

# Surface Chlorophyll *a* Concentration along the Course of the FUJI to and from Antarctica in 1977-1978

Hiroshi KANDA\* and Mitsuo FUKUCHI\*

「ふじ」航路 (1977-1978) における表面海水中のクロロフィル *a* 量

神田 啓史\*・福地 光男\*

**要旨:** 1977年11月から1978年4月まで、第19次日本南極地域観測隊の海洋生物定常観測の一環として、「ふじ」の航路に沿って表面海水中のクロロフィル *a* 濃度の測定を143点において実施した。南極大陸沿いの海域にて高濃度が見られ、プリンスオラフ海岸沖にて最高値 (2.48 mg/m<sup>3</sup>) が記録された。観測データは、今回はじめて電子計算機によるデータベースシステムによって処理された。

**Abstract:** During the relief cruise of the FUJI to Syowa Station, Antarctica, from November 1977 to April 1978, the chlorophyll *a* concentrations of the surface water were measured at 143 stations as a part of the routine observations of marine biological program of the 19th Japanese Antarctic Research Expedition. The high chlorophyll *a* concentrations were observed along the Antarctic Continent and the maximum value was recorded off the Prince Olav Coast, Antarctica (2.48 mg chl. *a*/m<sup>3</sup>). The attempt to use the computer for data processing was made for the first time.

## 1. Introduction

The chlorophyll *a* concentration of the surface water along the course of the FUJI between Tokyo, Japan, and Syowa Station, Antarctica, has been measured since 1965 as a part of the routine observations in the marine biological program of the Japanese Antarctic Research Expedition (JARE). The senior author was in charge of the marine biological program of JARE-19, 1977-1978 and conducted the chlorophyll *a* measurement on board. The data processing by means of the computer was first attempted by the junior author.

## 2. Method and Materials

Surface water was sampled with a plastic bucket two to three times a day at

\* 国立極地研究所. National Institute of Polar Research, 9-10, Kaga 1-chome, Itabashi-ku, Tokyo 173.

0800, 1200 and 1800 by local time at 143 stations along the cruise track of the FUJI. A Whatman GF/C glass fiber filter (dia. 47 mm) was used for the filtration of 3–8 liters of sea water under reduced pressure. The chlorophyll *a* concentration was determined by the colorimetric method of UNESCO (1966) using a HITACHI model 101 spectrophotometer. All values were expressed in mg chlorophyll *a* per cubic meter of the surface sea water. Concurrently, an aliquot of 500 ml of sea water was preserved in *ca.* 5% neutralized formalin solution for the taxonomical purpose, and the water temperature was measured. The results of oceanographic observations cited in the present paper will be published by ODA and NOBUKUNI (1979).

All the data, such as station number, date, time and position of sampling, chlorophyll *a* concentration, and water temperature, were filed with a data base system of HITAC M-160 II computer installed at the National Institute of Polar Research (IWABUCHI *et al.*, 1978). Data processed by means of the computer are listed in Appendix 1.

### 3. Results and Discussion

The first sampling was started on November 26th 1977 in the western part of the North Pacific and the last station (Stn. No. 143) was located in the same area on April 16th 1978. The cruise track of the present observations was similar to that of JARE-17 (OHYAMA and MAYAMA, 1976) and covered the area from the North Pacific to the Antarctic Ocean. The chlorophyll *a* concentrations of the surface water and the cruise track of the FUJI are shown in Fig. 1 which was drawn by an XY plotter. The lowest concentration of chlorophyll *a* was observed at Stns. 8 and 9 (0.01 mg) in the western part of the North Pacific on the outward leg and the highest value was seen at Stn. 62 (2.48 mg) off the Prince Olav Coast, Antarctica. The values higher than 0.5 mg were often observed not only in the Malacca Strait but also in the area between Fremantle and Syowa Station, Antarctica, on the outward leg. On the contrary, the chlorophyll *a* concentrations were low in the following areas; the western part of the North Pacific, the South China Sea, the eastern and the western and northern parts of the Indian Ocean, and the area between Syowa Station and Port Louis on the homeward leg. The regional distribution of chlorophyll *a* concentrations will be discussed in detail.

