Mem. Fac. Fish., Kagoshima Univ.
Vol. 18, pp. 99～114 (1969)

Oceanic Conditions near the Ryukyu Islands-II.
Oceanic Conditions on 125° E in Spring and Summer of 1966

Tadao TAKAHASHI* and Masaaki CHAEN*

Abstract

The general feature of oceanic conditions along the meridian of 125°E in spring and summer of 1966 is described, on the bases of the results of the Keiten-maru and the Kagoshima-maru cruises for CSK. A warm core is remarkable in spring in the region between the edge of the continental shelf and the Ryukyu submarine ridge, while it is less marked in summer. On the north of the warm core isotherms and isohalines over the continental slope decline sharply, especially in spring. The upwelling seems to take place on the south of the submarine ridge in spring and is not appreciable in summer. Saline water creeps further to the north on the continental shelf in summer than in spring. The volume transport of the east component of the Kuroshio in spring and summer is ca 31×10^6 m^3/sec and 28×10^6 m^3/sec respectively. Another eastward flow exists to the south of the submarine ridge in both seasons, shifting very much with season.

1. Introduction

A discussion on the general feature of oceanic conditions near the Ryukyu Islands in summer is presented in the previous paper (Takahashi and Chaen, 1967), on the bases of the results of CSK cruises in 1965 of the Kagoshima-maru and the Keiten-maru, Kagoshima University. In this paper, the general feature on the meridional section along 125°E from 20°N to 32°N in April and in August of 1966, made by the Keiten-maru and the Kagoshima-maru respectively, participating to CSK in the second year, is described. The serial oceanographic observations of temperature and salinity from surface to a depth of 1,500m or 2,000m and BT casts are made at every 30 miles or 60 miles, as shown in Fig. 1. Furthermore, direct current measurements are carried out at 3 stations within the Kuroshio itself in August. Quite similar observations at same stations in spring and summer will give good idea concerning comparison between conditions in the two seasons.

2. Temperature in Spring and Summer.

Distribution of temperature obtained by serial observations and BTs between 20°N and 32°N along the meridian of 125°E in spring and summer is given in Fig. 2 (a), (a′) and (b), (b′) respectively.

Temperature in spring is nearly uniform from the surface to the bottom on the continental shelf and the numerical value gradually increases southwards as far as ca 28°N near the edge of the continental shelf, where surface temperature increases abruptly, form-

* Laboratory of Oceanography, Faculty of Fisheries, Kagoshima University.

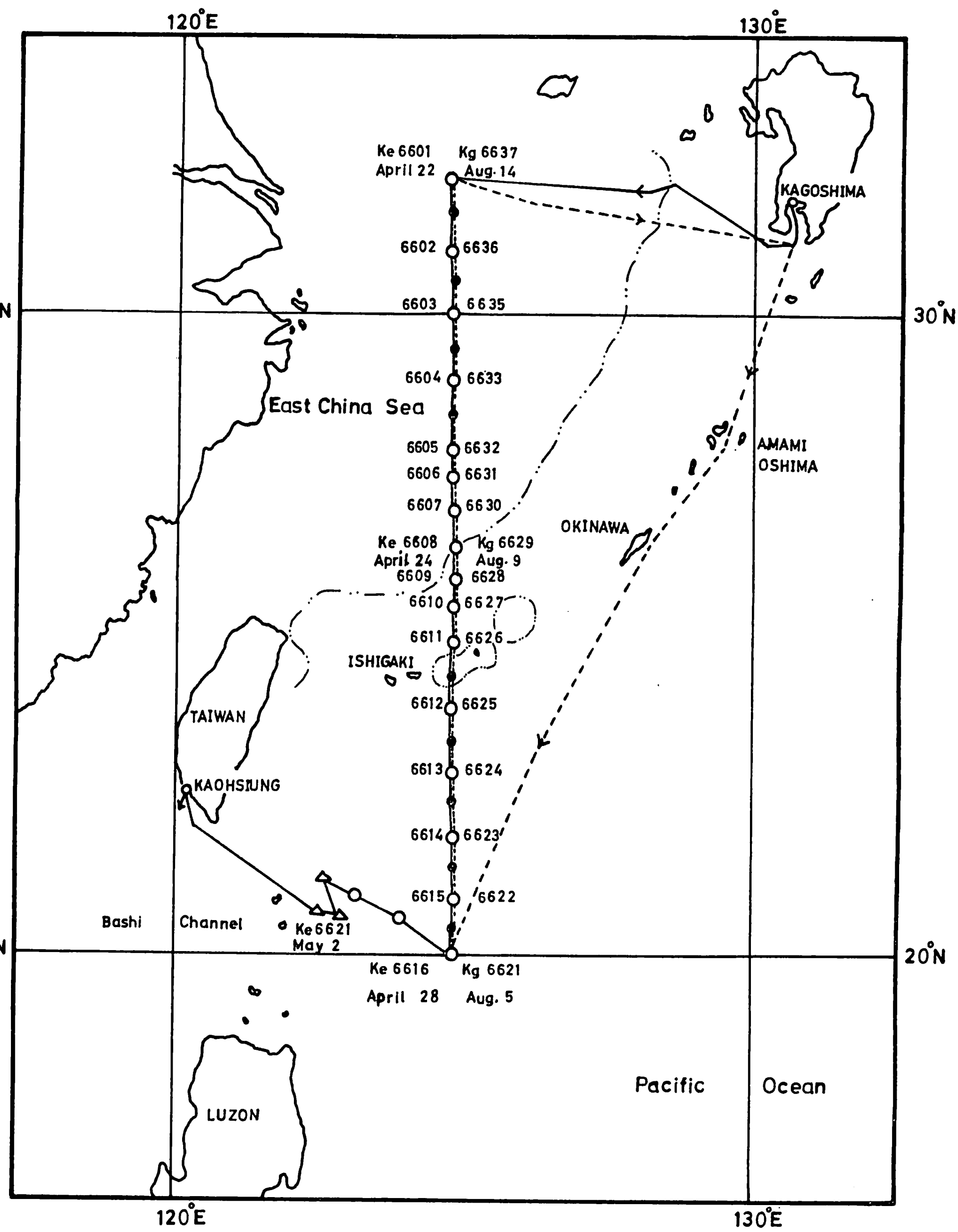


Fig. 1. Map showing the track and the observing points. The track of the Keiten-maru indicated by solid line, and the Kagoshima-maru, dashed line. Symbols of stations: circles, serial oceanographic observation and BT; dots, BT observation; triangles, tuna long-line fishing experiment.

