

SEA SURFACE TEMPERATURE GRADIENTS SOUTH OF AUSTRALIA

by J. W. Zillman

Central Office, Bureau of Meteorology, Melbourne

(Manuscript received February 1970)

ABSTRACT

Attention is drawn to the presence of a narrow zone of very steep sea surface temperature gradient south of Australia near 50°S and its approximate location mapped between 90° and 165°E.

1. INTRODUCTION

In a discussion of some preliminary results on sea-air energy exchange south of Australia, based on measurements taken aboard the USNS 'Eltanin' during the spring of 1968 (Zillman and Dingle, 1969), a persistent zone of steep sea surface temperature gradient a few hundred miles north of the Antarctic Convergence was shown to be associated with oceanic heat losses approaching 250 watts metre². The intensity and persistence of this oceanic frontal zone prompted an examination of some additional sea temperature records to see if it was peculiar to the August-December period of 1968 or in fact a quasi-permanent feature of the Southern Ocean.

2. SEA TEMPERATURE PROFILES 40° - 60°S

Sea temperature measurements from 43 approximately meridional traverses between southern Australia and 55° to 60°S were examined. They were extracted from the log books of the antarctic relief ships 'Thala Dan' and 'Nella Dan' (Bureau of Meteorology), the published meteorological data from the ice breaker 'Fuji' during the eighth Japanese Antarctic Expedition (Japan Meteorological Agency, 1968), and meteorological log books and supplementary measurements during USNS 'Eltanin' cruises 35-39 (Dingle, 1969). A number of additional traverses by Australian antarctic relief vessels could not be used because sea temperature measurements were recorded either too infrequently or only to the nearest whole degree.

For each traverse the recorded sea temperatures were plotted against latitude and in all but two cases a marked steepening of the poleward temperature decrease, extending over at most a few degrees of latitude, was observed within the Subantarctic Water between the observed or expected locations of the Subtropical and Antarctic Convergences. Fig. 1 shows the tracks and Fig. 2 (a-d) the temperature-latitude profiles for four well defined but fairly typical cases. The steep decrease of temperature centred at latitudes from 47° to 55°S (depending upon the meridian) is remarkable. It is bordered to the north by almost homogeneous water for several hundred miles. Relatively homogeneous water with temperatures around 3°-5°C is found also to the south for a hundred miles or more, terminating in the transition to Antarctic Surface Water through the Antarctic Convergence or Oceanic Polar Front. The latter is not clearly defined in any of the profiles shown but can tentatively be placed at 53°S in profile (a), 56.2°S in (b), 55.3°S in (c) and in the vicinity of 60°S in (d) of Fig. 2.

