The detailed thermal structure of the upper ocean layers between Cape Town and Antarctica during the period Jan.-Feb. 1978

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Two hydrographic sections consisting of closely spaced expendable bathy-thermograph stations have been undertaken between Cape Town and Antarctica. Surface salinities and continuous surface temperature measurements were undertaken simultaneously. The results show detail of the thermal fronts in this oceanic area and these are discussed in the light of previous comparable measurements.

Twee hidrografiese snitte, bestaande uit digte vaartlyne wegdoenbare batitermograafstasies, is tussen Kaapstad en Antarktika uitgevoer. Lesings van die soutgehalte en temperatuur van die seeoppervlak is terselfdertyd geneem. Die resultate vertoon besonderhede van die termiese fronte in hierdie oseaangebied wat hier in verband gebring word met vorige vergelykbare lesings.

Introduction

Detailed measurements have been made to determine the thermal structure of the upper layers of the Southern Ocean by means of expendable bathythermographs (XBTs), regular surface sampling and thermograph traces between Cape Town and the South African Antarctic base SANAE. We present here the results of these first two sections of an extensive programme which was designed to study the oceanic frontal systems between Africa and Antarctica (Lutjeharms *et al.* 1983).

The oceanic frontal systems in the Southern Ocean were first described in detail by Deacon (1937), who used data from the widely spaced hydrographic stations carried out from on board the RRS *Discovery II*. This information has lately been supplemented by further stations of this nature from the Japanese Antarctic Research Expeditions that concentrated on the ocean sector between Africa and Antarctica (e.g. Fukase 1962), and measurements made by Soviet (e.g. Treshnikov *et al.* 1970) and American investigators (Jacobs & Georgi 1977). Widely spaced stations have also been undertaken by South African researchers in the area of the Subtropical Convergence (e.g. Orren 1966). Closely spaced sea surface temperature readings were first used to define Southern Ocean fronts by Mackintosh (1946) and lately, in the area south of Africa, by Nieman (1965) and others. As yet only two detailed XBT sections for this area have been presented (Taylor *et al.* 1978). An extensive review of past research on oceanic frontal systems south of Africa is to be found in Lutjeharms (1983).

The thermal detail of the oceanic frontal systems in this area is thus virtually unknown. In January 1978 the opportunity arose to carry out a detailed XBT section on the last relief voyage to Antarctica of the South African supply vessel *RSA*. Measurements were made on the way to Antarctica as well as on the return voyage. The location of XBT stations on the cruise tracks is shown in Fig. 1.

Data and Methods

An attempt was made to launch an XBT probe every 20 nautical miles. Various problems arose, however, which hampered this attempt. On numerous occasions strong sidewinds blew the XBT wire across the magnetometer cable that was being streamed simultaneously, causing short-circuits. Such stormy conditions, with winds exceeding 28 knots, were experienced on 55 per cent of the cruise days. Between 13 and 15 January a defect in the launching tube prevented the launching of any XBT probes. Of the total of 186 probes launched, only 146 (74 %), were finally considered to be successful. The average distance between successful launches was thus 29 nautical miles.

Individual XBT traces were checked for errors using Kroner and Blumenthal (1977), and any showing spikes or radio interference in the record were discarded. Traces were temperature-adjusted whenever surface temperatures differed by more than 1 °C from the average temperature measured at the same time by Crawford bucket (Crawford 1965, 1972) and were also corrected for depth if required. Two consecutive measurements of sea surface temperature were made by bucket and the average taken as the correct value if the two readings did not differ by more than 0,1 °C. A Negretti & Zambra Mersteel thermograph made continuous recordings of sea water temperature as recorded at the engine room intake, at 3 m depth.

A sample of sea surface water was taken by bucket at each station. Salinities were determined by the conductivity method on a Plessey Environmental System Model 6230 N Laboratory Salinometer on return.

Results and Discussion

The results of the XBT measurements, as well as of the sea surface measurements of temperature and salinity, for the cruise leg to Antarctica are presented in Fig. 2, while those for the return leg to Cape Town are presented in Fig. 3.

Agulhas and Benguela Regime

During the first leg of the cruise, warm surface water, exceeding 20 °C, was measured as far as 40° south latitude and as far west as 14°E (Fig. 2). Steep slopes in the subsurface isotherms were noted adjacent to the continental slope and just south of 40°S.

Satellite images of the thermal infra-red radiation for the area may be used to indicate both the nature and the extent of this warm water. The METEOSAT images for 20-24 February 1978 (Fig. 4) show that an unusual loop of the Agulhas Current was present at about 37°S, 14°E on this occasion, and that the retroflection of the current lay far to the west at this time. This portrayal is about three weeks after the temperature section shown in Fig. 2, and it is known that rapid changes in the general distribution of current elements can occur here (Lutjeharms 1981d). Nevertheless, a strong resemblance between the satellite image (Fig. 4) and the temperature section (Fig. 2) exists. Particular note may in this regard be taken of the two warm-core elements at 36,5 and 40°S which are also evident in Fig. 4. It has been shown that such loops may form warm water rings (Lutjeharms 1981a). The section in Fig. 2 may thus represent measurements across a developing Agulhas Ring.

