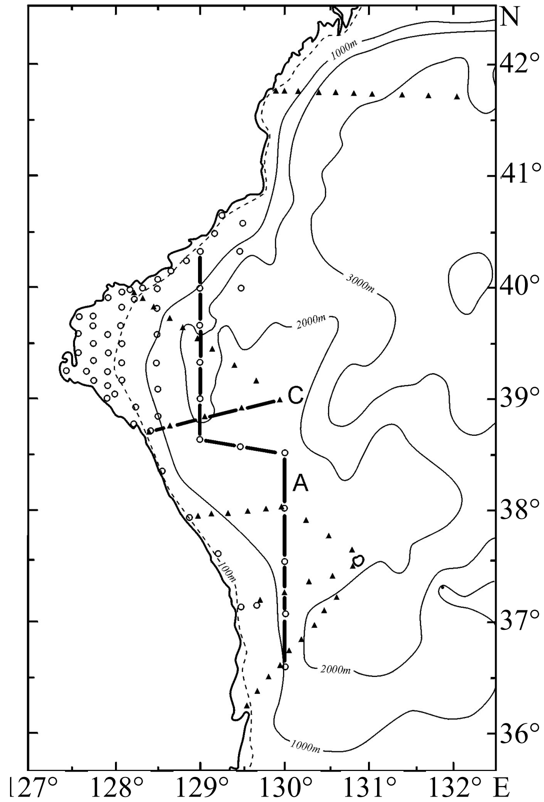

Fig. 2. Map showing hydrographic stations and the bottom topography in meters. The blank circles and the black triangles indicate the stations observed in February 1934 and averaged in February from 1922 to 1960, respectively. Lines of A and C are to show vertical distributions of water characteristics

Data

Sea Surface Temperature (SST) infrared images of NOAA satellites taken from Korea Ocean Research and Development Institute were analyzed from January 1997 to March 2000. To describe the EKB warm eddy, an image which had no clouds around the EKB was selected by the month.

To investigate characteristics of the warm eddy, historical hydrographic data were searched around the EKB. The data surveyed in February ~ March 1934 (The Fisheries Experiment Station, 1942) were found. The number of stations surveyed in February 1934 is 63 and the stations are distributed in the EKB and its neighboring sea (Fig. 2). The position of the station was determined by eye measurements or celestial observations. Below the sea surface, water temperature was measured with the reversing thermometers attached to the exterior of the Nansen bottle, at the sea surface, however, by direct reading the thermometer in a bucket of sea surface water on board. Salinity and dissolved oxygen were determined by Mohr-Knudsen method and modified Winkler method, respectively. The averaged data for 1922~1960 (Fisheries Research and Development Agency, 1964) were also analyzed to know climatological phenomenon in the EKB in February.

Infrared Images Around the East Korean Bay

Fig. 3 shows the SST in February from 1997 to 2000. On February 1997, the EKWC departed from the Korean coast about 37°N and flowed to the east (Fig. 3a). The SST of the EKWC was about 10~12 °C. A warm core existed in the EKB with the diameter of 120 km. The center of the warm core was located about 39°N, 129°E and its shape was an ellipse elongated to the zonal axis. The SST of the warm core was 6 °C and decreased from January about 2 °C because of winter cooling. The warm core was sustained on March 1997.

The image of the SST on February 1998 showed that the warm core existed in the EKB (Fig. 3b). The warm core had a diameter about 100 km which was smaller than that in 1997 and its shape was nearly a circle. The EKWC flow pattern was different from that in 1997. The EKWC did not depart from the Korean coast about 37°N but flowed to north along the coast and supplied warm water to the warm core. The SST of the EKWC and the warm core were about 7~6 °C and 10~13 °C, respectively. The location of the warm core was not much different form about 39°N, 129°E. The warm core was shown in infrared images from January to March 1998 (not shown here).

