Preliminary Report of the Oceanographical Observations of the Fifth Japanese Antarctic Research Expedition (1960-61)

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第5次南極地域観測隊海洋部門（物理関係）報告

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要　旨

第5次南極地域観測（1960年11月～1961年5月）において海洋部門の船上観測の一部としてBT観測および各層観測を行なった．BT観測は原則として，ケープタン・南極間は1日2回，その他においては1日1回行なった．各層観測は南極洋において7点，帰路のインド洋において2点行なった（Fig. 1）．これらの観測の結果はFigs. 2～7に示した通りであるが，本文においては，主として物理的海洋学の立場からこれらの観測結果を記述した．

Abstract

Bathythermograph and serial observations were performed on board the "SOYA" of the Japanese Antarctic Research Expedition (J.A.R.E.) as one of the research projects during the period of the expedition (Nov. 1960–May 1961). Bathythermograph observations were normally carried out once a day between Tokyo and Cape Town and twice a day between Cape Town and the Antarctic Region while the ship was at sea. Five hydrographic stations were occupied in the Antarctic Region, two after leaving the icy sea toward Cape Town and two in the northeastern part of the Indian Ocean on the way back to Singapore. Results of these observations are shown in the Figures and described mainly from the standpoint of physical oceanography.

Temperature distribution in upper layers observed by bathythermograph

a) South of Japan to the South China Sea 10 BT stations were occupied between south of Kyushu and Singapore on the going cruise and 8 on the return (Fig. 1). Fig. 2 shows the vertical temperature distribution in this section. The margin of the South China Sea is clearly defined by a remarkable temperature discontinuity in the Luzon Strait, where a strong narrow current flows northward which is the beginning of the Kuroshio. According to NITANI (1961), the speed of this northward current exceeds 2 knots at the surface, attaining to its maximum at the depth of 100–150 m, and it is hardly believable that any branch of the current enters the South China Sea across the Strait.

