Variations in Temperature, Salinity, Density and Circulation in Bransfield Strait, 9-14 March, 1985

(environmental properties | Bransfield Strait Antarctica | drifting buoy)

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INTRODUCTION

Although oceanographic measurements have been made in the Bransfield Strait over a number of years, published descriptions of water circulation and associated physical characteristics are limited. Using hydrographic data from several expeditions, Clowes (1934) determined that relatively warm surface water of low salinity present in the northern and western parts of the Strait is advected into the Bransfield from the Bellingshausen Sea. He also attributed the subsurface temperature and salinity maxima found in the Strait to this same source. Clowes (*op. cit.*) considered that the colder, more saline waters of the Weddell Sea influence the southeastern Bransfield. This water enters from the Weddell in the vicinity of Joinville and d'Urville Islands.

Gordon and Nowlin (1978) studied the deep and bottom water in the three basins in Bransfield Strait, using hydrographic data from the FDRAKE 75 expedition. They concluded that outflow of Bransfield basin water does not apparently influence the water masses characteristic of the Southern Drake Passage of the Weddell Sea, nor does there appear to be any direct outflow of bottom or deep basin water into the Weddell-Scotia Confluence Zone. No direct or indirect (geostrophic) current measurements are included in their report.

Stein (1978/79) used current measurements from the West German expedition of 1975/1976, off Elephant Island and found that the currents are strongly influenced by semi-diurnal tides as well as changes in atmospheric pressure. Stein (*op. cit.*) notes that such atmospheric forcing may result in advecting Weddell Sea Water into the site of the measurements. Using the same several day data set, Stein and Cornus (1979) observed a very uniform current flowing northeast, between Elephant and Clarence Islands, at about 13cm s^{-1}.

The significance of tidal currents in Admiralty Bay (King George Island, Bransfield Strait) has been reported by Pruszak (1980). He found tidal currents of up to 50cm s^{-1}. Surface water circulation was directly related to winds in excess of 4m s^{-1}. Pruszak measured current speeds of up to 100cm s^{-1}, depending upon the prevailing wind field.

Due to strong interest in the Southern Ocean circulation, about 300 satellite-tracked drifting buoys were launched during the 1979 FGGE (First GARP Global Experiment) program (Keeley and Taylor, 1981). During the experiment, 1-2 surface drifters apparently entered the Bransfield Strait, although no analysis of these trajectories has been published.

Detailed descriptions of water mass characteristics and relative geostrophic circulation in Bransfield Strait have been reported by Uribe (1983) and Ikeda *et al.*, (1985). Surface circulations described by them are considered relative, since no absolute reference levels were determined.

The objective of this study is to describe variations in the near surface temperature, salinity and density fields and the geostrophic circulation, based on data collected during the austral summer of 1985. A mean surface current is also to be estimated from the trajectory of a Brazilian drifting buoy and to be compared do the geostrophic current and the surface wind.

DATA AND METHODS

Seven hydrographic stations were completed in Bransfield Strait, located on the NW side of Palmer Peninsula, during 9-14 March, 1985, concurrent with a test of INPE's prototype, drifting oceanographic buoy. Each station (Fig. 1) consisted of two hydrographic casts with Nansen bottles and reversing thermometers, made to a maximum depth of 300m, to obtain temperature (T) measurements and water samples for salinity (S) determintions.

Water and air temperature readings were also made from the drifting buoy and were received by NOAA-6 and NOAA-9 satellites passing overhead in their polar orbits. Buoy data were later received at ARGOS Center in Toulouse, France, where geographic positions of the buoy were calculated. These data were later received at INPE in São José dos Campos, Brazil.

At each station, water temperatures were read to the nearest 0.01°C from precision reversing thermometers. Thermal corrections were later applied to these data and the corrected temperatures are considered accurate ±0.03°C.

Using the same Nansen bottles, water samples were obtained and subsequently processed by the Geophysics Department of the Hydrography and Navigation Directorate of the Brazilian Navy (DHN). An inductive laboratory salinometer and Substandard seawater were used to determine salinites to ±0.01, following the procedure for determination of the Practical Salinity Scale (UNESCO, 1984). In this new Scale, salinity is nondimensional.