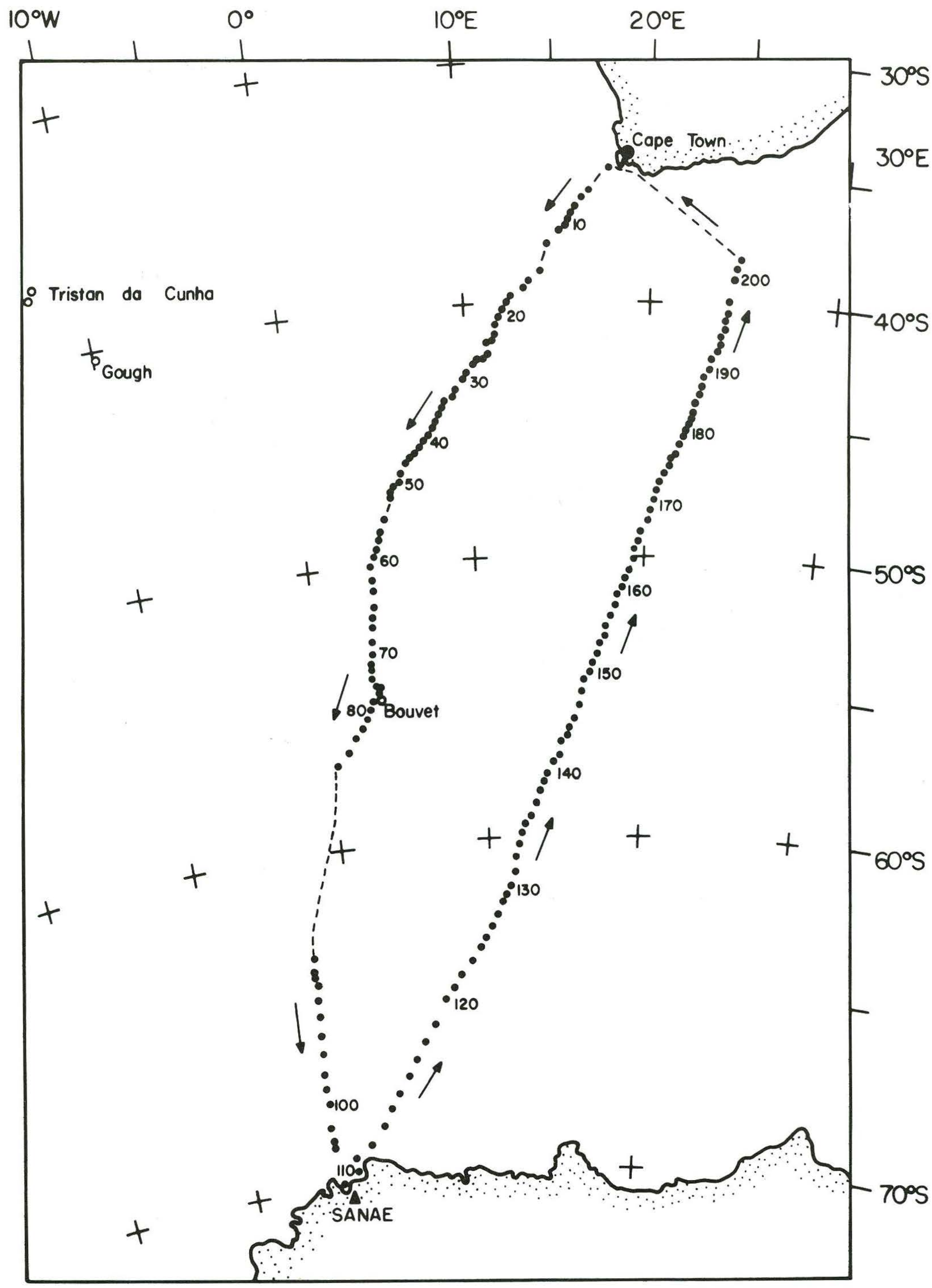

Fig. 1. The cruise track of the SANAE 19 relief voyage with XBT station positions. Numbers are for XBTs used. Between 57° and 63°S no XBT readings were undertaken and the cruise track is indicated by a dotted line.

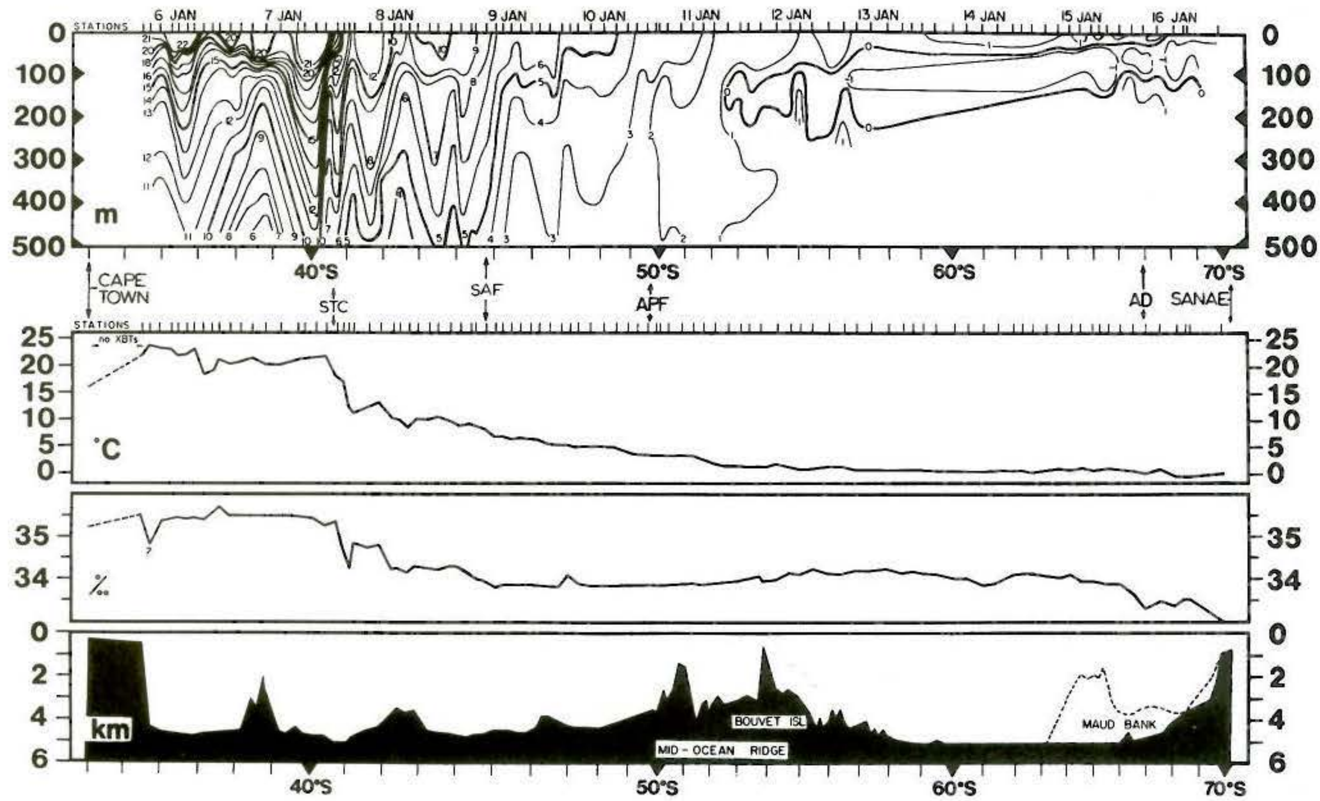

Fig. 2. Results of a detailed XBT-section between Cape Town and SANAE. The upper panel shows the isotherm distribution in the upper 500 m of the water column, the second panel the sea surface temperatures determined by Crawford bucket, the third panel the sea surface salinities and the bottom panel the bottom topography. The geographic location of the Subtropical Convergence (STC), the Subantarctic Front (SAF), the Antarctic Polar Front (APF) and the Antarctic Divergence (AD) are shown. The dotted line in the bottom topography shows the minimum depth of the Maud Bank which lies directly east of the section.

