Anticyclonic and cyclonic eddies of subtropical origin in the subantarctic zone south of Africa

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[1] Two eddies, one anticyclonic and the other cyclonic, intersected in the Subantarctic Zone south of South Africa during a hydrographic transect, are described using a large set of measurements including full depth hydrography, Acoustic Doppler Current Profiler velocities, biogeochemical tracers, air-sea fluxes and altimetric sea surface height. Both eddies have a subtropical origin. The anticyclone is an Agulhas ring with convected core water of ~12°C, and swirl velocities of 1 m s^{-1}. It was 9.5 months old when sampled and had crossed the Agulhas Ridge. Though sampled in summer, it was releasing ~200 W m^{-2} (sensible plus latent heat flux) to the atmosphere. It was observed adjacent to the Subantarctic Front, illustrating the usual encounters of such structures with this front. The cyclone, marked by pronounced low oxygen and CFC anomalies revealing an origin at the continental slope, was 4.5 months old. It had swirl speeds of 0.3 m s^{-1}, and was coupled with the anticyclone when observed. From their kinematics and water mass properties both structures were found to transport subtropical water down to ~900 m, the water trapped below this depth being either from the northern Subantarctic Zone, or local water. The two structures illustrate the capacity of eddies in the region to transfer subtropical and alongslope water properties into the Subantarctic Zone.

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1. Introduction

[2] *Lutjeharms* [1988] first suggested that the meridional propagation of mesoscale eddies at distinct sectors of the Subtropical Front (STF), such as those bordering the western boundary currents, might be an important process for the transport of heat into the Southern Ocean. The oceanic domain south of South Africa, where the Agulhas Current system abuts on the Antarctic Circumpolar Current (ACC), should naturally be counted among such sectors. In agreement with this view, *Dencausse et al.* [2011] recently observed that, due to the intense mesoscale activity of that region [e.g., *Boebel et al.*, 2003], the STF, which is present at 38°S–42°S in the eastern South Atlantic and western South Indian oceans, is interrupted between about 12°E and 23°E.

[3] This ~10-degree longitudinal interval appears as a preferential pathway for mesoscale structures. Here, indeed, warm eddies of subtropical origin have sometimes been observed to enter the Subantarctic Zone (SAZ) located between the STF and the Subantarctic Front (SAF) of the ACC [*Lutjeharms and Valentine*, 1988; *Arhan et al.*, 1999; *Gladyshev et al.*, 2008]. Most of these observed mesoscale features have been anticyclones, either *Agulhas eddies* shed southward by the meandering Agulhas Return Current, or *Agulhas rings* formed at the Agulhas Current retroflection. However, as anticyclones tend to propagate equatorward under the β-effect, Agulhas rings that enter the SAZ (located poleward of their formation region) are not numerous. *Dencausse et al.* [2010] observed that these structures (about 2 per year) often result from subdivisions of newly spawned rings at the northeastern tip of the Agulhas Ridge (Figure 1).

[4] On the other hand, owing to the β-effect, which tends to drive them poleward, the cyclones of subtropical origin present in the southeastern Cape Basin and in the Agulhas Basin (Figure 1) should be more prone to enter the SAZ. *Boebel et al.* [2003] and *Lutjeharms et al.* [2003] showed that these structures can fall into two categories, namely, Cape Basin cyclones, formed along the western coast of South Africa, and Agulhas cyclones formed inshore of the Agulhas Current. Tracking them from altimetric Sea Surface Height data and surface/subsurface float displacements, *Boebel et al.* [2003], *Morrow et al.* [2004], *Richardson* [2007], *Rubio et al.* [2009], and *Baker-Yeboah et al.* [2010a, 2010b] all found trajectories orientated southwestward, and clearly contrasting with the dominant northwestward

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