#### 3.1. Western part of North Pacific (Stns. 1–12 and 138–143)

The chlorophyll *a* concentration was in the range of 0.01–0.54 mg on the outward leg and ranged from 0.09 to 0.24 mg on the homeward leg. Although

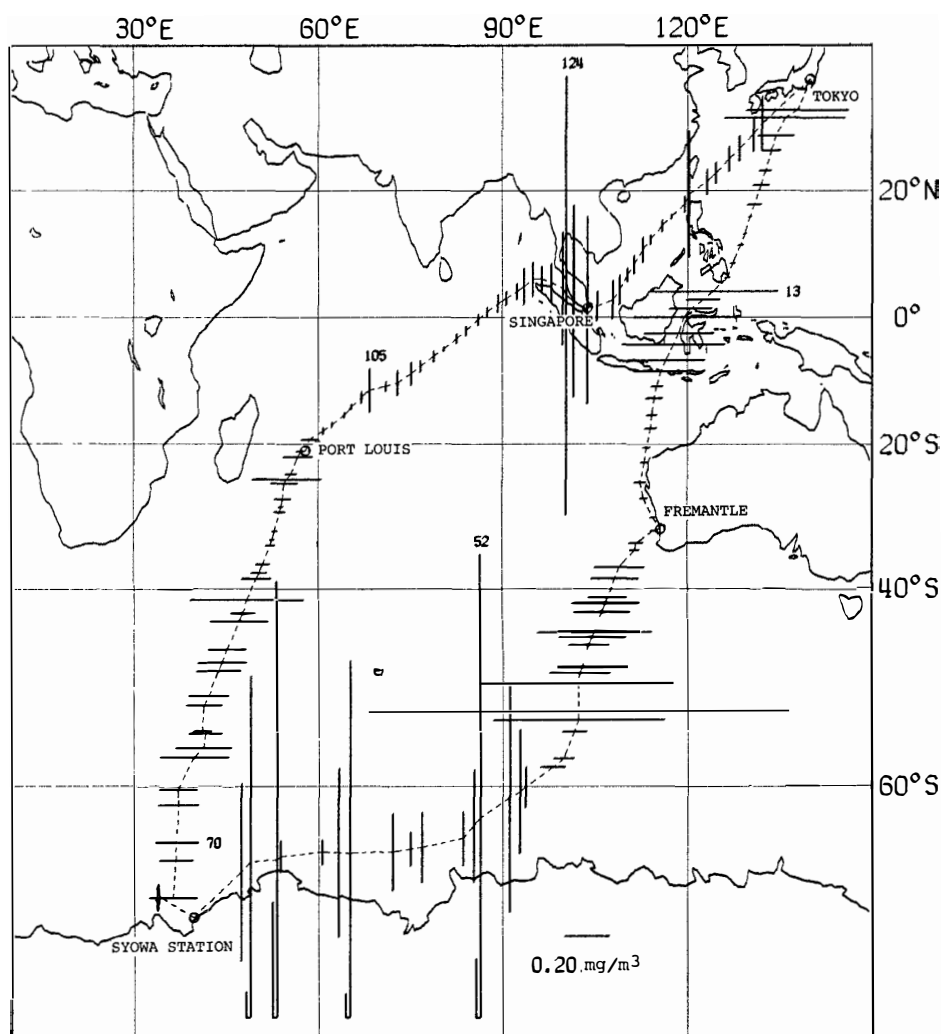


Fig. 1. The distribution of chlorophyll *a* (—) along the cruise track of the FUJI (----) in 1977-1978. Numeral indicates the serial number of the sampling station.

the high values were seen at Stns. 1 and 2, the chlorophyll *a* values are low in the same range of the previous results (HOSHIAI, 1968; OHNO, 1976; FUKUCHI, 1977).

