Instabilities around a differentially rotating ellipsoid embedded in a rotating stratified fluid

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To better predict Earth's climate evolution, the CO_2 and heat fluxes between the oceans and the atmosphere must be taken into account. These fluxes are governed by the vertical mixing in the ocean. But the measured mixing rate is 10 times smaller than necessary to balance the energy budget of the oceans: this calls for new, local mechanisms of mixing. At the edge of meso-scale eddies, an horizontal layering is observed, corresponding to density steps [1]. This is a local signature of an increased vertical mixing. To quantify its influence we need to determine the origin of the underlying instability/ies.

To model this geophysical flow, a heated solid ellipsoid differentially rotates anticyclonically in a rotating stratified medium. We numerically and experimentally study this setup to assess the intensity and the structures of instabilities around the ellipsoid in the different regions of the Rossby, Froude, Eckman, Prandtl and Schmidt numbers space.

The numerical analysis is conducted using the pseudo-spectral eigenvalue problem solver Dedalus [2]. The experimental apparatus uses a rotating cylindrical tank of 1 m in diameter. The base flow is analytically computed for any aspect ratio from 0 to infinity. Various types of instabilities are observed, including baroclinic, double diffusive, convective and centrifugal ones, see e.g. Fig. 1. Their efficiency and relevance to explain the observed mixing are systematically assessed.

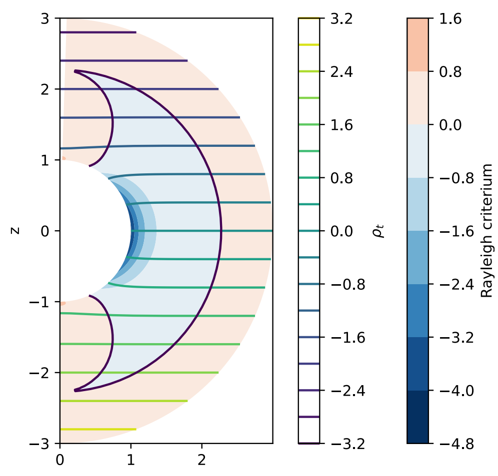

Figure 1. Rayleigh criterium map around a rotating sphere for Ro = −10, Fr = 0.32.

References

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