Abstract View

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Dynamics of Agulhas Retroflection and Ring Formation in a Numerical Model. Part I: The Vorticity Balance

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ABSTRACT

The Agulhas retroflection region of the wind-driven idealized South Atlantic–Indian Ocean model described by DeRuijter and Boudra is analyzed in detail. Here, in Part I, the physical mechanisms of the model retroflection are elucidated through illustration of Agulhas' vorticity balance among various experiments. In Part II, the ring formation process is described in terms of its vertical structure and the associated energy conversions.

A one-layer model demonstration shows that both inertia and internal friction may account for a partial retroflection where a linear, weakly viscous system has none. In the nonlinear, weakly viscous one-layer model, the retroflection is accomplished through a free inertial boundary layer, as suggested originally by De Ruijter. When stratification is introduced and baroclinicity increased, using the Bleck and Boudra quasi-isopycnic coordinate model with 2 or 3 layers, the stretching term exerts an increasing influence. With 40-km resolution, terms included so that the numerical model conserves potential vorticity become important as well. Both encourage retroflection of the fluid separating from Africa's trip. When grid spacing is halved, the importance of the extra conserving terms diminishes and the stretching term exerts an even greater influence. The importance of a substantial viscous stress curl along the coast of Africa, as provided by the no-slip condition, is illustrated through comparison with a slippery Africa experiment.

Finally, an experiment with a more realistic South Africa coastal geometry, giving a more realistic order of importance to βv in the separating Agulhas, is described. It is shown that the retroflection is still strong but that the associated recirculation is less intense. An interesting new aspect of the retroflection is the separation of the mean current core from the coast a few hundred kilometers upstream from the tip. The planetary vorticity advection term plays a smaller role along the coast. Viscous effects on the coastal side of the current are still strong, however, and are balanced primarily by stretching and relative vorticity advection. As the mean current passes Africa's tip, the sink of positive vorticity produced in the stretching and planetary vorticity advection terms is left behind, and the Agulhas turns eastward. These results support the notion, advanced by De Ruijter and Boudra, that the change in the vorticity balance at separation leads to the model retroflection, and they point to the increasing importance of the divergent

component of flow in the vorticity balance as more realism is introduced.