### 3.2. Celebes Sea and Makassar Strait (Stns. 13-20)

The high values of chlorophyll *a* were observed in these regions and ranged from 0.19 to 0.58 mg. The highest value of 0.58 mg was comparable to the value reported by OHYAMA and MAYAMA (1976).

### 3.3. Eastern part of Indian Ocean (Stns. 21-31)

In the eastern part of the Indian Ocean north of 35°S latitude, the values were quite low in the range of 0.02-0.07 mg. OHYAMA and MAYAMA (1976) and FUKUCHI (1977) observed the high chlorophyll *a* concentration in this region, but

no such high values were seen in the present observation.

#### 3.4. From Indian Ocean to Antarctica (Stns. 32–53)

In the Southern Ocean, it is well known that there exist several different water masses which are demarcated by the Subtropical and the Antarctic Convergences. The location of these two Convergences can be known by the sudden changes in surface water temperature (DEACON, 1937, 1963; MACKINTOSH, 1946) and the concentrations of nutrient salts, such as phosphate-P and silicate-Si (TORII *et al.*, 1959).

The longitudinal changes in the water temperature as well as phosphate-P, silicate-Si and chlorophyll *a* of the surface water are shown in Fig. 2. The sudden changes in temperature and nutrient salts occurred both between Stns. 37 and 40, and between Stns. 44 and 46. The locations of these stations might coincide with the Subtropical and the Antarctic Convergences, respectively. The chlorophyll *a* concentration increased at Stn. 38 (0.51 mg) in the Subtropical Convergence, and at Stn. 44 (1.81 mg) north of the Antarctic Convergence, and at Stn. 52 (2.35 mg)

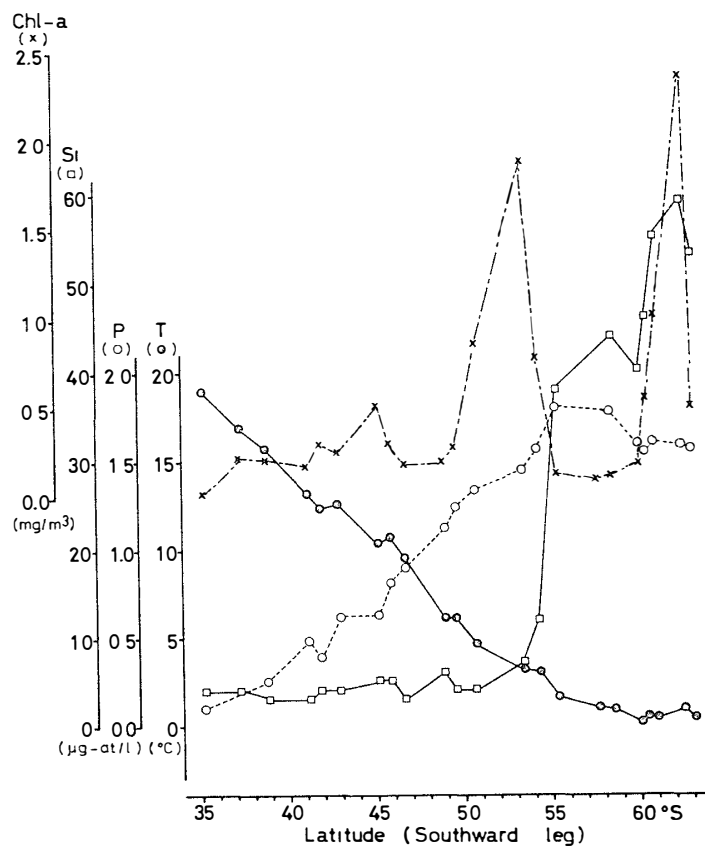


Fig. 2. Longitudinal changes in water temperature, phosphate-P, silicate-Si, and chlorophyll *a* on outward leg between 35°S and 63°S latitudes.

in the Antarctic Surface Water south of the Antarctic Convergence. The general tendency of the longitudinal changes of the chlorophyll *a* concentration from north to south agreed with the results obtained by TOMINAGA (1971), HOSHINO (1974), OHYAMA and MAYAMA (1976) and FUKUCHI (1977), but differed from the results by TAKAHASHI (1969) who reported the decreasing tendency toward the southern bound.