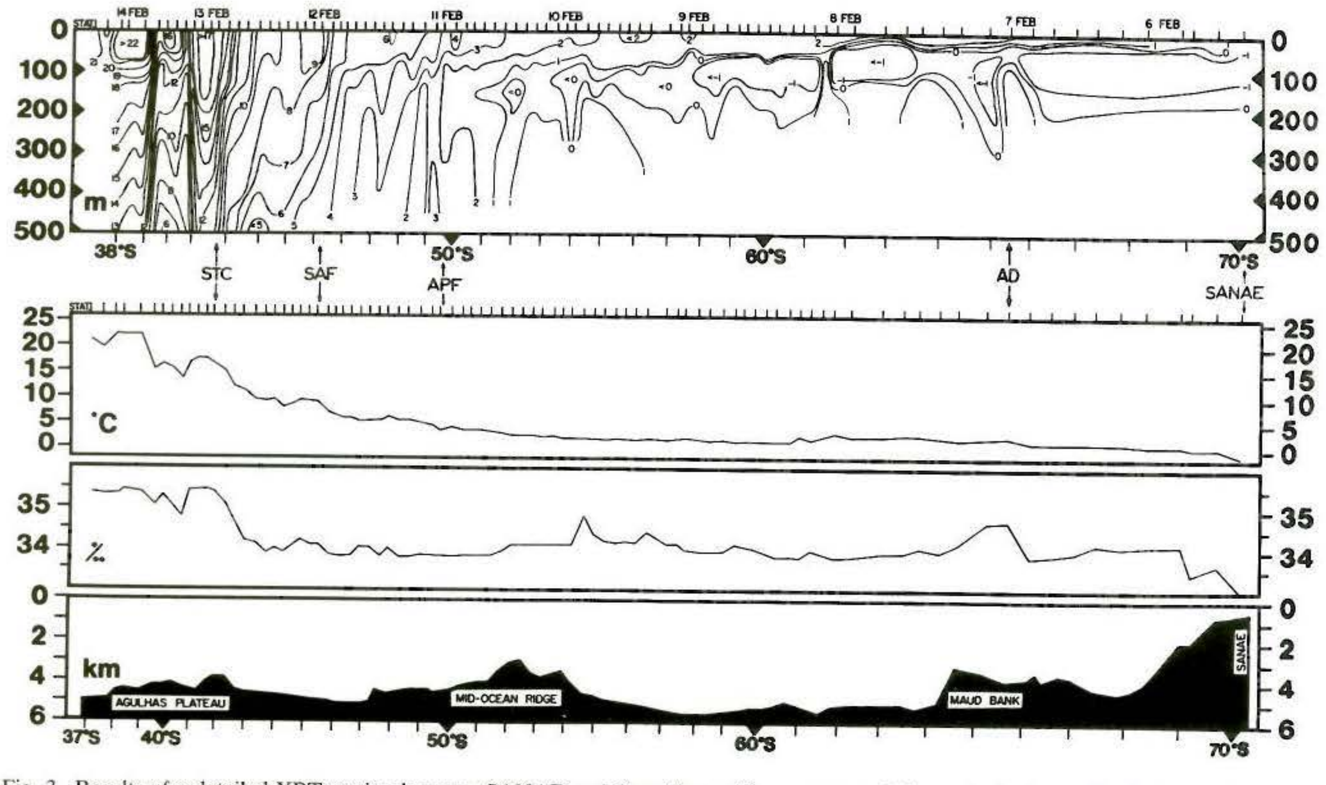

Fig. 3. Results of a detailed XBT-section between SANAE and Cape Town. The upper panel shows the isotherm distribution in the upper 500 m of the water column, the second panel the sea surface temperatures determined by Crawford bucket, the third panel the sea surface salinities and the bottom panel the bottom topography. The geographic location of the Subtropical Convergence (STC), the Subantarctic Front (SAF), the Antarctic Polar Front (APF) and the Antarctic Divergence (AD) are shown.

Supportive satellite evidence is also available from the weekly GOSSTCOMP images (NOAA 1980). These images portray the average temperatures derived from measurement over a 1° x 1° latitude-longitude grid over a full week by the NOAA 5 satellite. The combined image on Fig. 5 shows that Agulhas Current elements were indeed found at 15°E during the first leg of the cruise.

On the second leg of the cruise, measurements by XBT were terminated at the end of a great circle route (Fig. 1). The thermograph record for the last part of the cruise (Fig. 6) shows the location of the core of the Agulhas Current lying between 37 and 36°S, with strong thermal fronts exceeding 3 °C on either side. Surface temperatures over the Agulhas Bank averaged 22 °C, while a strong thermal gradient of over 6 °C was located at the Cape Upwelling Front in the proximity of Cape Town. A narrow band of cold water, about 100 km from the upwelling front, may have been part of the frontal eddies associated with this upwelling front (Lutjeharms 1981b, 1981c).

The satellite infra-red images for this period of the second leg, represented in the bottom panel of Fig. 4, were obtained only days after the vessel passed through the area. The resemblance between the temperature trace in Fig. 6 and the

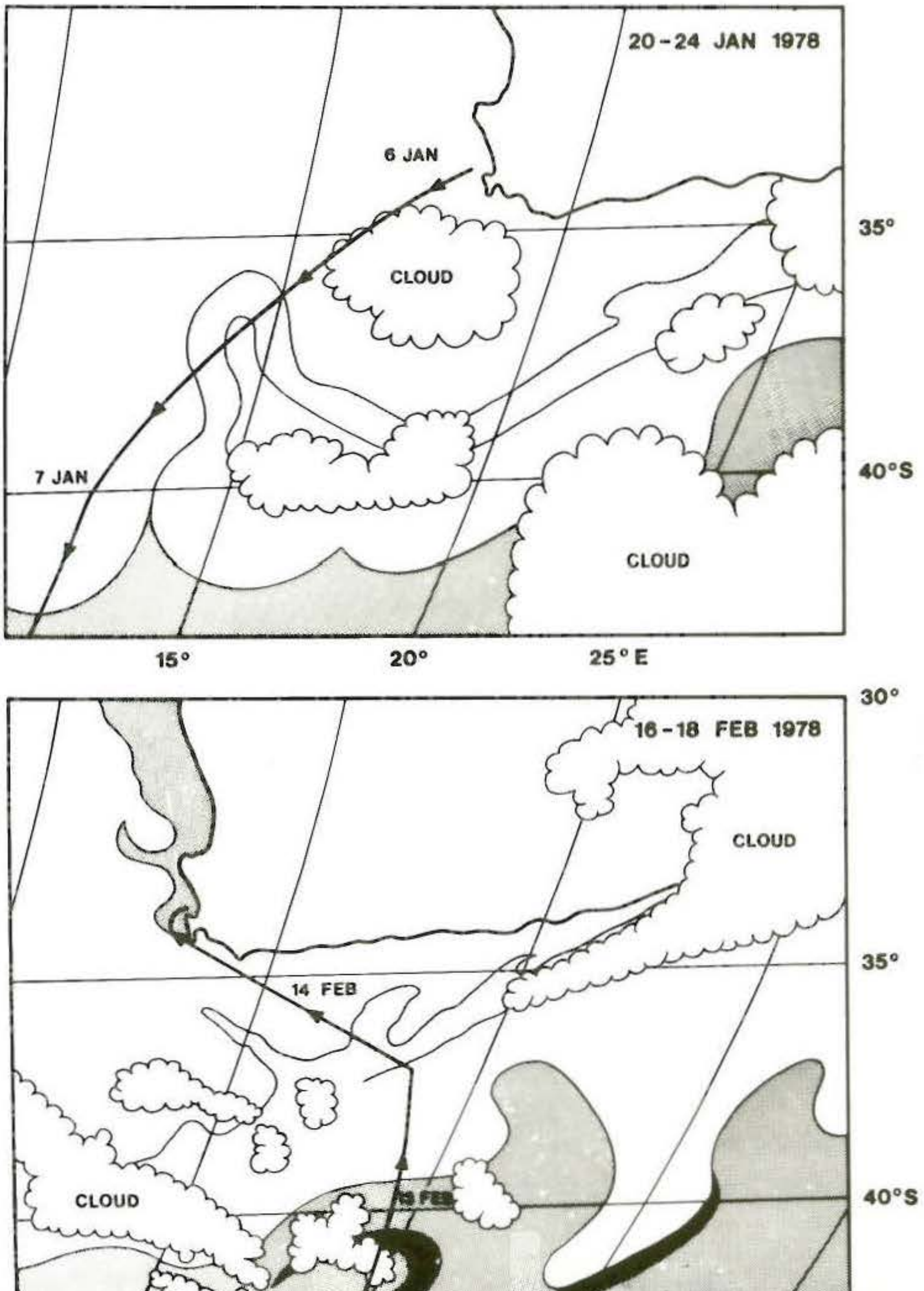

Fig. 4. Composite interpretation of a thermal infra-red satellite image from METEOSAT for the periods 20-24 January 1978 (upper panel) and 16-18 February 1978 (lower panel). Approximate tracks of the cruise are indicated by arrowed lines.

