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OCEANOGRAPHIC CONDITIONS OF THE AUSTRALASIAN SECTOR OF THE SOUTHERN OCEAN IN THE SUMMER OF 1983–84

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Abstract: Oceanographic conditions were examined along two meridional sections of 150 and 115°E in the Australasian sector of the Southern Ocean during the summer of 1983–84. Three major oceanic fronts were identified in these sections, *i.e.*, the Subtropical Convergence, the Subantarctic Front and the Polar Front. The vertical features of these fronts were identified by temperature, salinity, dissolved oxygen and some nutrient salts. The Subtropical Convergence was at 47°S along 150°E and 43.5°S along 115°E. The Subantarctic Front was at 49°S along 150°E and 47.5°S along 115°E. The Polar Front was at 56.5°S along 150°E and 55°S along 115°E. The geostrophic flow relative to 2000 db was calculated for both sections. The maximum valocity was 18 cm/s at the surface between 45 and 47.5°S along 115°E. The direction of the flow was mainly eastward for both sections. The volume transport was about 88×10^6 m^3/s between 45 and 65°S along 150°E and 105×10^6 m^3/s between 40 and 65°S along 115°E.

1. Introduction

Recently, a number of oceanographical observations were made in the Australasian sector of the Southern Ocean by various institutes and agencies of Australia, Japan and other nations. Especially, as part of the program of FIBEX (First International BIOMASS Experiments), similar sections were taken by the Training and Research Ship UMITAKA MARU III of Tokyo University of Fisheries, from December 1980 to February 1981, and MATSUURA *et al.* (1982) reported the identifications of the watermass structures and the oceanic fronts.

Research activities by R. V. HAKUHO MARU of Ocean Research Institute, University of Tokyo, were conducted in the Southern Ocean south of Australia during the austral summer of 1983–1984 as part of the SIBEX (Second International BIOMASS Experiments). This cruise is named KH-83-4. It is the purpose of this paper to describe the oceanographical conditions and to point out the location of the oceanic fronts for the biological studies.

2. Materials and Methods

Two observation lines were taken along the meridian of 150 and 115°E between 40 and 65°S. The two lines were named Section I for the eastern line and Section II for the western one, respectively. On Section I, 27 XBT (to 800 m depth) and 10 CTDO

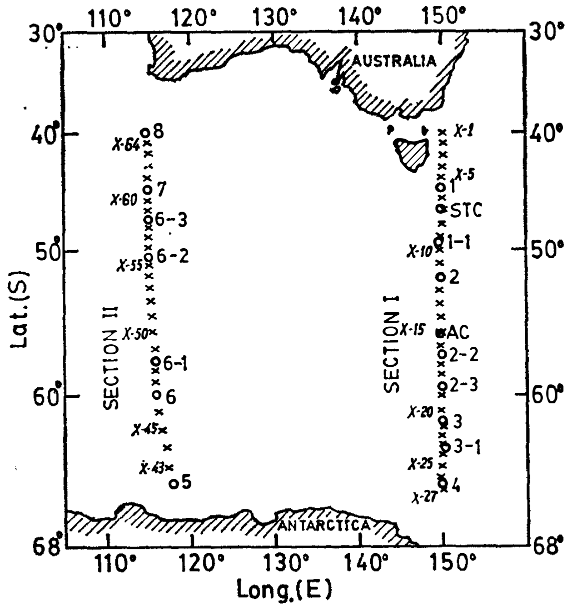

Fig. 1. Oceanographic stations and sections of the KH-83-4 cruise of the HAKUHO MARU during a period from December 11, 1983 to January 31, 1984. Open circles and crosses show CTDO and XBT stations, respectively.

(to 2000 m depth) observations were made from December 11, 1983 to January 2, 1984. On Section II, 22 XBT and 7 CTDO observations were made from January 18 to 31, 1984. Locations of the stations are given in Fig. 1.

The CTDO system (Neil Brown MARK III-B) was equipped with a Rosette Multi-sampler (General Oceanics 1010–5×24). Salinity (practical salinity) of the sampled water was measured with a salinometer (Guildline Autosal 8400A), and the dissolved oxygen was analyzed by the Winkler Method. These data were used for the correction of the data taken with CTDO. The concentrations of phosphate, silicate, nitrate and nitrite were measured using an AutoAnalyzer (Technicon AA-II). On Section I, serial observations were also made using 23 *l* Niskin samplers in layers between the depths of 2000 and 4000 m. Surface temperature and salinity were observed continuously with a thermo-salinograph (Union Denshi, ST-MK-15). The temperature analysis was made from the data of CTDO, XBT, thermo-salinograph and reversing thermometer.

3. Results and Discussions

3.1. Temperature and salinity

3.1.1. Section I

Figures 2a and 3a show the temperature and the salinity profiles along Section I, respectively. A steep gradient of the surface temperature was observed around 56.5°S, and the northern limit of subsurface temperature minimum (about 2°C) was seen at 200 m depth in the same area. These features show that the Polar Front is located around 56.5°S in Section I. The area south of the Polar Front is called the Antarctic Zone. The Antarctic Surface Water, which is represented by the temperature lower than 2°C and the salinity less than 34.0, covered this area. In this area, the temperature minimum layer became gradually shallower southward from the depth of 200 m around the Polar Front to 50 m in the vicinity of 65°S. Below the Antarctic Surface Water, the Circumpolar Deep Water characterized by the temperature maximum more