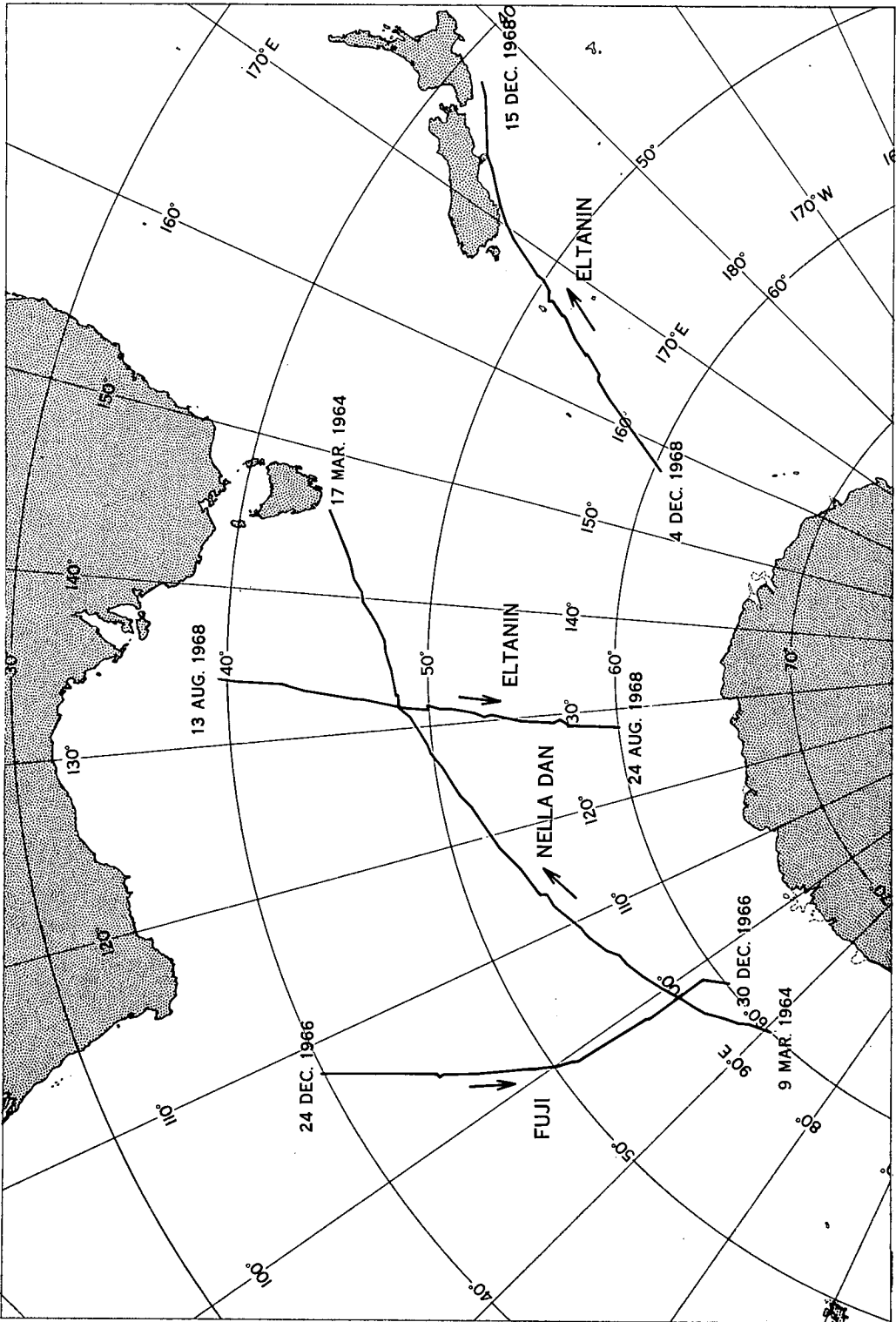
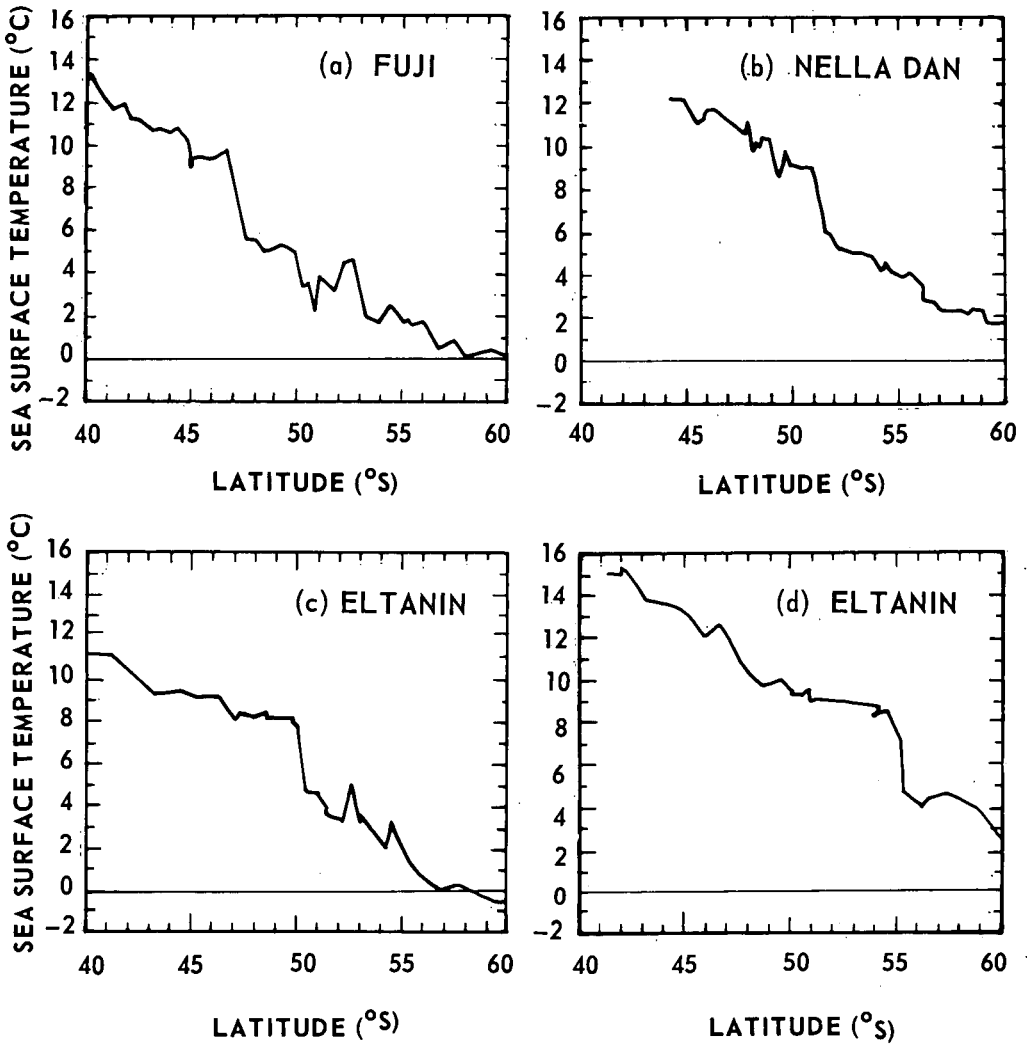


