VERTICAL DISTRIBUTION OF CHLOROPHYLL *a* ALONG 45°E IN THE SOUTHERN OCEAN, 1981

Kentaro WATANABE

National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173

and

Yasushi NAKAJIMA*

Tokyo University of Fisheries, 5–7, Konan 4-chome, Minato-ku, Tokyo 108

Abstract: Surface and vertical observations of chlorophyll *a* were carried out from the fast ice region to the north of the Subtropical Convergence (STC) on board the icebreaker FUJI in February and March 1981. Sampling stations were arranged along the 45°E meridian including nine vertical observation stations from 67°36′S (in polynya) to 43°18′S (in the subantarctic water) and nine other vertical observation stations located in a grid pattern in the area of 35°–45°E, 60°–65°S. At the latter vertical observation stations, the pattern of chlorophyll *a* distribution showed little latitudinal variation but large longitudinal variations. Subsurface chlorophyll *a* maximum was seen at 75–85 m deep at 65°E stations, at about 105 m deep at 62°30′S stations and was not clear at two 60°S stations. These maxima seemed to coincide with the temperature minimum layer. This is presumed to be related to the circumpolar structure of the antarctic waters as seen from vertical profiles of temperature and salinity.

Chlorophyll *a* standing stock along the 45°E meridian was large (44 mg/m^2, integrated from the surface to a depth of 200 m) in the water column under fast ice, but small (13 mg/m^2) in the pack ice water. The maximum integrated chlorophyll *a* (75 mg/m^2) was obtained at a 62°30′S station in the antarctic water. This value is about twice as much as those observed at two stations in the subantarctic water. The data from the pack ice and the fast ice area showed large variations and they suggest high standing stock of phytoplankton in some part of the ice-associated area.

1. Introduction

Since 1965, the surface observations on biological and physico-chemical oceanography have been carried out in the Southern Ocean by the Japanese Antarctic Research Expedition (JARE). As one of the biological programs, the measurements of surface chlorophyll *a* concentration have been routinely performed, and the results were published by HOSHIAI (1968), TAKAHASHI (1969), TOMINAGA (1971), NISHIWAKI (1972), HOSHINO (1974), OHNO (1976), OHYAMA and MAYAMA (1976), FUKUCHI (1977), KURODA (1978), KANDA and FUKUCHI (1979), TANIMURA (1981) and FUKUCHI

* Present address: Sanyo Hydrographic Survey Co., Ltd., 3–17, Nihonbashi Horidome-cho 1-chome, Chuo-ku, Tokyo 103.

and TAMURA (1982). From these data on surface chlorophyll *a*, FUKUCHI (1980) estimated the phytoplankton stock in the Indian sector of the Antarctic Ocean, and considered that the production in this region may be of nearly the same magnitude as that in the temperate areas of the world oceans. As far as the vertical observations of chlorophyll *a* are concerned, only two reports were published (KURODA and FUKUCHI, 1982; FUKUCHI and TAMURA, 1982), as the chances for vertical water collections were scarce. In this paper, the vertical observation data are mainly dealt with and the distribution of chlorophyll *a* standing stock in the western Indian sector of the subantarctic and the antarctic waters is discussed including that in the pack ice and the fast ice waters.

2. Materials and Methods

In JARE-22, chlorophyll *a* concentration was measured along the course of the icebreaker FUJI. Vertical and surface observations in this study were performed at 15 and 41 stations respectively from February 7 to March 6, 1981, in the Southern Ocean (Fig. 1). Of the fifteen vertical observation stations, nine were arranged in a grid pattern to investigate the latitudinal and logitudinal differences of vertical distributional pattern of chlorophyll *a* in the area of 35°–45°E, 60°–65°S. Another series of nine stations were positioned along the 45°E meridian to reveal the latitudinal changes of vertical distributional pattern of chlorophyll *a*. Stations 86–89 and