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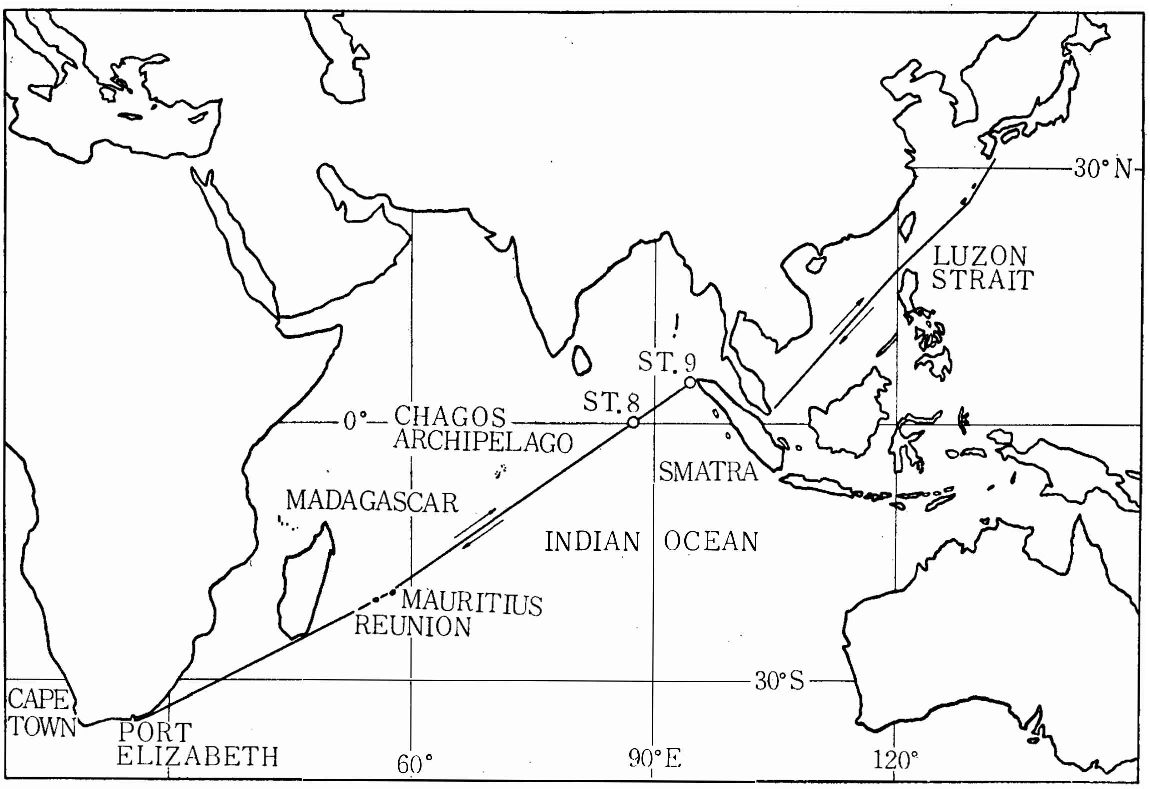
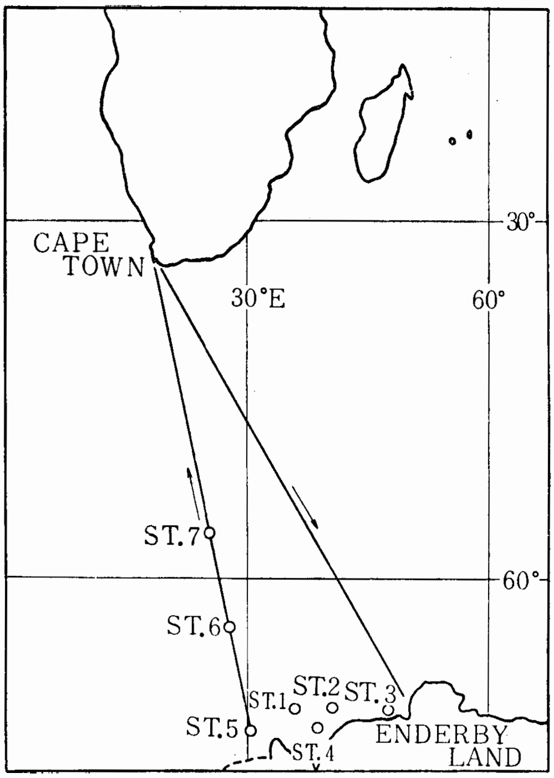
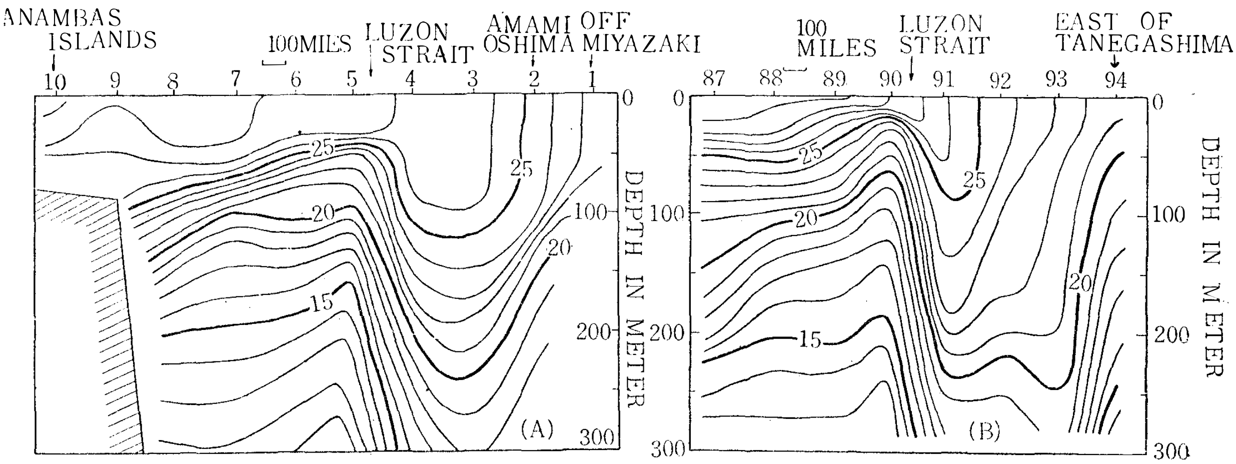




第 1 図 第 5 次南極観測における宗谷の航跡図 (○は各層観測点)

Fig. 1. Location of sections along which surface and bathythermograph observations were made by 5th Japanese Antarctic Research Expedition. November 1960-April 1961.
○: Hydrographic station.