Fig. 1. Tracks of vessels providing the four sea temperature - latitude profiles of Fig. 2.



- (a) *FUJI* - 24-30 Dec. 1966 (No. 18 in Table 1)
 (b) *NELLA DAN* - 9-17 Mar. 1966 (No. 13 in Table 1)
 (c) *ELTANIN* - 13-24 Aug. 1968 (No. 20 in Table 1)
 (d) *ELTANIN* - 4-15 Dec. 1968 (No. 27 in Table 1)

Fig. 2 Sea temperature versus latitude along the tracks shown in Fig. 1.

Though the extent of the steepened gradient was immediately obvious in most profiles, in a few the decrease continued unchecked into water of temperature around 2° - 3° C (and so probably embraced also the Polar Front). In others, a series of two or three steps in close proximity made selection of the temperature at which the major decrease commenced rather subjective. For this reason the gradients were selected according to the following arbitrarily set criteria:

- (i) Temperature on the warm side of the zone $6\frac{1}{2}^{\circ}$ to 11° C, with an average rise of no more than 2° C in the next 250 miles to the north.
- (ii) A drop of 3° C or more within 100 miles, the general level of temperatures being confirmed by at least 2 values and a subsequent recovery no greater than $1\frac{1}{2}^{\circ}$ C.
- (iii) Temperatures on the cold side of the gradient no lower than about 3° C in winter or $4\frac{1}{2}^{\circ}$ C in summer.

On this basis 35 of the 43 profiles exhibit the phenomenon and these are summarised in Table 1. Of the 35 a small number (marked with an asterisk) actually fall just outside the set criteria, whilst in another 6 (not included in Table 1) the steepened gradient is evident but does not approach the criteria. In each case the latitude, longitude and sea temperature on the warm and cold edges of the zone are listed. Surface winds at the time of measurement are also included.

Table 1. Dates, positions, temperatures and surface winds at the warm (upper line) and cold (lower line) edges of the zone of steep sea surface gradient in the Southern Ocean south of Australia

No.	Ship	Date (GMT)	Lat. ($^{\circ}$ S)	Long. ($^{\circ}$ E)	Sea Temp. ($^{\circ}$ C)	Surface Wind (deg/kt)
1	Thala Dan	Dec 31, 1958	47.2	131.8	10.5	350/28
		Jan 1, 1959	48.8	128.5	7.0	260/20
2	Thala Dan	Feb 27, 1959	48.2	129.0	9.8	310/14
		Feb 26, 1959	50.1	124.3	6.5	300/18
3	Thala Dan*	Dec 20, 1959	50.5	155.9	10.6	350/10
		20, 1959	52.2	157.2	7.8	050/15
4	Thala Dan	Mar 16, 1961	49.1	118.0	8.0	300/36
		Mar 15, 1961	50.7	108.5	5.0	180/25
5	Thala Dan	Dec 25, 1961	49.7	140.6	10.6	270/16
		25, 1961	51.3	139.1	6.7	260/06
6	Thala Dan	Dec 25, 1962	50.3	138.9	8.3	250/35
		25, 1962	51.4	136.8	5.3	280/12
7	Nella Dan	Jan 23, 1963	47.5	86.8	9.4	260/40
		Jan 24, 1963	48.8	83.2	5.7	260/30
8	Nella Dan*	Dec 14, 1963	51.4	156.1	8.9	300/20
		Dec 15, 1963	53.5	158.2	6.1	280/04
9	Nella Dan	Dec 22, 1963	50.9	156.0	8.6	280/35
		22, 1963	52.5	157.3	5.6	280/23
10	Nella Dan*	Jan 7, 1964	48.8	130.0	8.9	200/10
		Jan 8, 1964	50.6	127.7	6.1	170/06