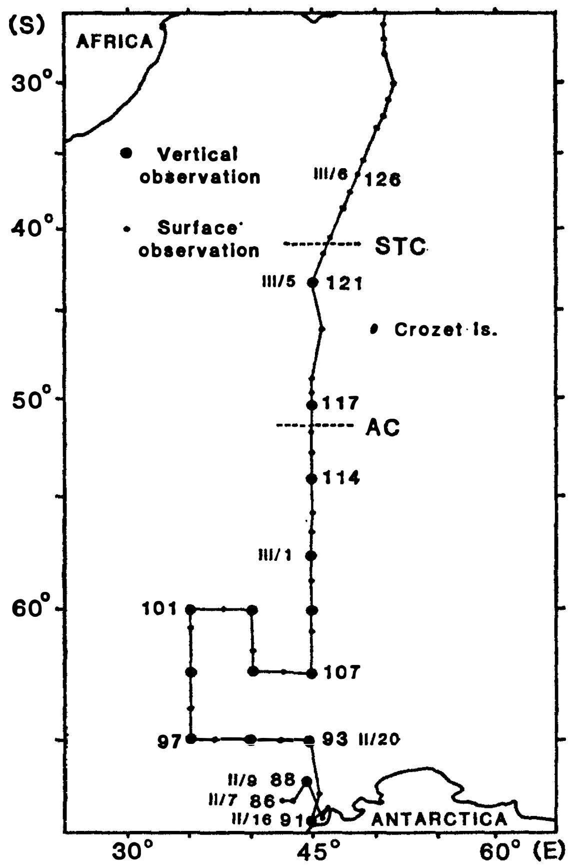

Fig. 1. Position of the stations for vertical and surface observations. Station numbers and the date of sampling are indicated.

92 were in the pack ice region, Stn. 89 being near the edge of the fast ice sheet. Stations 90 and 91 were situated in polynya, surrounded by the fast ice. From Stn. 93 onward, water sampling was carried out in the open water.

At vertical observation stations, water samples were collected from 9 depths down to *ca.* 200 m, with a plastic bucket and Nansen bottles. Surface water of 5–15 *l* and vertical water samples of 1.0–1.7 *l*, usually 1.5 *l*, were filtered with a 47 mm Whatman GF/C glass fiber filter. Pigments were extracted with 90% acetone after centrifuging the ground filter. Chlorophyll *a* concentration was determined by the fluorometric technique described in FUKUCHI and TAMURA (1982) with a Shimadzu Model RF-500 spectrofluorometer. Other physico-chemical oceanographic parameters were measured by KURAMOTO and KOYAMA (1982).

3. Results

3.1. Physical parameters

Figure 2 shows surface temperature and salinity at Stns. 86–126 and the data obtained at stations around the 45°E meridian are linked with lines (data from KURAMOTO and KOYAMA, 1982). There was a remarkable change in both of the parameters between Stns. 122 and 123. The change of surface temperature and that of salinity between Stns. 121 and 124 were 8.2–19.7°C and 33.80–35.53‰ respectively.

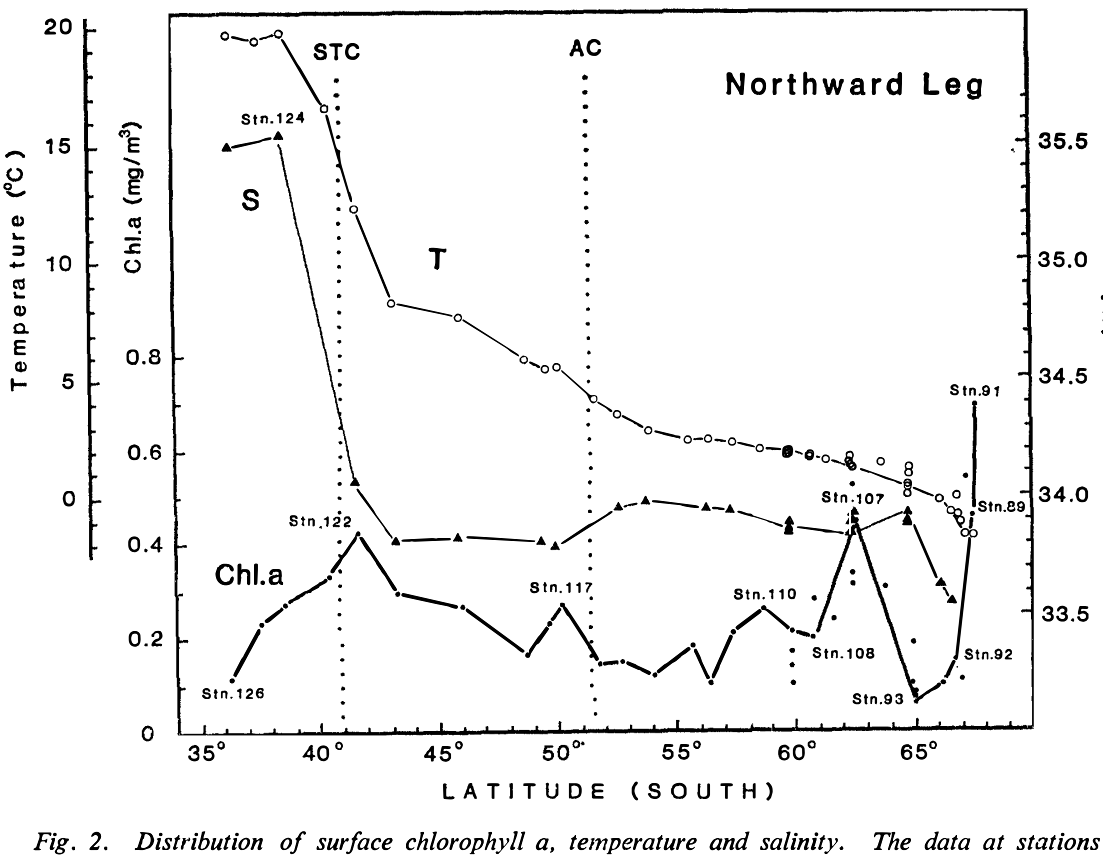

Fig. 2. Distribution of surface chlorophyll a, temperature and salinity. The data at stations near the 45°E meridian are linked with lines. Temperatuare and salinity data are from KURAMOTO and KOYAMA (1982).

