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Instabilities of a barotropic rotating shear layer in a rotating fluid

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The Earth's core and the eye of a hurricane are two examples of rotating fluid systems where differential rotation results in a detached shear layer. The aim of this project is to provide new insights into the dynamics and instabilities of a barotropic shear layer in a rotating fluid. Above a critical value of horizontal stress, the flow within a bounded system in rotation is driven to an unstable limit, beyond which it develops chains of vortices. The number of vortices depends not only upon the value of the stress imposed (measured by a suitably-defined Reynolds number) but also (commonly, though not always) on the sense of the shear. Hide & Titman reported an asymmetric behaviour for opposite signs of stress, whereas Früh & Read found no major differences between each sign.

Boundary layer theory based on the quasi-geostrophic approximation, however, predicts that there should be no qualitative differences in dynamics or instability with respect to the sign of the stress. Experimental evidence may therefore indicate some weaknesses in such a theory.

In the present work, I have been running laboratory experiments in cylindrical geometry where a detached shear layer occurs tangential to the differentially rotating sections at the base and lid of the tank. Results will be presented for flat, stepped and sloping bottoms, exploring the effects of different ranges and configurations of topographically-induced 'planetary' vorticity gradient whose profile across the shear layer seems to determine the instability's behaviour. In particular, very small steps in the depth of the tank (O(Rossby number)) are sufficient to induce detectable asymmetries between positive and negative imposed stresses. In addition to the experimental results, we will present some results of simulations using a 2D Navier-Stokes numerical model, to investigate the detailed structure of the shear layer. In the future work,

it is hoped to use a quasi-geostrophic numerical model to further investigate the fully-developed nature of the instabilities.