* Outside the set criteria (see text)

Table 1. (Cont'd)

No.	Ship	Date (GMT)	Lat. ($^{\circ}$ S)	Long. ($^{\circ}$ E)	Sea Temp. ($^{\circ}$ C)	Surface Wind (deg/kt)
11	Nella Dan	Jan 26, 1964	48.1	112.8	10.0	360/35
		26, 1964	50.0	112.2	5.0	350/25
12	Nella Dan*	Feb 8, 1964	46.6	98.0	10.0	310/22
		Feb 9, 1964	48.3	96.0	6.9	310/28
13	Nella Dan	Mar 13, 1964	50.9	124.6	8.9	030/31
		13, 1964	51.9	121.1	5.9	360/22
14	Nella Dan*	Dec 25, 1964	49.2	131.3	10.0	040/08
		Dec 26, 1964	51.8	127.2	6.4	230/21
15	Nella Dan	Jan 1, 1966	48.8	136.6	10.0	270/17
		1, 1966	50.7	136.6	6.1	290/28
16	Thala Dan*	Jan 13, 1966	50.2	142.6	9.9	290/25
		Jan 14, 1966	52.5	143.9	6.1	290/15
17	Nella Dan*	Mar 9, 1966	47.2	142.3	11.2	240/15
		9, 1966	48.6	139.2	8.2	240/24
18	Fuji	Dec 26, 1966	46.6	102.9	9.6	260/20
		26, 1966	47.6	102.2	5.5	210/35
19	Nella Dan*	Jan 1, 1967	48.7	128.6	9.9	230/32
		Jan 2, 1967	51.2	127.6	6.1	360/15
20	Eltanin Cruise 35	Aug 18, 1968	50.0	131.3	8.1	170/22
		Aug 19, 1968	50.6	131.4	4.6	160/36
21		Aug 31, 1968	48.0	128.1	8.4	250/30
		Aug 29, 1968	50.5	128.0	3.5	310/35
22		Sep 18, 1968	48.8	117.0	6.8	280/15
		Sep 19, 1968	50.1	117.0	3.0	260/29
23		Oct 1, 1968	47.9	127.6	8.3	300/24
		Sep 30, 1968	49.9	125.8	4.7	200/25
24	Eltanin Cruise 36	Oct 25, 1968	49.0	140.1	8.8	210/11
		Oct 27, 1968	51.8	140.0	3.0	280/21
25		Nov 14, 1968	51.0	150.0	8.9	260/37
		Nov 13, 1968	52.0	150.0	5.0	300/09
26		Nov 25, 1968	50.8	154.9	9.1	270/26
		Nov 26, 1968	52.8	155.1	5.8	360/12
27		Dec 7, 1968	54.6	164.0	8.6	270/38
		7, 1968	55.3	163.0	4.8	050/29
28	Eltanin Cruise 37	Jan 15, 1969	52.0	162.5	10.9	050/06
		Jan 16, 1969	53.6	159.5	8.0	350/12
29	*	Feb 26, 1969	48.0	125.0	10.0	290/16
		Feb 25, 1969	49.3	120.3	6.9	300/28
30	Eltanin Cruise 38	Mar 24, 1969	53.6	149.8	8.0	280/20
		Mar 25, 1969	55.0	150.0	5.1	060/10
31		Apr 9, 1969	54.8	149.0	7.8	060/20
		9, 1969	55.2	149.0	4.3	040/13

* Outside the set criteria (see text)

Table 1. (Cont'd)