第 2 図 BT による水温断面図. 日本南海-南支那海 A) 1960年11月, B) 1961年4月

Fig. 2. Temperature profile in upper layer observed by bathythermograph. South of Japan to South China Sea. A) November 1960. B) April 1961. Figures in °C.

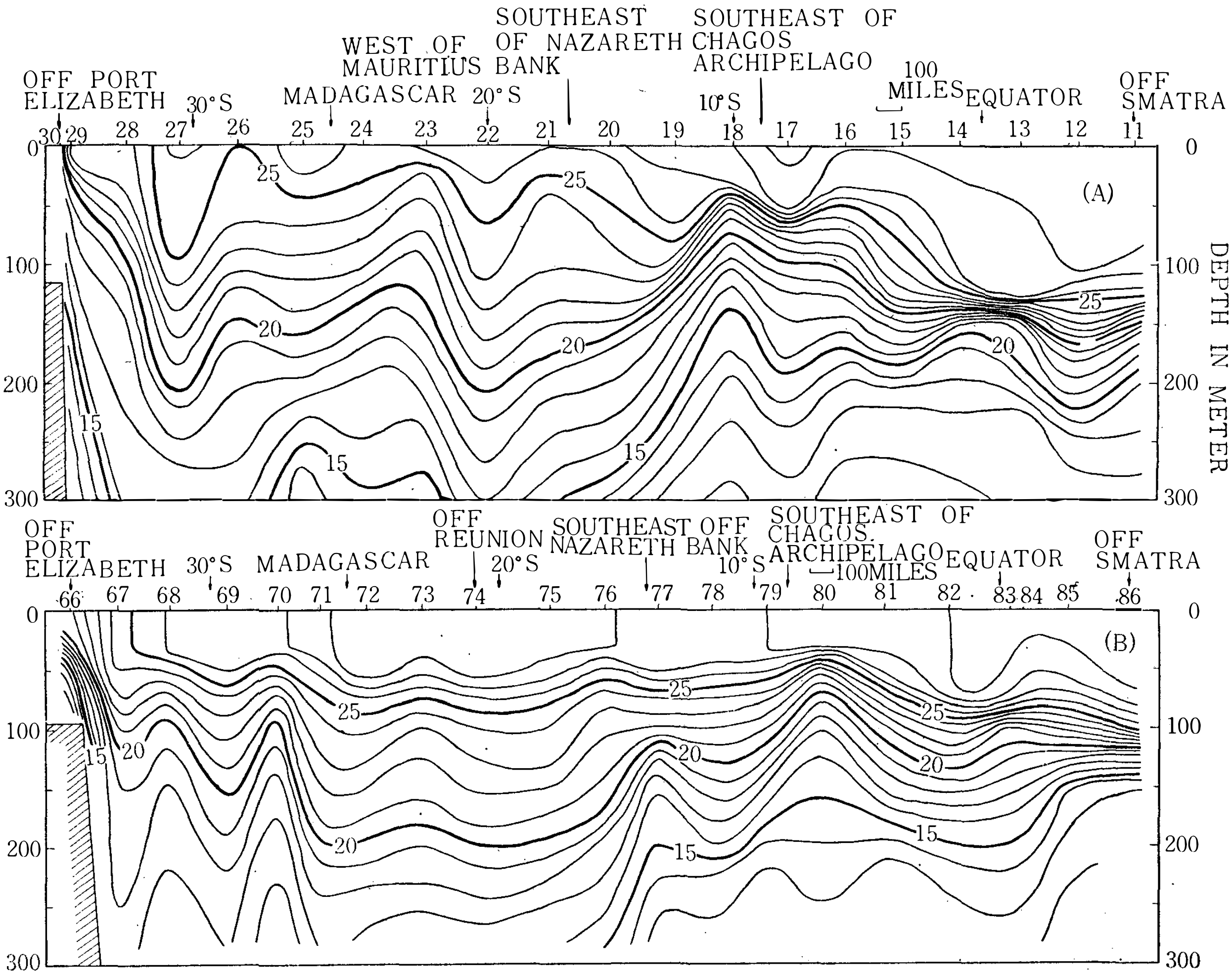
In the South China Sea the depth of the thermocline which corresponds to the 23°C isotherm changes from about 50 m near the Luzon Strait to about 100 m at 10°N in latitude to the southwest direction. Above the thermocline, the homogeneous water of about 28°C, on the average, extends to farther south where the water depth becomes shallower than 100 m. Below the thermocline, the temperature decreases almost linearly and lowers to about 11°C at the depth of 300 m. Isotherms rise near the Strait showing an upwelling feature, but this phenomenon is supposed to be limited to the upper layer according to the previous observation (NITANI, 1959). The Luzon Strait is considered to be the only place deep enough to permit the intermediate water to intercourse with the adjacent oceans (SVERDRUP, 1942); however, at the present time very little is known about water exchange through the strait owing to lack of sufficient observations.

