TURBULENCE, INERTIAL WAVES AND VORTEX COLUMN FORMATION IN A ROTATING FLUID

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Abstract In order to investigate turbulence in rotating fluids, we consider in this experimental-numerical study, the locally generated turbulence though inertial-wave focusing and the role of inertial waves in the inverse energy cascade and the transfer of momentum. With a vertically oscillating torus in a rotating fluid, two inertial waves cones are generated; their energy focusing at the apex of the wave cones. For large amplitude oscillations, turbulence is generated locally around the focal point resulting in angular momentum mixing and the generation of a columnar cyclonic vortex, suggesting that there are nonlinear dynamics underlying the wave induced transport of momentum towards columnar vortices in rotating turbulence (see [1]). Quantitative data is acquired from Stereo PIV measurements and complementary information about the flow is obtained from high resolution numerical simulations.

Turbulence in rotating fluids, and the transition to quasi-two dimensional flow has been investigated experimentally intensively over the past 3 to 4 decades (see e.g. [1,2,3]). In most of these studies on rotating turbulence, inertia waves and vortices are generated simultaneously with oscillating grids.

In order to show the relevance of momentum redistribution to the organization of the flow into a quasi two-dimensional flow, we consider here a localized turbulent flow, as generated by a vertically oscillating torus. The torus is placed at the axes in the centre of the rotating tank and the focusing inertial waves generate, for large enough amplitude, turbulence in the apex of the two wave cones above and below the oscillating torus.

In a fluid that is rigidly rotating about a vertical axis, vortex lines expand over the entire depth of the fluid and are attached to the top and bottom boundaries of the domain. When turbulence is created , these vortex lines bend and twist in different directions. Momentum may be redistributed, whereas the vortex lines may conduct (inertial) wave motions, also known as gyroscopic or Kelvin waves. Since they transport momentum, they play an important role for the organization in a quasi two-dimensional flow. In the present experiments, a columnar cyclonic vortex emerged from the turbulent region and occupied the entire fluid depth. The results suggests that its formation is due to the mixing of angular momentum within the turbulent blob.

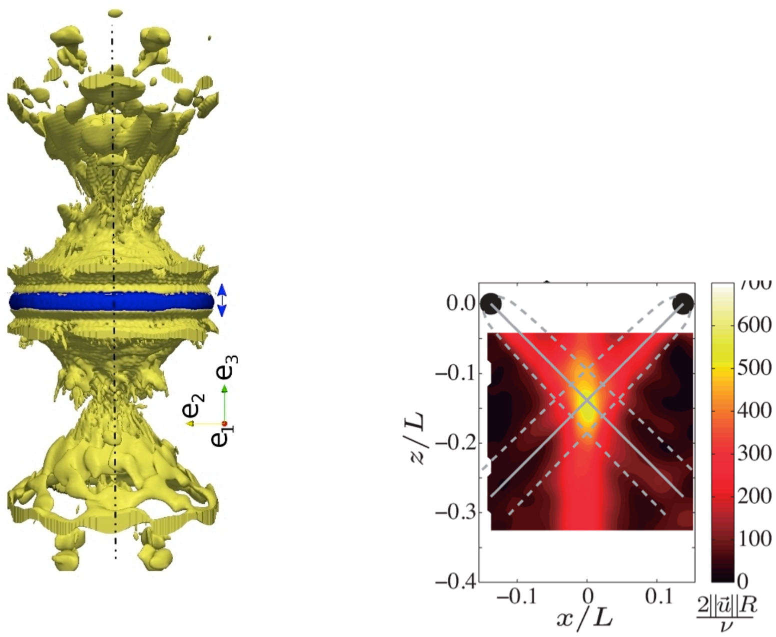

Figure 1. a) Inertial-wave cones excited by the oscillating torus as depicted by iso-surfaces of the vertical velocity from DNS. The torus is shown in blue, and b), the cyclonic vortex column emerging from the turbulent focal region.

References

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