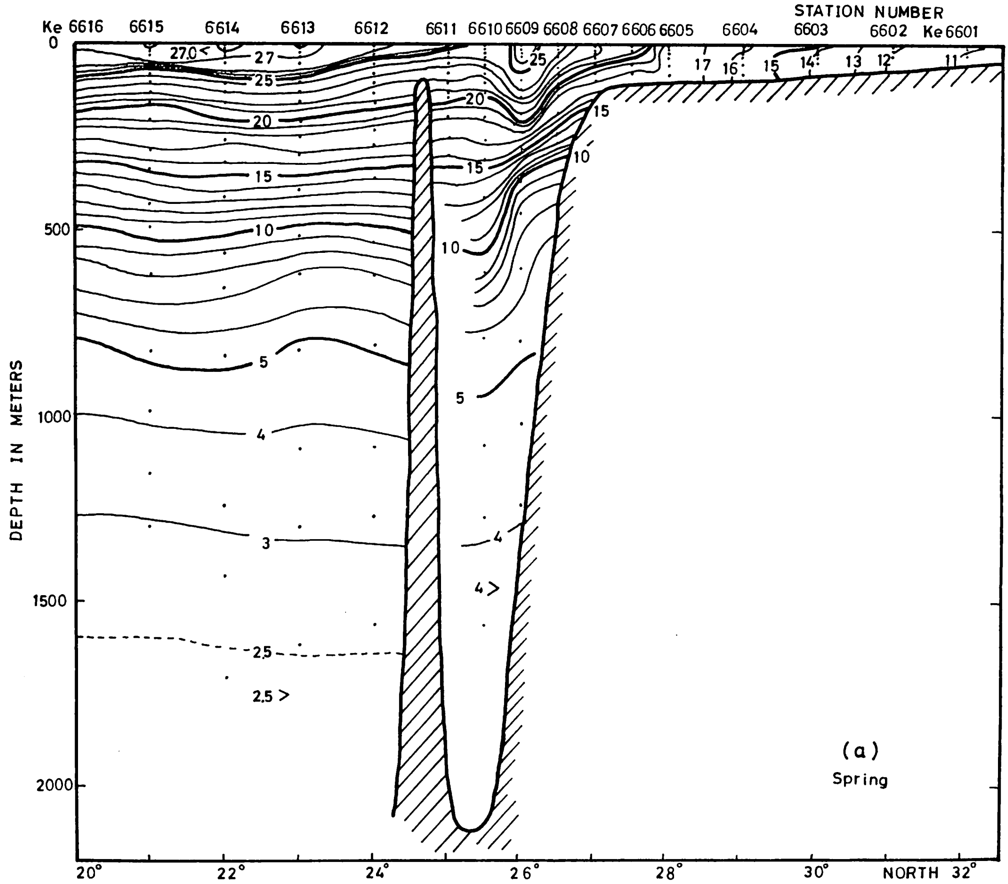


Fig. 2. Temperature distribution (°C) along the meridian of 125°E by serial observation and by BT in spring (a), (a′) and summer (b), (b′).

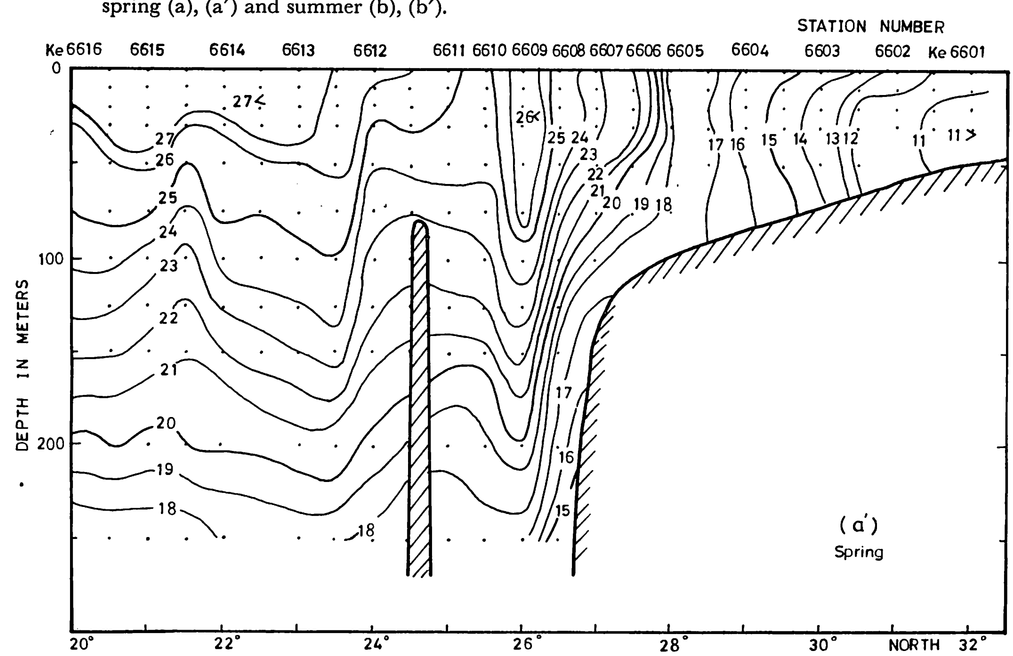


Fig. 2. (a′)

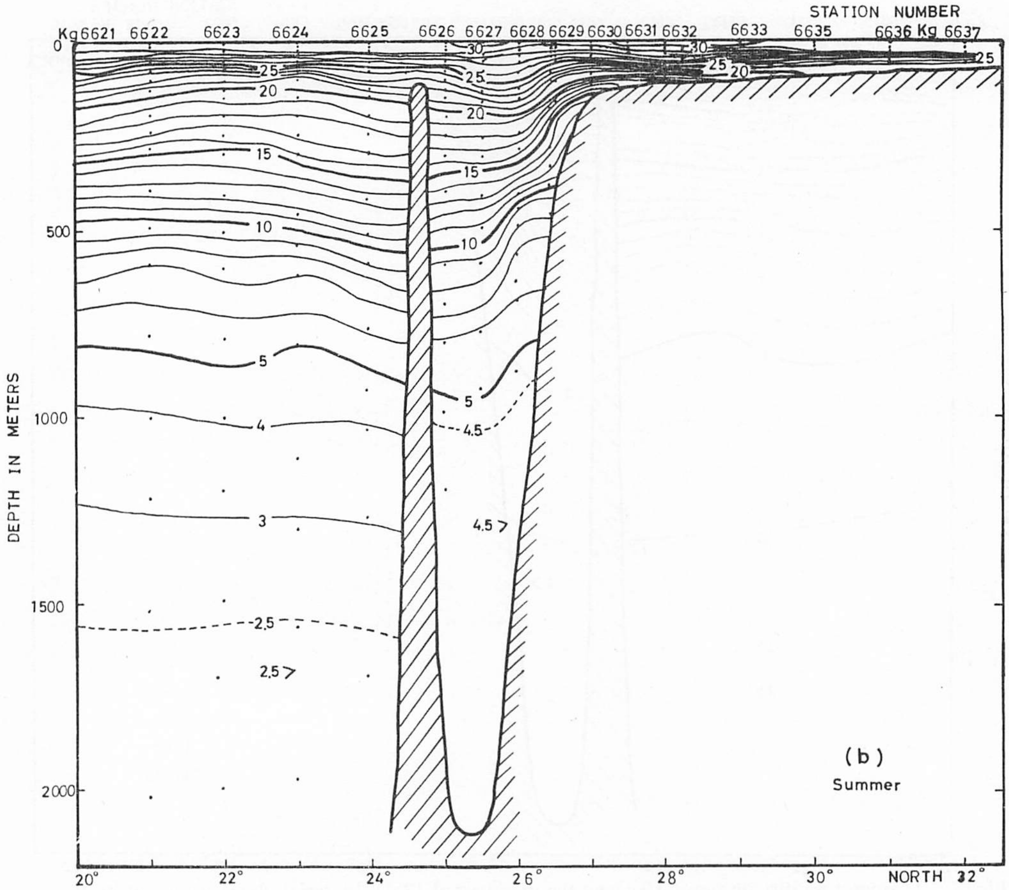
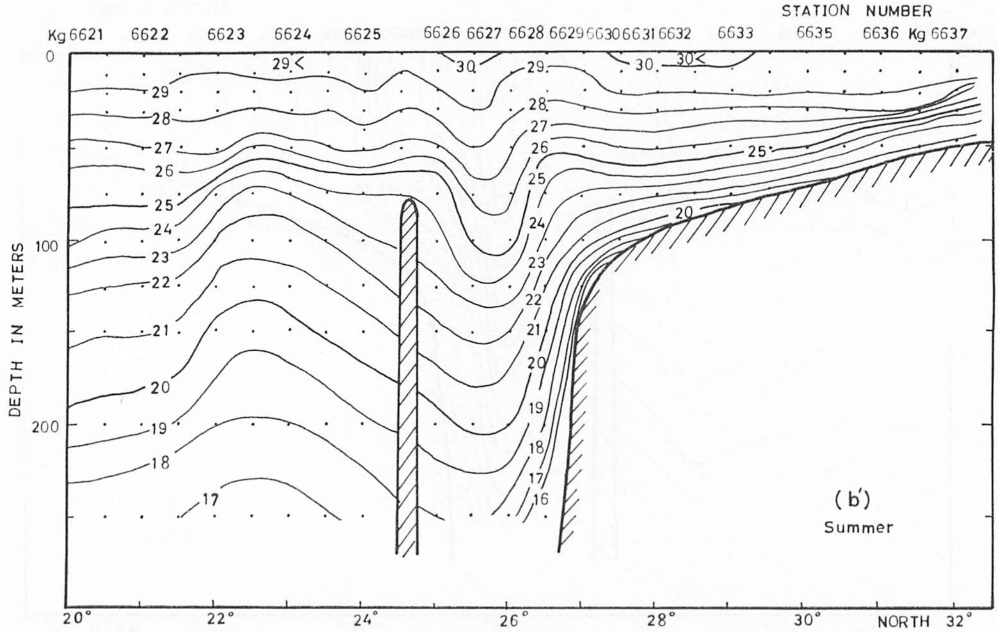