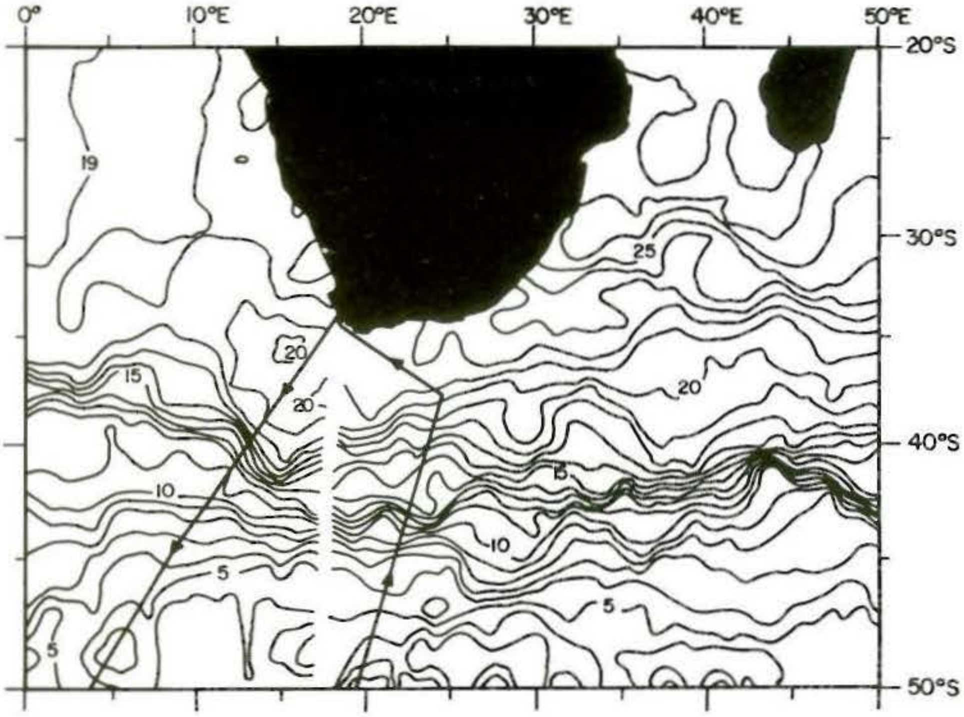

Fig. 5. Cruise track of the SANAE 19 cruise superimposed on the averaged sea surface temperatures for the periods in question after the satellite-derived GOSSTCOMP products for 4-10 January 1978 (east of 17°E) and 8-14 February 1978 (west of 17°E).

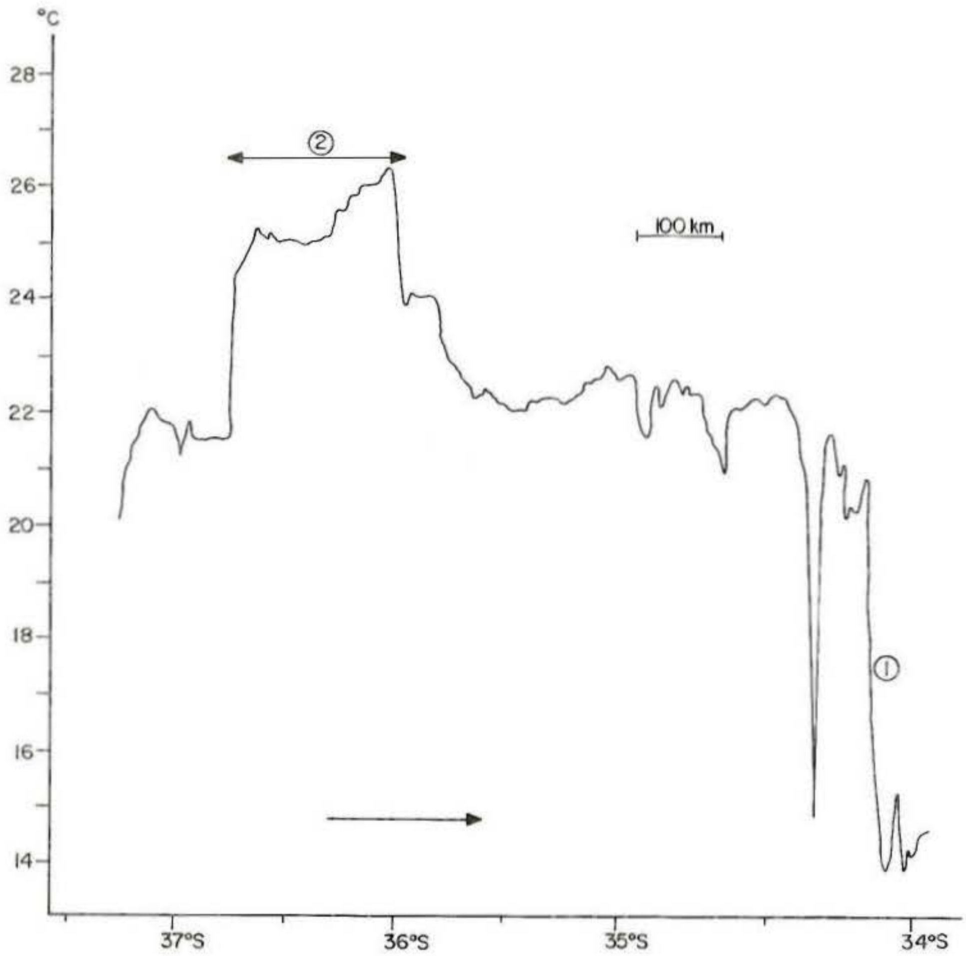

Fig. 6. A sea surface thermograph trace from the last part of the second leg of the SANAE 19 cruise between SANAE and Cape Town. The numbered features are (1) the Cape Upwelling Front and (2) the core of the Agulhas Current.

satellite portrayal is therefore, as could be expected, much closer than on the first leg. The location of the Agulhas Current core as portrayed in Fig. 4 agrees remarkably well with the sea surface temperature trace.

Subtropical Convergence

The Subtropical Convergence forms the most substantial frontal system between Africa and Antarctica. The results of previous investigations on the front have been summarised by Lutjeharms (1983), while Lutjeharms and Valentine (1983) have established the average geographic location and thermal characteristics for the surface expression of this front.

The Subtropical Convergence was crossed on both legs of the cruise, on the second occasion to the east of the first crossing. On the first leg a very strong thermal front was found straddling 41°S, noticeable in the sea surface temperature, the sea surface salinity and in the upper 500 m of the water column (Fig. 2). This manifestation of the Subtropical Convergence is depicted in greater detail in Fig. 7, where the continuous thermograph trace shows a double front consisting of horizontal temperature gradients exceeding 4 °C per 10 km. There was a total drop from 22 to 10 °C over a distance of about 25 km. On