After temperature and salinity data were processed and corrected, density (σ_t) was determined from the UNESCO equations of state (UNESCO, *op. cit.*) that were programmed into a microcomputer. Since the accuracy of σ_t, now given in units of gm cm^{-3}, is limited by the combined quality of T and S data, values of σ_t are considered known to ±0.02-0.03 gm cm^{-3}.

Estimation of geostrophic current is based on vertical profiles of water density. Because of technical problems, it was only feasible to make casts down to 300 m, and 250 m (or 250 dbar) was selected as the reference level of no horizontal motion.

Positions of the drifting buoy are determined from the buoy's transmissions, by the ARGOS Center. The accuracy of each determination is affected by various factors, including the stability of the buoy transmitter. On the average, the buoy positions are considered known to ±300 m (±0.003° latitude, for example).

Horizontal maps of T, S, σ_t and geostrophic circulation for 0 m and 10 m depth were made, using data from the field work. Buoy position data from ARGOS were also used to construct a trajectory of the buoy, from which a mean current was estimated. Because the subsurface sail of the buoy was 10 m below the buoy (11 m below the water surface), the trajectory represents water motion at about 10 m depth.

RESULTS

Maps of T, S and σ_t are shown in Figures 1-6. The relatively smooth contoured fields are a result of the data interpolation between stations. Warmer surface water (1.26-1.50°C) was observed along the west side of the Strait, in contrast with temperatures of 0.51-0.56°C along the eastern stations in the Strait. Surface salinity had a similar pattern with less saline water (33.89-34.03) on the west side and salinities of 34.22-34.24 on the eastern side. The surface σ_t field agrees with the T and S patterns, with less dense water (27.12-27.25 gm cm^{-3}) on the west side and more dense water (27.39-27.46 gm cm^{-3}) along the eastern stations. Warmest, least saline and dense surface water was found just

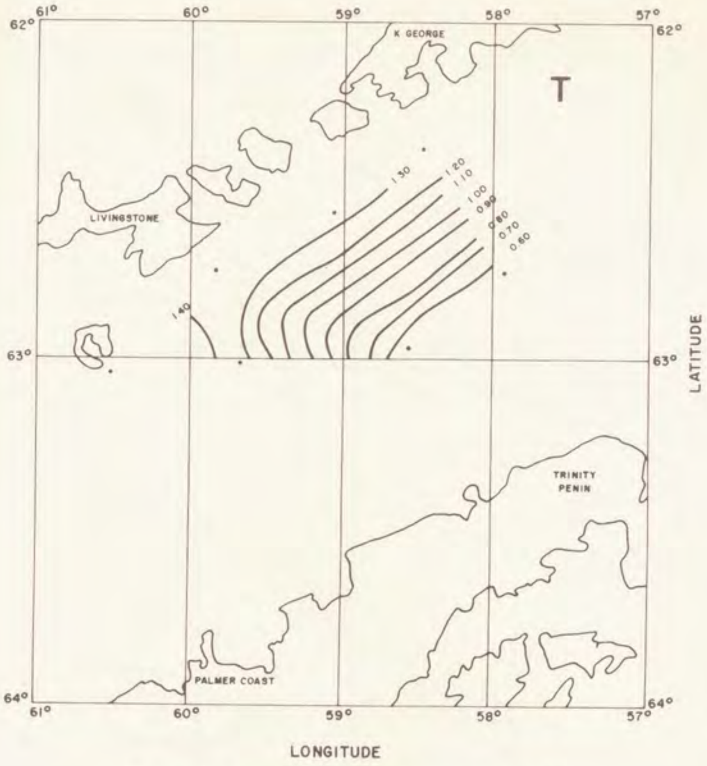

Fig. 1 – Surface distribution of temperature (in °C).