STATION NUMBER
Kg6621 6622 6623 6624 6625 6626 6627 6628 6629 6630 6631 6632 6633 6635 6636 Kg 6637
DEPTH IN METERS
0
500
1000
1500
2000
20° 22° 24° 26° 28° 30° NORTH 32°
(b)
Summer

Fig. 2. (b)


STATION NUMBER
Kg 6621 6622 6623 6624 6625 6626 6627 6628 6629 6630 6631 6632 6633 6635 6636 Kg 6637
DEPTH IN METERS
0
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20° 22° 24° 26° 28° 30° NORTH 32°
(b')
Summer

Fig. 2. (b′)

ing a front. In the region between the edge of the continental shelf and the Ryukyu submarine ridge, a warm core is remarkable in the surface layer and stretches to a depth of ca 500m. The maximum slope of isotherm is found on the north of the warm core. On the south of the submarine ridge, the upwelling towards the surface seems to take place. The isotherms below ca 500m depth slope slightly down from 23°N toward the north and south, which may indicate the upwelling of the lower water to be continued to the surface on the south of the submarine ridge. The slope of isotherms almost disappears below a depth of ca 1,200 m. However, numerical value of temperature below ca 1,200 m to the north of the submarine ridge is ca 1°C higher than that to the south of the submarine ridge.

In summer, the highest temperature of 30°C is found on the very surface in around 25°30′N and in a region between 27°30′N and 29°N. The well-mixed surface layer obscures in these regions and thermocline also, while they are appreciable to the north of 29°30′N and to the south of the submarine ridge. The warm core found in spring in the region between the edge of the continental shelf and the submarine ridge is less marked in summer, and the slope of isotherms on the north of the warm core is less than that in spring. This fact suggests that the current velocity of the Kuroshio is higher in spring than in summer. The upwelling found in spring on the south of the submarine ridge disappears. In summer of 1965, the upwelling of the lower water is clearly found in around 23°N (Takahashi and Chaen, loc. cit.), but it is obscure in summer of 1966, though the slight slope of the isotherms still exists below a depth of ca 100 m.

3. Salinity in Spring and Summer

Distribution of salinity between 20°N and 32°N along the meridian of 125°E in spring and summer is given in Fig. 3 (a) and (b) respectively.

In spring two regions of lower salinity than 33.0‰ are found, one in the entire layer from the surface to the bottom to the north of 31°N and the other in the thin surface layer at 29°N, which may be the Yellow Sea origin. Beneath this layer the saline water creeps from the oceanic area to the north on the continental shelf, forming a transition zone between the subsurface salinity maximum and the surface minimum. To the south of the edge of the continental shelf, a tonguelike protuberance of the salinity maximum of higher than 34.8‰ extends to the north from the south in a layer between the surface and 300m. The extreme part of the core of the subsurface salinity maximum in the region between the edge of the continental shelf and the submarine ridge corresponds to the warm core in temperature distribution. The sharp slope of isohalines also corresponds to the sharp slope of isotherms on the north of the warm core. The intermediate water of salinity lower than 34.4‰ is found in a layer around 600m to the south of the submarine ridge. Below ca 1,000m layer the numerical value of salinity to the north of the submarine ridge is ca 0.1‰ lower than that of the south of the submarine ridge.

In summer, the numerical value of the salinity minimum of the Yellow Sea origin at 32°N is ca 4‰ lower than that in spring. The thin surface water characterized by lower