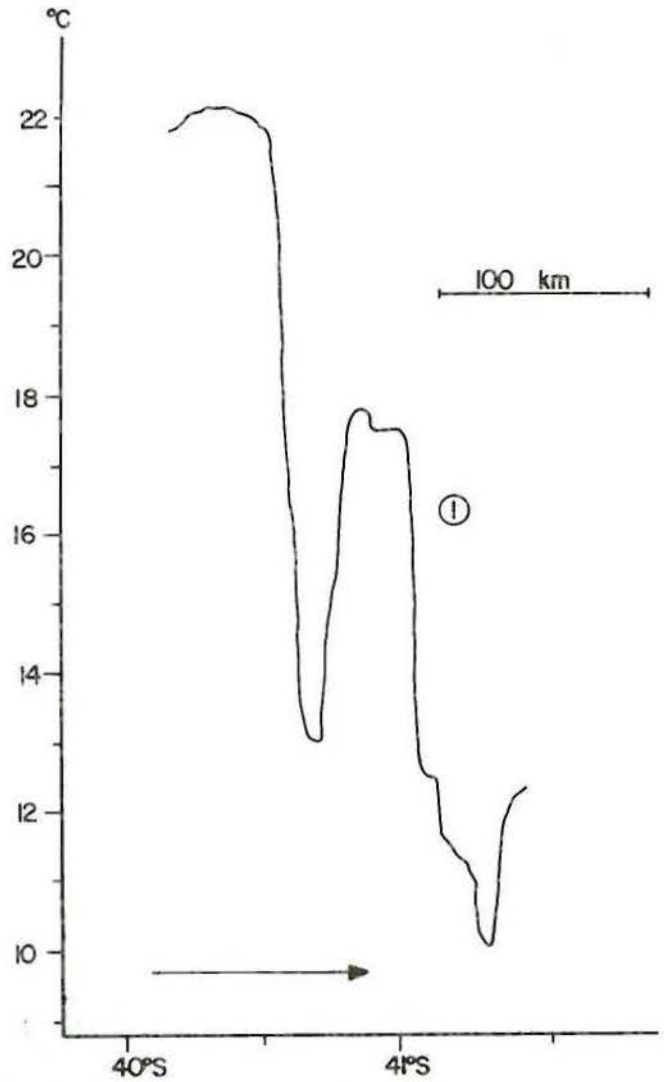

Fig. 7. Sea surface thermograph trace from the first leg of the SANAE 19 cruise between Cape Town and SANAE. The numbered temperature slope indicates the Subtropical Convergence. The arrow shows the direction in which the ship steamed.

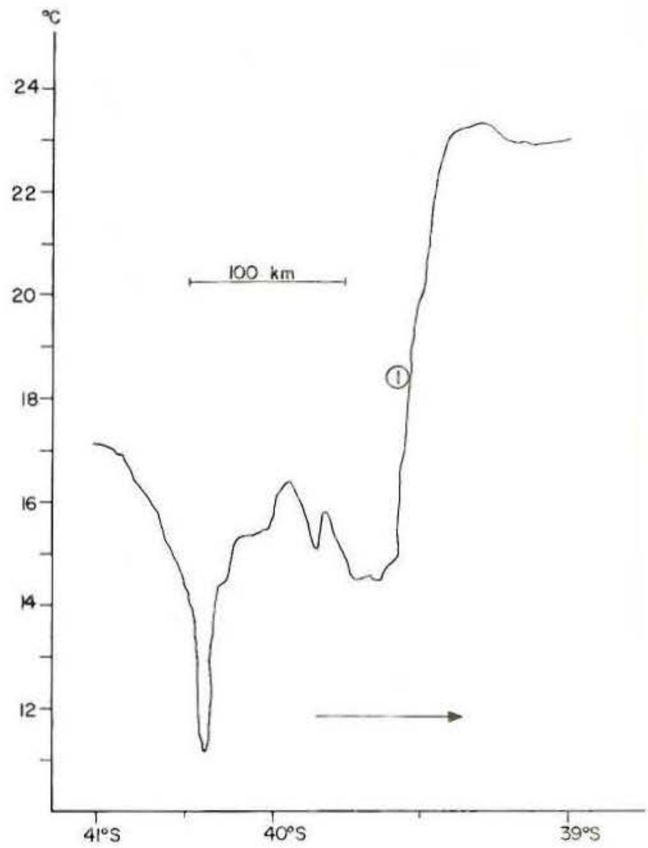

Fig. 8. A sea surface thermograph trace from the second leg of the SANAE 19 cruise between SANAE and Cape Town. The numbered slope (1) is the strongest thermal slope in the Subtropical Convergence on this occasion. The arrow indicates the direction of the ship's movement.

the second leg of the voyage the Subtropical Convergence was crossed at 42°S and, while the meso-scale turbulence to the immediate north may have complicated the thermal portrayal somewhat, the sea surface salinities (Fig. 3) located the front unambiguously. The strongest horizontal temperature gradient on this occasion was at 40,5°S (Fig. 8) and consisted of an increase in sea surface temperature from 14,5 to over 23 °C over a distance of 70 km (1,3 °C per 10 km). The sharpest gradient was 3 °C per 10 km. Details of the surface characteristics of the front are given in Table 1. A *drop* is here defined as the decrease experienced when travelling southward.

Table 1
Surface characteristics of the Subtropical Convergence

Location		Temperature °C		Salinity ‰	
Lat. S	Long. E	Centre	Drop	Centre	Drop
41°00′	11°30′	16,8	10,8	35,10	0,40
42°54′	23°00′	13,3	8,0	34,83	1,32

On the occasion of the crossing portrayed in Fig. 2, the Subtropical Convergence consisted of a singular front well within the mean location band presented by Lutjeharms (1983). The central temperature (16,8 °C) was rather high. Lutjeharms and Valentine (1983) give a middle temperature of 14,2 °C (standard deviation 1,7 °C), with an average range across the front of 7,3 °C. It would seem that the southern edge of the Agulhas Return Current, also called the Agulhas Convergence (Fukase 1962), or Agulhas Front (Lutjeharms *et* *al.* 1981), had on this occasion coalesced with the Subtropical Convergence, thus raising the mean temperature and increasing the frontal intensity. South of the main front an area of increasing temperature and increasing salinity is found (Fig. 2), thus creating a double front about 50 km apart. This feature is of particular interest since it has been found here on numerous occasions, but is not always present. It may be seen in the readings of Kuga and Watanuki (1963), Ono (1960), Kusunoki (1959), Torii *et al.* (1959) and Fukase (1962), where this feature is evident to a greater or lesser extent. Nieman (1965) has discussed four sections across the Convergence and has found that this feature is more prominent towards the east. It is also noticeable in the temperatures measured by La Grange (1961) and Taljaard (1958). During the first trip of the South African Antarctic supply vessel *RSA* (Lloyd 1974), it was very evident on the southward journey to Antarctica, but absent on the return cruise. These occasionally occurring features probably are eddies spun off from the Convergence itself, and may consist of subtropical water. Surface temperature characteristics of such an eddy would soon diminish in the colder environment, while the saline characteristics would be more conservative. This agrees with the characteristics of the feature depicted in Fig. 2, where the surface temperature has been reduced much more than have the surface salinities.

Cast-off eddies of this nature have been observed in satellite infra-red images of the general area (Lutjeharms 1981a, Lutjeharms & Baker 1980), and have been observed to carry meso-scale turbulence southwards (Lutjeharms 1981b). Such eddies have also been found to occur in the Subtropical Convergence south of Australia (Cresswell *et al.* 1978), and may thus be inherent features of the frontal system.

On the return leg of the cruise, further to the east (Fig. 1), a more complicated frontal area was found (Fig. 3). The salinity front at 42°S was more intense than usual (Lutjeharms 1983), and is considered to be the Subtropical Convergence proper, while the strongest thermal gradient (Fig. 8) may be a manifestation of the Agulhas Front. This allocation is based also on previous experience relating thermal fronts to nutrient fronts, the latter in many cases being better definers of the fronts (Allanson *et al.* 1981, Jacobs *et al.* 1980). The geographical location falls well within the band defined in the literature (Lutjeharms 1983).

The satellite imagery of Fig. 4b is particularly useful in this case, since the time of the ship's track and of the satellite image are only days apart. The sea surface temperature trace of Fig. 3 shows that the vessel traversed a body of warmer water between 41 and 42 °C. This is shown in Fig. 4b as a ring of warmer water surrounded by colder sub-Antarctic water south of the final temperature gradient. This sequence is also clearly portrayed in the thermograph trace of Fig. 8, which shows a thin element of cold water at about 40,5°S, a warmer element at 40°S and the main thermal front at 39,5°S. Narrow ribbons of colder water drawn around and into warmer eddies in this area have also been observed on other occasions (Lutjeharms *et al.* 1981), and may occur regularly in the Subtropical Convergence.