No.	Ship	Date (GMT)	Lat. ($^{\circ}$ S)	Long. ($^{\circ}$ E)	Sea Temp. ($^{\circ}$ C)	Surface Wind (deg/kt)
32	Eltanin Cruise 38	Apr 15, 1969	54.7	149.6	7.8	300/25
		Apr 16, 1969	55.5	149.9	3.3	280/21
33		Apr 25, 1969	49.7	152.5	10.2	010/20
		Apr 24, 1969	50.6	151.9	6.9	280/16
34	Eltanin Cruise 39	Jun 29, 1969	49.2	126.0	8.9	040/29
		Jul 1, 1969	51.1	126.1	4.5	320/28
35	*	Jul 12, 1969	48.9	134.0	7.8	150/20
		Jul 11, 1969	50.8	134.0	4.9	020/10

* Outside the set criteria (see text)

One particular feature of interest evident in many profiles was the existence of patches or channels of relatively warm water within a few hundred miles south of the main gradient. These are evidently neither spurious effects of measurement error nor random effects of local winds. Fig. 3 shows two profiles between one and two weeks apart in time and along 126° E and 134° E respectively (with scales shifted 4° C for clarity). Some decrease in the main gradient is apparent in the 134° E profile but the warm water to the south persists. Several other examples are equally striking and in fact in cases Nos. 30-32 of Table 1 the warm channel and subsequent poleward drop, rather than the main gradient further north, fit the set criteria.

3. MEAN LOCATION OF THE ZONE OF STEEP GRADIENT

The gradients from Table 1 are shown in Fig. 4 as line segments numbered as in the table. The six additional sub-criteria gradients are included as broken lines. There is no conclusive evidence of seasonal shift in those longitudes where both summer and winter fixes were available, and the smooth curve extending from 90° to 165° E has been adopted as an approximate mean location of the middle of the zone pending the availability of more definitive data. Fig. 4 includes also the Oceanic Polar Front Zone as summarised by Zillman and Phillipot (1970) and the "mean" location of the Subtropical Convergence as given by Deacon (1963). Ivanov's (1961) so-called Subantarctic Divergence as given by Tolstikov et al. (1966) is shown as a dotted line.

4. DISCUSSION

There seems little doubt that the zone of steep sea temperature gradient noted earlier (Zillman and Dingle, 1969) is a quasi-permanent feature of this sector of the Southern Ocean. It is usually the most prominent feature of the temperature decrease between Australia and Antarctica, being much more easily recognisable in sea surface temperature behaviour than in either the Subtropical Convergence or the Polar Front. When averaged, irrespective of season, the decrease through the zone of steep gradient is 3.6° C and its average latitudinal extent 95 miles. Temperatures at its northern edge would appear to have an annual average between $8\frac{1}{2}^{\circ}$ and 9° C.