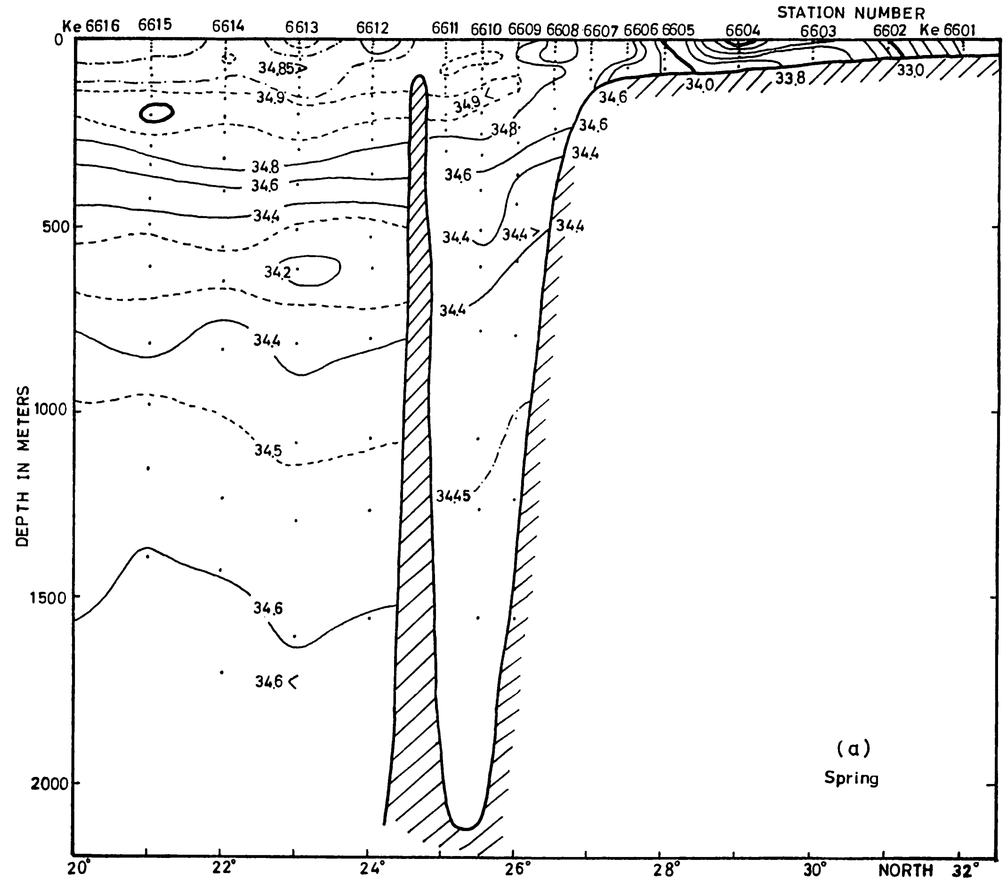

Fig. 3. Salinity distribution (‰) along the meridian of 125°E by serial observation in spring (a) and summer (b).

salinity than 33.8‰ is found in a region between 26°30′N and 29°N, which is a branch of the Yellow Sea origin recognized at 29°N in spring. This water, characterized by lower salinity and higher temperature in summer, spreads southwards. To the south of the edge of the continental shelf, the numerical values of surface salinity and the subsurface salinity maximum are ca 0.3‰ and 0.1‰ lower than those in spring respectively. Isohalines below the subsurface salinity maximum over continental slope declines less in summer than in spring. A part of the tonguelike protuberance of subsurface salinity maximum creeps on the continental shelf as far as 31°N beneath the thin surface water of low salinity stated above.

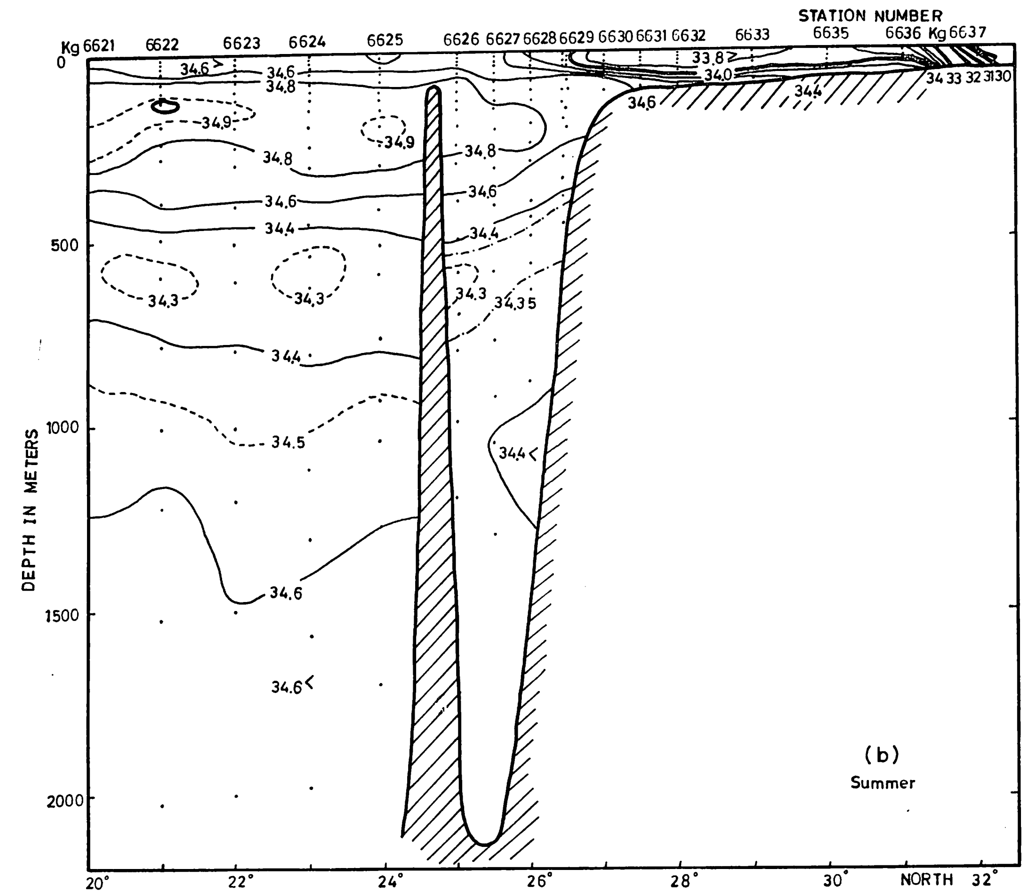

Fig. 3. (b)

4. Temperature-Salinity Relation in Spring and Summer.

Temperature-salinity diagrams at several stations in spring and in summer are shown in Fig. 4. T-S diagrams for St. Ke6614 (22°N), Kg6623 (22°N), Ke6610 (25°30′N), and Kg6627 (25°30′N) are almost similar to one another, showing the Kuroshio water characterized by a salinity maximum at a depth of ca 150–200m and by a salinity minimum at a depth of ca 600 m, which is consistent with those for Kg6523 (22°N, 125°E) and Kg65 27 (25°30′N, 125°E) in the previous paper.

In the region near the edge of the continental shelf, T-S diagrams for St. Ke6608 (26°30′N) and Kg6629 (26°30′N) are still similar to those stated above, though some discrepancies are seen in the surface layer. The salinity maximum still remains at a depth of 100 m in spring. The water characteristics at 250 m for these stations correspond to those at ca 300–400m for the four stations stated above. T-S diagrams for St. Ke6606 (27°30′N) and Kg6631 (27°30′N) at the edge of the continental shelf are quite different, showing different stratifications, i. e., upper oceanic water in spring and lower oceanic water in summer.

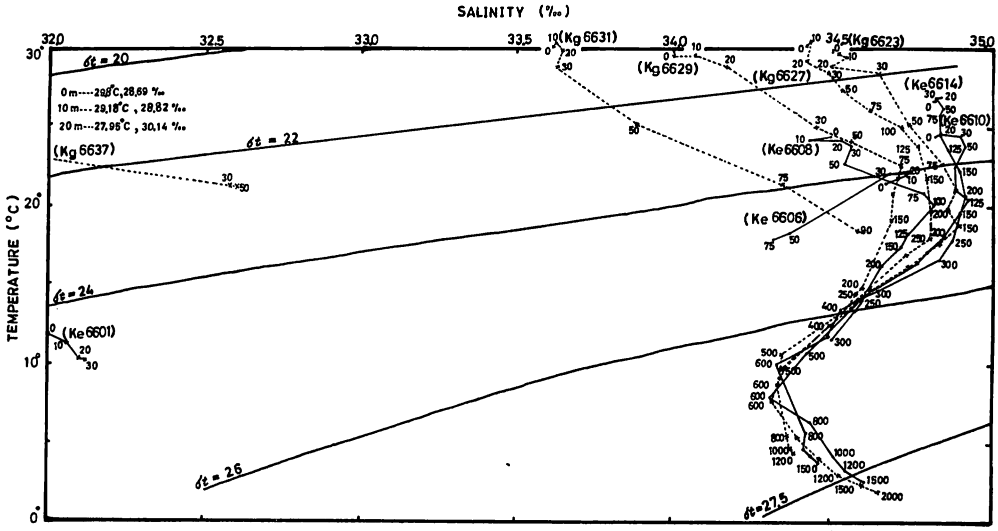

Fig. 4. Temperature-Salinity diagrams at the selected stations along the meridian of 125°E in spring (Ke, solid line) and summer (Kg, dashed line). Number of stations and the observing depth are indicated.