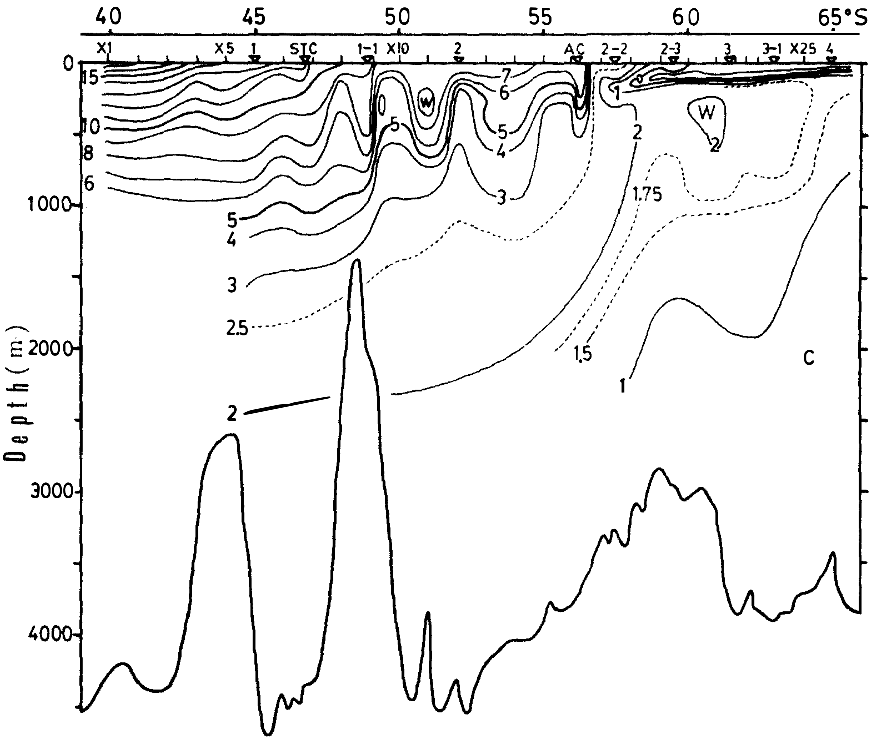

Fig. 2a. Vertical section of temperature (°C) along 150° E.

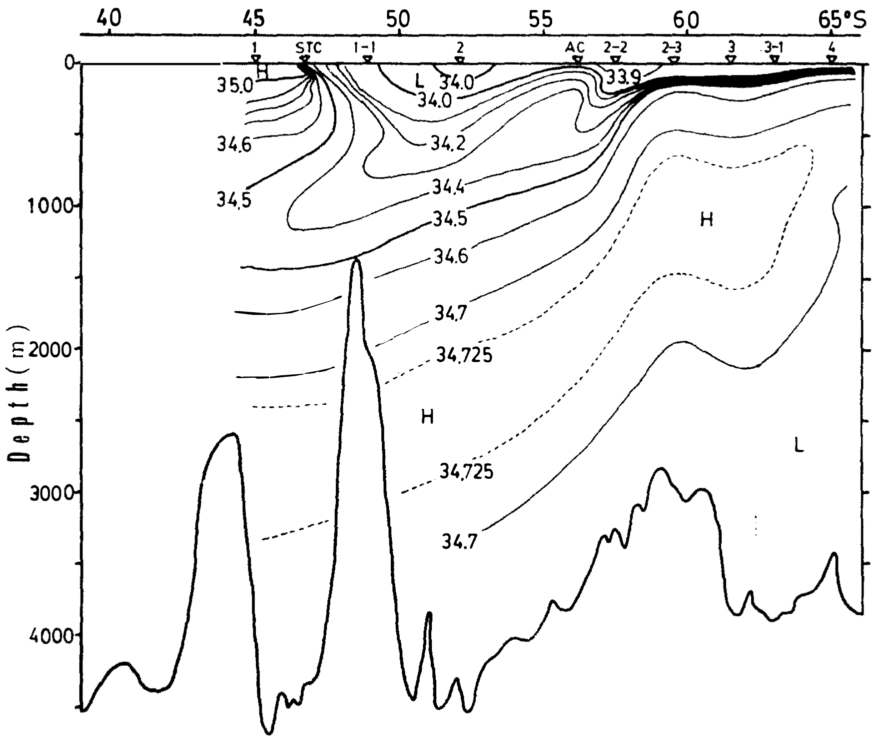

Fig. 3a. Vertical section of salinity along 150° E.

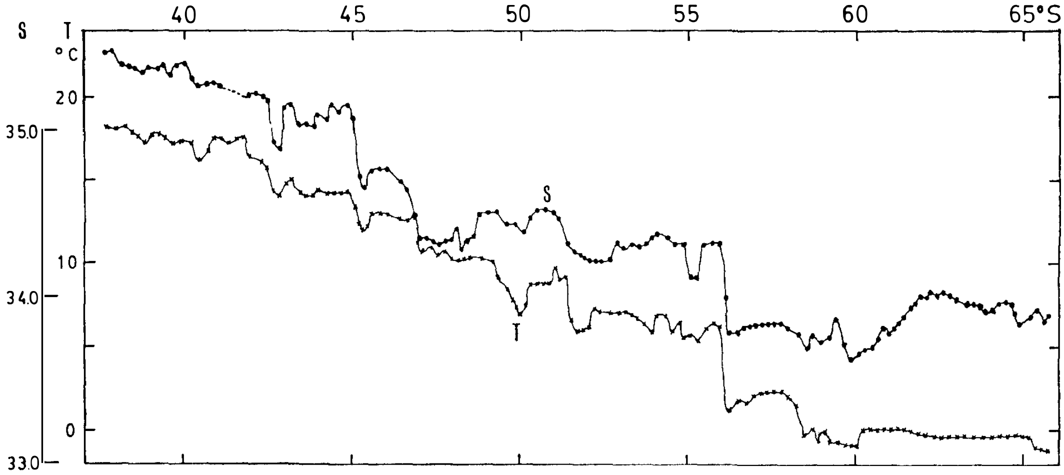

Fig. 4a. Sea surface temperature and salinity along 150°E.

than 1.5°C and the salinity maximum more than 34.7 occupied thickly and it extended down to a depth of nearly 3000 m in the region of the Polar Front.