### 3.5. Along Antarctic Continent (Stns. 54–64)

In the region south of 63°S latitude on the outward leg the FUJI turned west toward Syowa Station and the latitudinal changes in temperature, phosphate-P, silicate-Si and chlorophyll *a* were as shown in Fig. 3. The temperature was in the range of  $-1.9$ – $1.6^{\circ}\text{C}$ . The chlorophyll *a* values fluctuated largely in the range of 0.11–2.48 mg. The high values were observed at Stns. 58 (1.72 mg) and 62 (2.48 mg). HOSHIAI (1968) and TAKAHASHI (1969) reported the low chlorophyll *a* concentrations between 80°E and 45°E longitudes. However, the present observation revealed the high concentrations in the same region which was quite similar to the results obtained by FUKUCHI (1977).

### 3.6. From Antarctic Ocean to Indian Ocean (Stns. 65–87)

The longitudinal changes in temperature, phosphate-P, silicate-Si and chlorophyll *a* between 68°S and 35°S latitudes on the homeward leg are shown in Fig. 4. The Antarctic and the Subtropical Convergences were thought to exist at about 50°S

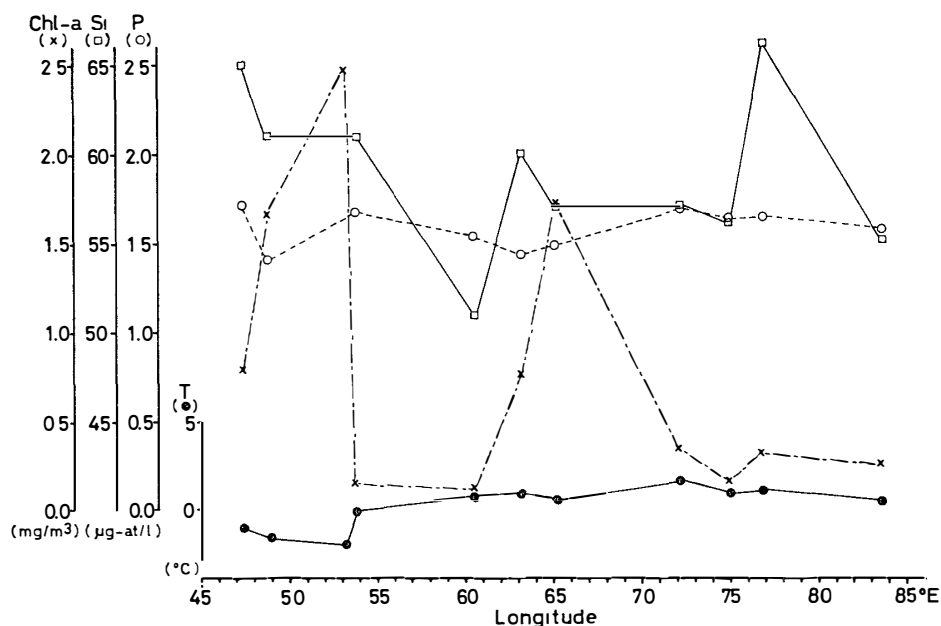


Fig. 3. Latitudinal changes in water temperature, phosphate-P, silicate-Si, and chlorophyll *a* along the Antarctic Continent south of 63°S latitude.