T-S diagrams for St. Ke6601 (32°N) and Kg6637 (32°N) represent the water from the Yellow Sea origin, and the surface salinity above 20 m depth is extremely lower in summer than in spring.

5. Current Structure in Spring and Summer.

The geostrophic relative current referred to 1,200 m depth is computed in the vertical section along the meridian of 125°E, using not only materials obtained by two vessels stated above but also those by other vessels participating to CSK. The dynamic calculation on the continental slope, where the depth is shallower than 1,200 m, is based on the method of B. Groen (1948). The distribution of east-west component of current velocity in spring and summer of 1966 is shown in Fig. 5 (a) and (b) respectively, and that in summer of 1965 is recalculated and shown in Fig. 5 (c). The eastward flow over the continental slope indicates the Kuroshio. It is narrower and deeper in spring than in summer. The maximum speed of the east component is ca 80 cm/sec or more at the surface layer in both seasons, and the second maximum speed having ca 70 cm/sec or more is found at a depth of ca 300 m in spring. In summer the relative currents referred to a depth of 1,000m are measured by means of two current meters of Ekman-Mertz type at three stations, Kg6626, Kg6627 and Kg6628. The maximum current speed is 91.1 cm/sec with direction of 47° at a depth of 10 m at St. Kg6628. Therefore, the calculated maximum

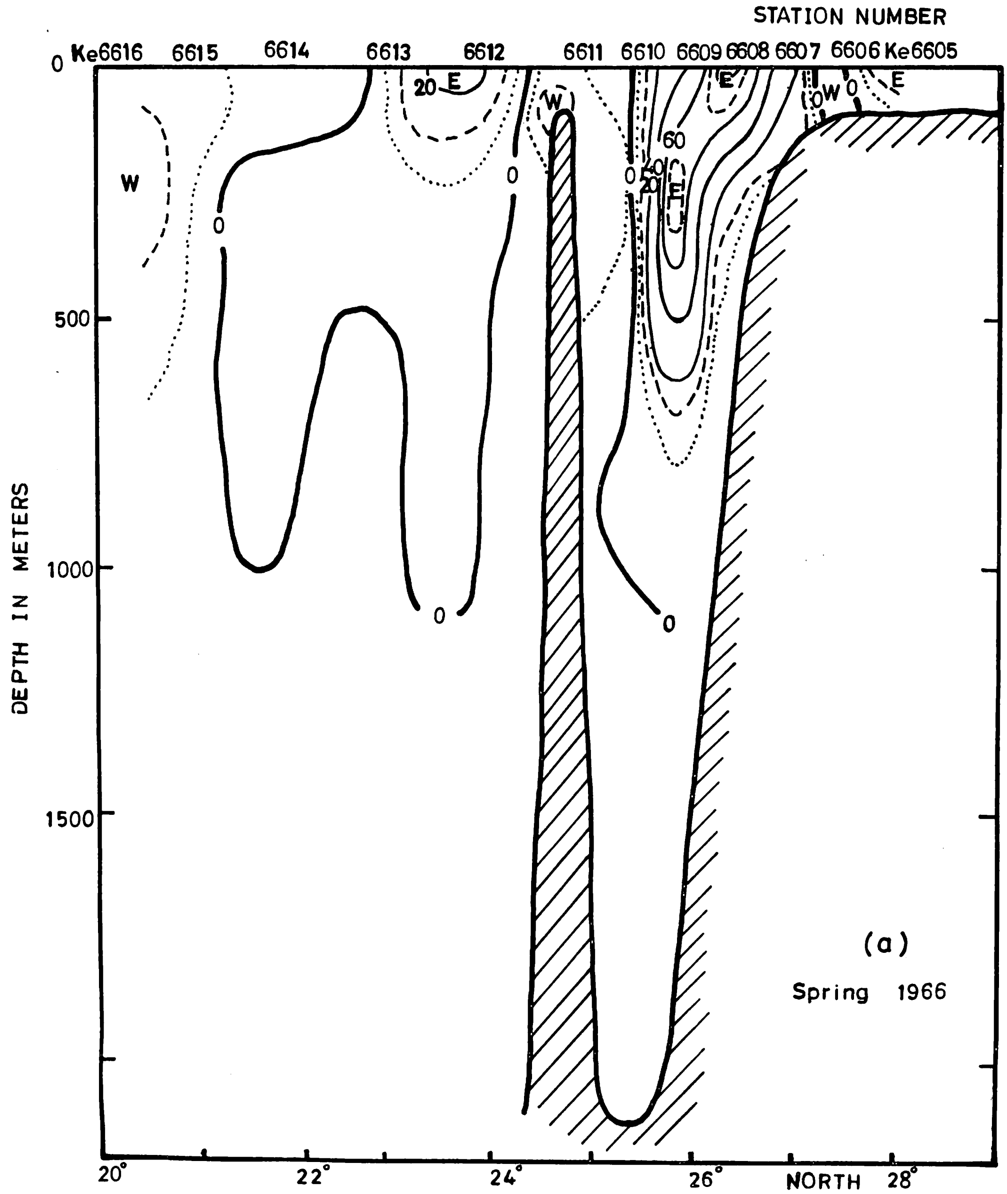

Fig. 5. The east-west component (cm/sec) of calculated relative current velocity across 125°E referred to 1,200 m in spring (a) and summer (b) of 1966. and in summer (c) of 1965.

