A mechanism for the growth of anisotropy in rotating turbulence

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In this study we present an investigation into a mechanism that drives the formation of columnar structures in a rotating turbulent flow field. The mechanism we explore here is similar to one found in magnetohydrodynamic turbulence at low magnetic Reynolds number1. Contrary to other studies2,3 on the subject the mechanism presented assumes viscous or inertial forces opposing the growth of anisotropy, rather than a mechanism driven by inertial waves. For the case of a flow forced through fluid injection or subtraction aligned with the axis of rotation it is shown that the bulk velocity ⟨U⟩ perpendicular to the axis of rotation is expected to scale as Q or Q^{2/3} depending on whether viscous or inertial forces oppose anisotropy, where Q is the applied flow rate. These scaling laws are tested experimentally. The experiment consists of a rectangular tank filled with fluid mounted on a rotating turntable. The flow is forced by simultaneously injecting and subtracting fluid through four small orifices arranged in a square pattern at the bottom of the tank. Using a single camera PIV system we are able to characterise ⟨U⟩ as a function of the rotation rate Ω and Q. Our results (fig.1) show good agreement with the proposed scaling laws. They suggest a transition from a viscous regime to an inertial regime as Q is increased, which is consistent with a relative increase in inertial forces. Turbulent motions close to the point of injection are too small to be affected by the Coriolis force. As such, strong three-dimensional structures form. Close to these structures inertial wave-packets are emitted and propagate through the flow field. The exact relation between these 3D structures, the inertial wave-packets and how they relate to the proposed scaling laws is still not fully understood.

Figure 1: Bulk flow velocity ⟨U⟩ scaled by a) predicted velocity U_{visc} (—) and b) U_{in} (−−) where viscous or inertial forces oppose the growth of anisotropy

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