Around 49°S, a steep horizontal temperature gradient was found in the layer between the depths of 200 and 1000 m. We identify these structures as the Subantarctic Front. The area between the Subantarctic Front and the Polar Front is called the Antarctic Polar Frontal Zone or the Complex Zone (EMERY, 1977). Several meso-scale (200–300 km) features in the horizontal distribution of temperature were seen in the upper 1000 m layer (Fig. 2a). EDWARD and EMERY (1982) reported that the same phenomenon was found frequently in this area. The Antarctic Intermediate Water represented by relative low salinity extends northward like a tongue from the upper layer to the mid-layer (Fig. 3a) and is distributed widely in the South Pacific Ocean and the Indian Ocean (REID, 1965).

A steep front of both surface salinity and temperature was found at 47°S (Figs. 2a, 3a and 4a). This front was marked as a southern limit of surface saline water which is called the Subtropical Surface Water characterized by a high salinity value more than 35.0. Thus, this front was identified as the Subtropical Convergence. The area between the Subtropical Convergence and the Subantarctic Front is called the Subantarctic Zone.

3.1.2. Section II

Figures 2b and 3b show the temperature and the salinity profiles along Section II, respectively. No distinct surface temperature gradient was observed (Fig. 2b), so it was difficult to define the Polar Front exactly. However, the subsurface cold water which seems to have originated around 65°S or more south had a break around 55°S at the 200 m depth. The Antarctic Circumpolar Deep Water was observed at the depth below 1000 m at least in the south of 55°S. These features were consistent with those in Section I (Fig. 2a). Thus, the Polar Front is located probably around 55°S in Section II. The patch-like structures of the cold water between 50 and 55°S might have resulted from the meso-scale eddies or double fronts activity as discussed by GORDON (1971, 1972).

Around 47.5°S, the isotherms between 8 and 3°C showed that there was a steep horizontal temperature gradient at the depth between 200 and 1000 m (Fig. 2b), indicating that the Subantarctic Front was located around 47.5°S. The salinity minimum

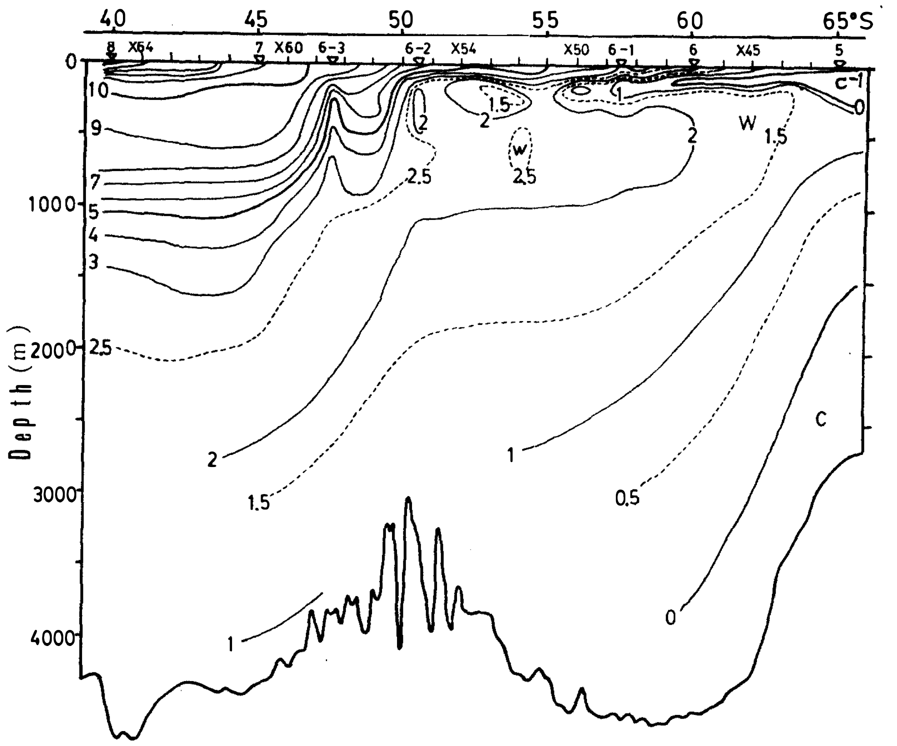

Fig. 2b. Vertical section of temperature (°C) along 115°E.

