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Generation of vortex lens from turbulence collapse in a stratified fluid

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Through laboratory experiments, we address the question of the selection of robust vortex structures resulting from the collapse of a turbulent flow produced in a static uniformly stratified fluid. A background rotation is applied, using the large rotating “Coriolis” platform in Grenoble.

We compare two methods of generation, which both produce vortices with zero total circulation:
• Production of a horizontal circulation inside a cylinder by a pumping system. The cylinder is then lifted to release the vortex. This is used with or without background rotation.
• Injection of fluid through a localised source in the case of a rotating background. Vorticity is then produced by the Coriolis Effect acting on the radial pumping.

Different vortex structures are obtained after collapse of the turbulence. We distinguish in particular monopoles, dipoles and tripoles. Velocity fields are measured by Particle Imaging Velocimetry in a volume using a scanning system for the laser sheet. Laser Induced Fluorescence is also used to analyse the mixing of the injected fluid, marked with dye.

We focus the study on monopoles which takes the form of anticyclonic lenses with aspect ratio scaling in N/f (around $\frac{1}{4}$ in our experiments). In that case, the density field, hence the potential vorticity, can be deduced from the measured azimuthal velocity in a vertical plane by the combination of the hydrostatic balance on the vertical and the cyclo-geostrophic balance in the radial direction. It is found that the centrifugal term in v2/r is small so that the geostrophic balance is a good approximation. The measured potential vorticity profile is not monotonic, with a central negative (anticyclonic) ring and an outer cyclonic ring.

The resulting vortex is stable with respect to the vertical shear instability (Ri>1/4) and with respect to the double diffusion instability of McIntyre. It is also observed to be stable with respect to the baroclinic and barotropic instabilities although the potential vorticity profile does satisfy the (necessary) criterion of instability of Charney and Stern (generalisation of the Rayleigh criterion to a circular stratified flow). No layering or internal wave emission is observed after the initial collapse. The connection with maximum entropy states and oceanic observations will be discussed.