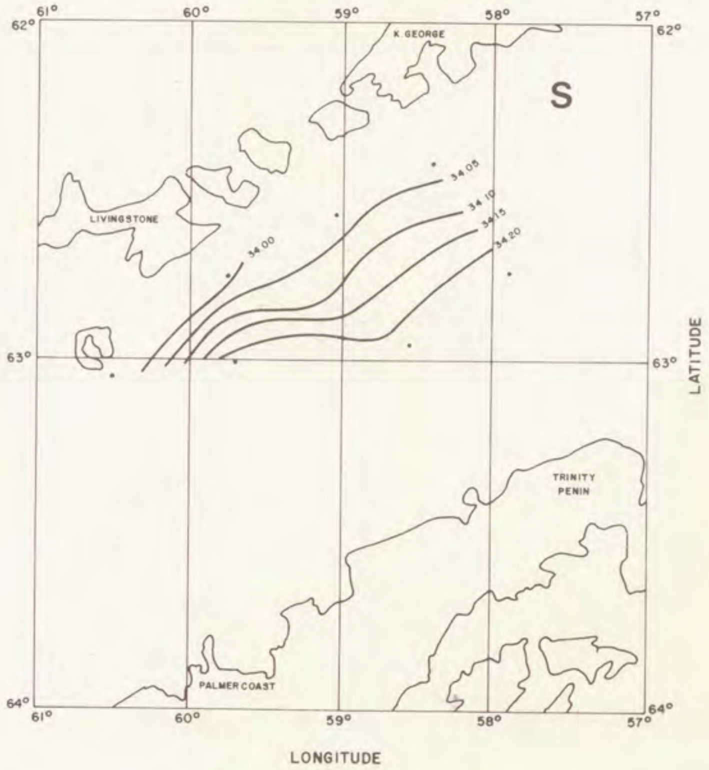

Fig. 2 – Surface distribution of salinity.

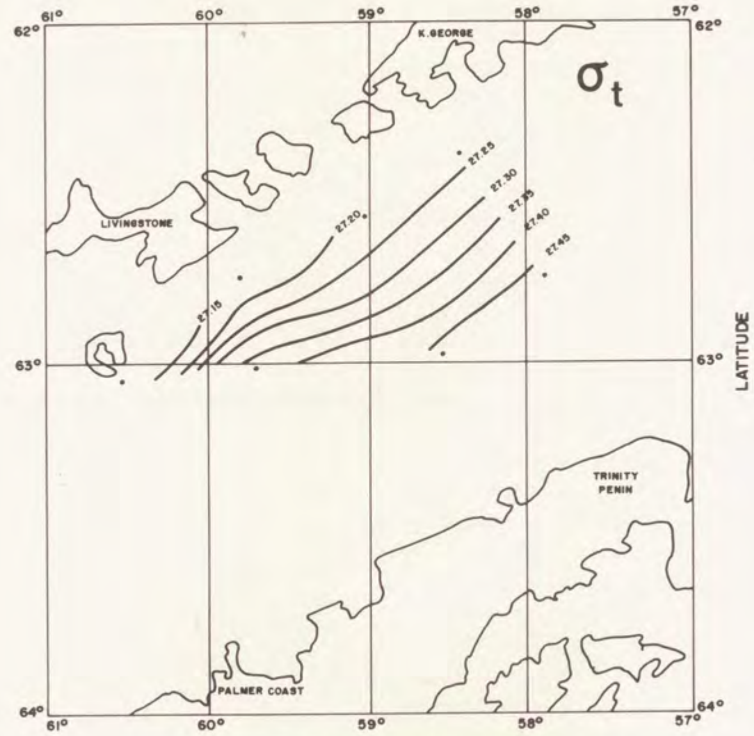

Fig. 3 – Surface distribution of σ_t (density in gm cm^{-3}).

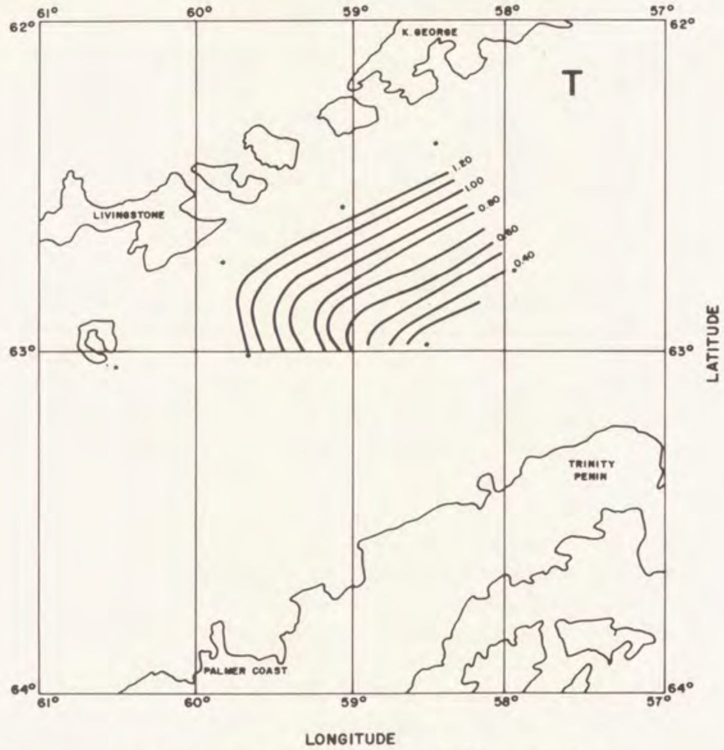

Fig. 4 – Distribution of temperature (in °C) at 10 m depth.