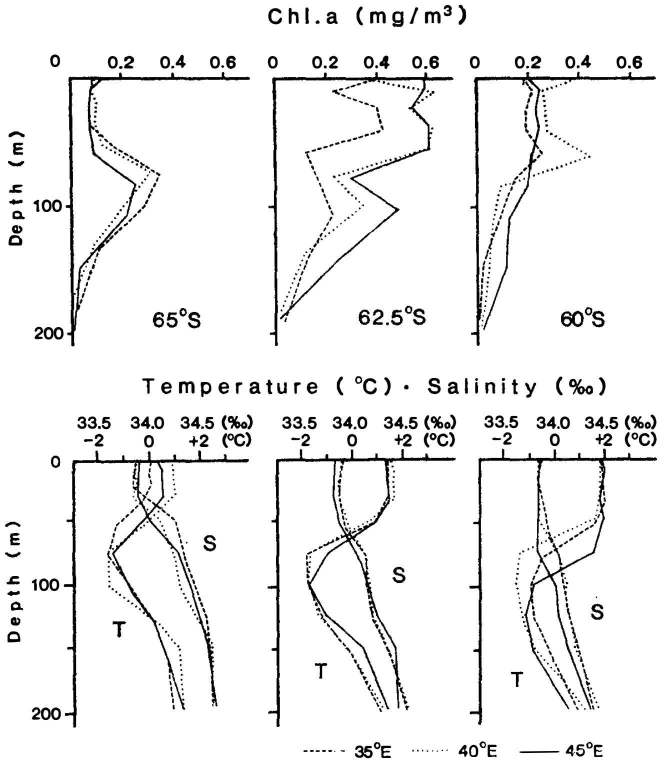

Fig. 3. Vertical profiles of chlorophyll a (upper), temperature and salinity (lower) at nine stations located in a grid pattern (35°–45°E, 60°–65°S). Temperature and salinity data are from KURAMOTO and KOYAMA (1982).

As the Subtropical Convergence (STC) is featured by the rapid change of surface temperature and salinity, the STC was determined to lie around 41°00′S (between Stns. 122 and 123). From the vertical profiles of temperature and salinity, the Antarctic Convergence (AC or polar front) was determined to lie around 51°30′S (between Stns. 116 and 117), where the temperature minimum layer and the salinity minimum terminated at the 200 m level (GORDON, 1971).

In the area of grid-allocated stations (35°–45°E, 60°–65°S), the vertical profiles of temperature and salinity in the same latitude had the similar tendency as shown in Fig. 3. The depth of the temperature minimum layer along 45°E in the antarctic open water (Stns. 93, 107, 109, 111 and 114 in Fig. 4) increased from 75 m to 150 m with the advance to the north. Water temperature from the surface down to 200 m deep was below 0°C at Stn. 88 in the pack ice region. At Stn. 91 in polynya, temperature of upper water from 10 m to 200 m deep was almost uniform ranging around −1.7°C to −1.8°C. The depth of pycnocline along 45°E became deeper from the south to the north (Stns. 88 to 114) in the antarctic water (Fig. 4). At Stn. 88 the pycnocline lay between 20 m and 40 m deep, whereas the depth at Stn. 114, was around 100 m. The upper water column above pycnocline was unstable at Stns. 88–114.