GOSSTCOMP images of the area (Fig. 5) indicate that the Subtropical Convergence was crossed at 40°S (14 – 17 °C) on the first leg and at about 43°S (10 – 14 °C) on the return leg. These temperatures agree well with those measured at sea, as do the locations of the Convergence. The GOSSTCOMP images thus seem to be reliable indicators of the general sea surface temperature distributions at these frontal regions.

Much thermal detail for each XBT station is lost in portraying the XBT readings as temperature sections (Figs. 2 and 3). Some of the more interesting temperature traces are therefore reproduced in Figs. 9 and 10. Gordon (1975) and Gordon *et al.* (1977) have demonstrated that interleaving of water masses is represented as aberrations on such temperature profiles.

Traces made south of the Subtropical Convergence (Fig. 9) showed that a great deal of interleaving of water masses was taking place there during the first leg of the cruise. Traces 22, 23 and 24 (Fig. 9) are particularly prominent in this regard, trace 24 showing small-scale distortions at all depths. This was not the case on the return leg of the cruise, when more interleaving was found to occur north of the Subtropical Convergence (Fig. 10). Figs. 2 and 3 show that this correlates with the location of meso-scale turbulence, first occurring predominantly to the south and then predominantly to the north of the Convergence.

Subantarctic Front

The Subantarctic Front south of South Africa has not yet been described. An additional Southern Ocean front was first postulated on theoretical grounds by Ivanov (1959, 1961), and a corresponding front was indeed observed south of New Zealand by Burling (1961) and Zillman (1970) using bathythermograph sections. It has since become known as the Subantarctic Front (Emery 1977). Most previous observations south of Africa have been too widely spaced to resolve this frontal system. Using the definition employed by Sievers and Emery (1978) in the Drake Passage, namely, a subsurface temperature gradient lying between the 3 and 5 °C isotherms, and then identifying the most vertically orientated isotherms within this gradient to geographically locate the front, it may be discerned in the closely spaced XBT sections of Taylor *et al.* (1978) and of Jacobs *et al.* (1980).

On the first leg of the cruise the isotherms between 4 and 8 °C showed a sharp incline in the upper 500 m of the water column at about 45°S (Fig. 2). This corresponds closely to the characteristics of the Subantarctic Front as defined by both Burling (1961) and Sievers and Emery (1978) for other locations in the Southern Ocean. The location is also marked by noticeable decreases in sea surface temperature and salinity. On the second leg the Subantarctic Front was crossed at about 45,5°S and, as on the first leg (Fig. 2), it exhibited an inverted-L shape (Fig. 3) with attendant sea surface thermal and haline fronts. On both legs the Subantarctic Front was well separated geographically from the Antarctic Polar Front. Details of the surface expression of the front are given in Table 2.

Table 2
Surface characteristics of the Subantarctic Front

Location		Temperature °C		Salinity ‰	
Lat. S	Long. E	Centre	Drop	Centre	Drop
44°50′	7°50′	8,2	2,6	34,18	0,37
45°34′	21°50′	8,1	2,1	34,02	0,23

The *drops* in salinity and temperature in this table once again refer to measurements made by a vessel proceeding southwards and may be influenced by the subjective demarcation of a frontal region. From these preliminary data it would seem that the drop in sea surface temperature across the Subantarctic Front is relatively constant, although the absolute values of the temperature may vary. The salinity drops are consistent, but more variable; Allanson *et al.* (1981) have also shown that the Subantarctic Front may be associated with the sea surface Chlorophyll *a* maximum, thus indicating the possi-

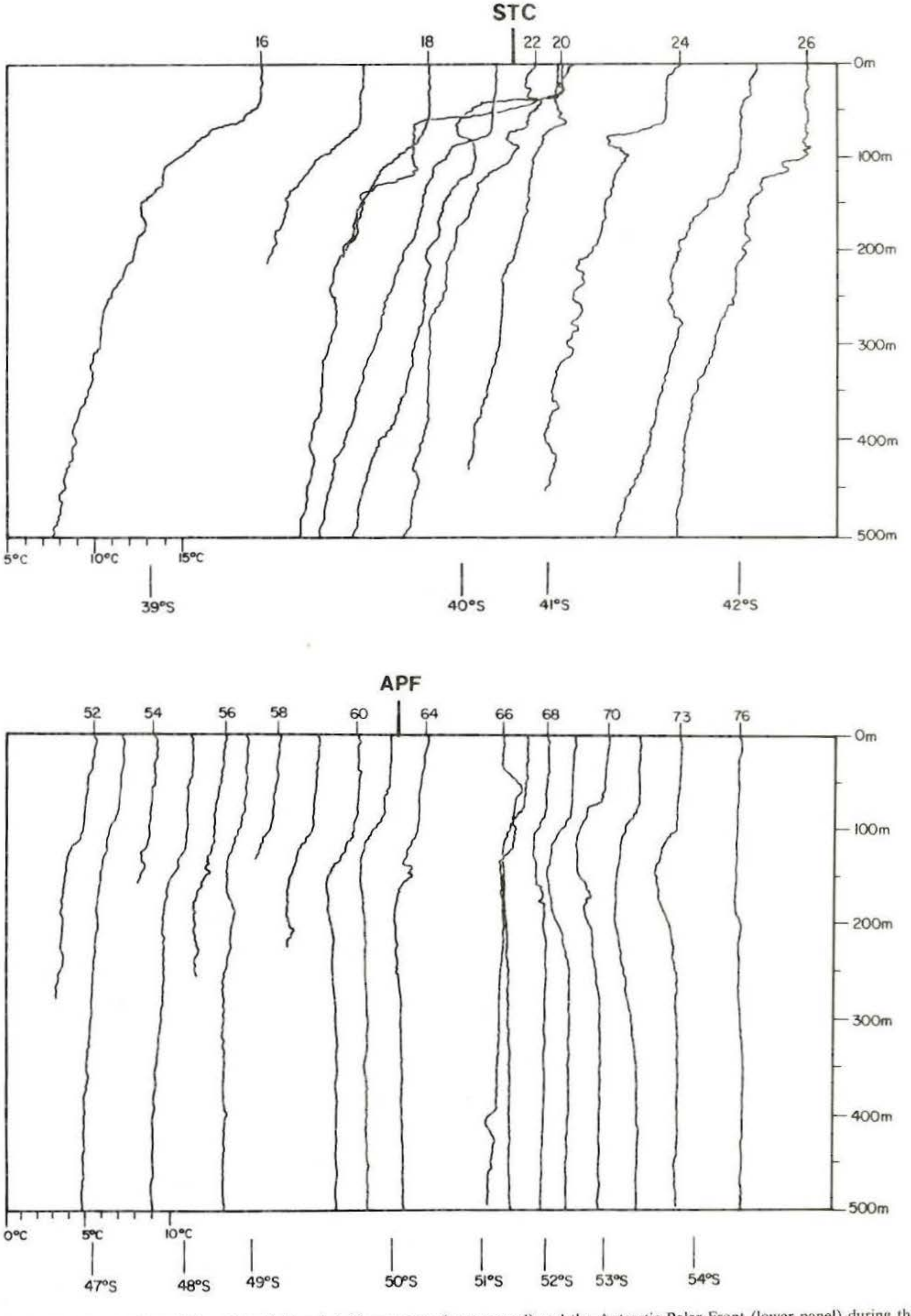

Fig. 9. XBT traces in the vicinity of the Subtropical Convergence (upper panel) and the Antarctic Polar Front (lower panel) during the SANAE 19 cruise between Cape Town and SANAE. To separate them individual traces have been offset by 4 °C on the upper, 2 °C on the lower panel.

