Physical and biological variability in the Antarctic Polar Frontal Zone: report on research cruise 103 of the MV *SA Agulhas*

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A detailed hydrographic and biological survey was carried out in the region of the South-west Indian Ridge during April 2002. Hydrographic data revealed that the Andrew Bain Fracture Zone, centred at 30°E, 50°S, functions as an important choke point to the flow of the Antarctic Circumpolar Current, resulting in the convergence of the Antarctic Polar Front (APF) and the southern branch of the Sub-Antarctic Front (SSAF). Total chlorophyll-*a* concentration and zooplankton biomass were highest at stations occupied in the vicinity of two frontal features represented by the APF and SSAF. These data suggest that the region of the South-west Indian Ridge is an area of elevated biological activity and probably acts as an important offshore feeding area for the top predators on the Prince Edward Islands.

Introduction

The region upstream of the Prince Edward Islands, particularly where the Antarctic Circumpolar Current (ACC) traverses the South-west Indian Ridge, has been identified as an important foraging ground for a number of top predators found on the islands.[1] The importance of this region is thought to reflect increased food availability resulting from features such as meanders in fronts and countereddies which promote phytoplankton growth with subsequent increase in zooplankton/nekton biomass.[1,2] It has, therefore, been suggested that this region represents a vital component of the 'life support' system enabling globally significant populations of seabirds and seals to breed at the Prince Edward Islands.[1]

Despite the potentially important role that this region may play in the island ecosystem, few studies have been conducted in the vicinity of the South-west Indian Ridge.[3] The main objective of the cruise reported here was to investigate the exact nature of the variability associated with the interaction of the ACC with the South-west Indian Ridge and to determine the biological responses.

Data and methods

A macro-scale oceanographic survey en route and in the vicinity of the South-west Indian Ridge was conducted aboard the research and supply vessel MV *SA Agulhas* during early austral autumn (4 –18 April) 2002. The survey consisted of a grid of seven north–south sections extending across the Andrew Bain Fracture Zone in the South-west Indian Ridge between 49°00′–51°45′S and 29°–33°E (except the first two transects, which extended only to 49°45′S) (Fig. 1). Each line consisted of alternate CTD (conductivity-depth-temperature) and XBT (expendable bathythermograph) stations occupied at intervals of 16 nautical miles. At each hydrographic station vertical profiles of salinity, temperature and density were obtained with a Neil Brown Mark IIIc WOCE upgrade underwater unit to a maximum depth of 1500 m. Water samples were collected on average at 10 standard depths and analysed for dissolved oxygen, salinity, macronutrient (silicate, phosphate, nitrate and nitrite) concentrations, and microbial activity.

Total chlorophyll-*a* (chl-*a*) concentration was determined at six depths in the upper 300 m of the water column at each CTD station. In addition, mesozooplankton (0.2–2 cm in size) community structure and grazing impact were determined from samples collected with a WP-2 net. Net tows were conducted to a depth of 250 m during the daytime and to 150 m at night.

Sippican T5 XBTs (deployed to a maximum depth of 1200 m) and surface chl-*a* concentrations were determined at intermediate stations (30-nm intervals). In total, 135 hydrographic (34 CTD/biological and 101 XB/surface chl-*a*) stations were occupied during the survey (Fig. 1).