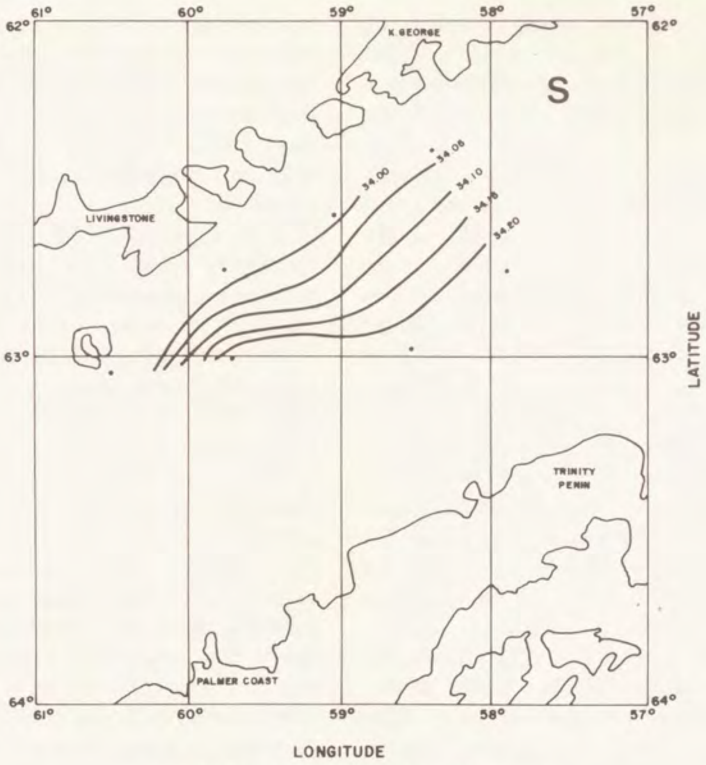

Fig. 5 – Distribution of salinity at 10 m depth.

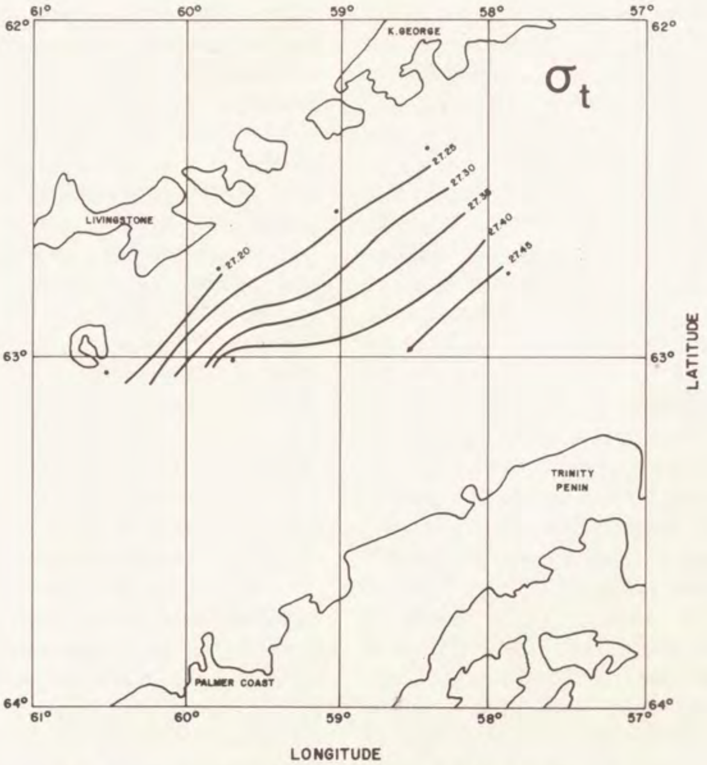

Fig. 6 – Distribution of σ_t (density in gm cm^{-3}) at 10 m depth.

to the SE of Deception Island (Station 1). Distributions of T, S, and σ_t for 10 m depth were generally similar to those on the surface but with cooler, more saline and dense water at 10 m depth.

