Mean Flow, Eddy Variability and Energetics of the Subantarctic Front South of Australia

by

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Submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

University of Tasmania
September, 2000
Declaration

This thesis contains no material which has been accepted for a degree or diploma by the University of Tasmania or any other institution. To the best of my knowledge this thesis contains no material previously published or written by another person except where due acknowledgment is made in the text of the thesis.

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Abstract

This thesis describes the variability and mean flow of the Subantarctic Front (SAF) south of Australia using time series measurements of velocity and temperature from 1993 to 1995, and six hydrographic transects along WOCE line SR3 from Tasmania to Antarctica over the period 1991 to 1996. The SAF is the strongest jet of the Antarctic Circumpolar Current (ACC) south of Australia. The time series of velocity and temperature are only the third such dataset collected in the ACC and provide insight into the dynamics of this massive current and into the heat and momentum balances of the Southern Ocean.

The SAF was found to be an energetic, meandering jet with vertically coherent fluctuations. These fluctuations varied on a timescale of 20 days, and had a typical amplitude of 30 cm s\(^{-1}\) at 1150 dbar. The analysis used a coordinate frame that rotated daily to be in alignment with the direction of flow. This allowed the mesoscale variability of the SAF to be isolated from variability due to meandering of the front and proved very successful for examining eddy fluxes. Vertically averaged cross-stream eddy heat flux was 11.3 kW m\(^{-2}\) poleward and was significantly different from zero at the 95% confidence level for fluctuations with periods between 2 and 90 days. Zonally integrated, this eddy heat flux (=0.9\times10^{15} \text{ W}) is more than large enough to balance the heat lost south of the Polar Front and is as large as cross-SAF fluxes found in Drake Passage. Cross-stream eddy momentum fluxes were small and not significantly different from zero but were tending to decelerate the mean flow. A relationship between vertical motion and meander phase identified in the Gulf Stream was found to hold for the SAF. Eddy kinetic energy levels were similar to those in Drake Passage and southeast of New Zealand. Eddy potential energy was up to an order of magnitude larger than at the other ACC sites, most likely because meandering of the front is more common south of Australia. Baroclinic conversion was found to be the dominant mechanism by which eddies grow south of Australia. The typical time for the growth of an eddy is estimated to be 30 days, approximately half that in Drake Passage. This is consistent with observations from satellite altimetry which indicate that eddy energy is growing rapidly downstream of the Australian measurement site, while the eddy field in Drake Passage is mature.

Mean cross-stream profiles of absolute and baroclinic velocity in the SAF at five current meter levels have been obtained from two streamwise profiling techniques using specific volume anomaly at 780 dbar as the cross-stream coordinate. One of the techniques, using hydrographic data to estimate the baroclinic velocity profile, is presented for the first time. The mean SAF
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velocity profile is composed of one central peak, reaching 52 and 34 cm s$^{-1}$ at 420 dbar, absolute and baroclinic respectively, and several smaller peaks. The SAF flow is coherent at all levels, reaches the sea floor, and is at least 220 km wide. The cross-stream structure of baroclinic and absolute transport of the SAF has been characterized for the first time. The integrated mean transport is at least $116\pm10 \times 10^6$ m$^3$ s$^{-1}$, of which approximately 14% is barotropic. The linear conditions for baroclinic and barotropic instability are satisfied at the array, consistent with the eddy growth rates calculated.
Acknowledgments

Foremost, I would like to say thankyou to my three supervisors.

To Steve Rintoul, on whom the lion’s share of supervision fell, for providing excellent supervision – a subtle blend of endless encouragement, generosity of time and knowledge, reading countless thesis revisions, and allowing me the freedom to find my own way.

To Nathan Bindoff, for encouragement, for valuable discussions on the definition of the cross-stream coordinate and subsequent error analysis in Chapter 4, for detailed comments on the final draft of the thesis, and for being the buffer between me and the Administration.

To Richard Coleman, for encouragement, for helpful comments in reviewing my work, and for a particularly careful reading of the final draft of the thesis.

I would also like to thank John Church for his detailed reviews of two journal articles arising from the thesis.

The current meter and hydrographic data used in the thesis would not have been collected without the contribution of the officers and crew of the RSV Aurora Australis. The successful design, deployment and recovery of the current meter moorings is thanks to Fred Boland, Kevin Miller, Danny McLaughlin and Mark Rosenberg. This work was supported in part by Environment Australia through the National Greenhouse Research Program, and by the Australian National Antarctic Research Expeditions (ANARE).

During my PhD candidature I was supported by an Australian Postgraduate Award, an Antarctic Cooperative Research Centre “Top-up” Award, and a CSIRO Postgraduate Award.

Finally, thankyou to my family. To Leigh and Isabel, for making home such a pleasure that I almost didn’t want life to move on. And to Joseph, for kicking me on at the finish.
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