Another abrupt change in temperature on the right hand side of Fig. 2 shows the Kuroshio flowing to the northeast off Kyushu after changing its direction along the west of the Riukiu Islands.

No essential difference in temperature distribution was observed in November 1960 and in April 1961 (Figs. 2A and B), however, it was noticed that the thermocline in the South China Sea was better defined in November 1960.

b) The Indian Ocean 19 BT observations were made in December 1960 and 21 in March and Aplil 1961 along the almost same section which acrosses the Indian Ocean from the north of Sumatra to the offing of Port Elizabeth, South Africa (Fig. 1). Fig. 3 shows the temperature distribution down to the depth of 300 m obtained from these observations.

Along the section, the temperature of the surface layer increases to the east from Port Elizabeth rather abruptly from around 20°C to about 25°C within a distance of about 200 miles. Farther northeast the temperature increases gradually to 29°C across



第 3 図 BT による水温断面図．インド洋 A) 1960年12月, B) 1961年3～4月

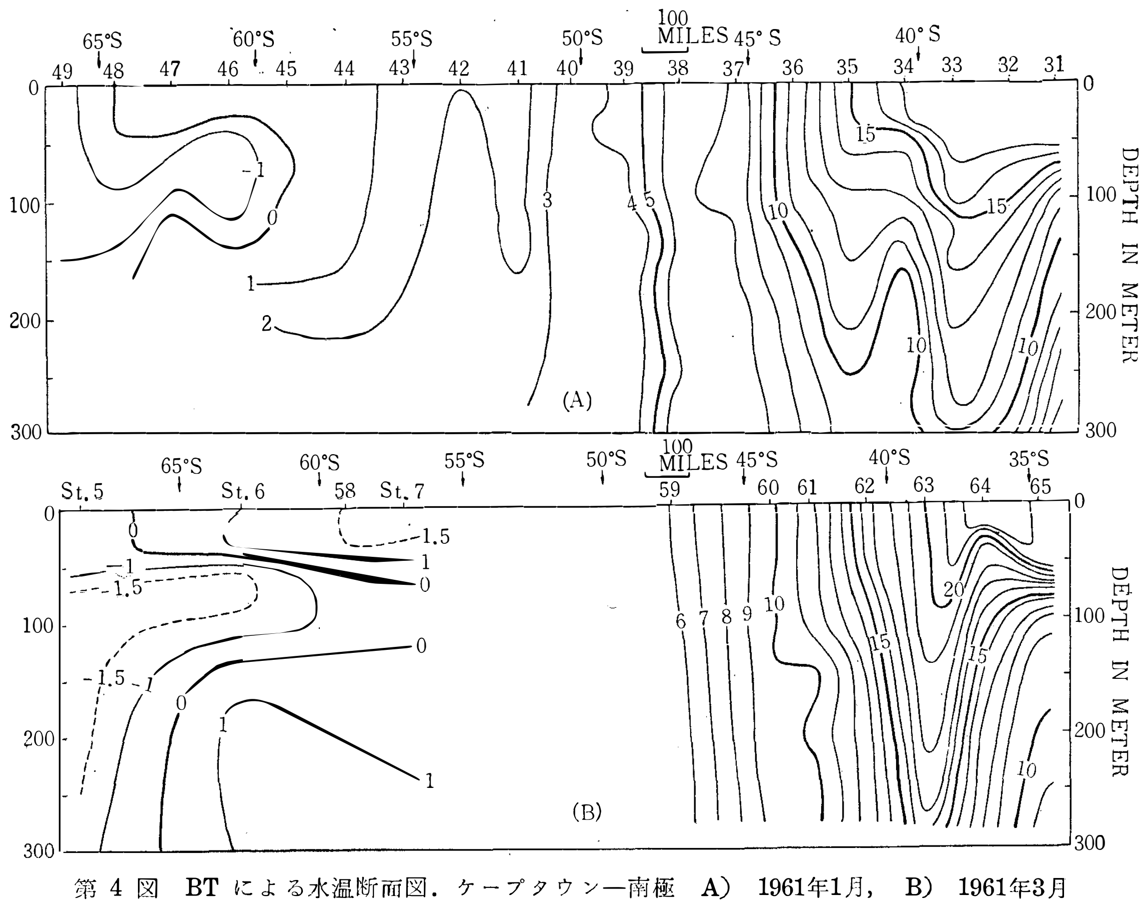
Fig. 3. Temperature profile in upper layer observed by bathythermograph. Indian Ocean. A) December 1960. B) March-April 1961. Figures in °C.