Surface temperature and salinity conditions during 1985 appear to be quite similar to those of 1983 (Ikeda *et al.*, 1985). Ikeda reported temperatures of 1.6°C on the west side of the Strait, compared to our 1.3-1.4°C for 1985. In the central part of the Strait, the temperature was 0.6°C for both expeditions. Surface salinities for 1985 were even closer to those of 1983, with the same general isohaline patterns. By contrast, surface temperature and salinity from the FDRAKE 75 section (Gordon and Nowlin, 1978) were 0.2-0.4°C and 34.15, respectively in the interior of the Strait. While the salinity is the same as for our 1985 data, FDRAKE surface temperatures are about 0.8°C cooler.

A comparison of T-S profiles from our stations with those of FIBEX (Uribe *et al.*, 1983) suggests that our profiles were most similar to the Br_W and Br_C water classes. According to Uribe and his colleagues, Br_w water is found along the eastern side of the Strait, with Br_C water in the central part of the Strait. The parts of our T-S curves associated with the surface water layer contained higher temperatures than indicated for the Br_W and Br^c water classes, evidently due to strong summer heating of the surface layer.

Geostrophic velocity maps were also made for 0 m and 10 m depth (Figs. 7 and 8), using a 250 dbar reference level. Surface geostrophic flow was toward 020° at 4 cm s^{-1} near Deception Island (Station 1/Station 3). Near Station 3 the flow continued toward the NE, parallel to the axis of the Strait. In the central part of the Strait, flow was toward the NE. At 10 m depth, flow was also northerly at 5 cm s^{-1} between Stations 1 and 3. In the center of the Strait, flow was toward the NE again, but slightly weaker than at the surface.

For purposes of comparison, the surface geostrophic current averaged 3 cm s^{-1} during 31 January – 9 March, 1983, south of Deception Island (63°S, 60°30'W) (Ikeda *et al.*, 1985). Ikeda used two reference levels: 200 dbar and 400 dbar, with little apparent difference in circultion patterns between the two reference levels. Our 10/250 dbar circulation pattern is quite similar to the relative dynamic topography of the 200 dbar surface, reported by Uribe *et al.* (1983), for the austral summer of 1981. The strong curvature, in current direction from north to east near 60°W, is evident in the three data sets, and suggests that this curvature may be a persistent feature.

Comparison of the drifting buoy trajectory (Fig. 9) with the geostrophic circulation showed good agreement in terms of direction of water movement. During the 5 hours that position data were received for the buoy, the mean speed was 27 cm s^{-1} toward 042°. Best agreement was found between the buoy trajectory and the geostrophic circulation at 10 m. The buoy speed, however, was larger than the geostrophic current. Although some of this "excess" may be attributed to wind drag on the buoy, resulting in a velocity greater than the water motion, it is most probable that the actual near surface current speed was greater than the geostrophic speed, due to the wind friction on the water surface. Also, the time scale envolved in geostrophic currents is much larger than for momentum transfer of surface winds to the sea surface. Strong currents of relatively short duration often do not appear in a geostrophic circulation field. Because the selection of the reference level for the geostrophic field was limited to the upper 300 m, while the absolute level of zero motion most likely was at some greater depth, the 240 dbar reference level may well underestimate the actual surface geostrophic current.

When the buoy was launched on 9 March and for one day thereafter, winds were 0-9 kts toward 090° (Fig. 10). About one day later, the winds changed direction and blew toward 250° at speeds, that over the following two days increased up to 16 kts, in opposition to the surface (geostrophic) water motion. During the first few days of the experiment, both estimates of near surface current indicated the flow to be to the left of the wind direction, consistent with Ekman drift.