Preliminary results and discussion

In this article we describe only the subsurface (200 m) temperature characteris-

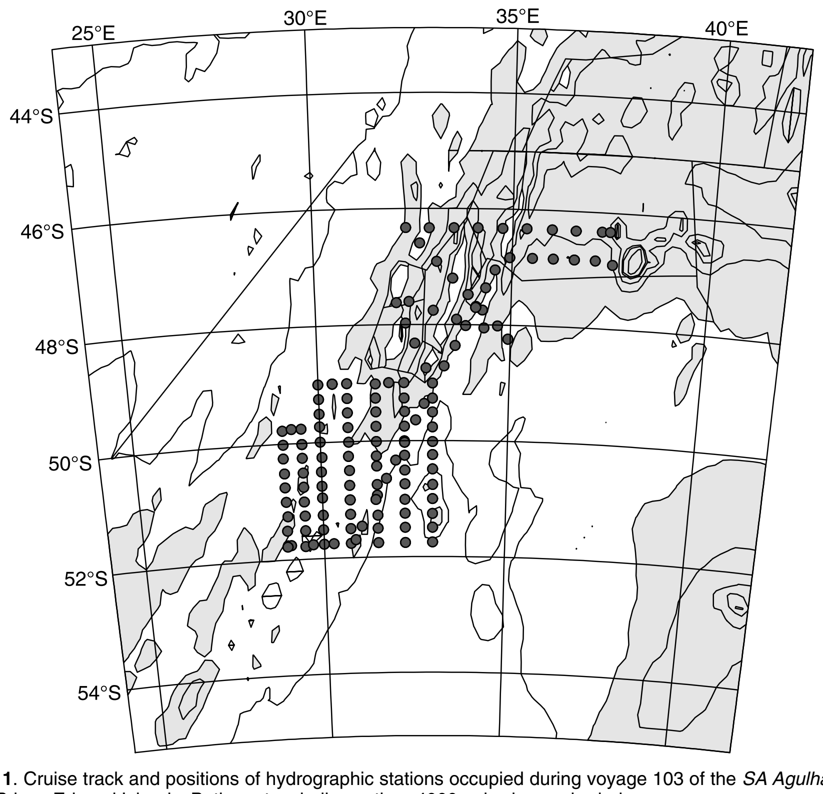

Fig. 1. Cruise track and positions of hydrographic stations occupied during voyage 103 of the *SA Agulhas* to the Prince Edward Islands. Bathymetry shallower than 4000 m is shown shaded.

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tics of this region and the water column profiles of selected physical and biological data collected along 30°45′E. A detailed description of both the physical and biological results collected during the survey will be given elsewhere.

A large number of regions in the Southern Ocean have been identified as 'choke points' in the flow of the ACC, resulting in extensive meso-scale activity and enhanced cross-zonal exchange of water masses[4–6]. These regions have been identified as the Drake Passage and the Scotia Sea in the southwest Atlantic Ocean[7], the oceanic region surrounding the Crozet and Kerguelen islands,[8] and the Macquarie Ridge in the southwest Pacific Ocean[9]. Previous investigations in the southwest Indian Ocean from either hydrographic data[10,11], altimetry or drifter trajectories[12] have identified that complex fracture zones in the South-west Indian Ridge act as major choke points in the flow of the ACC. Extensive hydrographic surveys in this region have reported the southward deflection and intensification of the ACC as it passes through the deep Andrew Bain Fracture Zone at 50°S, 30°E.[10] In such a zone the frontal bands associated with the Antarctic Polar Front (APF) and Subantarctic Front (SAF) have been known either to merge as an intensive single band or to meander, forming a double front.[10,11,13]

Hydrographic data collected during the survey imply that the fracture zone does in fact function as a choke point to the flow of the ACC. The APF was identified by the northern limit of the temperature minimum and was found to lie at approximately its mean position of 51°S (Fig. 2). The APF forms a veritable wall between the Antarctic Zone to the south and the transitional characteristic of the Polar Frontal Zone to the north.[11] In this region surface temperatures across this front range from 6° to 2.8°C, which are in agreement with previous observations.[11] However, of greater interest was the merging of the APF with a frontal band to the north (Fig. 2). The sub-surface thermal characteristics of this band were too cold (3.5°C) to represent the true SAF, which is commonly identified by the sub-surface 6°C axial value (Fig. 3). Closer inspection suggests that this frontal band may represent the Southern SAF (SSAF). Extensive XBT transects south of New Zealand have shown that the SAF bifurcates into northern (6°C, z = 200) and southern (3.5°C, z = 200) branches as a result of the topographical influence of the Macquarie Ridge. During such occasions both branches have been shown to separate by as much as 900 km. We, therefore, suggest that the SAF, on approaching the South-west Indian Ridge, splits into two branches; the southern branch, channelled by the fracture zone, temporarily merges with the APF, whereas the northern branch remains to the north of the survey grid (encountered during both underway XBT transects) at its mean location of 48°S (Fig. 2). East of 32°E, the APF/SSAF separate with the APF meandering eastwards across the Enderby Abyssal Plain, whereas the SSAF is deflected northwards, where it converges with the SAF at 48°S (Fig. 2). Current moorings deployed during the U.K. SWINDEX programme in 1993 and 1995 have shown that the western flank of the South-west Indian Ridge largely controls the flow of the SAF.[10] The northeastward deflection of the 3.5°C isotherm, representative of the SSAF, supports this observation.

Concentrations of silicate and phosphate during the survey ranged between 0.9 and 10.8 μmol kg^{-1} and between 1.5 and 2.75 μmol^{-1}, respectively. Throughout the survey, maximum concentrations of silicate and phosphate were recorded at stations south of the APF and minimum concentrations north of the SSAF. Intermediate concentrations were recorded at stations occupied in the Polar Frontal Zone. Minimum concentrations of silicate during the survey were recorded in the upper surface waters (<100 m), which probably reflects biological uptake by phytoplankton (Fig. 4).