3.2. *Chlorophyll a standing stock*

The data of chlorophyll *a* and phaeopigments concentration at vertical and sur-

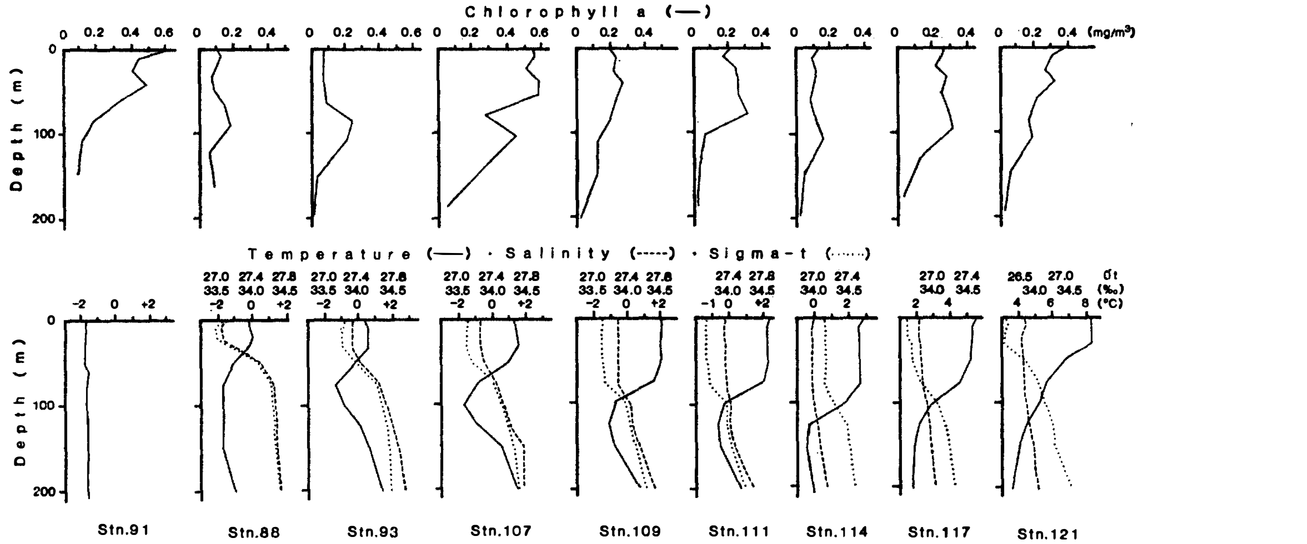

Fig. 4. Vertical profiles of chlorophyll a (upper), temperature, salinity and sigma-t (lower) at nine stations along 45°E. At Stn. 91 salinity was not measured. Temperature, salinity and sigma-t data are from KURAMOTO and KOYAMA (1982).

face observation stations are tabulated in Appendixes I and II. The pigment ratio was calculated by dividing chlorophyll *a* (mg/m^3) with the total of phaeopigments (mg/m^3) and chlorophyll *a* (mg/m^3).

3.2.1. In the area of grid-allocated stations, 35°–45°E, 60°–65°S

The surface distribution of chlorophyll *a* in this area showed longitudinal variations rather than latitudinal ones. The range of chlorophyll *a* concentration (mg/m^3) at stations near 65°, 62°30′ and 60°S was 0.06–0.19, 0.31–0.52 and 0.10–0.21 respectively. Vertical profiles of chlorophyll *a* at nine stations in this area are shown in Fig. 3. Each set of three stations in the same latitude is arranged in a diagram. As is clearly seen in this figure, vertical profiles of chlorophyll *a* in the same latitude were quite similar to each other at three stations compared with those at others. Three stations in 65°S (Stns. 93, 95 and 97) have almost the same pattern of vertical chlorophyll *a* distribution. Despite the strong similarity of temperature and salinity profiles at three stations (Stns. 99, 105 and 107) in 62°30′S, the pattern of chlorophyll *a* distribution differed to some extent among stations. The upper part of the chlorophyll *a* profile at Stn. 99 (35°E) shifted to the lower part by about 0.2 mg/m^3 from that at Stn. 107 (45°E).

3.2.2. Longitudinal variations in the Southern Ocean

Surface distribution of chlorophyll *a* along the 45°E meridian is shown in Fig. 2. Chlorophyll *a* concentration was comparatively high (0.42 and 0.33 mg/m^3) at Stns. 122 and 123 near the STC. The mean and the range of the surface chlorophyll *a* at six stations in the subantarctic water (Stns. 117–122) are 0.27 and 0.16–0.42 mg/m^3, while near the AC only a small peak (0.27 mg/m^3) was observed at Stn. 117 north of the AC. In the antarctic open water, the surface chlorophyll *a* concentration was generally low except for those around 62°30′S. The mean values of surface chlorophyll *a* at stations in 60°, 62°30′ and 65°S were 0.16, 0.40 and 0.10 mg/m^3 respectively. Of all the stations in the antarctic open water (Stns. 93–116), the surface chlorophyll *a* ranged 0.06–0.33 mg/m^3 and the mean was 0.20 mg/m^3 which is lower than that of the subantarctic water. In the pack ice region, the surface chlorophyll *a* concentration was very low (0.10–0.15 mg/m^3), except at Stn. 89 which was close to the edge of the fast ice. The highest value in this study (0.69 mg/m^2) was obtained at Stn. 91 in polynya. Another high value was obtained at Stn. 90 in the fast ice region.

