



Thesis Abstract

## Observing Southern Ocean subsurface circulation and variability using satellite altimetry

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August 2009

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CSIRO-UTAS Joint PhD Program in Quantitative Marine Science

We present a gravest empirical mode (GEM) projection of temperature and salinity fields in the Southern Ocean that, combined with satellite altimetry, produces time evolving temperature, salinity and velocity fields, and use these to observe the mean and synoptically varying properties of the Southern Ocean from 1992-2006.

Historical hydrography from 1920-2006 is used to produce GEM projections of the circumpolar temperature and salinity fields in longitude/dynamic height space between 25-5400 dbar. Combining these fields with altimetric SSH creates synoptic temperature and salinity fields (satGEM fields) at seven-day time intervals on a  $\frac{1}{2}^\circ$  grid. The satGEM fields resolve front and eddy features significantly more accurately than climatologies and can reproduce the time evolution of the T-S fields. These are used to create baroclinic velocities that produce realistic ACC volume transports and correlate well with ARGO velocities ( $u$  and  $v$  coefficients of 0.60 and 0.53). Although these fields accurately estimate a pointwise mean southward eddy heat transport of  $-37.7 \text{ KWm}^{-2}$  in the SAF, the global mean northward eddy heat and freshwater transports of  $-0.08 \pm 0.01 \text{ PW}$  and  $0.025 \pm 0.01 \text{ Sv}$  are small due to the satGEM's inability to resolve eddy tilt. An explicit eddy tracking method produces similar transports, and as the two methods work at different length scales we combine them for a minimum bound on the eddy transport across the SAF of  $0.14 \pm 0.03 \text{ PW}$  of heat southward and  $0.04 \pm 0.03 \text{ Sv}$  of freshwater northward.

There is a warming ( $1.219 \pm 0.089 \text{ Wm}^{-2}$ ) and weak freshening ( $5.85 \pm 0.16 \text{ mmy}^{-1} \text{m}^{-2}$ ) of the ACC induced by adiabatic water mass movement between 1992-2006. The diabatic contribution due to heat and freshwater fluxes drives a cooling ( $-0.628 \pm 0.129 \text{ Wm}^{-2}$ ) and freshening ( $30.27 \pm 0.70 \text{ mmy}^{-1} \text{m}^{-2}$ ), with a net trend of  $0.591 \pm 0.093 \text{ Wm}^{-2}$  and  $36.12 \pm 0.68 \text{ mmy}^{-1} \text{m}^{-2}$ . Although there is no trend in zonal ACC mass transport at any longitude, nor a change in eddy kinetic energy, eddy number or eddy meridional property transport, there is substantial variability driven by the Southern Annular Mode (SAM) and the El Niño Southern Oscillation (ENSO). The SAM influences the Southern Ocean at frequencies of less than three months, while ENSO operates on interannual timescales. The ENSO driven trend in the Pacific dominates the total adiabatic heat and freshwater content change during strong El Niño and La Niña years (1997-2002), while outside this period the SAM is a greater contributor, but with a lag of 4-5 years.

An increased SAM leads to a roughly circumpolar 5% increase in the zonal volume transport of the ACC. Additionally, there is a clear lag of 1.6- 3.2 years between an increase in the SAM and an increase in the EKE and number of eddies across the whole ACC. The response of eddy heat and freshwater transport is less clear, but at a similar lag there is an increase of 0.01-0.1 PW of southward heat transport and 0.01-0.1 Sv of northward freshwater transport across the SAF. The weak transport response to wind stress change and lagged eddy transport indicates that the ACC is in an eddy saturated state.