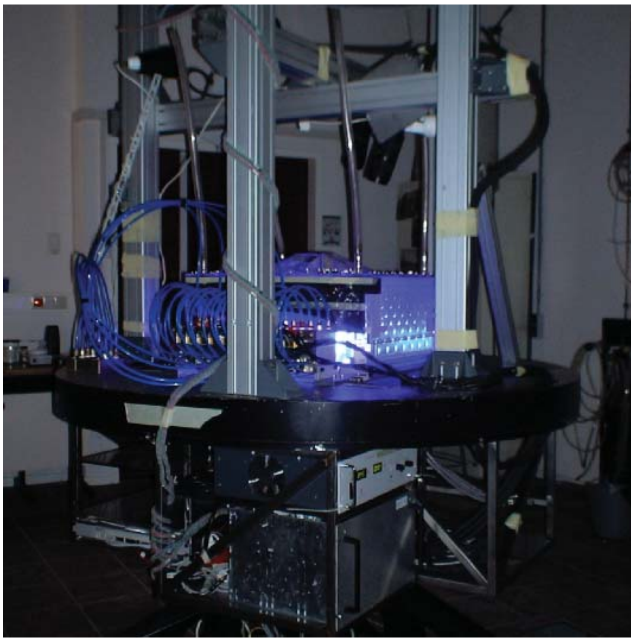
Table-top rotating turbulence : an experimental insight through PTV

Lorenzo Del Castello and Herman Clercx, Dept. Applied Physics, TU/e

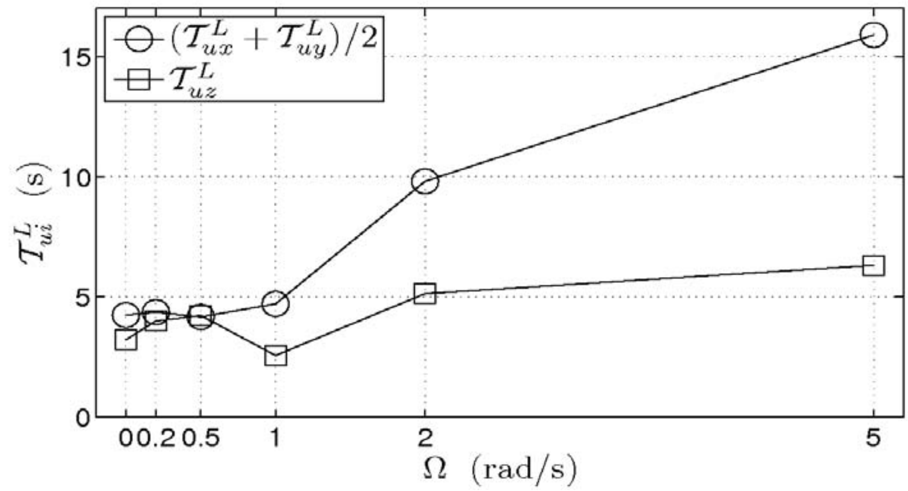
The influence of the rotation of the Earth on oceanic and atmospheric currents, as well as the effects of a rapid rotation on the flow inside industrial machineries like mixers, turbines, and compressors, are only the most typical examples of fluid flows affected by rotation. Despite the Coriolis acceleration term appears in the Navier-Stokes equations with a straightforward transformation of coordinates from the inertial system to the rotating non-inertial one, the physical mechanisms of the Coriolis acceleration are subtle and not fully understood. Several fluid flows affected by rotation have been studied by means of numerical simulations and analytical models, but the experimental data available is scarce and purely of Eulerian nature. Here we focus on a class of fluid flows of utmost importance: confined and continuously forced rotating turbulence.



Experimental set-up mounted on the rotating table.

Experiments of the turbulent flow (maximum $Re_\lambda \equiv 110$ for $\Omega = 0$ rad/s) subjected to different background rotation rates (with Ω in the range of zero to five rad/s) are performed, visualised by optical means, and measured quantitatively by means of Particle Tracking Velocimetry (PTV). The measurement system is designed and implemented around the experimental set-up (see Fig. 1), using several innovative solutions. The data collected is processed in the Lagrangian frame, where the trajectories are filtered and the 3D time-dependent signals of position, velocity, acceleration, temporal velocity derivatives, and full velocity gradient tensor are extracted. The data is further interpolated over a regular grid, in order to analyse it also in the Eulerian frame.

The rotating turbulent flow is investigated in terms of Eulerian spatial correlations of the velocity field, and – for the first time – of Lagrangian correlations of the velocity, acceleration, and vorticity vectors extracted along fluid particle trajectories. The increase of vertical (parallel to the rotation vector) and horizontal velocity correlations induced by rotation is measured in the Eulerian and the Lagrangian frames. The vertical and horizontal Lagrangian integral time scale against the rotation rate Ω behaves remarkably different (see Fig. 2). Moreover, rotation is seen to strongly enhance the correlation of the vertical vorticity component, characteristic of a flow dominated by columnar vortex structures. It is also seen to enhance the longitudinal horizontal acceleration correlation, confirming the direct role of the Coriolis acceleration in the amplification of the Lagrangian acceleration correlations in turbulence.



Horizontal and vertical Lagrangian integral time scale against the rotation rate Ω.