Based on this brief experiment then, it appears that near surface environmental conditions, as evidenced by temperature, salinity and surface geostrophic circultion were similar to those of 1981 and 1983. Questions still remain, however, about the time response of the near surface circulation to changes in winds. More detailed

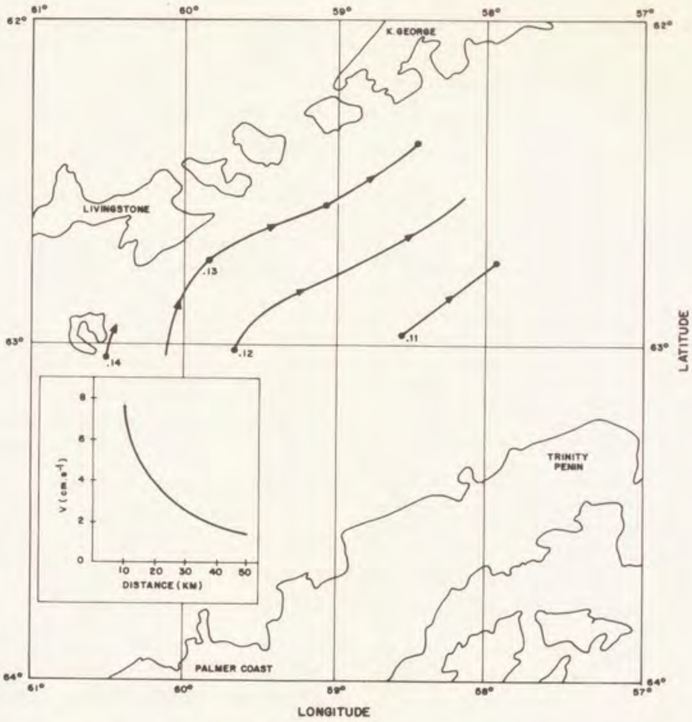

Fig. 7 – Surface geostrophic circulation (in dynamic meters) referenced to 250 dbar surface, for 9-14 March 1985.

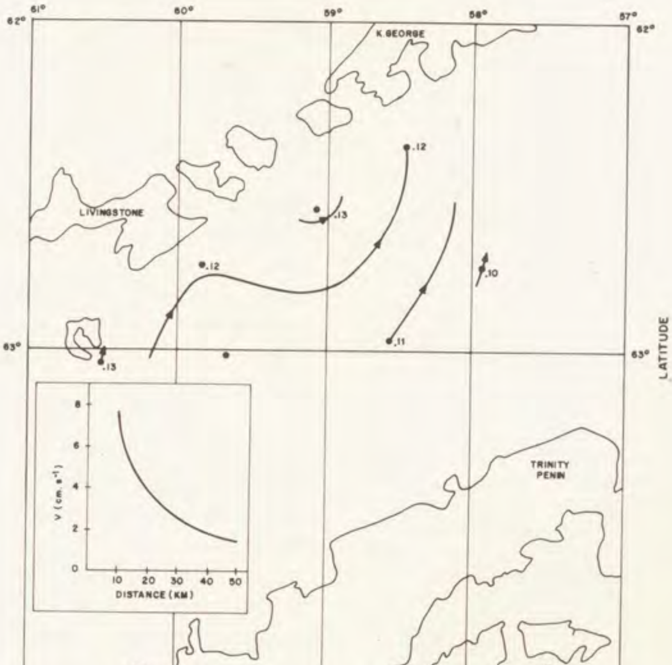

Fig. 8 – Geostrophic circulation (in dynamic meters) at 10 m referenced to 250 dbar surface, for 9-14 March 1985.