the Ocean. On the other hand, the temperature below 200 m is lower to the north and two fairly uniform water masses occur between 25°S and 15°S, and between 15°S and the equator, forming the Central Water and the Equatorial Water of the Indian Ocean, respectively (SVERDRUP, 1942). In the Equatorial Water region the thermocline is well developed, while the temperature in the Central region decreases almost linearly from the surface.

The change of the depth of thermocline is considered to depend on the current system which is subjected to seasonal variations by the monsoon in the northern part of the Indian Ocean (SVERDRUP, 1942, WYRTKI, 1957, YAMANAKA, 1959). However, no data were obtained during the period of prevailing monsoon. The shallowest part of the thermocline is found at the depth of about 60 m at about 8°S (75°E) which corresponds to the northern margin of the South Equatorial Current. The southern margin of the South Equatorial Current seems to be on the northern boundary of the Central Water (15°S). To the north of 8°S the thermocline lowers, indicating the existence of the Equatorial Countercurrent, having the northern boundary around 2°S. If there exists the North Equatorial Current to the north of the Countercurrent, the thermocline must rise at the Equator. According to SVERDRUP (1942), the North Equatorial Current is well developed during February and March and disappears in August—September. According to the present data, in December the thermocline is almost horizontal at the equator (Fig. 3A) and the North Equatorial current seems to be still absent, but in April there can be seen a little rise of the thermocline at the equator, indicating the existence of the North Equatorial Current at the depth of about 120 m, speed of which is supposed to be not very high.

The section between Madagascar and Port Elizabeth is in a nearly east-west direction. In this part of the section, an adrupt change in temperature within a short distance indicates that the Agulhas Current is well defined and is flowing to the south very close to the coast of South Africa. To the east of the Agulhas Current there exists a northward countercurrent. In March 1961 a southward current was observed near the west coast of south Madagascar. These currents between Madagascar and the Agulhas Current are probably subjected to considerable seasonal variations.

The temperature in the region of the Central Water Mass is higher in March than in December, while in the northern part no essential change in temperature distribution is recognized.



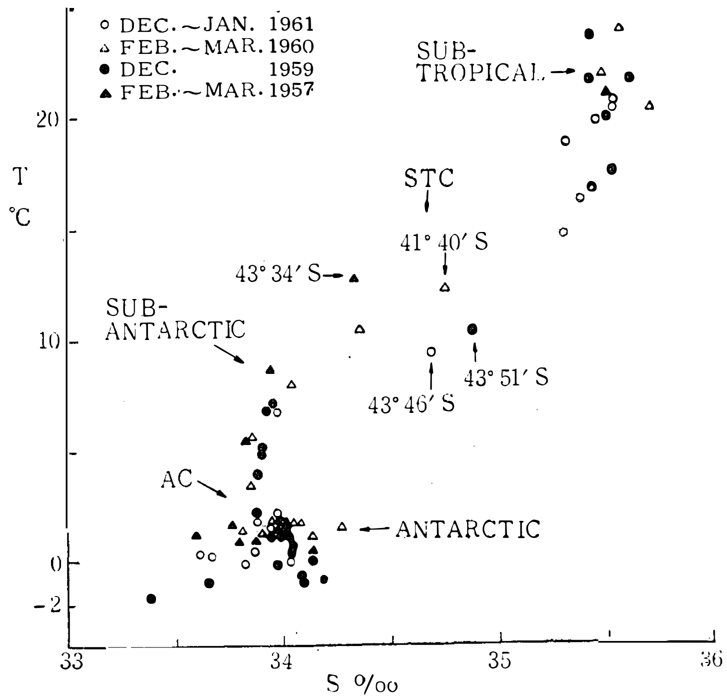
第 4 図 BT による水温断面図. ケープタウン—南極 A) 1961年1月, B) 1961年3月