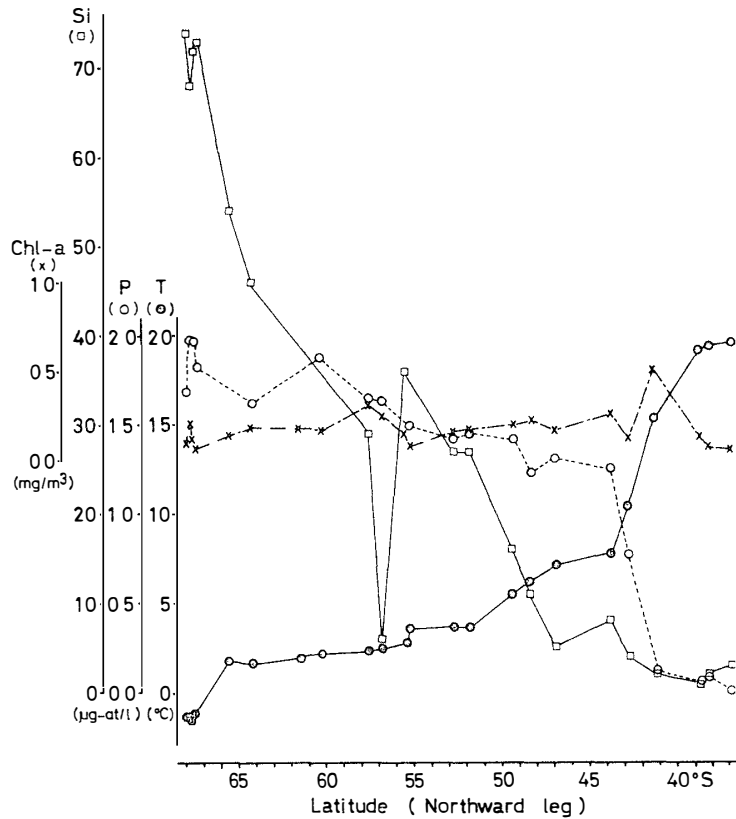


Fig. 4. Longitudinal changes in water temperature, phosphate-P, silicate-Si, and chlorophyll *a* on homeward leg between 68°S and 35°S latitudes.

between Stns. 78 and 80, and at about 43°S between Stns. 82 and 84, respectively. The locations of the Convergences were quite similar to those observed by FUKUCHI (1977). The chlorophyll *a* concentrations were generally low in the range of 0.06–0.26 mg in comparison with the values observed on the outward leg, but the high value of 0.51 mg was seen at Stn. 84 north of the Subtropical Convergence. The values obtained south of 63°S latitude (Stns. 65–70) were lower than those on the outward leg (Stns. 54–64). The longitudinal change of chlorophyll *a* concentration on the homeward leg was different from that observed on the outward leg (cf. Fig. 2). Furthermore, the longitudinal change differed from that reported by FUKUCHI (1977) in the same region, although the locations of the Convergences were the same in two observations. Therefore, the difference between the two observations seems to be the results of annual fluctuation in the chlorophyll *a* concentration.

### 3.7. Western and northern parts of Indian Ocean (Stns. 88–119)

The chlorophyll *a* concentrations remained low (0.02–0.19 mg) in this region except a high value of 0.31 mg at Stn. 95. These low values were in the range of

Table 1. Mean value and standard deviation of chlorophyll *a* content and range of water temperature in observed regions.