Total surface chlorophyll-*a* concentration during the survey ranged between 0.09 and 0.38 μg l^{-1}. Generally, the highest chl-*a* concentrations were recorded at stations occupied in the vicinity of the

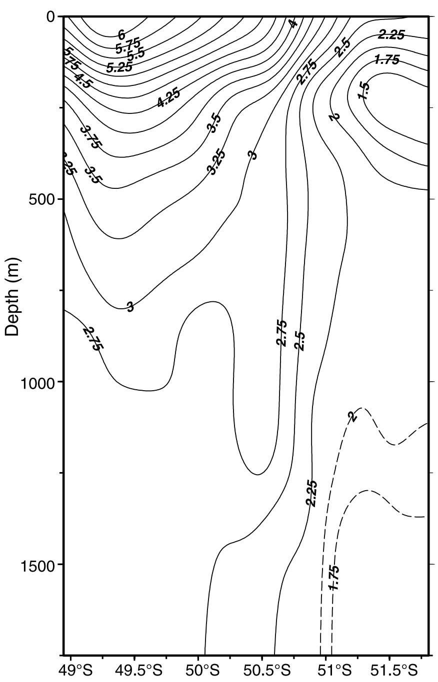

Fig. 2. Temperature section along 30°45′E, which transverses the Andrew Bain Fracture Zone. The position of the Antarctic Polar Front is denoted by the dashed 2°C isotherm and the southern Subantarctic Front by the 3.5°C isotherm.

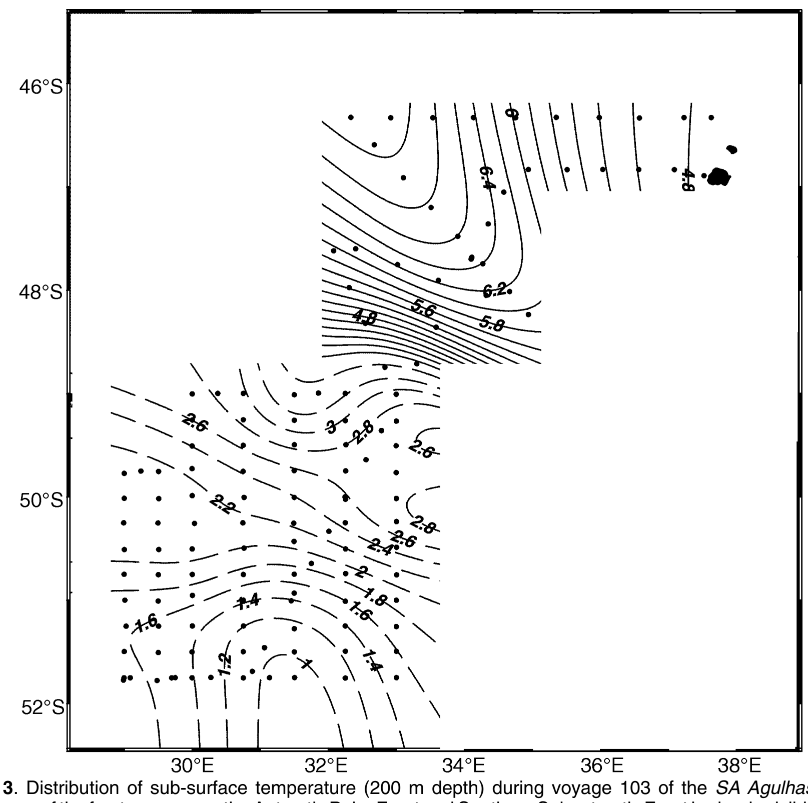

Fig. 3. Distribution of sub-surface temperature (200 m depth) during voyage 103 of the *SA Agulhas*. The influence of the fracture zone on the Antarctic Polar Front and Southern Subantarctic Front is clearly visible, with both fronts temporarily converging at 31°30′E.

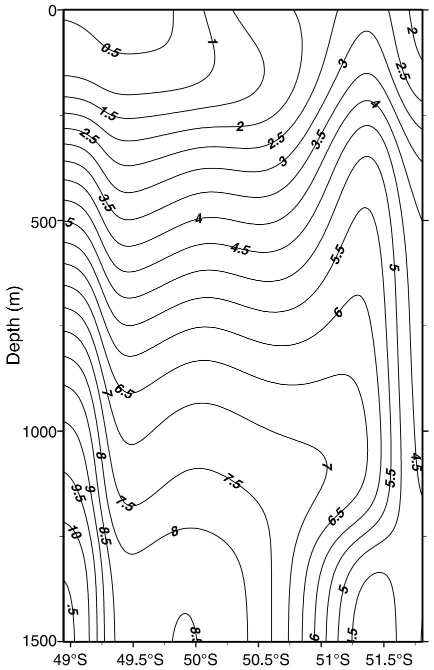

Fig. 4. Silicate concentrations (μmol kg^{-1}) along the 30°45′E transect.