Fig. 4. Temperature profile in upper layer observed by bathythermograph. Cape Town to Antarctica. A) January 1961. B) March 1961. Figures in °C.

c) Cape Town to Antarctica On the going cruise (Jan. 1961) BT observations were made twice a day along the section between Cape Town and off Endarby Land (50°E) (Figs. 1 and 4A). On the return cruise (March 1960) the section lied between off Riiser Larsen Peninsula (30°E) and Cape Town. In the latter section 3 serial observations and 1 BT observation were carried out in the south of 55°S, no observation was made between 55°S and 50°S because of a stormy weather, and in the north of 50°S BT observations were made twice a day until Cape Town is reached (Figs. 1 and 4B).

The temperature distribution down to 300 m obtained through these observations are shown in Fig. 4. The locations of the Sub-tropical Convergence estimated from these temperature distributions are about 43°S in Fig. 4A and 42°S in Fig. 4B, and that of the Antarctic Convergence is 51°S in Fig. 4A at the surface, respectively. In the north of the Antarctic Convergence the isotherms run almost vertically showing a great horizontal variation, although the vertical scales have been greatly exaggerated.

More than 20 years ago the Discovery Expedition made a complete survey of the sea around Antarctica including the section which we have covered, and the data was analysed and reported by DEACON (1937) and SVERDRUP (1933) in the Discovery Report, which is still considered a standard work on the southern ocean. DEACON states in the report that the main part of the Agulhas Current turns back to the east in the southeast of the Cape of Good Hope (22°E) and other part possibly flows to the west into the Atlantic Ocean. In our observation the turning back of the Agulhas Current was not confirmed; however, in Fig. 4 we can see a subsurface



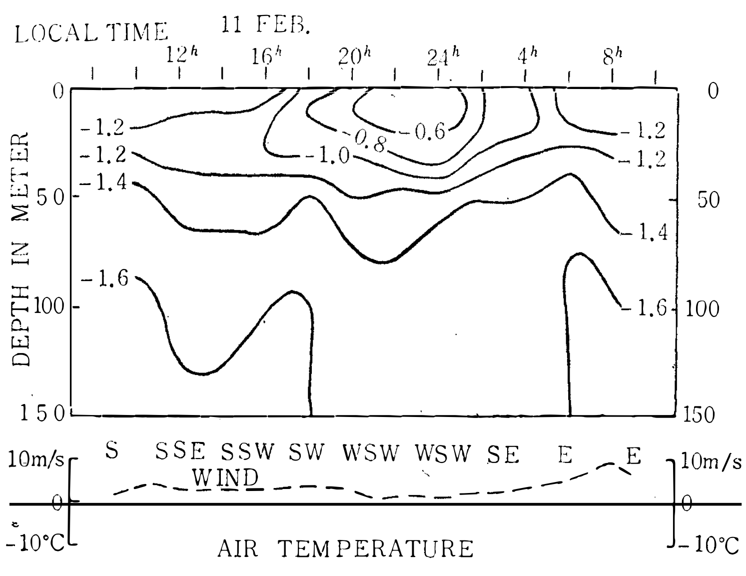
第 5 図 ケープタウン南極間の表面 T-S ダイヤグラム

Fig. 5. Horizontal T-S diagram from Cape Town to Antarctica.

temperature gradient along the coast of South Africa under a rather homogeneous water of thickness of about 60 m, and this is considered an extension of part of the Agulhas Current. The axis of this westward current seems to be shifted to the north in the western section (Fig. 4A) suggesting a bending of the current along the coast.

Overlying and to the south of the above subsurface flow the Sub-tropical Water of high temperature exists, making a great temperature gradient with the colder Sub-antarctic Water, i.e., the Sub-tropical Convergence. This boundary of two different water masses is more clearly indicated by the horizontal T-S diagram, as shown in Fig. 5 in which the data of the previous cruise were also entered. In the Sub-antarctic Region a gradual temperature decrease to the south shows the general eastward flow of the Antarctic Circumpolar Current.

