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Radiative instability of a stratified Lamb-Oseen vortex

X. Riedinger, S. Le Dizès, and P. Meunier
(riedinger@irphe.univ-mrs.fr)

In this presentation, we willl show that internal gravity waves generation can be explained by the instability of a flow. A jet flow, a shear flow or a vortex flow, in presence of stratification, may be subject to an instability which is radiative. We focus here on the case of the stratified Lamb-Oseen vortex with a stratification along the vortex axis.

Le Dizès and Billant[1] have shown that, when the stratification is strong, the vortex is inviscidly unstable. The unstable modes are radiative and extend far from the vortex core. Our objective is to analyse the effects of viscosity and stratification on these unstable modes. A linear temporal stability analysis is performed using a Chebychev collocation spectral code. The equations are the linearized Navier-Stokes equations with Boussinesq approximation. The parameters are the Froude number $F = \Omega_{max}/N$ and the Reynolds number $Re = \Gamma/(2\pi\nu)$ with Ω_{max} the maximal angular velocity of the vortex, N the Brunt-Väisälä frequency, Γ the vortex circulation and ν the kinematic viscosity.

For fixed m (azimuthal wavenumber), k (axial wavenumber), F and Re the spectral code provides the complex frequency ω of the eigenmodes. By maximising the growth rate $Im(\omega)$ over the axial wavenumber, we obtain typical growth rate curves. The instability is the strongest for a Froude number around one and the vortex remains unstable for all Reynolds numbers. We shall explain that the stabilization for small Froude number is due to the scaling in $\frac{1}{F}$ of the most unstable wavenumber and that the stabilization for large Froude number is linked to the appearance of a critical layer.

For intermediate Froude numbers, another instability mechanism responsible for growth rate oscillations has been discovered. This new instability which will be explained in detail is due to resonances between the radiative modes and the neutral modes of the unstratified flow.

Experimental results are given. We tried to produce the most realistic Lamb-Oseen vortex in a tank filled with a stratified fluid made using salted water. We found a destabilisation of the vortex which creates an ondulation of the vortex axis. The wavelength and the value of the Froude number at which the instability occurs are in correct agreement with the numerical results.

[1] Le Dizès and Billant, *Radiative instability of a stratified vortex, submitted to Phys. Rev. Letters.* (2008).