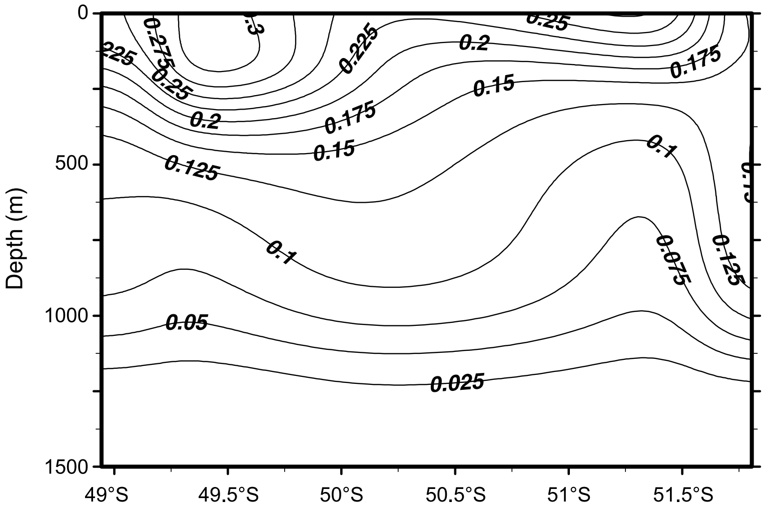

Fig. 5. Total chlorophyll-*a* concentrations (μg l^{-1}) along the 30°45′E transect.

APF and SSAF (Fig. 5). The increase in chl-*a* concentration in the region of the two fronts can probably be related to elevated primary production resulting from increased water column stability and nutrient availability, particularly in the region of the APF.[14] Outside the region of the two fronts, total chl-*a* concentration decreased with depth with values always <0.05 μg l^{-1} below 100 m.

Total zooplankton abundance and biomass during the survey was dominated by mesozooplankton (0.2–2 cm), mainly copepods of the genera *Oithona, Calanus* and *Ctenoclanaus*. Exceptions were recorded at stations located in the southwestern sector of the survey, where the amphipod *Themisto gaudichaudii* dominated total zooplankton biomass, and at stations occupied in the northeastern sector of the grid, where the salp, *Salpa thompsoni,* dominated total zooplankton biomass. Among the larger zooplankton (>2000 μm), the chaetognaths, *Sagitta gazellae* and *Eukrohnia hamata,* dominated numerically and by biomass. The contribution of the euphausiids, mainly *Euphausia vallentini* and *Thysanoessa vicina,* was always <1% of total zooplankton abundance. Total zooplankton abundance and biomass was highest at stations occupied in the immediate vicinity of the APF and SSAF. Grazing data are currently being analysed.

This survey indicates that the region of the South-west Indian Ridge does indeed represent a choke point in the flow of the ACC, resulting from the convergence of the APF with the SSAF. The merging of the two frontal systems results in a localized area of enhanced biological activity.

The research cruise was a collaboration between the Dynamic of Eddy Impacts on Marion's Ecosystem (DEIMEC) Programme of the Oceanography Department, University of Cape Town, and the Marion Offshore Variability Ecosystem Study (MOVES) Programme of the Southern Ocean Group at Rhodes University.

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S_2A_3 centenary awards

The following awards were made at the centenary meeting of the Southern African Association for the Advancement of Science at the Transvaal Museum, Pretoria, on 4 November: South Africa Medal (gold) to **William F. Harris** (Rand Afrikaans University); British Association Medal (silver) to **Jaco M. Greeff** (Pretoria University); S_2A_3 centenary award to **Govert C. van Drimmelen**. Merit certificates were presented to: **W.J.R. Alexander**, **C.K. Brain**, **P.C. Minnaar**, **P.D. Tyson**, **J.C. Vogel**, and the SABC team responsible for the television programme '*50/50*'.

- **Wesley Kotzé**, head of the Department of Mathematics at Rhodes University, has been awarded a medal for contributions to the advancement of mathematics by the South African Mathematics Society.
- **William Froneman** of Rhodes University has received the Meiring Naudé gold medal of the Royal Society of South Africa for his contributions to oceanography (see article on page 534 of this issue).