On February 1999, the infrared image showed that the warm core existed in the EKB with a diameter of 110 km (Fig. 3c). The center of the warm core was about 39°N, 129°E. The EKWC flows along the coast and depart from the coast around 38°N. A part of the EKWC supplied warm water. The SST was 10~11 °C in the EKWC and 7~8 °C in the warm core. The SST of the warm core decreased with time from 8~9 °C on January to 7~8 °C on February.

On February 2000, the SST image also showed the warm core in the EBK with a diameter of 120 km. The center of the warm core was moved from 39°N, 129°E to the northwest. The warm core was affected by the EKWC which flowed from the Korean coast.

All the SST images on February during 1997~2000 showed the warm core in the EKB. This implies a possibility that the warm core always exists around in the EKB in winter.

Hydrographic Structure of the Warm Core

For a recent oceanographic data were not available, the hydrographic data observed on February 1934 were analyzed to investigate the warm core in the EKB. Fig. 4 shows temperature-salinity relations of the data. Although the data accuracy was low, water masses were managed to be classified by tracers of temperature, salinity and dissolved oxygen. The first one was the EKWC water that was warm, saline and low dissolved oxygen (t>10 °C, S>34.1 psu, D.O<6.85 ml/l). The second one was the intermediate water (1<t<5 °C, S<34.1 psu, D.O>6.85 ml/l) and the last one was the proper water that was low temperature, low dissolved oxygen and nearly constant salinity of 34.1 psu.

The surface temperature decreased with latitude and showed the thermal front around 38°N (not shown here). The EKWC water that was warm and saline occupied the southern part of the front. The shape of the warm core was not clear in the surface horizontal distributions of temperature and salinity. It was notable that low salinity water appeared in the EKB and the coldest water below 1 °C appeared in the westernmost part of the EKB.

Fig. 5 shows horizontal distributions of temperature and salinity at 100 m depth. An isolated core of warmer water than surrounding area about 2 °C appeared in the EKB at 39°N, 129°E. This suggests that the warm core exist in the EKB. In the same position, a core of low salinity water was shown.

Vertical sections of temperature and salinity show that the warm and saline EKWC water occupied the south of 38°N (Fig. 6). A bowl-shaped structure was shown around 39°N. At the center of the warm core, the temperature and salinity were homogeneous with 4 °C and 34.0 psu from the surface to about 200 m depth. The bowl-shaped structure was not clear in the