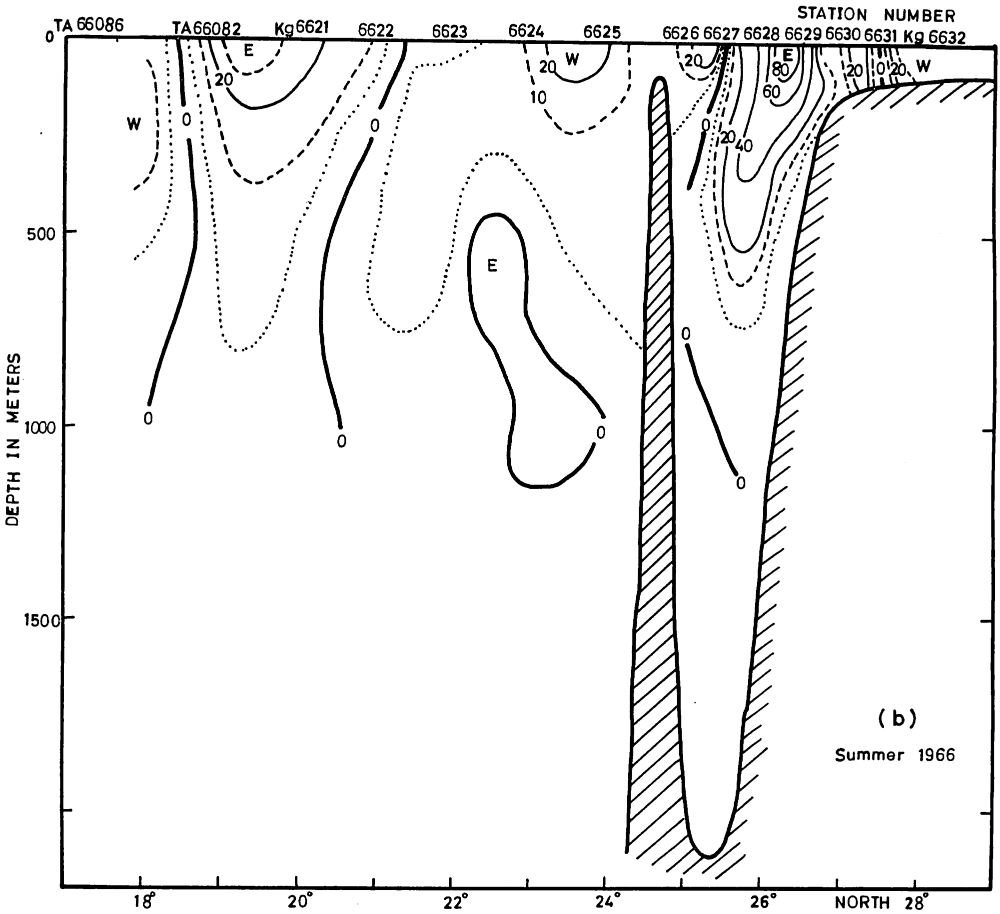

Fig. 5. (b)

speed nearly coincides with the observed fact. Thus the volume transport of the east component across the meridian of 125°E in spring and summer is estimated to be ca 31×10^6 m^3/sec and 28×10^6 m^3/sec respectively. The amount of the volume transport of the Kuroshio is a little larger in spring than that in summer. On the south of the Kuroshio, the current flows to the west near the submarine ridge and flows to the east again to further south of the submarine ridge. However, these two flows shift very much according to seasons or years, as shown in Fig. 5 (a), (b), and (c).

The eastward flow to the south of the submarine ridge may be a part of the Subtropical Counter Current, reported by Uda and Hasunuma (1967, unpublished), which is the geostrophic flow in the subtropical Western-North Pacific and is found during winter to spring having a current speed of ca 40 cm/sec and ca one-tenth of the volume transport of the Kuroshio. Voorhis and Hersey (1964) find the similar eastward flow associating with thermal fronts in the southern Sargasso Sea. Besides these observed facts, Yoshida and

Kidokoro (1967) indicate the relatively narrow eastward flow in subtropical latitudes over the world oceans during winter and spring by the calculations based on the distribution of surface wind stress. According to Fig. 5, the eastward flow across 125°E is situated at just south of the submarine ridge (23°–24°N) in spring, and at the further south in summer (18°–21°N), corresponding approximately to the southern side of the upwelling. The eastward flow may be considered as the geostrophic current in reference to the declination

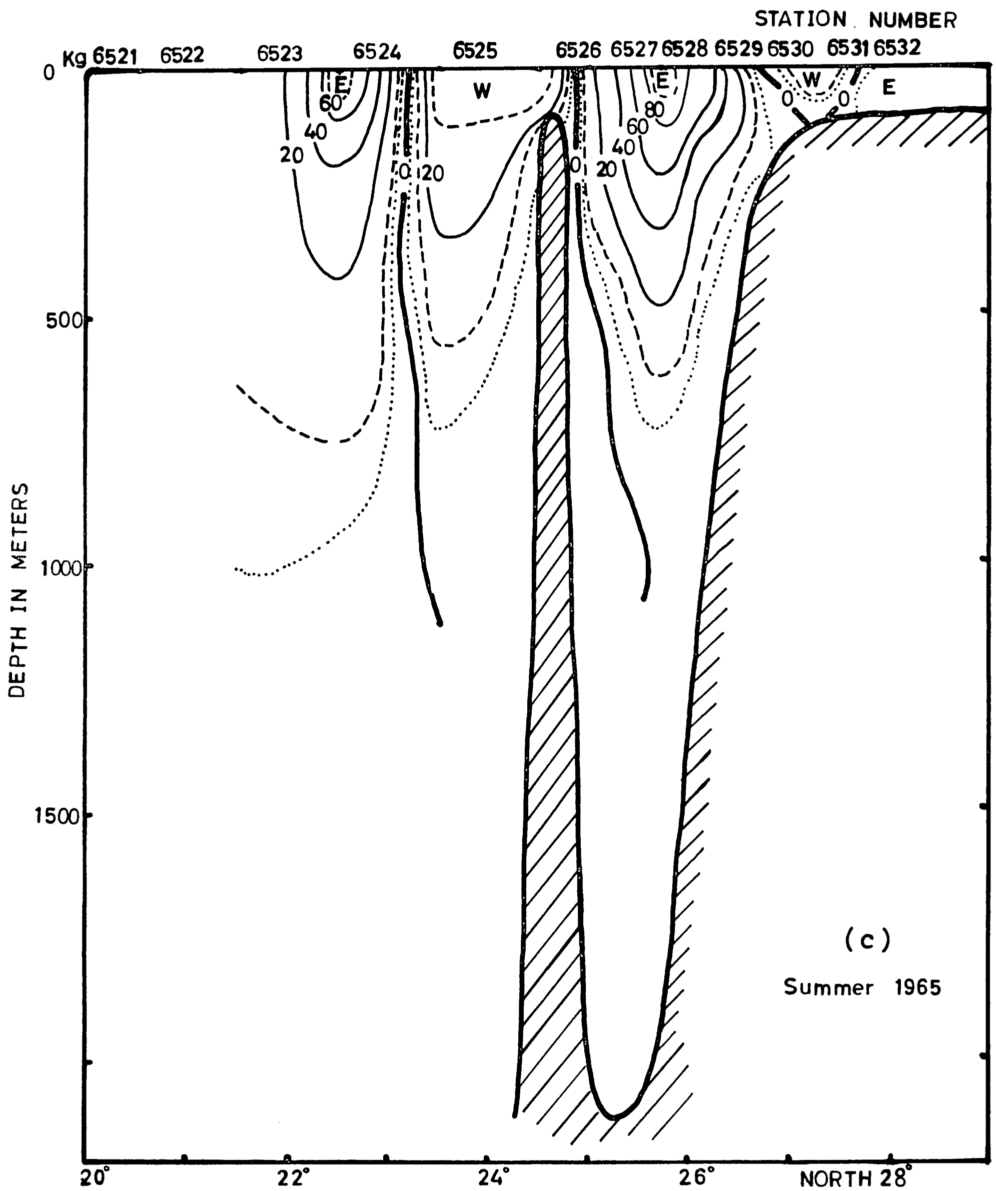

Fig. 5. (c)

of the isotherms. The maximum current speed in spring and summer of 1966 is ca 20 cm/sec and ca 30 cm/sec or more respectively, and the volume transport ca 8×10^6 m^3/sec in spring and ca 20×10^6 m^3/sec in summer. In summer of 1965 it is so strong that the maximum speed is ca 70 cm/sec at the surface and the volume transport is ca 30×10^6 m^3/sec, which is nearly equal to that of the Kuroshio. The amount of the transport of the eastward flow is quite large compared with that presented by Uda and Hasunuma, especially in summer.