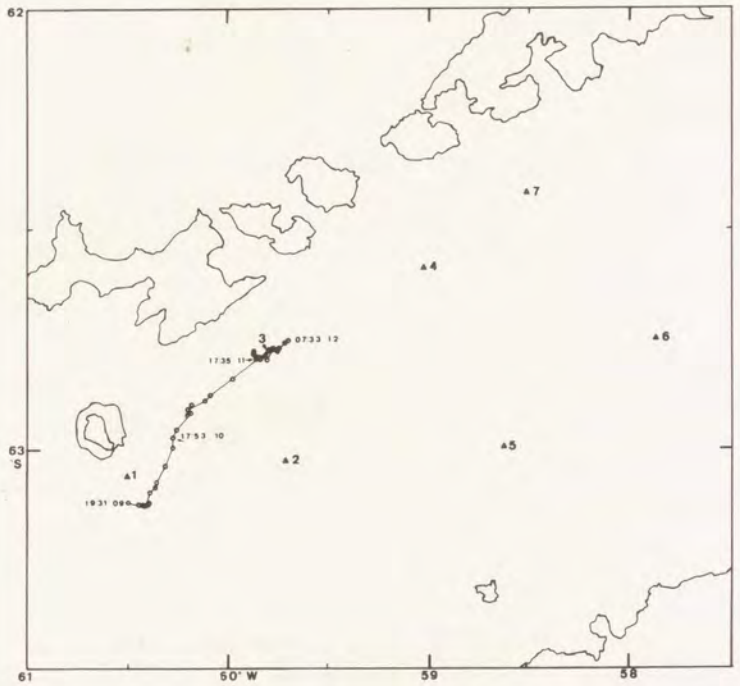

Fig. 9 – Trajectory for drifting buoy set for 11 m depth, for 9-12 March 1985. Circles represent positions determined by SERVICE ARGOS from NOAA-6 and NOAA-9 satellites; triangles indicate oceanographic stations.

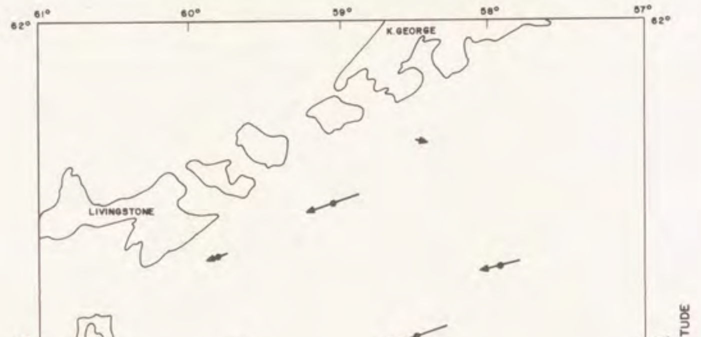

Fig. 10 – Wind speed and direction measured from the bridge of the Barão de Teffé at the oceanographic stations. Arrowheads indicate directions wind are blowing toward.

Measurements over a longer period of time are required to provide a better understanding of the spatial variations of properties such as temperature and salinity, and for time variations of currents in the Bransfield Strait.

CONCLUSIONS

Although the experiment was of short duration, several conclusions may be drawn from this work.

1. Warmer (0.7-1.0°C), less saline (0.21-0.33), and therefore less dense water (0.21-0.27 gm cm^{-3}) occurred along the west side of the Strait than along the eastern line of oceanographic stations.
2. This near surface water had a northerly motion near Deception Island, close to the southern entrance to the Strait, but curved toward the NE in the central part of the Strait. This curvature may be a persistent feature in the surface circulation.
3. Near surface water motion was 5 cm s^{-1} toward 020°, using geostrophic estimates and 27 cm s^{-1} toward 042°, based on the buoy trajectory. The greater buoy speed is attributed to a combination of wind drag on the exposed part of the buoy and an actual wind-driven current greater than the geostrophic current referenced to the 250 dbar surface.
4. During 9-12 March, surface currents were in the direction of the wind but offset of the left, consistent with Ekman wind drift currents.
5. The distributions of surface temperature and salinity, as well as the pattern of geostrophic circulation during this experiment (1985) were very similar to those during the summer of 1983 and in general with those of FIBEX (1981).

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SUMMARY

During a test of INPE's prototype drifting buoy, 7 hydrographic stations were made, in Bransfield Strait during 9-14 March, 1985. At each station Nansen bottles and reversing thermometers were used in casts to 300m, to obtain measurements of temperature and salinity. Horizontal maps of temperature (T), salinity (S) and density (σ_t) were prepared from these data for 0m and 10m depth. Warmer (T = 1.26-1.50°C), less saline (S = 33.89-34.03) and dense (σ_t = 27.12-27.25gm cm^{-3}) surface water was present on the west side, compared to T = 0.51-0.56°C, S = 34.22-34.24 and σ_t 27.39-27.46gm cm^{-3} respectively, along the eastern stations. Variations at 10m depth were similar to those at 0m. The geostrophic velocity field was also determined for 0m and 10m, using a 250 dbar reference level. Surface flow was toward the NE at 4cm s^{-1}, and in the same direction at 5cm s^{-1} at 10m depth. The mean buoy speed was 27cm s^{-1} toward 042°, during 9-12 March. Differences between geostrophic and buoy-derived currents are discussed and compared with surface wind measurements.

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