The Antarctic Convergence was found to be better defined in Fig. 4A (no observation in Fig. 4B) as compared with the Sub-tropical Convegence, by the increase of the surface temperature to the north and by the downward bend of the 2°C isotherm. In the Antarctic Region the isotherms run almost horizontally and the temperature gradient is not very large as compared with that of the northern portion of the section. The cold core of the Antarctic Surface Water extends to about 58°S in Fig. 4A and to farther north of 52°S in Fig. 4B, having its axis at the depth of about 80 m. It is not known whether the difference in locations of northern boundary of of the cold core between two figures is due to a local variation or to a seasonal variation. However, the temperature in this region is much lower in Fig. 4B, especially in the southern part, and the difference mentioned above is probably due to a seasonal cause. The upper discontinuity of temperature usually exists at the depth of about 60 m in the southern portion and the effect of summer heat seems to reach this depth.



第 6 図 漂泊中の宗谷で行なった BT 連続観測の結果

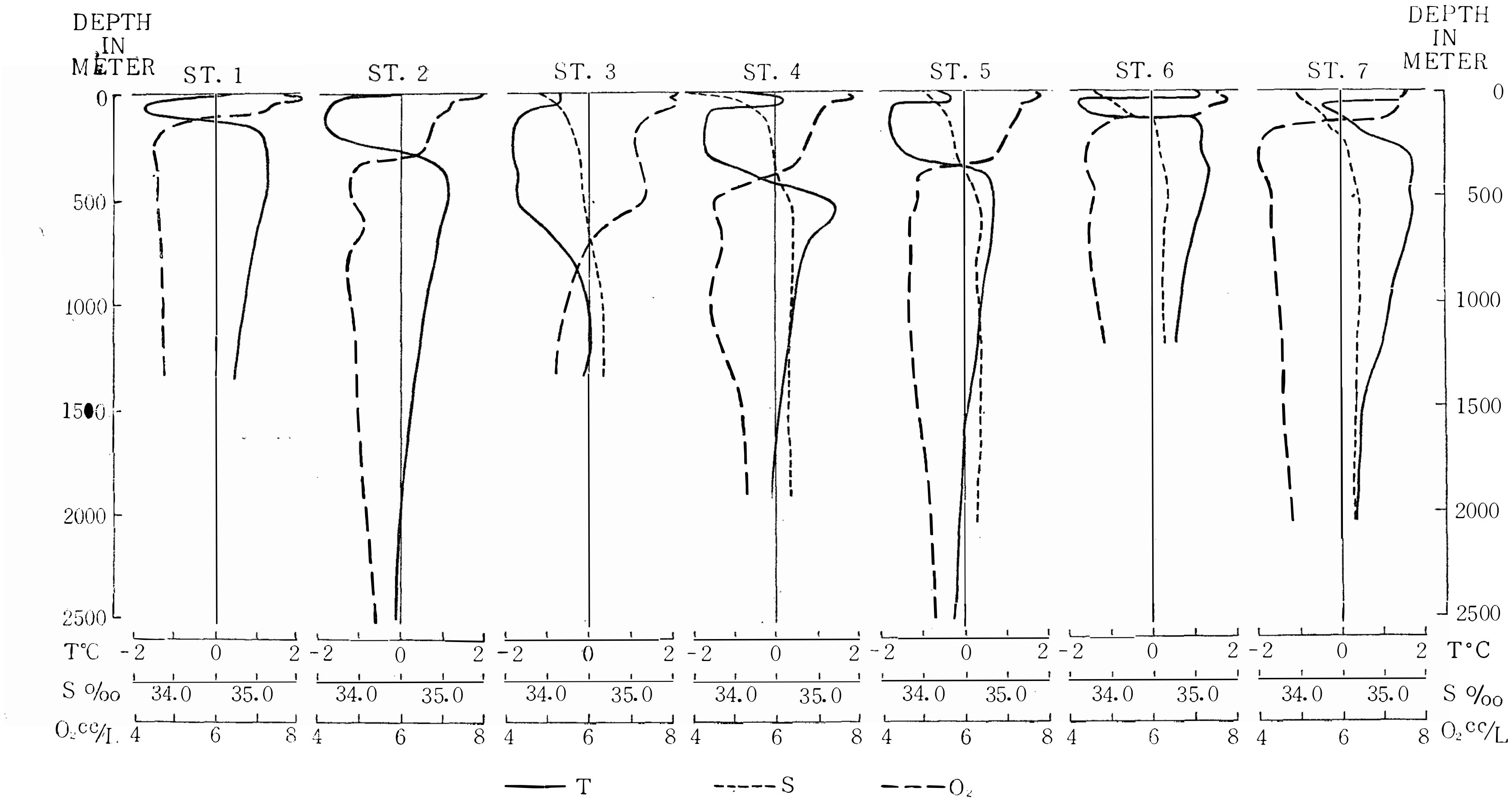
Fig. 6. Result of every 2 hour BT observation from drifting ship in icy region.

