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ISOTROPIC TURBULENCE IMPINGING ON BOUNDARIES

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A number of numerical simulations, studying the influence of boundary conditions on isotropic turbulence, have been performed. The turbulence, generated by a Large Eddy Simulation (LES) of isotropic turbulence in a periodic box, is introduced as the bottom boundary condition in a Direct Numerical Simulation (DNS) running concurrently with the LES. Both LES and DNS employ fourth-order-accurate central discretisations of convection and diffusion. To ensure a divergence-free flow field, the pressure Poisson equation is solved using the conjugate gradient method with simple diagonal preconditioning. The standard Smagorinsky model is used to model the subgrid scale stresses in the LES.

Both no-slip and stress-free surface boundary conditions are combined with a variety of turbulence levels and integral length scales. In the lower bulk, in agreement with [1], it is found that as the turbulence diffuses upwards its horizontal fluctuation level, u_∞, reduces while simultaneously its integral length scale, L_∞, increases such that the turbulent Reynolds number, $R_T = \frac{2L_\infty u_\infty}{\nu}$, remains constant. When approaching the upper boundary, in the so-called surface-influenced layer, the turbulence begins to lose its isotropy. For the stress-free boundaries, the thickness of the surface-influenced layer is confirmed to be one L_∞ (see also [2]). Also, very close to the boundary, the vertical fluctuations, w_{rms}, begin to rapidly reduce to zero while the horizontal fluctuations, u_{rms}, increase due to exchange of kinetic energy [3]. In the presence of no-slip boundaries u_{rms}, w_{rms} and the normal gradient of w_{rms} all become zero towards the surface. Despite the significantly lower turbulence level close to the surface in the no-slip case, similar flow structures as in the stress-free case are found for comparable R_T numbers. In DNS with low R_T large vortical structures are observed, while for higher R_T a more dynamic pattern of small vortical structures can be seen, clearly indicating the dominance of large and small eddies at low and high R_T, respectively.

In conclusion, upward diffusing isotropic turbulence impinging on a flat surface tends to lose its isotropy well before the turbulence reaches the surface. It was observed that the diameter of the vortical structures near the surface is related to the Kolmogorov length, η, which in turn depends on R_T.

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