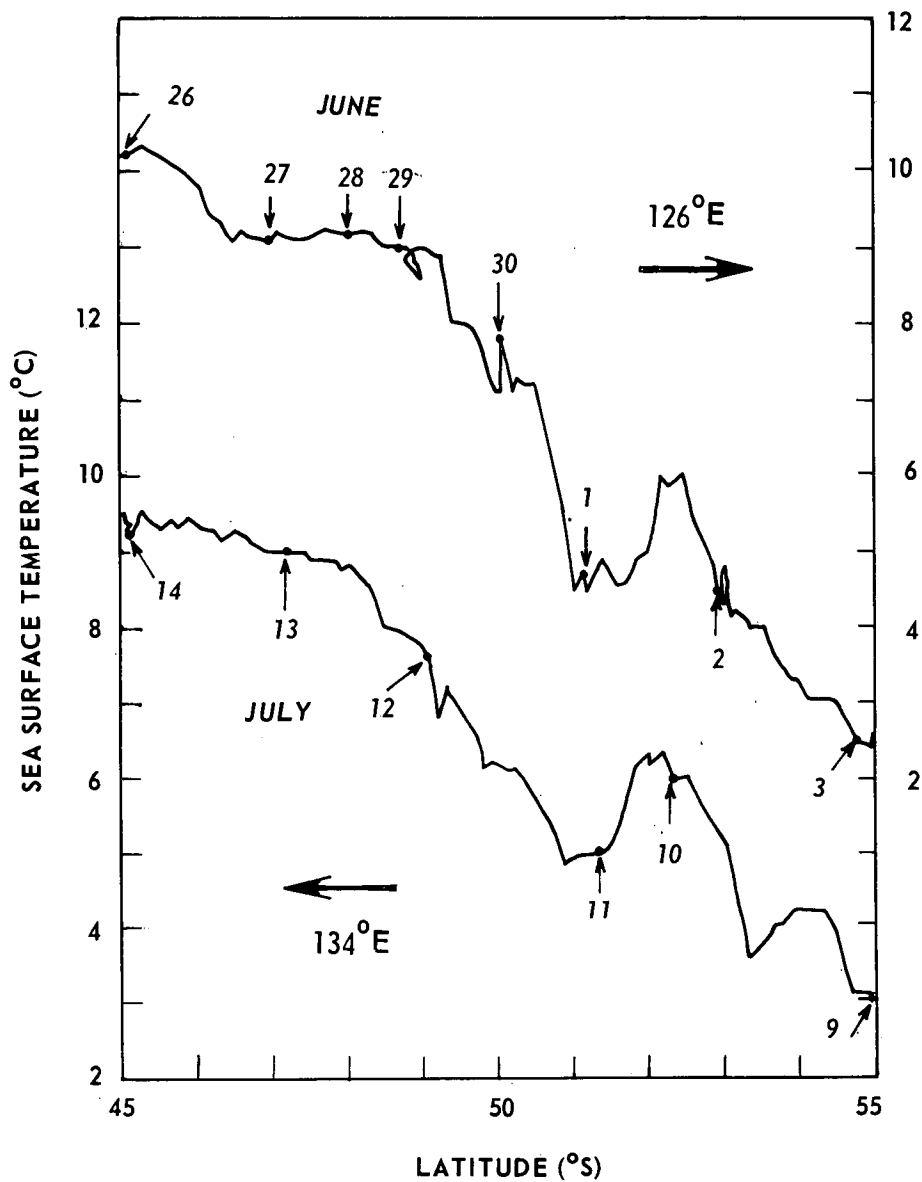


Fig. 3 Sea temperature profiles 45° – 55° S along meridians 126° E (top) and 134° E in June, July 1969 (dates as shown). Note 4° C downward displacement of the temperature scale for the 134° E profile.