Vertical profiles of chlorophyll *a* at nine stations along the 45°E meridian are shown in Fig. 4. At Stn. 91 in polynya, chlorophyll *a* concentration in the upper water column above 40 m was also very high and declined gradually with depth. In contrast with this phenomenon, the concentration was lower than 0.17 mg/m^3 throughout the water column down to 200 m at Stn. 88 in the pack ice region. This profile had a small peak at 90 m deep. As was described before, three stations at 65°S had the similar profile, that is, the concentration at the surface was very low (0.07–0.09 mg/m^3) and had a remarkable maximum (0.24–0.33 mg/m^3) at about 75–85 m deep. At 62°30′S stations, surface values of chlorophyll *a* were high (0.36–0.56 mg/m^3) and the concentration was generally high down to about 55 m deep at Stns. 105 and 107. The profiles had a small peak at a deeper layer (101–107 m).

Chlorophyll *a* values were integrated from the surface to 200 m deep at 15 vertical observation stations on the basis of the data at nine depths (Appendix II), and the results are shown in Fig. 5. At Stn. 88 in the pack ice region, the integrated chlorophyll *a* was the lowest (13 mg/m^2) in the present study whereas at the next station (Stn. 91) in the fast ice region the value was as high as 44 mg/m^2. The largest integrated value of 75 mg/m^2 was observed at Stn. 107 in 62°30°S. Other stations in this latitude (Stns. 99 and 105) had high standing stock of chlorophyll *a*, which contrasted with low values at 65°S and 60°S stations. With decrease of latitude towards the AC, the value decreased gradually. The mean value of the integrated chlorophyll *a* in the antarctic water was 32 mg/m^2. At two stations in the subant-

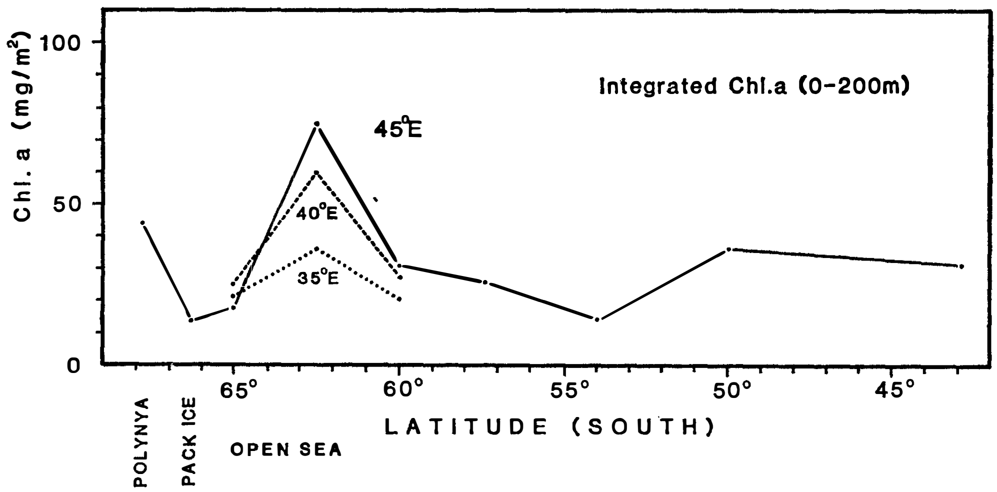

Fig. 5. Integrated chlorophyll a in the water column from the surface to a depth of 200 m at 15 stations. Nine data along 45°E are linked with solid lines.

Table 1. Mean and range of surface chlorophyll a and integrated chlorophyll a values to a depth of 200 m, in different regions of the Indian sector of the Southern Ocean.

	Subantarctic water	Antarctic water	Pack ice	Polynya
Surface chlorophyll *a* (mg/m^3)				
Mean	0.27	0.20	0.19	0.62
(number of data)	(6)	(24)	(5)	(2)
Range	0.16–0.42	0.06–0.33	0.10–0.46	0.54–0.69
Integrated chlorophyll *a* (mg/m^2)				
Mean	34	32	13	44
(number of data)	(2)	(11)	(1)	(1)
Range	31–37	14–75	—	—

arctic water, the values (31 and 37 mg/m^2) became larger than that at Stn. 114 just south of the AC. The mean and the range of the integrated chlorophyll *a*, together with the surface chlorophyll *a* concentration, are shown for each region (Table 1).