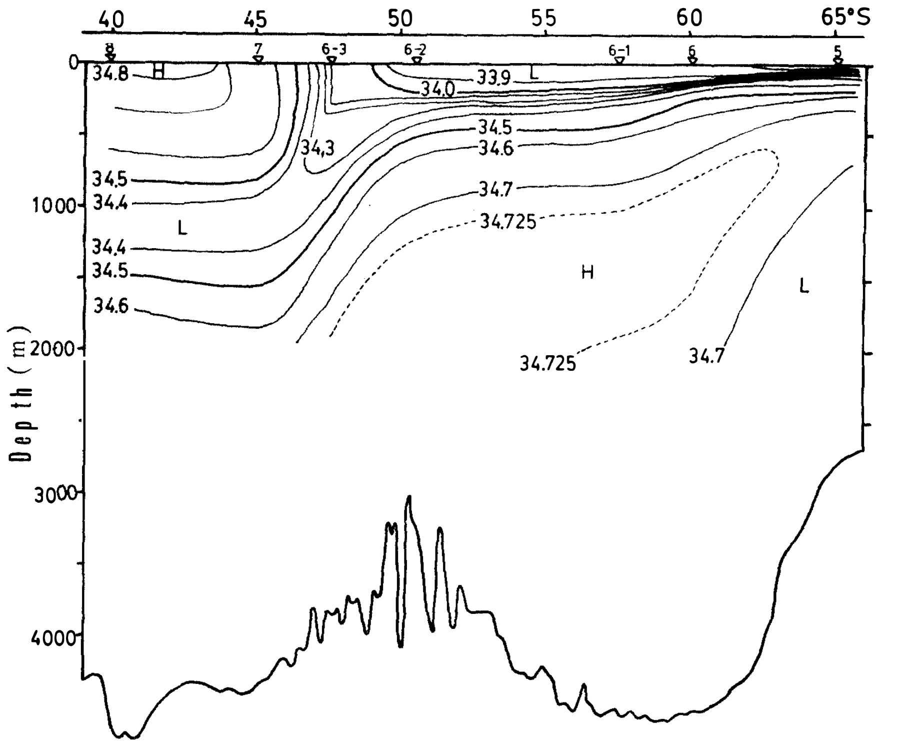

Fig. 3b. Vertical section of salinity along 115°E.

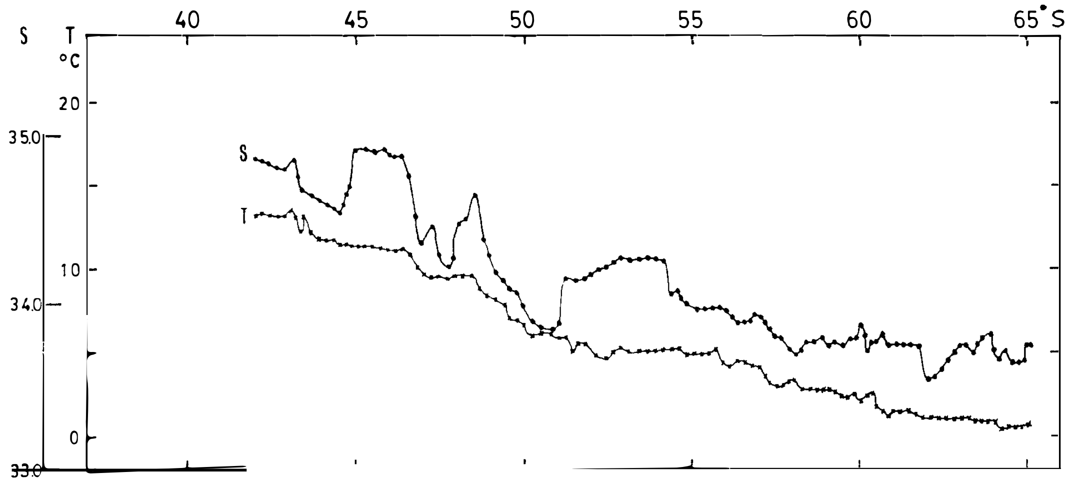

Fig. 4b. Sea surface temperature and salinity along 115°E.

layer originated in the region between the Subantarctic Front and the Polar Front, showing a resemblance to Section I.

The isotherms of 12 and 13°C intersected the sea surface between the XBT stations of X61 and X62 (Fig. 2b), showing the surface temperature gradient around 43.5°S. In Section I, the Subtropical Convergence was identified clearly (Figs. 2a, 3a and 4a). However, in the case of Section II, no frontal structure was found in the salinity cross section (Fig. 3b). We observed only small gaps at 43°S in the surface salinity and temperature plots (Fig. 4b). So, we could not apply the same standard to find the Subtropical Convergence in Section II as in Section I. According to the surface temperature record (Fig. 4b), the gradient found around 43.5°S might be the Subtropical Convergence. However, more detailed observation of temperature and salinity is needed to describe the spatial structure of the Subtropical Convergence. There was a thermostad between the isotherms of 10 and 9°C around 45°S (Fig. 2b). The water in this

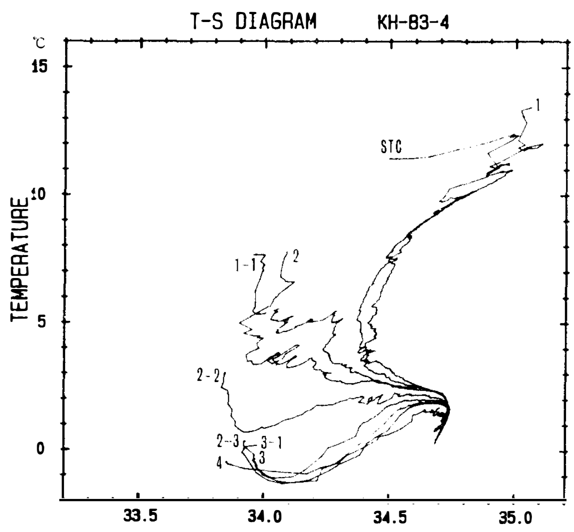

Fig. 5a. T-S diagrams at CTDO stations along 150°E.

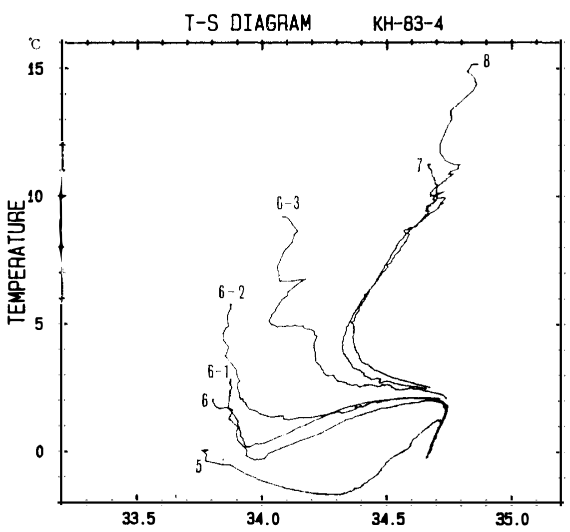

Fig. 5b. T-S diagrams at CTDO stations along 115°E.

thermostad is called the Subantarctic Mode Water (McCartney, 1977; Matsuura *et al.*, 1982).