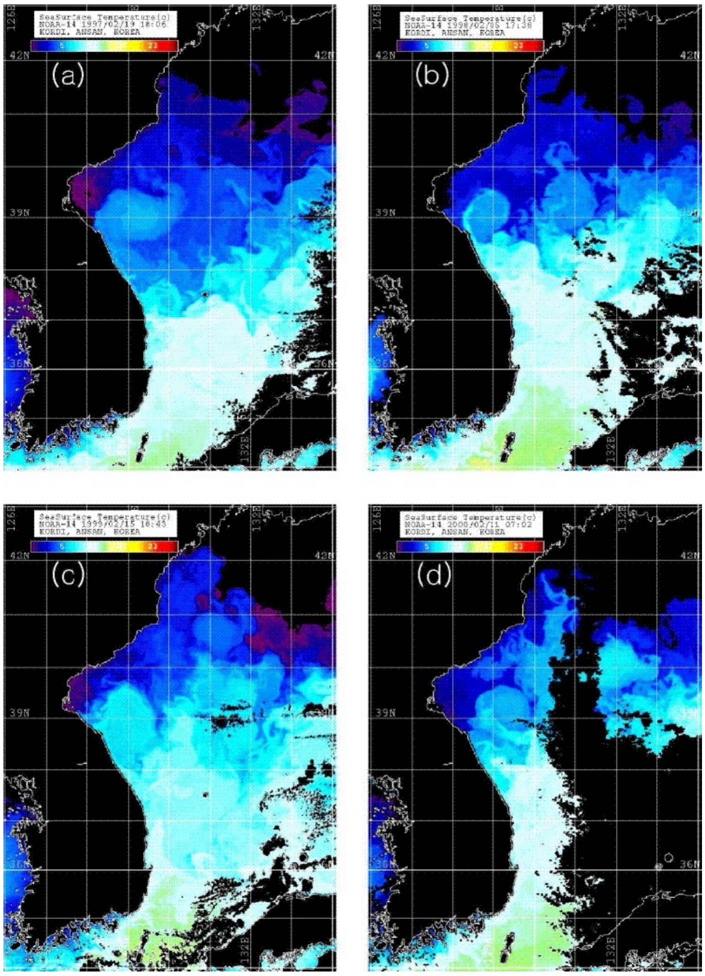

Fig. 3. SST infrared images around the EKB taken from Korea Ocean Research and Development Institute. (a) February 19, 1997, (b) February 05, 1998, (c) February 15, 1999 and (d) February 11, 2000

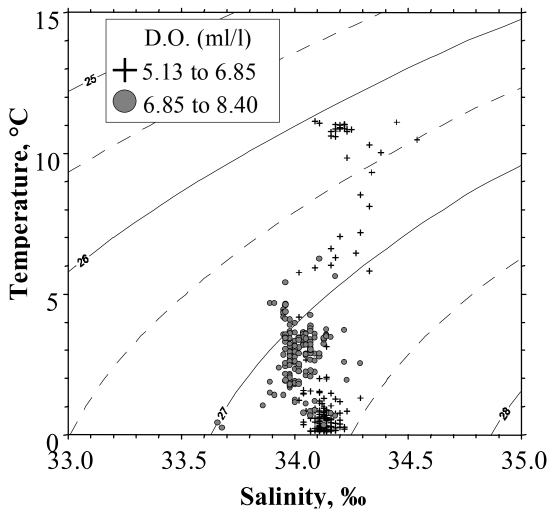

Fig. 4. Temperature-salinity relations with dissolved oxygen to classify water masses of the data observed on February 1934 around the EKB

section of dissolved oxygen (not shown here). The density (sigma-t) section shows that the warm core affects the vertical structure more than 1000 m depth.

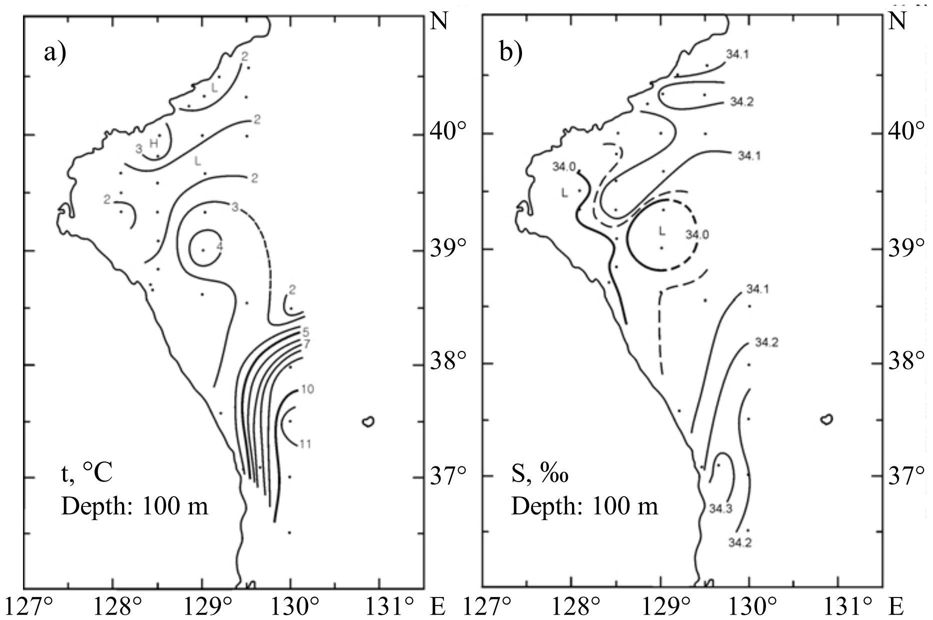

Fig. 5. The horizontal distributions of (a) temperature and (b) salinity at 100 m depth