d) On the result of every 2 hour BT observation from drifting ship in the icy region Every 2 hour BT observation was made in the icy sea during a period of 24 hours while the ship was drifting. Observation was started at 1000 on 11 Feb. and repeated to 0800 next morning and the ship's drift during the period was about 7 miles in the eastward direction. The results of the observation are shown in Fig. 6 in which air temperature and wind data are also entered. The weather during the observation period was cloudy and the sea surface had been covered with ice floe and brashes. In Fig. 6 the temperature below 75 m remained almost unchanged, which suggests that the effect of summer heat at the surface did not reach this depth. The increase of temperature is seen to start not from the very surface but from a deeper layer and the maximum temperature has appeared between 2000 and 0100 next morning. During the period the air temperature remained almost unchanged, −4° to −5°C, and the wind velocity was also constantly low, so that the temperature rise in the upper layer may have been a local variation within a very short distance. Moreover, there was observed a wave-like feature of the isotherms of the tidal period in the temperature discontinuity layer, although they are not considered sufficient to discuss as an internal wave.

Vertical distribution of temperature, salinity and dissolved oxygen at stations

7 stations of serial observation were occupied in the Antarctic Region, 3 of which (Sts. 5, 6 and 7) were included in the section of Fig. 4B (return cruise). 5 sections (Sts. 1–5) were distributed in the south of 67°S and between 30°E and 48°E (Fig. 1), and even the stations farthermost from the Antarctic coast (Sts. 1 and 4) were in the distance of about 130 miles. Vertical distributions of major elements at each station are shown in Fig. 7. General features of distributions of temperature, salinity and dissolved oxygen are not essentially different among stations and agree with the statement by Deacon (1937) and Sverdrup (1933 and '42). Above the depth of 75 m, warmed surface water of low salinity exists, produced by summer heating and by melting of ice. Below this, water or lower temperature is encountered, thickness of which depends largely on the distance from the continent, and within this cold water salinity increases and oxygen decreases. Below this cold water the Antarctic Circumpolar Water from the north appears to the depth of about 1500 m with maximum temperature and salinity and minimum oxygen. As depth increases, temperature and salinity decrease and oxygen increases. The distribution of salinity below the upper cold water does not differ at all stations, that is, the salinity, after having reached the maximum of 34.70‰, slightly decreases downward. However, the absolute values of temperature and oxygen vary with the distance from the continent.

At St. 3, which is the closest to the continent, the subsurface cold water of −1.8°C extends to the depth of about 500 m. In the low temperature region the temperature has a minor effect on the density and the density is mainly determined



第 7 図　各層観測点における水温，塩分および溶在酸素量の鉛直分布

Fig. 7. Vertical distributions of temperature, salinity and dissolved oxygen at stations. Jan.-Mar., 1961.

by the salinity, so that the stability of water is approximately proportional to the vertical gradient of the salinity curve as shown in Fig. 7, in which the maximum salinity gradient is found at the boundary between the upper cold water and the Antarctic Circumpolar Water. Hence, such a rather large body of cold water as found at St. 3 might have been formed in situ during the preceeding winter, that is, the winter cooling and the increasing salinity related to freezing may extend to a depth where the Antarctic Circumpolar Water of greater density is encountered. However, the stability is not very great except in the surface layer, so that this cold water is considered to be ready to extend to greater depths if the cooling near the surface becomes more effective. This leads to an assumption that the bottom water formation such as in the Weddel Sea (SVERDRUP, 1933 and '42) may take place somewhere in this region and the downward increase of dissolved oxygen seems to support the assumption.

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