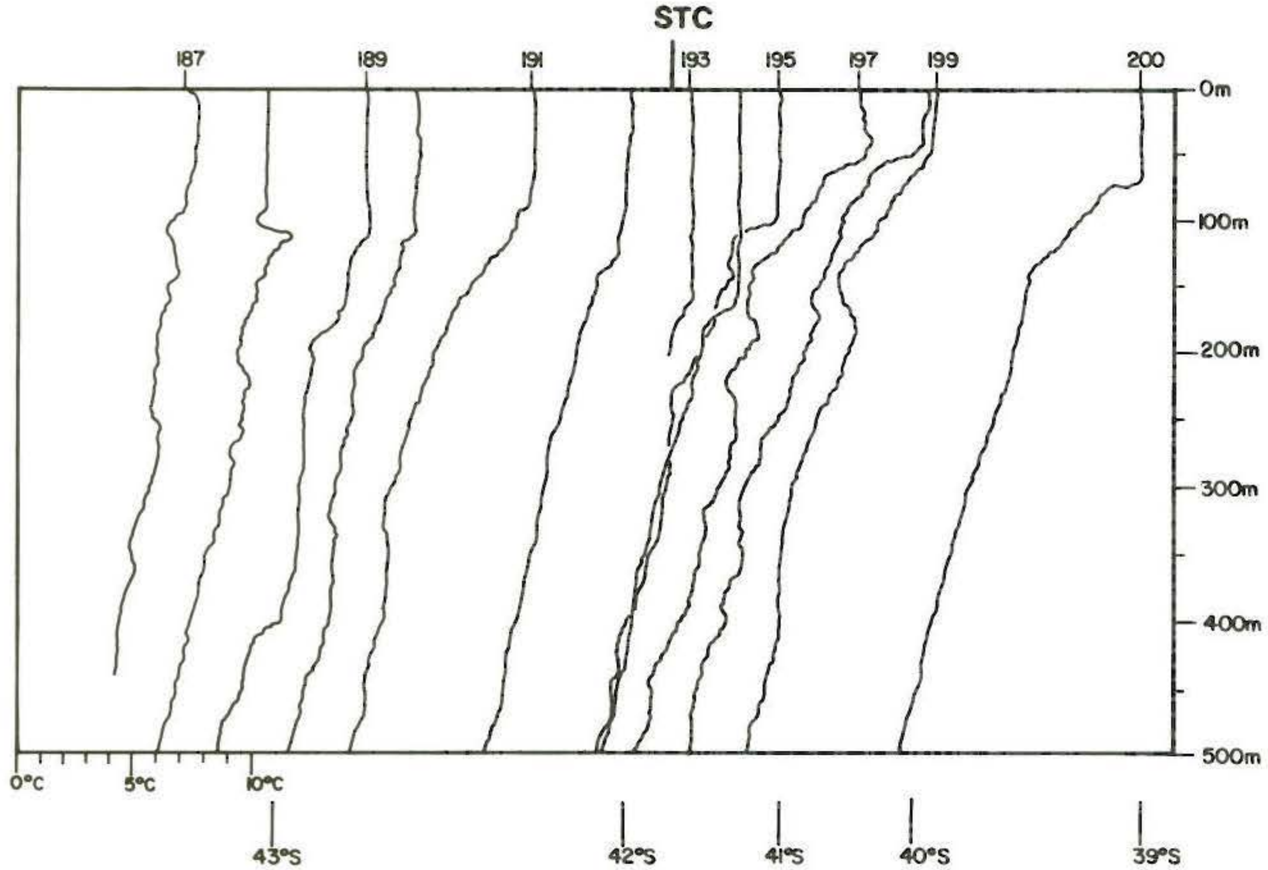

Fig. 10. XBT traces in the vicinity of the Subtropical Convergence during the SANAE 19 cruise between SANAE and Cape Town. To separate them individual traces have been offset by 2 °C.

bility of a surface convergence, or shear, of water masses. Both traverses (Figs. 2 and 3) showed the Subantarctic Front to have a step-like structure. The subsurface frontal characteristic isotherms did not cut the sea surface at the same location, but lay horizontally at a smaller depth and surfaced between the Subantarctic Front and the Antarctic Polar Front.

Antarctic Polar Front

The Antarctic Polar Front, defined as the furthest northward extension of the subsurface 2 °C water (Botnikov 1964), or as the intersection of the subsurface temperature minimum with the 200 m isobath (Ostapoff 1962), was located between 49 and 50° south latitude on the first cruise leg. The surface expression of the Antarctic Polar Front was clearly visible on the thermograph record during this leg, and is depicted in Fig. 11 as a drop from about 4,5 to 3 °C over a distance of less than 10 km just north of 49°S, which would thus lie a short distance north of the subsurface expression.

This surface temperature agrees with the definitions given by Ostapoff (1962), namely, a maximum gradient at the sea surface temperature in the temperature regime between 2 and 6 °C, and by Gordon (1967) namely, changes of more than 2 °C in one-half degree of latitude. According to the predictions made by Mackintosh (1946), the middle temperature of the Antarctic Polar Front at 49°S in January should be 4,8 °C, while the range should be about 0,9 °C. Houtman (1964) has adjusted these values in the light of 168 crossings, on many of which more accurate readings were made than those available to Mackintosh (1946), and predicts a middle temperature of 4,5 °C for our crossing. Both agree fairly well with our reading, Houtman's (1964) being slightly better.

It is instructive to note that Houtman (1964) has stated that a peculiarity common to many gradients is that, south of the Polar Front, the temperature may increase over a short distance. Similarly, according to him, there is often a small area of slightly lowered temperature north of the front. This phenomenon may also be observed on the thermograph trace presented in Fig. 11. Houtman (1964) has ascribed these temperature inversions to the effects of a system of wind-induced, up- and downwellings (Wexler 1959, Wyrtki 1960, Ostapoff 1963).

On this occasion the surface expression (Fig. 11) was found slightly to the north of the subsurface expression (Fig. 2). On the return leg of the cruise (Fig. 1) the opposite occurred. On this occasion the subsurface expression was found at 49,2°S (Fig. 3), while a less clearly distinguishable surface expression (Fig. 11) was located just south of 50°S. On this occasion a dome of water with temperatures of less than 2 °C was found to lie north of the subsurface temperature minimum between 48 and 49°S, thus upsetting the definition used for the Polar Front allocation. Such a dome is in agreement with observations of Wexler (1959) and also some of those of Taylor *et al.* (1978). The middle temperature of the Polar Front surface expression was 3,3 °C (range 0,7 °C) on the return voyage, while that predicted by Mackintosh (1946) is 5 °C (range 1,4 °C) and that by Houtman (1964) is 4,8 °C. Whether the small thermal gradient portrayed in Fig. 11 is in actual fact the Antarctic Polar Front may thus be open to question.

The surface location and thermal characteristics of the Antarctic Polar Front observed during this cruise are given in Table 3.