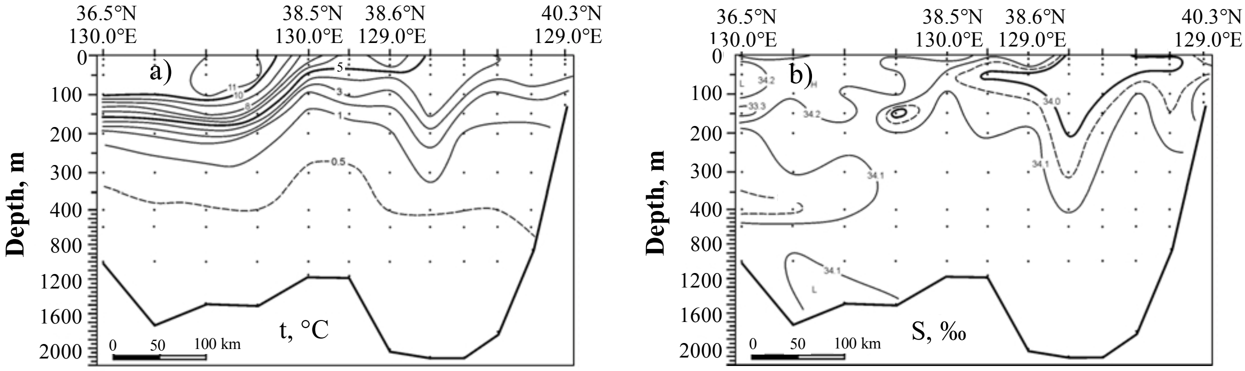

Fig. 6. Vertical sections of (a) temperature and (b) salinity along line A

Fig. 7 shows the dynamic height at surface relative to 1000 m depth. The EKWC flowed to the north and turned to the east at 38°N. The currents circulated anticyclonically in the warm core region. The maximum geostrophic current of the warm core was about 20 cm/s (Fig. 8). Recently, satellite-tracked drifters showed also anticyclonic circulation with a mean speed of 40 cm/s in the warm core around the EKB in winter (Seo, personal communications, 2000).

Fig. 9 shows the horizontal distributions of temperature and salinity at 100 m depth for the averaged data on February during 1922-1960. The thermal front formed at 38°N and the shape of the warm core was not clear in the EKB because of variability of the core position. In the salinity distribution, however, the isolated low salinity water indicated the existed core in the EKB. The bowl-shaped structure was formed in vertical sections along line C both temperature and salinity for the averaged data on February during 1922-1960 (Fig. 10). These suggest that the warm core always exist in the EKB in winter.

The following questions arise from the above results. The first one is why the warm core exists in the same location in winter. The second one is if the warm core exists in summer. These are subjects to study further.