3.1.3. T-S diagram

The T-S diagrams made from the CTDO data on Sections I and II are shown in Figs. 5a and 5b, respectively. The water around the salinity minimum (about 34.4) at Stns. 1 and STC in Section I (Fig. 5a) and at Stns. 7 and 8 in Section II (Fig. 5b) was identified as the Antarctic Intermediate Water. Stations STC and 7 are located very close to the Subtropical Convergence, and Stns. 1 and 8 in the north of the Subtropical Convergence. Stations 1–1, 2, 6–2 and 6–3 are located in the Antarctic Frontal Zone. At each of these stations the mixing of different waters took place, as seen in the rugged curves on the T-S diagrams. Other stations than mentioned above are located in the Antarctic Zone which is characterized by low temperature and low salinity.

The water characterized by the temperature between 1 and 2°C and by the salinity around 34.7 in the T-S diagrams was the Circumpolar Deep Water, and were observed at almost all stations.

3.2. *Dissolved oxygen*

In Section I (Fig. 6a), the dissolved oxygen content was comparatively high in the surface layer, especially in the south of the Polar Front, the values ranging from about 7 to 8 m*l*/*l*. The core of oxygen minimum less than 4 m*l*/*l* was found at the depth about 200–500 m in the Antarctic Zone. In the north of the Polar Front, the core steeply sank from 500 to 1000 m and gradually became deeper northerly. This oxygen-minimum layer coincided with the upper part of the Antarctic Circumpolar Deep Water.

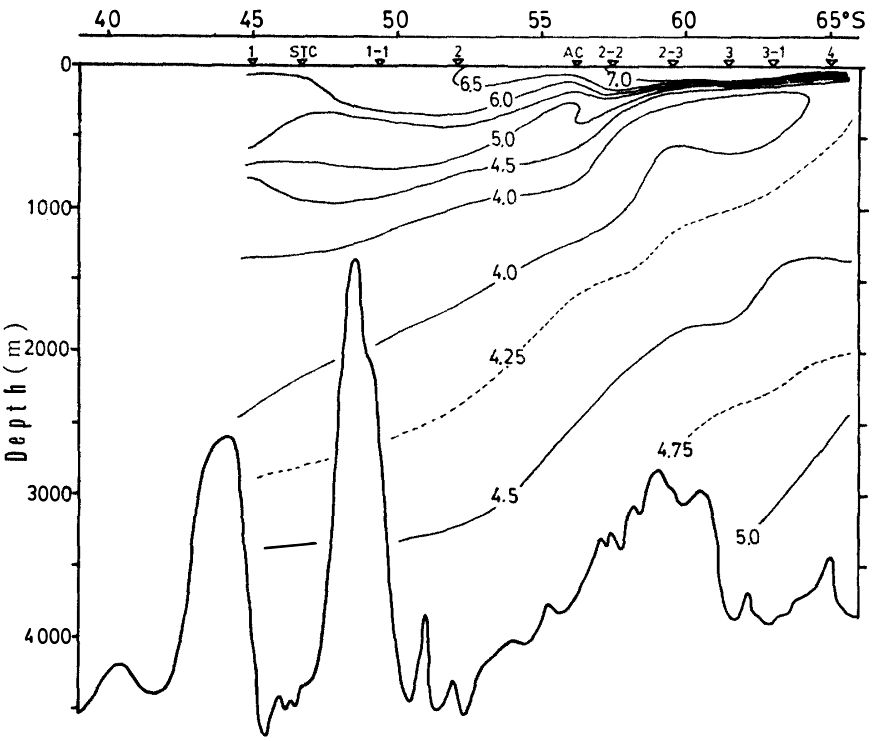

Fig. 6a. Vertical section of dissolved oxygen (ml/l) along 150°E.

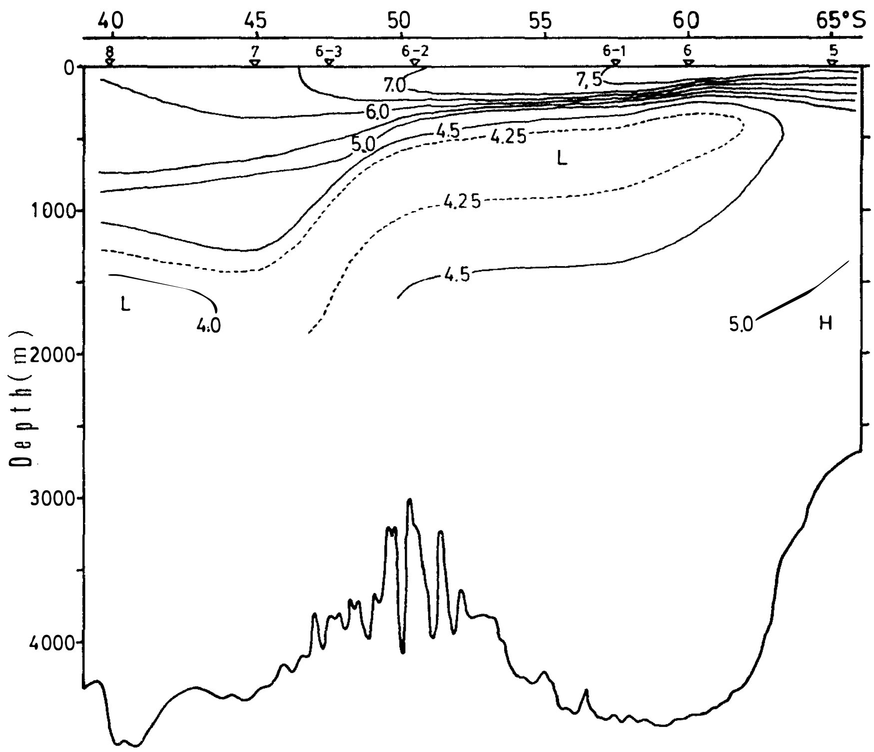

Fig. 6b. Vertical section of dissolved oxygen (ml/l) along 115°E.