Region	Station number	Month	Chl. <i>a</i> (mg/m <sup>3</sup> ) Mean±S.D. (N)	Range of water temperature (°C)
Western part of North Pacific	1-12	Late Nov.	0.13±0.18 (12)	22.3-28.9
	138-143	Middle Apr.	0.14±0.06 (6)	20.2-25.6
Celebes Sea and Makassar Strait	13-20	Early Dec.	0.34±0.15 (8)	28.6-29.9
Malacca Strait	120-126	Late Mar.	0.65±0.65 (7)	29.4-29.8
South China Sea	127-137	Early Apr.	0.13±0.15 (11)	25.8-29.3
Eastern part of Indian Ocean	21-31	Middle Dec.	0.04±0.02 (11)	19.4-29.7
Western and northern Indian Ocean	88-119	Mar.	0.07±0.06 (32)	21.8-30.2
Northern part of Subtropical Convergence	32-37	Middle Dec.	0.20±0.09 (6)	12.3-19.0
	84-87	Early Mar.	0.19±0.21 (4)	15.3-19.6
	(32-37, 84-87)		(0.20±0.14 (10))	
Subtropical Convergence	38, 39	Late Dec.	0.41±0.15 (2)	10.3-10.7
	83	Early Mar.	0.11 (1)	10.4
Subantarctic Upper Water	40-44	Late Dec.	0.68±0.73 (5)	3.1-9.5
	80-82	Early Mar.	0.22±0.05 (3)	6.2-7.8
	(40-44, 80-82)		(0.51±0.60 (8))	
Antarctic Convergence	45	Late Dec.	0.77 (1)	2.9
	79	Early Mar.	0.20 (1)	5.5
	(45, 79)		(0.49±0.40 (2))	
Antarctic Surface Water	46-53	Late Dec.	0.61±0.77 (8)	0.0-1.5
	71-78	Late Feb.	0.19±0.07 (8)	2.0-3.7
Along Antarctic Continent	54-64	Late Dec.	0.79±0.81 (11)	-1.9-1.6
	65-70	Late Feb.	0.14±0.05 (6)	-1.5-1.8
	(46-78)		(0.48±0.65 (33))	

previous results (HOSHINO, 1974; OHNO, 1976; FUKUCHI, 1977).

### 3.8. Malacca Strait (Stns. 120–126)

In the Malacca Strait, the value increased and the maximum value of 1.95 mg was observed at Stn. 124. This value was much higher than that reported by HOSHINO (1974), OHNO (1976) and FUKUCHI (1977).

### 3.9. South China Sea (Stns. 127–137)

The chlorophyll *a* concentrations became low in the South China Sea, ranging from 0.02 to 0.17 mg, although an exceptional high value (0.56 mg) was observed at Stn. 137.

### 3.10. Summary of regional distributions

The present observations of the chlorophyll *a* distributions were extended over a long period of five months and covered a wide area from the Northern Hemisphere to the Southern Hemisphere. The oceanographical nature of the observed regions also varied from a coastal one to an oceanic one. For these reasons, the comparison of the chlorophyll *a* values among different regions might be difficult. However, it seems important to accumulate the information about the chlorophyll *a* concentrations peculiar to each region for evaluating the level of the phytoplankton standing stock among different regions.

Summarizing the chlorophyll *a* concentrations in the observed regions, the mean value and the standard deviation of chlorophyll *a* in different regions were calculated, and are listed in Table 1 together with the station number, date, range of temperature. The mean value was highest along the Antarctic Continent on the outward leg (0.77 mg) among the observed regions. The Subantarctic Upper Water and the Antarctic Surface Water on the outward leg showed high mean values of 0.68 and 0.61 mg, respectively. Also, the high values were obtained in the Malacca Strait (0.65 mg) and in the Celebes Sea and the Makassar Strait (0.34 mg). The mean chlorophyll *a* concentrations in other regions were low in comparison with the regions mentioned above.

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*Appendix 1. Chlorophyll a contents and water temperatures obtained during the relief voyage of FUJI to Syowa Station, Antarctica, 1977-1978.*