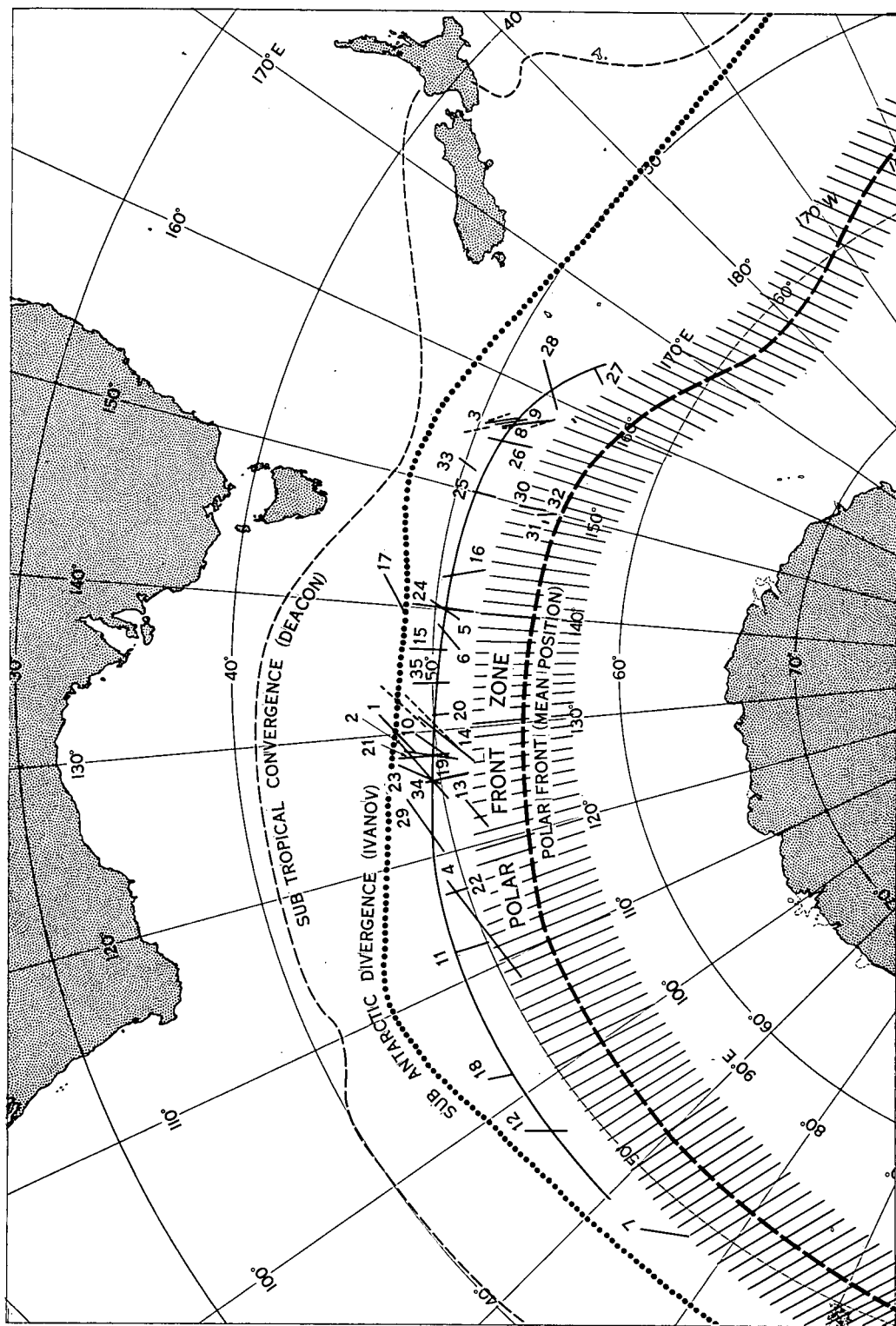


Fig. 4 Location of the zone of steep sea temperature gradient (crossings numbered as in Table 1).

Though sea surface temperatures only have been examined and no information is yet available to the author on subsurface temperatures or salinity distribution, it would seem that this feature may be identified in a general sense with the Australasian Subantarctic Front discussed by Burling (1961) and Houtman (1967) on the basis of hydrological data. It appears to bear less direct relation to Ivanov's (1961) Subantarctic Divergence as positioned by Tolstikov et al. (1966). Though it can be readily identified in several of the "Discovery" cross-sections (e.g. Deacon, 1937) it does not appear to have been previously noted as a quasi-continuous feature of the surface temperature regime.

REFERENCES

- | | | |
|-------------------------------------|------|--|
| Bureau of Meteorology | 1969 | Meteorological logbooks of 'Thala Dan' and 'Nella Dan'. (Unpublished). |
| Burling, R. W. | 1961 | Hydrology of circumpolar waters south of New Zealand. N. Z. D.S.I.R. Bull. 149, 66 pp. |
| Deacon, G. E. R. | 1937 | The hydrology of the Southern Ocean. Discovery Report, <u>15</u> , pp. 1-124. |
| | 1963 | The Southern Ocean: in The Sea (M. N. Hill, ed.) 2 pp. 281-296. Interscience Publishers, New York. |
| Dingle, W. R. J. | 1969 | (Personal communication) |
| Houtman, Th. J. | 1967 | Water masses and fronts in the Southern Ocean south of New Zealand. N. Z. D.S.I.R. Bull. 174, 40 pp. |
| Ivanov, Yu. A. | 1961 | Frontal zones in antarctic waters. Okeanolog Issled 3, pp. 30-51. |
| Japan Meteorological Agency | 1968 | Antarctic Meteorological Data, <u>6</u> , Tokyo. |
| Tolstikov, Ye. I., et al. | 1966 | Atlas of Antarctica; <u>I</u> , Main Administration of Geodesy and Cartography of the Ministry of Geology, USSR, Moscow. |
| Vowinckel, E. | 1957 | Climate of the Antarctic Ocean: in Meteorology of the Antarctic (M. P. van Rooy, ed.), Pretoria. |
| Zillman, J. W. and Dingle, W. R. J. | 1969 | Southern Ocean sea-air energy exchange. Aust. Met. Mag. <u>17</u> , 3. |
| Zillman, J. W. and Phillpot, H. R. | 1970 | November sea surface temperature distribution in the Southern Hemisphere. (To be published). |