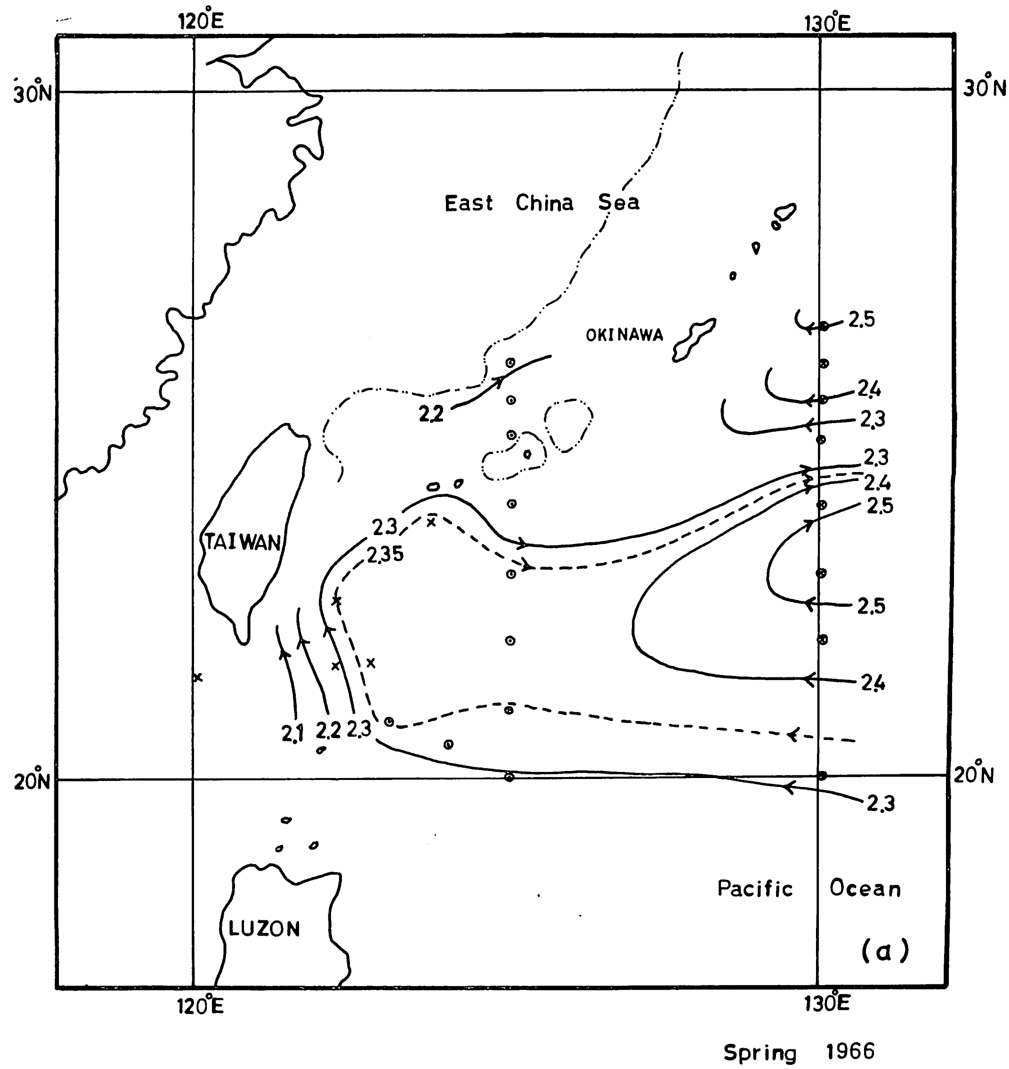

Fig. 6. Dynamic topography of the sea surface referred to 1,200 m depth in spring (a) and summer (b) of 1966, and in summer (c) of 1965. Approximate current direction indicated by arrows. Symbols of stations; circles including dots, Keiten-maru; circles, Kagoshima-maru; circles including crosses, G. Nevelskoy; crosses, Yang Ming; duble circles, TAKUYO; squares, Chofu-maru; triangles, Uliana Geomova.

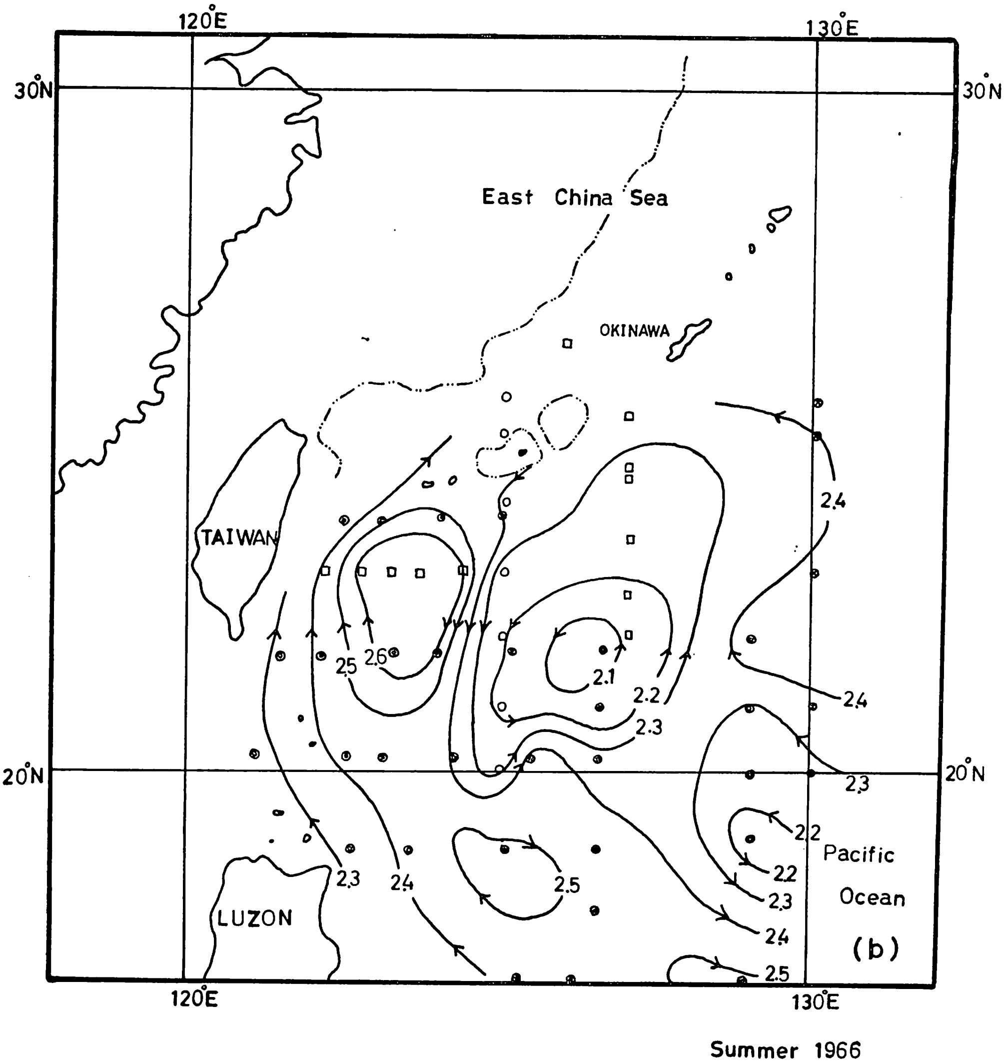

Fig 6. (b)