STATION NO.	DATE	TIME	LATITUDE	LONGITUDE	CHLOROPHYLL-A	WATER TEMP.
1	1977 NOV. 26	0800	31 33 N	137 48 E	0.46	22.3
2		1800	30 30	135 48	0.54	23.3
3	27	0800	27 58	134 18	0.16	23.3
4		1800	25 52	133 35	0.08	24.8
5	28	0800	22 52	132 36	0.05	27.2
6		1800	20 43	131 55	0.07	27.2
7	29	0800	17 45	130 47	0.06	27.6
8		1800	15 53	130 7	0.01	27.6
9	30	0800	13 16	129 16	0.01	28.0
10		1820	11 28	128 34	0.02	28.9
11	DEC. 1	0800	8 39	127 15	0.02	28.9
12		1800	6 23	126 26	0.02	28.8
13	2	0800	4 9	124 4	0.58	28.7
14		1800	2 48	122 27	0.15	29.1
15	3	0800	1 23	120 35	0.19	28.6
16		1800	0 2	119 26	0.45	29.0
17	4	0800	2 36 S	118 37	0.31	28.9
18		1800	4 23	117 44	0.46	29.9
19	5	0800	6 56	116 29	0.35	29.4
20		1800	8 39	115 44	0.24	29.4
21	6	0800	11 5	115 1	0.05	28.9
22		1800	12 56	114 37	0.07	29.7
23	7	0800	15 34	114 13	0.04	28.1
24		1800	17 33	114 0	0.05	28.8
25	8	0800	20 31	113 19	0.03	25.5
26		1800	22 42	112 57	0.03	24.4
27	9	0800	25 40	112 22	0.05	22.7
28		1800	27 56	112 55	0.03	21.9
29	10	0800	30 36	114 25	0.02	21.1
FREMANTLE						
30	16	1800	32 28	114 24	0.02	21.0
31	17	0800	34 6	111 41	0.06	19.4
32		1800	35 2	111 26	0.04	19.0
33	18	0800	37 17	108 57	0.22	16.9
34		1800	38 43	108 13	0.21	15.7
35	19	0800	41 9	107 1	0.17	13.1
36		1200	41 50	106 39	0.30	12.3
37		1800	42 54	106 4	0.25	12.6
38	20	0800	45 6	104 51	0.51	10.3
39		1200	45 45	104 30	0.30	10.7
40		1800	46 36	103 54	0.18	9.5

STATION NO.	DATE	TIME	LATITUDE	LONGITUDE	CHLOROPHYLL-A	WATER TEMP.
41	DEC. 21	0800	48 55 S	102 54 E	0.20	6.1
42		1200	49 33	102 32	0.27	6.1
43		1800	50 40	102 14	0.86	4.6
44	22	0800	53 26	102 13	1.89	3.1
45		1200	54 14	102 13	0.77	2.9
46		1800	55 18	101 29	0.11	1.5
47	23	0800	57 40	99 48	0.09	0.9
48		1800	58 25	98 2	0.11	0.8
49	24	0800	60 1	93 41	0.18	0.0
50		1200	60 24	92 42	0.55	0.3
51		1700	60 53	91 5	1.02	0.3
52	25	0800	62 26	86 20	2.35	0.8
53		1200	63 0	85 14	0.50	0.3
54		1800	63 54	83 29	0.24	0.3
55	26	0800	64 32	76 48	0.31	1.0
56		1200	64 39	74 57	0.15	0.8
57		1800	64 50	72 6	0.34	1.6
58	27	0800	64 57	65 5	1.72	0.5
59		1200	64 54	63 13	0.75	0.9
60		1800	64 53	60 30	0.11	0.7
61	28	0800	65 11	53 46	0.14	-0.1
62		2000	65 22	53 14	2.48	-1.9
63	29	0800	65 32	48 53	1.66	-1.6
64		1200	66 12	47 23	0.79	-1.0
ICE EDGE OFF SYOWA STATION						
65	1978 FEB. 23	1800	67 44	34 0	0.07	-1.2
66	24	0500	67 52	33 44	0.10	-1.3
67		1800	67 46	33 54	0.12	-1.5
68	25	0500	67 50	36 16	0.21	-1.3
69	26	0800	65 28	36 41	0.15	1.8
70		1800	64 13	36 59	0.19	1.7
71	27	0800	61 30	37 4	0.18	2.0
72		1800	60 12	37 6	0.17	2.2
73	28	1200	57 33	39 41	0.31	2.3
74		1800	56 45	41 14	0.25	2.5
75	MAR. 1	0800	55 24	41 34	0.15	2.8
76		1800	55 14	41 1	0.08	3.6
77	2	1200	52 46	41 19	0.16	3.7
78		1800	51 49	42 5	0.18	3.7
79	3	0800	49 15	43 49	0.20	5.5
80		1200	48 22	44 23	0.22	6.2