4. Discussion

The standing stock of chlorophyll *a* in the Indian sector of the Southern Ocean has been investigated by many workers. In a large scale, the Southern Ocean is divided into some water masses forming circumpolar water belts (DEACON, 1937). As the present data of the grid-allocated stations show, oceanic waters in the Southern Ocean do not seem to exhibit large fluctuation of chlorophyll *a* standing stock within the same water mass. For the southeastern Indian sector of the Southern Ocean, HOLM-HANSEN *et al.* (1977) and EL-SAYED and TURNER (1977) reported from the data of ELTANIN Cruise 46 in late spring, that the integrated chlorophyll *a* ranged 11.7–76.7 (mean 38.9) mg/m^2 in the upper 200-m water column of the subantarctic waters and 11.6–21.6 (mean 16.5) mg/m^2 in the euphotic zone of the ice-free antarctic waters. FUKUCHI (1980) estimated the average chlorophyll *a* standing stock of the surface water in the western Indian sector of the Southern Ocean (late February–early March) from many data obtained during the nine JARE cruises. He reported the surface chlorophyll *a* of 0.34 ± 0.20 mg/m^3 (mean $\pm$ standard deviation) for the subantarctic water, 0.46 ± 0.25 mg/m^3 for the antarctic surface water north of 63°S and 0.39 ± 0.46 mg/m^3 for the antarctic surface water south of 63°S. KURODA and FUKUCHI (1982) integrated chlorophyll *a* in the euphotic zone from vertical observation data at nine stations along 15°E (late February–early March), and reported that the integrated values were 17 and 20 mg/m^2 at two stations in the subantarctic waters and 8–43 (mean was 21 mg/m^2) in the antarctic waters saying that the southernmost station (67°05′S) was the richest. FUKUCHI and TAMURA (1982) calculated the integrated chlorophyll *a* (16.8–39.4 mg/m^2) in the upper 250-m water column at six stations in the antarctic waters along 40°–43°E longitudes (late February–early March). The present results in the subantarctic water (31 and 37 mg/m^2) correspond to those of HOLM-HANSEN *et al.* (1977). For the data on the antarctic waters, surface chlorophyll *a* concentrations were low (0.06–0.33, mean 0.20 mg/m^3) compared with those of FUKUCHI (1980), but, the integrated chlorophyll *a* values (14–75, mean 32 mg/m²) were higher than those of HOLM-HANSEN *et al.* (1977), KURODA and FUKUCHI (1982) and FUKUCHI and TAMURA (1982). This is because the high values observed at 62°30′S stations were included into the calculation of the mean value. If the three high values are excluded, the mean value decreases to 23 mg/m² which is comparable to those of the above-mentioned authors. However, relatively high concentrations of surface chlorophyll *a* were observed in the southern part of the antarctic waters. TANIMURA (1981) observed high chlorophyll *a* (0.69–0.79 mg/m³) around 63°34′–65°50′S in February during JARE-21 cruise. The high value of integrated chlorophyll *a* (43 mg/m²) reported by KURODA and FUKUCHI (1982) was also recorded in the southern part of the antarctic water (67°05′S). These results from the grid-allocated stations in 35°–45°E, 60°–65°S suggest that there exists a zone of high standing stock of chlorophyll *a* in the southern part of the Antarctic Ocean. And in the southernmost antarctic open water, south of this zone, low values of surface chlorophyll *a* were generally obtained in JARE cruises as were seen at 65°S stations (0.06–0.19 mg/m³).

In the ice-associated waters (*i.e.*, pack ice and fast ice regions), the data of chlorophyll *a* standing stock seem to be more complicated. OHNO (1976) observed a large fluctuation of surface chlorophyll *a* concentrations (0.12–2.01 mg/m³) in the pack ice region from January to February and reported that the surface water collected there contained "sludge of ice colored by micro-organisms". EL-SAYED and TURNER (1977) reported that stations in the pack ice waters were the least productive (6.0–18.5 mg/m²; integrated in the euphotic zone) in the southeastern Indian sector of the Southern Ocean in December. TANIMURA (1981) reported also a large fluctuation of surface chlorophyll *a* (0.84–2.89 mg/m³) in the pack ice waters (39°35′–49°18′E). FUKUCHI and TAMURA (1982) observed the surface chlorophyll *a* concentration and obtained not only high values of 0.41–2.13 mg/m³ in the pack ice region, but also low values of 0.03–0.56 mg/m³ in the lead water surrounded by fast ice in December. The minimum value (0.03 mg/m³) was obtained at the mouth of Lützow-Holm Bay (39°13′E, 68°16′S). FUKUCHI and SASAKI (1981) estimated quite a low value of integrated chlorophyll *a* (3.06 mg/m², 0–150 m) in the water column beneath the fast ice in Lützow-Holm Bay (39°21.2′E, 68°20.3′S, February 1979). According to the results from the fast ice region in Lützow-Holm Bay, standing stock of chlorophyll *a* beneath the sea ice seems to be very low. However, the present results revealed that there was a high standing stock of chlorophyll *a* (44 mg/m², 0–200 m) at a station in polynya surrounded by the fast ice, whereas in the pack ice waters, both the surface values and the integrated values of chlorophyll *a* were low in late February. It is evident that not only the surface values of chlorophyll *a* but also the integrated values in the upper water column in the ice-associated regions vary largely. But it seems that standing stock of chlorophyll *a* in the fast ice region is more abundant than that in the pack ice region. As is observed sometimes in the pack ice and the fast ice regions, the micro-algae grow in and on the undersurface of sea ice. With the advance of spring and summer, the sea ice melts and releases the ice-associated micro-algae to the ambient water column as was observed by OHNO (1976). It may be presumed that high chlorophyll *a* concentration in the ice-associated waters is contributed by ice-algae released from sea ice in spring and summer.