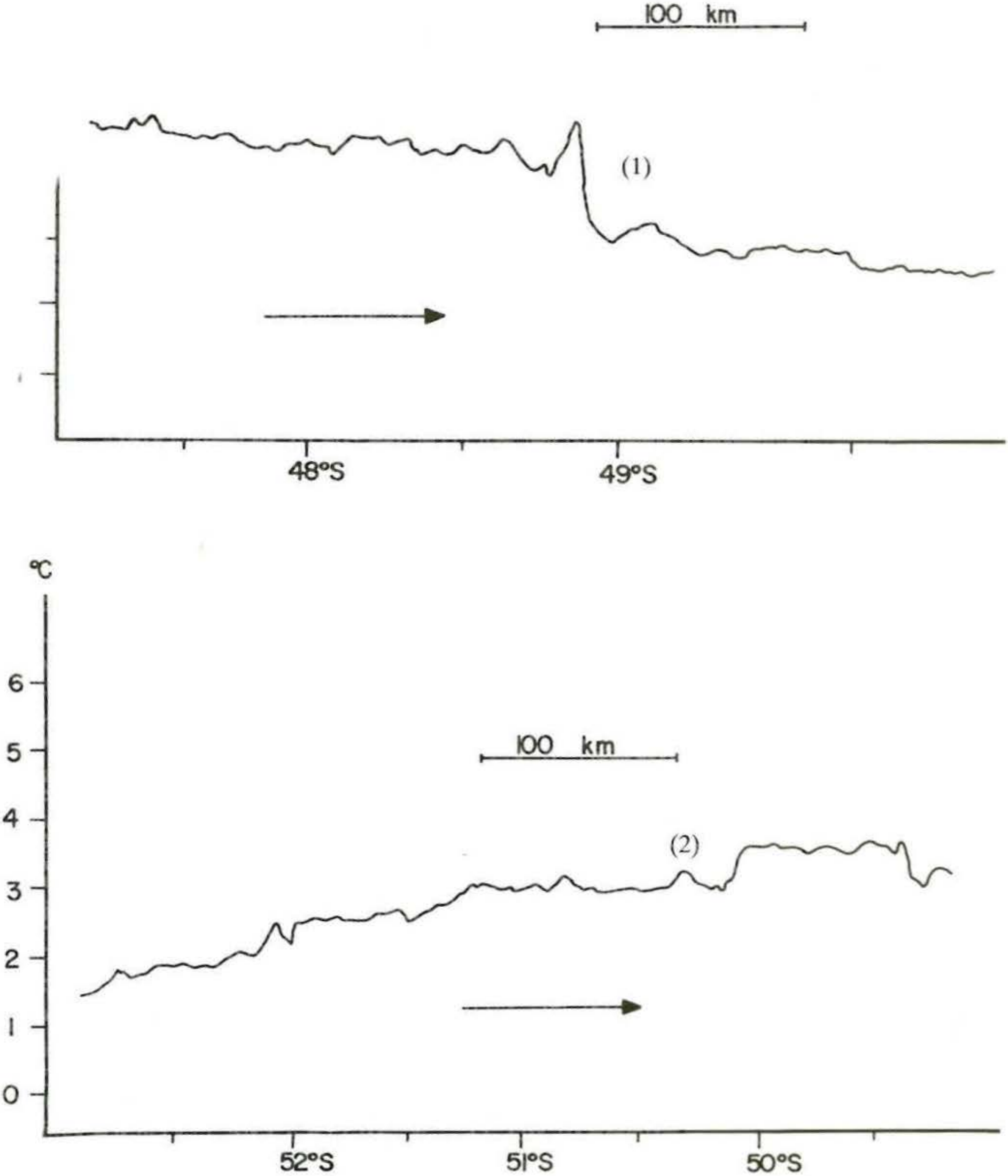

Fig. 11. Sea surface thermograph traces from the ship's thermograph. The numbered portion of the upper trace (1) shows the thermal gradient at the Antarctic Polar Front on the first leg of the cruise while the numbered section of the lower trace (2) is at the presumed location of the Antarctic Polar Front's surface expression during the second leg of the cruise. The arrow indicates the direction of the ship's movement.

Table 3
Surface characteristics of the Antarctic Polar Front

Location		Temperature °C	
Lat. S	Long. E	Centre	Drop
49°	4°	2,6	2,0
50°	19°	3,3	0,7

An investigation of the small-scale vertical thermal structure on the XBT traces astride the Antarctic Polar Front is also instructive. By contrast to the Subtropical Convergence, traces adjoining the Antarctic Polar Front (Fig. 9, lower panel) show much more depth-localised distortions. South of the front, mixing of water masses seems to be taking place predominantly at the edges of the subsurface temperature minimum, while north of the front step-like structure is found mostly at about 100 m depth, corresponding to the upper step of the Subantarctic Front, described above (Fig. 2).

Antarctic Divergence

The Antarctic Divergence is perhaps the least understood classical front of the Southern Ocean. Koopman (1953) has located it at about 64°S latitude south of Africa, based on surface stress due to reigning wind regimes. Ostapoff (1962), using the salinity distribution at 200 m, found that this location agrees well with a core of high salinity which also corresponds, in a general way, with areas of maximum vertical rise of water (Ivanov & Neiman 1967). Ivanov and Tareev (1959) have postulated that this front is not zonal, but that it is found only at certain longitudes.

Figs. 2 and 3 show assumed locations for the Antarctic Divergence. On the southward leg (Fig. 2) this location corresponded to a strong sea surface salinity decrease, but on the northward leg (Fig. 3) the location was at the same latitude as a strong surface saline maximum, lending extra credence to the latter location. Very localised upward bends in isotherms at 65°S have also been described by Taylor *et al.* (1978) in the same vicinity.

Conclusions

It may be concluded, from this first of a series of XBT sections between Africa and Antarctica, that the near-surface thermal detail of all the known fronts in the Southern Ocean can be delineated with great accuracy using measurements of this kind. General locations and surface characteristics of the various fronts during this period are given in Table 4.

The Subtropical Convergence is shown to be an area of extensive meso-scale turbulence, with mixing of Subtropical Surface and Subantarctic surface water types. Small temperature increases, often seen south of the Convergence, are presumed to be meso-scale eddies forming part of the general turbulence in the area.

The existence, location and nature of a Subantarctic Front south of Africa is described for the first time. Located at an average latitude of 45,5°S, it occurs at a mean, central, sea surface temperature of about 8 °C, with a temperature drop of about 2,3 °C and with a mean, central, sea surface salinity of about 34,05‰, with a drop across the front of 0,26‰. Its subsurface expression is even more consistent and unambiguous.

Acknowledgements

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Table 4
Location of Southern Ocean fronts January – February 1978.

Thermal front	Geographic location		Sea surface	
	from	to	Temperature °C	Salinity ‰
LEG 1				
Agulhas Current northern front	36°03'S, 16°10'E	36°33'S, 15°46'E	23,6 – 22,1	35,41 – 35,50
Subtropical Convergence	40°33'S, 11°58'E	41°25'S, 11°17'E	22,2 – 11,4	35,30 – 34,90
Subantarctic Front	44°21'S, 08°20'E	45°46'S, 06°52'E	9,5 – 6,9	34,20 – 33,92
Antarctic Polar Front	49°51'S, 03°54'E		3,6	33,90
Antarctic Divergence	65°50'E, 03°11'E	67°48'S, 03°35'E	1,1 – 0,7	33,92 – 33,51
LEG 2				
Antarctic Divergence	65°02'S, 19°38'E	65°55'S, 20°46'E	0,5 – 0,7	34,71 – 33,85
Antarctic Polar Front	49°26'S, 19°34'E	—	4,5	33,87
Subantarctic Front	44°10'S, 22°35'E	46°35'S, 21°10'E	8,0 – 6,0	34,05 – 33,87
Subtropical Convergence	41°30'S, 23°42'E	42°40'S, 23°13'E	17,4 – 12,0	35,49 – 34,86
Agulhas Current southern front	39°00'S, 24°15'E	39°33'S, 24°11'E	22,1 – 15,2	35,40 – 35,09

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