In Section II (Fig. 6b), the dissolved oxygen content of the surface layer was higher than that in Section I. Water with oxygen content above 7 m*l*/*l* extended northward as far as 50°S. The dissolved oxygen minimum layer lay thickly in the upper part of the Antarctic Circumpolar Deep Water.

In Figs. 6a and 6b, water with dissolved oxygen content higher than 5 m*l*/*l* lies below 2500 and 1500 m at 65°S, respectively. It might have resulted from the influence of the Antarctic Bottom Water sinking along the Antarctic Continental Shelf, but the details of this phenomenon are not clear.

3.3. Nutrient salts

In the surface water of Section I (Fig. 7a), the concentration of inorganic phosphate was high in the Antarctic Zone and was detected to be about 1.9 μg-at/*l*. The lowest value of 0.3 μg-at/*l* was found at Stn. 1 in the subtropical area. The phosphate concentration increased until some depth showing a peak. The concentration of silicate in the surface water increased southwardly from almost zero at Stn. 1 in the Subtropical Zone to more than 50 μg-at/*l* at Stn. 4 in the Antarctic Zone. The silicate concentration increased monotonously with depth to 2000 m. The concentration of nitrate also increased southwardly and with depth.

The general features of nutrient salts in Section II were similar to those in Section I (Fig. 7b). In the northern side of the Subtropical Convergence, nutrient salts were hardly detected in the surface water. On the contrary, those were very high in concentration in the southern side. The high concentrations of the nutrient salts around 65°S might have resulted from the upwelling in the Antarctic Divergence.

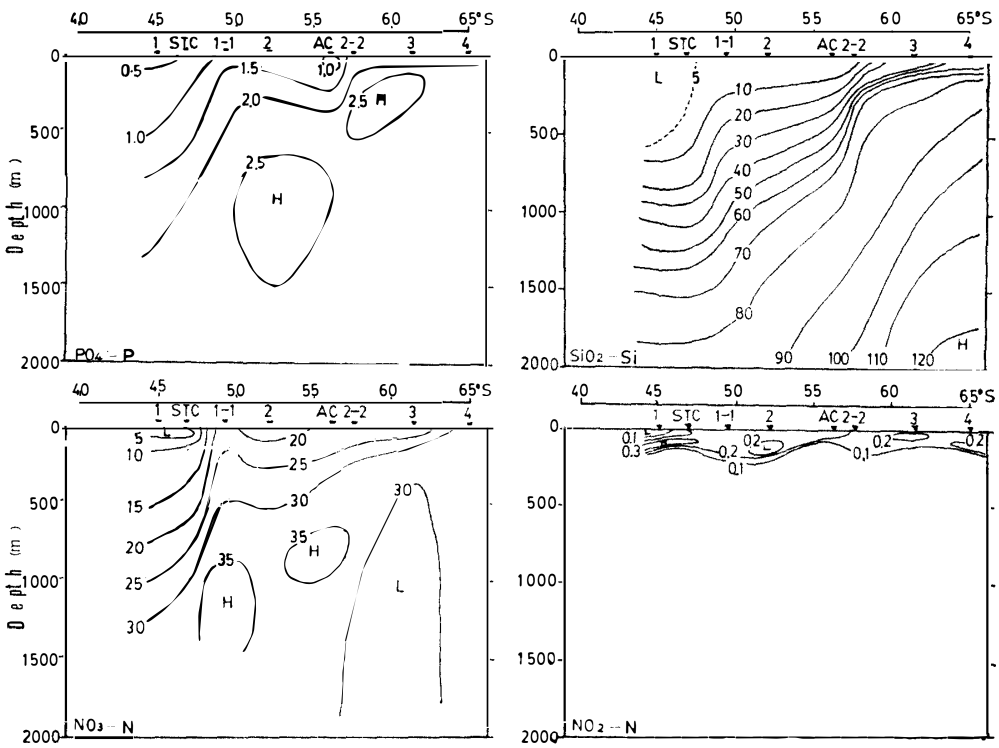

Fig. 7a. Vertical sections of nutrient salts (μg-at/l) along 150° E.