However, as the data of chlorophyll *a* standing stock in the ice-associated waters are still insufficient, more investigations of the vertical chlorophyll *a* distribution in the pack ice and the fast ice waters will be necessary to obtain better estimates of the standing stock of micro-algae in the ice-associated regions.

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Appendix I. Data of surface observation on board the FUJI in the Southern Ocean; chlorophyll a, phaeopigments and pigment ratio.

Stn. No.	Date			Time (LT)	Latitude (S)	Longitude (E)	Chl. *a* (mg/m³)	Phaeopigments (mg/m³)	Pigment ratio (%)
86	1981	Feb.	7	0800	67 01	42 35	0.11	0.49	18
87			8	1800	67 01	43 43	0.11	0.39	22
88			9	0800	66 18	44 45	0.10	0.39	21
89			10	0800	67 31	45 45	0.46	3.23	13
90			11	0800	67 11	46 21	0.54	2.50	18
91			16	1800	67 36	45 06	0.69	3.11	18
92			19	1800	66 47	45 22	0.15	0.80	16
93			20	0800	65 00	44 55	0.06	0.27	19
94				2300	64 59	42 33	0.08	0.40	17
95			21	0800	65 00	40 08	0.10	0.30	26
96				2300	65 00	36 56	0.19	0.53	27
97			22	0800	65 01	35 00	0.07	0.23	33
98				2300	63 52	35 00	0.31	0.79	28
99			23	0800	62 28	35 03	0.33	0.85	28
100				2300	60 51	35 02	0.28	0.75	27
101			24	0800	60 00	34 58	0.10	0.59	14
102				2300	59 59	37 43	0.17	0.96	15
103			25	0800	60 00	39 59	0.14	0.79	15
104				2300	61 43	40 03	0.24	0.54	31
105			26	0800	62 29	40 01	0.52	1.16	31
106				2300	62 26	42 26	0.31	1.40	18
107			27	0800	62 31	45 03	0.44	1.06	29
108				2300	60 52	45 00	0.20	0.44	31
109			28	0800	59 58	45 03	0.21	0.47	31
110				2300	58 46	45 04	0.26	0.83	24
111	1981	Mar.	1	0800	57 31	44 59	0.21	0.68	23
112				1800	56 35	45 00	0.10	0.27	28
113				2300	55 45	44 59	0.18	0.45	28
114			2	0800	54 06	45 00	0.12	0.30	28
115				1800	52 46	45 00	0.15	0.39	28
116				2300	51 47	45 00	0.14	0.36	27
117			3	0800	50 13	45 01	0.27	0.77	26
118				1800	49 41	45 04	0.23	0.61	27
119				2300	48 51	45 00	0.16	0.46	26
120			4	1800	46 02	45 52	0.26	1.21	18
121			5	0800	43 18	44 57	0.29	1.17	20
122				1800	41 39	45 55	0.42	1.44	23
123				2300	40 31	46 31	0.33	1.25	21
124			6	0800	38 37	47 34	0.27	0.20	58
125				1300	37 33	48 11	0.23	0.14	62
126				1800	36 22	48 44	0.11	0.52	18

Appendix II. Data of vertical observation on board the FUJI *in the Southern Ocean; chlorophyll a, phaeopigments and pigment ratio.*

Stn. No.	Date Time (LT)	Position	Depth (m)	Chl. *a* (mg/m³)	Phaeopigments (mg/m³)	Pigment ratio (%)
88	1981 Feb. 9	66°18′S	0	0.10	0.39	21
	0800-0818	44°45′E	8	0.12	0.46	20
			20	0.10	0.46	19
			33	0.07	0.32	18
			49	0.08	0.35	19
			70	0.15	0.67	18
			90	0.17	1.39	11
			123	0.05	0.36	11
			164	0.08	0.15	6
91	1981 Feb. 16	67°36′S	0	0.66	3.56	16
	1730-1750	45°06′E	10	0.45	2.34	16
			25	0.41	2.15	16
			40	0.49	2.13	19
			60	0.34	1.67	17
			85	0.18	1.90	8
			110	0.11	1.65	6
			150	0.08	1.09	7
93	1981 Feb. 20	65°00′S	0	0.07	0.33	18
	0818-0838	44°55′E	10	0.07	0.33	17
			25	0.07	0.28	19
			40	0.07	0.31	18
			65	0.09	0.35	20
			85	0.24	0.64	27
			110	0.20	1.33	13
			150	0.33	0.31	9
			200	0.00	0.17	2
95	1981 Feb. 21	65°00′S	0	0.09	0.35	21
	0820-0845	40°08′E	9	0.08	0.32	21
			22	0.10	0.37	21
			35	0.09	0.32	21
			52	0.12	0.39	23
			74	0.29	0.96	24
			95	0.22	0.86	20
			130	0.08	0.51	14
			173	0.00	0.14	2
97	1981 Feb. 22	65°01′S	0	0.09	0.34	20
	0808-0828	35°00′E	9	0.07	0.30	20
			23	0.06	0.26	19
			36	0.07	0.27	21
			54	0.16	0.52	23
			77	0.33	1.10	23
			100	0.27	1.40	16
			136	0.09	0.71	12
			181	0.02	0.57	4