On the bases of CSK data for spring (March, April) and summer (July, August, early in September) of 1966 and for summer (July, August, early in September) of 1965 (Data Report of CSK), the dynamic topography of the sea surface referred to 1,200m depth in the region under consideration is shown in Fig. 6 (a), (b), and (c) respectively. The charts of dynamic topography show that the cyclonic and anticyclonic vortices exist at the right hand boundary of the Kuroshio, though they are not conspicuous in spring, due to perhaps insufficiency of data compared with those in summer. It is already indicated by Nitani (1961) that vortices exist at the western boundary region of the North Pacific and that the cyclonic and anticyclonic vortices correspond to cold and warm areas respectively. However, the current patterns are considerably different one another. In spring the eastward

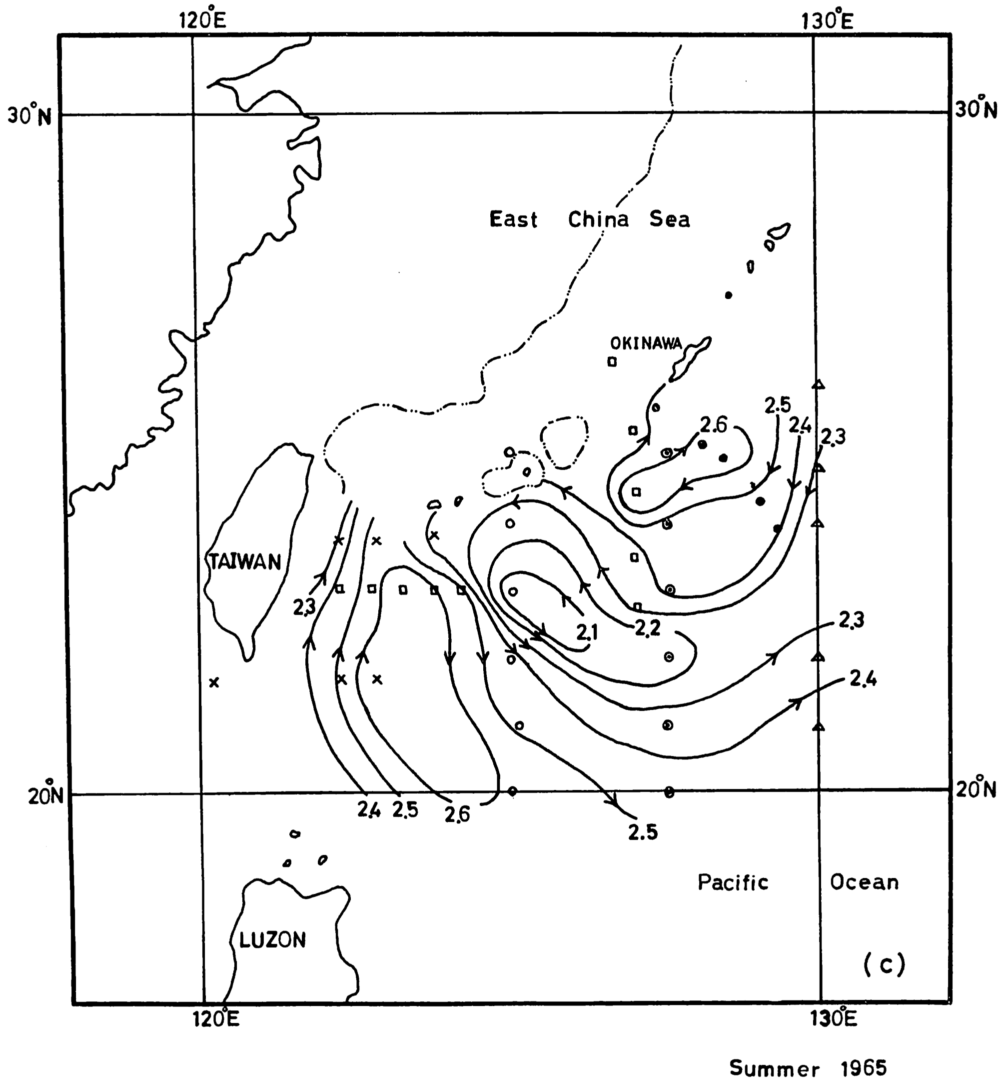

Fig. 6. (c)

flow to the just south of the submarine ridge proceeds to the further east in relatively narrow zone (Fig. 6 (a)), while in summer the eastward flow is situated on the southern side of the cyclonic vortex to the further south of the submarine ridge (Fig. 6 (b) (c)). The inner part of the cyclonic vortex circulates around and the outer part proceeds to the further east with remarkable meandering. The aspect of the eastward flow is expected to be variable very much in connection with the conditions of upwelling and of the vortices.

6. Conclusion

The oceanographic description along the meridian of 125°E in spring and summer of

1966 is presented, based on oceanographic data of the Keiten-maru and the Kagoshima-maru cruises for CSK in April and August respectively and the additional data of other vessels participating to CSK.

Temperature in spring is almost uniform vertically on the continental shelf, and the surface temperature increases abruptly near the edge of the continental shelf, forming a front. In summer the well-mixed surface layer and thermocline are appreciable to the north of ca 29°N. In the region between the edge of the continental shelf and submarine ridge, a warm core is remarkable in spring, on the north of which the maximum slope of isotherms is found. They are less marked in summer. On the south of the submarine ridge, upwelling towards the surface is found in spring and is not appreciable in summer.

Two salinity minima are found on the continental shelf in both seasons, though the numerical values are somewhat different. A tonguelike protuberance of subsurface salinity maximum extends to the north from the tropical area, part of which creeps further to the north on the continental shelf, especially in summer. The salinity of the surface excluding a region on the continental shelf and of the subsurface maximum is ca 0.3‰ and 0.1‰ lower in summer than that in spring respectively. The maximum declination of isohalines below the subsurface salinity maximum over the continental slope is less in summer than in spring.

Temperature-salinity relation at the edge of the continental shelf shows different stratification according to season, upper oceanic water in spring and lower oceanic water in summer.

The current structure in spring and summer is shown by the geostrophic relative current referred to 1,200 m depth in the vertical section. The eastward flow over the continental slope across 125°E indicates the Kuroshio. It is narrower and deeper in spring than in summer. The eastward volume transport of the Kuroshio referred to 1,200m in spring and summer is estimated to be ca 31×10^6 m^3/sec and 28×10^6 m^3/sec respectively. On the south of the Kuroshio, the current flows to the west near the submarine ridge, and flows to the east again to the further south of the submarine ridge. These two flows shift very much according to seasons or years, and their volume transports are variable also. The eastward flow to the south of the submarine ridge across 125°E may be the starting portion of the Subtropical Counter Current. The charts of dynamic topography show that cyclonic and anticyclonic vortices exist and that the outer part of cyclonic vortex proceeds to the further east with meander.

The authors wish to express their hearty thanks to Capt. S. Ueda, Kagoshima-maru, and his crew, and to Capt. T. Henmi, Keiten-maru, and his crew, for their works in observations on the sea.

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