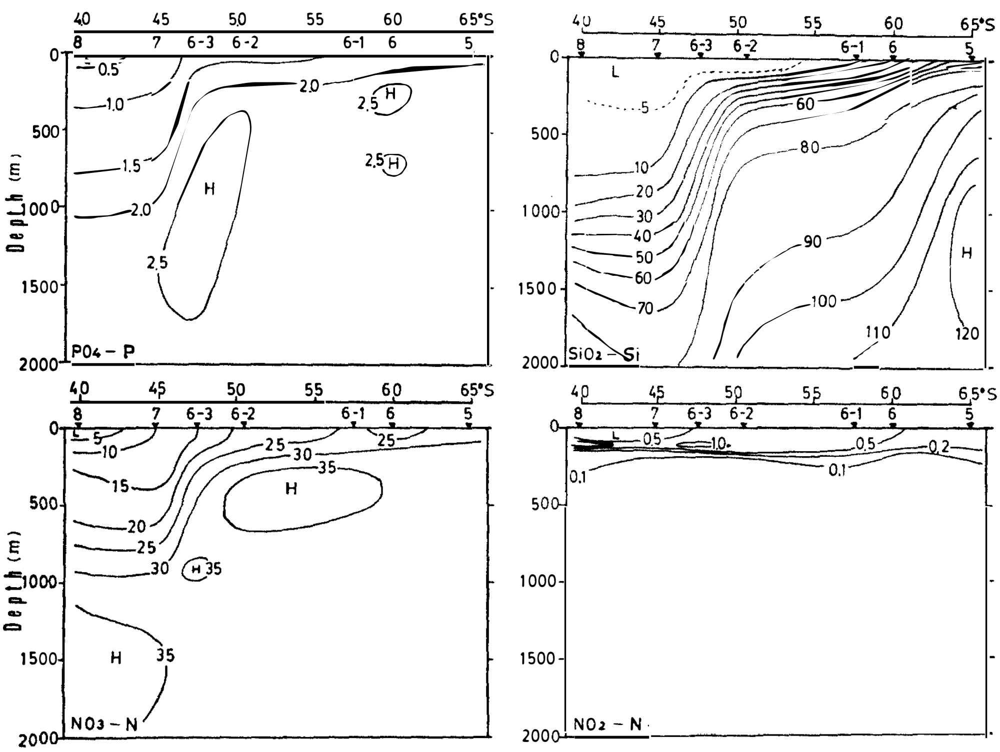

Fig. 7b. Vertical sections of nutrient salts (μg-at/l) along 115° E.

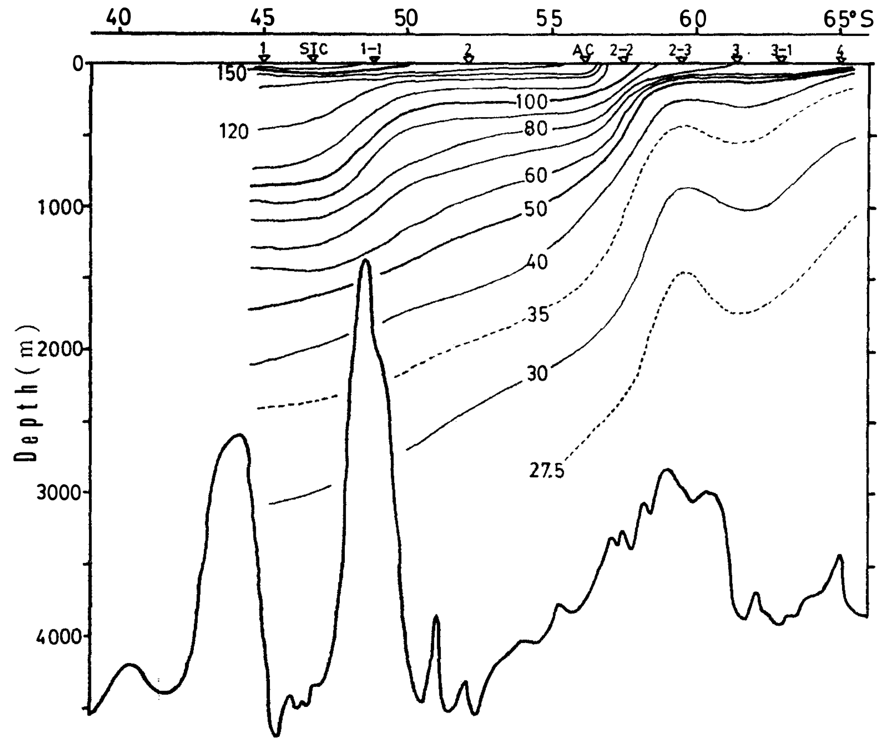

Fig. 8a. Vertical section of thermosteric anomaly (cl/t) along 150°E.