STATION NO.	DATE	TIME	LATITUDE	LONGITUDE	CHLOROPHYLL-A	WATER TEMP.
81	MAR. 3	1800	46 57 S	45 12 E	0.17	7.1
82	4	0800	43 45	47 0	0.26	7.8
83		1200	42 49	47 35	0.11	10.4
84		1800	41 23	48 23	0.51	15.3
85	5	0800	38 47	49 53	0.13	19.2
86		1200	38 4	50 23	0.07	19.4
87		1800	36 56	50 56	0.06	19.6
88	6	0800	34 29	52 12	0.04	22.1
89		1200	33 43	52 29	0.02	21.8
90		1800	32 33	52 53	0.02	22.5
91	7	0800	29 54	53 42	0.05	23.6
92		1200	29 11	53 55	0.02	23.8
93		1800	28 4	54 14	0.07	24.4
94	8	0800	25 49	54 28	0.12	26.1
95		1200	25 14	54 47	0.31	26.1
96		1800	24 27	55 26	0.05	26.1
97	9	0800	21 56	56 36	0.13	26.9
98		1200	21 5	57 3	0.04	26.6
PORT LOUIS						
99	16	1800	19 19	58 28	0.07	27.5
100	17	0800	17 59	60 43	0.03	27.4
101		1800	17 0	62 11	0.02	27.9
102	18	0800	15 33	64 12	0.02	27.6
103		1800	14 17	65 20	0.02	27.8
104	19	0800	12 49	67 1	0.05	27.8
105		1800	11 39	68 26	0.19	26.7
106	20	0800	11 3	71 4	0.04	27.9
107		1800	10 33	72 59	0.11	28.6
108	21	0800	9 5	75 12	0.10	28.6
109		1800	7 55	76 43	0.05	28.6
110	22	0800	6 18	78 52	0.05	28.7
111		1800	5 8	80 30	0.02	28.8
112	23	0800	3 26	82 36	0.04	29.0
113		1800	2 10	84 6	0.04	29.7
114	24	0800	0 22	86 8	0.05	30.1
115		1800	0 51 N	87 35	0.04	30.2
116	25	0800	2 14	89 17	0.08	29.7
117		1800	3 3	90 33	0.06	30.1
118	26	0800	4 8	92 18	0.07	29.7
119		1800	4 56	93 26	0.16	29.1
120	27	0800	6 7	94 54	0.15	29.5

STATION NO.	DATE	TIME	LATITUDE	LONGITUDE	CHLOROPHYLL-A	WATER TEMP.
121	MAR. 27	1800	6 8 N	96 17 E	0.11	29.8
122	28	0800	5 32	97 54	0.17	29.7
123		1800	4 36	99 45	0.50	29.7
124	30	1200	3 28	100 22	1.95	29.4
125		1800	2 33	101 28	0.85	29.7
126	31	0800	1 10	103 47	0.83	29.6
SINGAPORE						
127	APP. 8	1800	1 46	105 21	0.13	29.1
128	9	0800	2 45	107 53	0.17	28.6
129		1800	4 23	108 58	0.13	29.3
130	10	0800	6 50	110 17	0.06	28.5
131		1800	8 30	111 18	0.08	28.7
132	11	0800	10 50	112 47	0.11	28.8
133		1800	12 26	113 58	0.04	28.9
134	12	0800	14 34	115 52	0.05	28.7
135		1800	15 59	117 20	0.02	28.8
136	13	0800	17 55	119 33	0.07	28.4
137		1800	19 24	120 16	0.56	25.8
138	14	0800	21 15	123 13	0.11	25.6
139		1800	22 34	124 39	0.09	24.8
140	15	0800	24 39	126 45	0.11	23.0
141		1800	26 7	128 27	0.11	22.6
142	16	0800	28 13	130 44	0.15	20.2
143		1800	29 45	132 4	0.24	20.4