Appendix II. (*Continued*)

Stn. No.	Date Time (LT)	Position	Depth (m)	Chl. *a* (mg/m³)	Phaeopigments (mg/m³)	Pigment ratio (%)
99	1981 Feb. 23	62°28′S	0	0.37	1.08	26
	0812–0830	35°03′E	10	0.22	0.80	21
			24	0.38	1.04	27
			39	0.40	1.20	25
			58	0.12	0.49	19
			83	0.16	0.79	17
			107	0.21	1.34	13
			146	0.12	0.68	15
			195	0.03	0.30	9
101	1981 Feb. 24	60°00′S	0	0.17	0.54	24
	0805–0830	34°58′E	10	0.20	0.58	25
			25	0.18	0.56	25
			39	0.18	0.56	25
			59	0.24	0.76	24
			83	0.13	0.56	19
			108	0.08	0.54	14
			147	0.02	0.29	6
			197	0.01	0.17	3
103	1981 Feb. 25	60°00′S	0	0.38	0.99	28
	0800–0822	39°59′E	10	0.24	0.69	26
			25	0.26	0.69	26
			40	0.26	0.77	25
			60	0.39	1.08	27
			85	0.08	0.45	15
			110	0.06	0.62	9
			149	0.04	0.33	11
			199	0.01	0.22	6
105	1981 Feb. 26	62°29′S	0	0.36	1.68	18
	0805–0825	40°01′E	9	0.59	1.74	25
			23	0.51	1.46	26
			37	0.59	1.68	26
			55	0.57	1.58	27
			78	0.22	0.85	20
			101	0.33	1.37	19
			138	0.11	0.63	14
			184	0.02	0.22	8
107	1981 Feb. 27	62°31′S	0	0.56	1.53	27
	0800–0818	45°03′E	9	0.56	1.55	27
			23	0.52	1.40	27
			37	0.58	1.56	27
			56	0.58	1.51	28
			79	0.28	0.94	23
			103	0.46	1.70	21
			140	0.26	1.24	18
			187	0.03	0.29	11

Appendix II. (*Continued*)

Stn. No.	Date Time (LT)	Position	Depth (m)	Chl. *a* (mg/m³)	Phaeopigments (mg/m³)	Pigment ratio (%)
109	1981 Feb. 28	59°58′S	0	0.19	0.49	28
	0802–0830	45°03′E	10	0.23	0.54	30
			25	0.22	0.51	30
			40	0.26	0.56	31
			60	0.23	0.52	31
			85	0.19	0.55	25
			110	0.12	0.54	18
			149	0.11	0.52	18
			199	0.02	0.16	9
111	1981 Mar. 1	57°31′S	0	0.21	0.43	33
	0810–0835	44°59′E	9	0.17	0.59	22
			23	0.23	0.53	31
			38	0.25	0.59	29
			56	0.25	0.58	30
			80	0.31	0.71	31
			103	0.06	0.46	11
			141	0.03	0.22	12
			188	0.01	0.17	6
114	1981 Mar. 2	54°06′S	0	0.12	0.39	24
	0800–0820	45°00′E	10	0.09	0.37	20
			24	0.11	0.35	24
			39	0.10	0.33	23
			58	0.08	0.29	22
			83	0.10	0.36	23
			107	0.15	0.66	19
			146	0.04	0.28	14
			195	0.01	0.20	6
117	1981 Mar. 3	50°13′S	0	0.26	0.83	24
	0805–0825	45°01′E	9	0.25	0.81	23
			22	0.22	0.74	23
			35	0.27	0.87	24
			52	0.25	0.81	24
			74	0.28	1.05	21
			96	0.31	1.38	19
			131	0.12	0.64	16
			175	0.02	0.31	7
121	1981 Mar. 5	43°18′S	0	0.35	1.30	21
	0800–0820	44°57′E	10	0.30	1.24	20
			25	0.26	1.09	19
			39	0.31	1.18	21
			59	0.21	0.88	19
			83	0.16	0.80	17
			108	0.17	0.93	15
			147	0.05	0.40	11
			196	0.01	0.28	4