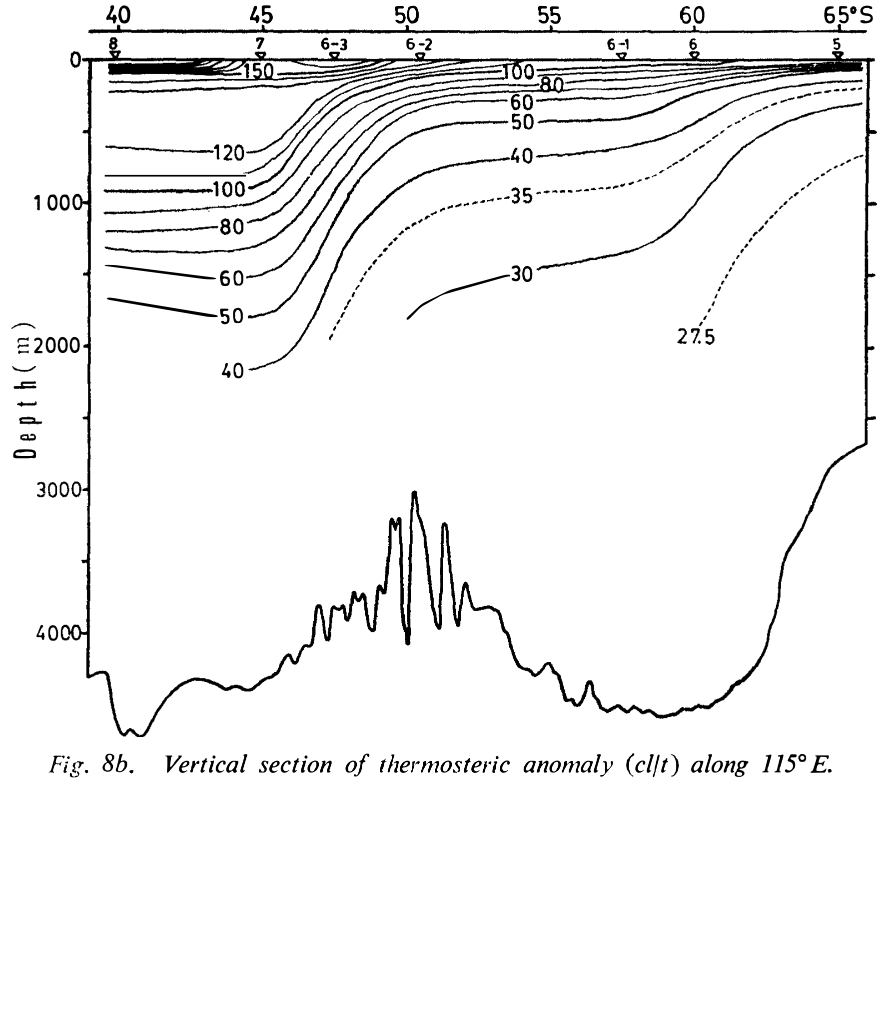

Fig. 8b. Vertical section of thermosteric anomaly (cl/t) along 115°E.

The nitrite in the surface water was comparatively rich between the Subtropical Convergence and the Polar Front in both sections. The peak concentration was formed at a depth of 50 to 100 m and the value was high in the Subtropical Zone.

3.4. Thermosteric anomaly and geostrophic flow

In Section I (Fig. 8a), the contours of thermosteric anomaly generally declined toward the north even in the layers deeper than 2000 m. So the direction of geostrophic flow was east, and the geostrophic current still existed at depths below 2000 m. In Section II, some isosteres were shallower than in Section I and were roughly arranged horizontally between the Subantarctic Front and the Polar Front (Fig. 8a). Within the temperature range in the present analysis, the thermosteric anomaly almost resulted from the functions of salinity. We found the same character as thermosteric anomaly in the salinity distributions (Figs. 2b and 3b).

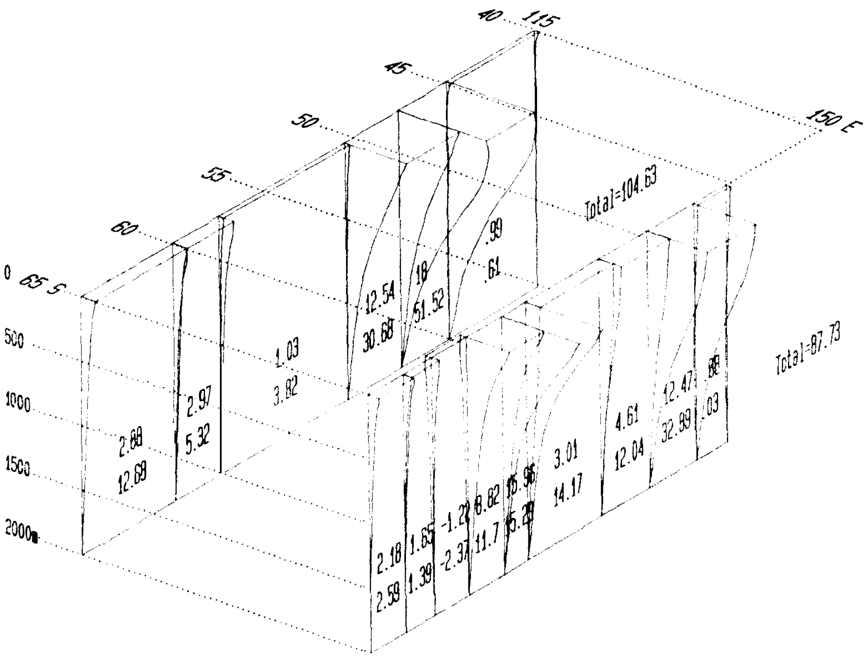

Fig. 9. Perspective diagram showing the geostrophic flow relative to 2000 db. Upper numeric: geostrophic velocity at surface (cm/s). Lower numeric: volume transport ($10^6 m^3/s$).

The geostrophic velocities and transports relative to 2000 db were calculated for both sections (Fig. 9). The geostrophic velocity depended in the reference level, and the level of 2000 db in the analysis was only for convenience. Maximum velocity was 18 cm/s at the surface between 45 and 47.5°S along 115°E. The direction of the flow was mainly eastward for both sections. The volume transports were about $88\times10^6 m^3/s$ between 45 and 65°S along 150°E and about $105\times10^6 m^3/s$ between 40 and 65°S along 115°E. In the vicinity of each major oceanic front, between 47 and 49°S and between 56 and 58°S along 150°E and between 45 and 50°S along 115°E, the current speed was higher than that in other regions. These phenomena seem to have been caused by the complicated bottom configuration, such as the Mcquarie Ridge, the Tasmania Ridge and the Mid-ocean Ridge. CALLAHAN (1971) and GORDON (1975) reported that the higher speed of current is found in the vicinities of the oceanic fronts, and they also showed the possibility that the bottom configuration accelerates the current speed.

3.5. Oceanic front

Three oceanic fronts, the Subtropical Convergence, the Subantarctic Front and the Antarctic Polar Front (Antarctic Convergence), were found in the Southern Ocean from the data of the KH-83-4 as follows:

	Section I	Section II
Subtropical Convergence	47°S	43.5°S
Subantarctic Front	49°S	47.5°S
Polar Front	56.5°S	55°S

The location of the Antarctic Divergence may be important for the biological studies because our analysis showed the high concentrations of nutrient salts in the Antarctic Zone near the Antarctic Divergence. However, it is rather difficult to point out the location clearly through the data of the present cruise.

Acknowledgments

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