ILES MODELLING OF TURBULENCE AND FLOW AROUND A CUBE

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Introduction and numerical method

The Implicit Large Eddy Simulation (ILES) is a relatively new method for simulation of turbulent flows. The main difference between ILES and a classical Large Eddy Simulation is usage of numerical dissipation of so-called hi resolution schemes (schemes that are at least second order in smooth areas and do not produce unphysical wiggles near discontinuities) instead of explicit subgrid stress models. Our aim is to develop a similar ILES code, but in the framework of traditional incompressible flows on a staggered grid. The staggered grid does not store all velocity components in the same cells and therefore causes additional problems. We developed a 3D version of projection method of Tau (1994), which is an adoption of a method by Bell J. B. et al. (1989) to a staggered grid. Detailed description of our advection scheme can be found in (Fuka V. and Brechler J., 2008). The temporal discretization belongs to a class of projection (or fractional step) methods that solve first a momentum equation alone and then correct the velocity fields to follow the continuity equation. The pressure is also calculated during the correction.

Results

The first computed case is a Taylor-Green vortex. It is a flow with simple initial conditions and periodic boundary conditions, which exhibits transition to turbulence and a development of an energy cascade (Brachet, 1991). The presented results are computed at the resolution 256^3. As a main quantitative criteria we choose a time history of kinetic energy dissipation, kinetic energy spectra and probability density functions (PDFs) of the velocity components and the pressure. The dissipation rate for several slope limiters used in the advection scheme is compared for DNS data of (Brachet, 1991). The kinetic energy spectra after sufficient time show a $k^{-5/3}$ inertial range, but the higher wavenumbers are affected by the numerical dissipation.

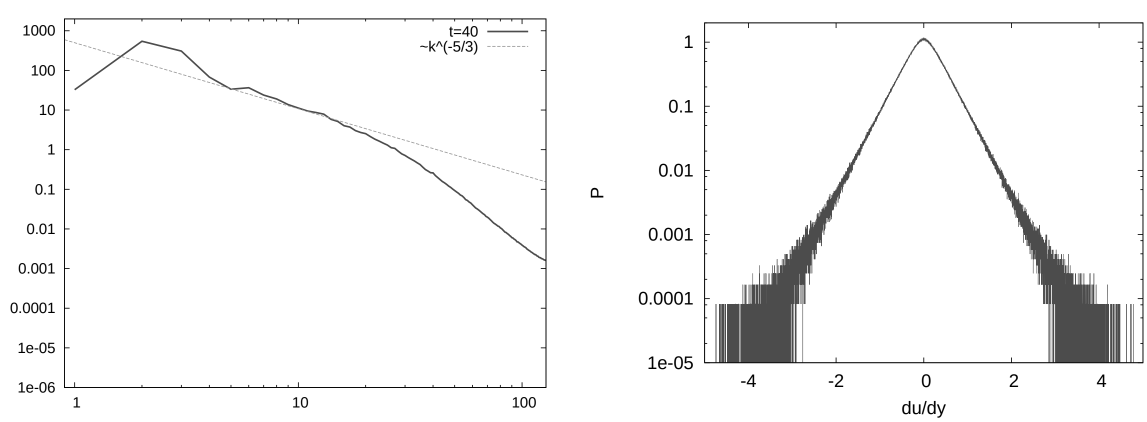

Figure 1: a) The energy spectrum at $t = 40$, b) A PDF of $\frac{\partial u}{\partial y}$.

The other example we chose is a flow through a channel with a wall mounted cube in a similar setup as (Shah and Ferziger, 1997) and (Martinuzzi and Tropea, 1996). The computation domain consists of a channel made from 2 solid walls in a distance of 2 units. On the bottom walls is placed a cube with edges 1 unit long. Because our model is still in development, we used simple inflow and outflow boundary conditions, i.e. laminar constant profile at inflow and Neumann outflow, which probably affected the results. On the solid walls we used the noslip boundary conditions, but with the current uniform grid we weren't able to correctly describe the laminar boundary layer. The Reynolds number was 3000. The flow shows intensive separation and turbulence in the wake. However the length of the main recirculation zone is considerably larger than in (Shah and Ferziger, 1997) and (Martinuzzi and Tropea, 1996). We will examine this difference in further computations with more advanced versions of the model.

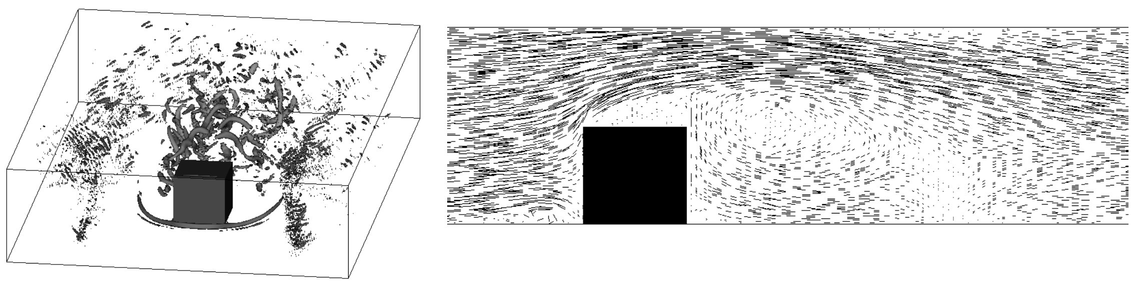

Figure 2: a) A snapshot of visualized vortices behind the cube, b) An averaged flow field in a xz plane of symmetry.

Conclusions

We developed a 3D model for incompressible flow and we tested its abilities to correctly describe a turbulent flow. In the case of Taylor-Green vortex it computed correctly the main features of the flow. In the case of the cube mounted on the wall in the channel, the flow field was qualitatively correct, but there were some quantitative discrepancies. We think these can be attributed to the simplified boundary conditions.

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