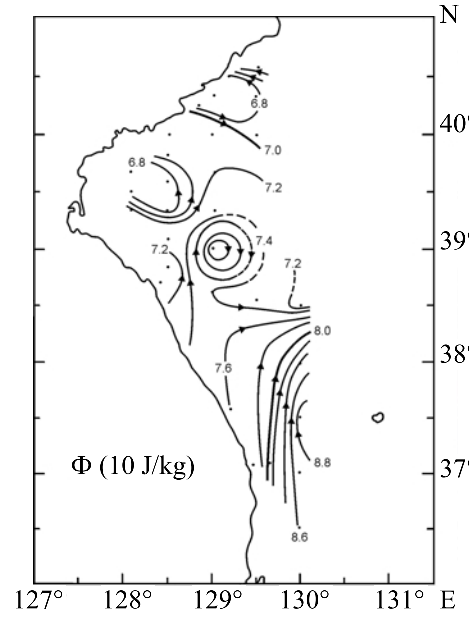

Fig. 7. Dynamic height at surface relative to 1000 m depth

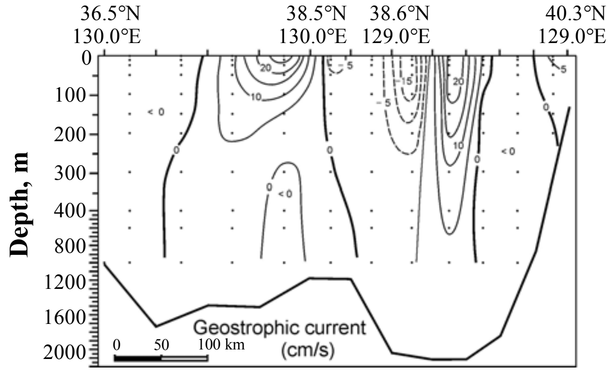

Fig. 8. Geostrophic currents along line A relative to 1000 m depth

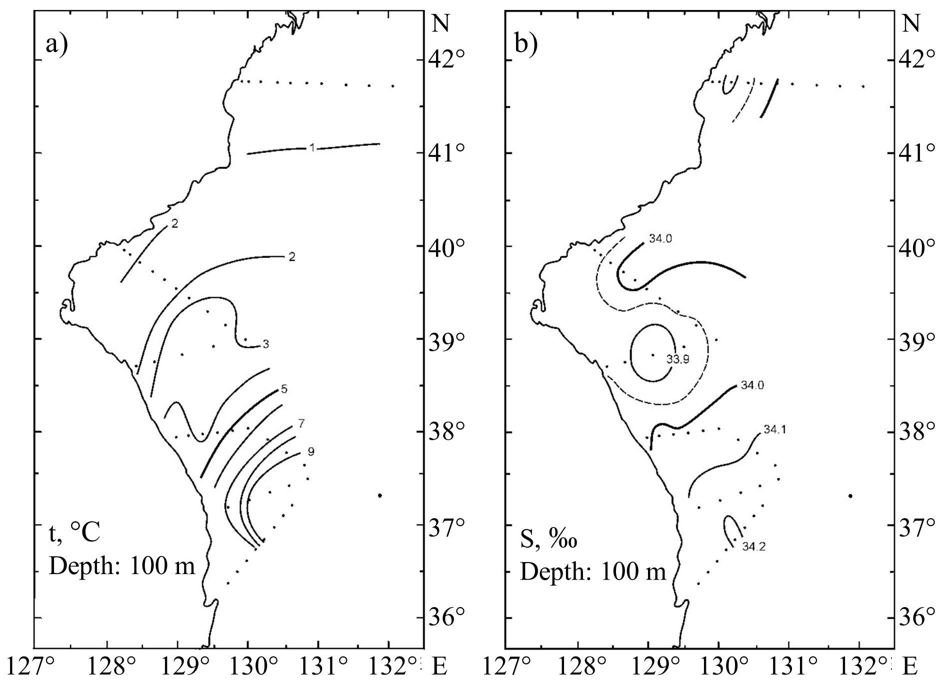

Fig. 9. The horizontal distributions of (a) temperature and (b) salinity at 100 m depth for the averaged data on February during 1922-1960

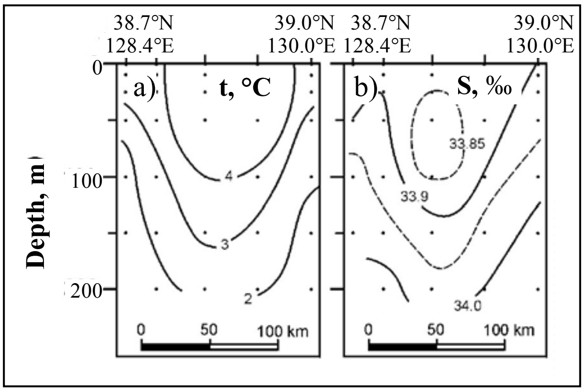

Fig. 10. Vertical sections along line C of (a) temperature and (b) salinity for the averaged data on February during 1922-1960

References

1. The Fisheries Experiment Station. 1942 / Annual report of hydrographic observations N 9 for the year 1934. The Fisheries Experiment Station. Pusan. 219 pp.
2. Fisheries Research and Development Agency. 1964 / Oceanographic handbook of the neighboring seas of Korea. Fisheries Research and Development Agency. Pusan. 214 pp.