Analysing spiral eddies as an example of baroclinic Mixed Layer Instabilities

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Abstract

An asymmetry between anticyclonic and cyclonic spiral eddies is observed in the submesoscale regime. The predominant cyclonic rotation, reported e.g. by Munk et al. (2000), is not fully understood yet and contrasts with a more symmetric balance between cyclones and anticyclones observed for mesoscale dynamics.

In this study we investigate the connection between spiral surface flow pattern in the ocean and their cyclonic rotation. We find that ageostrophic flow components in submesoscale dynamics lead to smaller sized cyclones, with enhanced horizontal velocity and pressure gradients. These sharpened horizontal gradients, which are not geostrophically balanced yield enhanced vertical velocities. Spiral structures can only evolve on a horizontally non-divergent velocity field and are thus also associated with enhanced vertical velocities, contrary to nearly two-dimensional mesoscale dynamics. In contrary the submesoscale anticyclonic regions have less enhanced gradients and vertical velocities and thus do not favour spiral structured eddies, but closed, vortex-like structures similar to mesoscale dynamics.

To study different dynamical regimes from submesoscale to mesoscale and to verify our hypothesis we use numerical simulations of the idealised python Ocean Model (pyOM, *Eden* (2011)). Several experiments are performed with initial conditions corresponding to mesoscale and submesoscale dynamics.

The simulated instabilities correspond to time and length scales predicted by linear stability analysis and are similar to observed baroclinic instabilities. Especially the cyclonic dominance in the submesoscale simulation is confirmed.

An analysis of pressure perturbation, relative vorticity and vertical velocities for different dynamical regions confirms our hypothesis of the coherence of cyclonic eddies and enhanced vertical velocities, as well as the different sizes of cyclones and anticyclones in the submesoscale regime.