INTERCOMPARISON OF OPENFOAM AND ELLIPSYS3D FOR LARGE EDDY SIMULATION: *A PRIORI* TESTS AND WAKE DEVELOPMENT FROM AN ACTUATOR LINE

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Abstract

Intercomparison of two finite volume solvers is performed in the context of large eddy simulation (LES). Ellipsys3D [2], [3], the in-house code developed at the Technical University of Denmark (DTU) and open source toolbox OpenFOAM [1] maintained by the OpenFoam Foundation. Ellipsys3D is written in Fortran 90 and has been used for almost two decades. it is well known for performing Reylolds average Navier-Stokes (RANS) and LES of wind turbines in the atmospheric boundary layer (see e.g. [4]). OpenFOAM is on the other hand written in object-oriented C++ language. it has become increasingly popular for flow simulations in the recent years. Both codes use the collocated grid arrangement and Rhie-Chow type of pressure velocity coupling, and in this study are run in parallel using Message Passing Interface (MPI) system on the same block structured grids.

The first part of the comparison consists of *a priori* tests where turbulent channel flow and decay of isotropic homogeneous turbulence is simulated. The behaviour of both codes are analysed and useful conclusions is drawn regarding grid sensitivity, SGS implementation and code performance.

The next comparison is performed on an actuator line simulation (ALS) in the uniform inflow. The actuator line [1] representation of wind turbines is used in an infinite domain with uniform inflow in both cases. In the actuator line approach, rather than resolving the blade boundary layer with a fine mesh, each blade is modelled as a straight line and the forces are applied to the flow according to the velocity field and the angle of attack. These forces are commonly smeared out by an e.g. Gaussian distribution to the flow field to avoid numerical oscillations [4]. The OpenFOAM package SOWFA [5], recently developped by the National Renewable Energy Laboratory (NREL) is usedwith some solver and parameter modifications for the validation against Ellipsys3D results. SOWFA includes pre-defined solvers capable of performing ALS in the atmospheric boundary layer.

Figures 1 and 2 show visualization of some of the obtained results for the channel flow and vorticity field as well as the normalized velocity contours in the actuator line simulation. Similar test cases are performed and the effect of different code architectures, sub-grid scale (SGS) modelling and numerical errors are studied in some detail. The results basically show a similar trend in the wake deficit but with rather different eddy viscosity distributions. This kind of comparison could be of importance among wind energy and atmospheric boundary layer experts who use these major codes.

References

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[4] Troldborg N, Sørensen JN and Mikkelsen RF 2010 Numerical simulations of wake characteristics of a wind turbine in uniform inflow *J Wind Energy* (**13**)1 86-99.

[5] NWTC Design Codes (SOWFA by Matt Churchfield and Sang Lee). http://wind.nrel.gov/designcodes/simulators/SOWFA/. Last modified 14-March-2012; accessed 14-March-2012.

[1]Open Source Field Operation and Manipulation *www.openfoam.org*

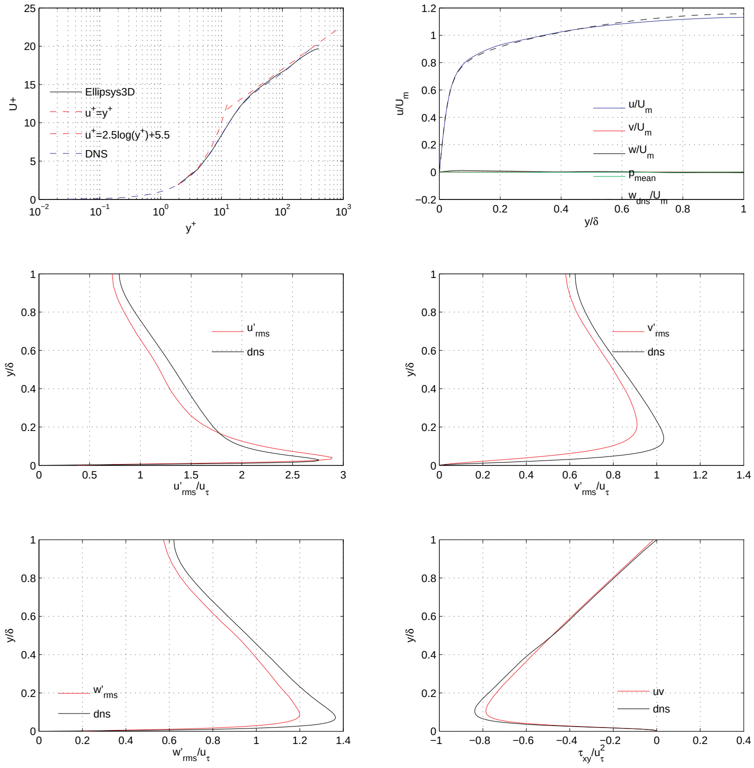
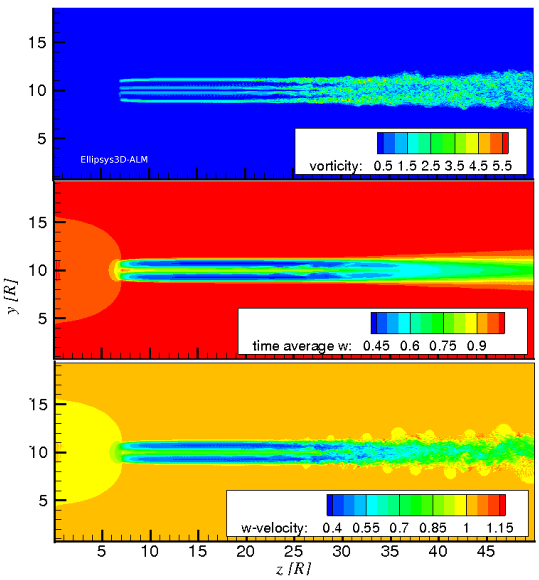
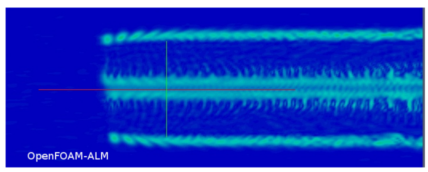


Figure 1. Ellipsys3D results of mean velocity, variance and Reynold's stresses for wall resolved channel flow at $Re_\tau = 395$ on a 64^3 grid



(a)



(b)

Figure 2. Wake development behind the actuator line representation of a wind turbine (a): contours of velocity and vorticity fields obtained from Ellipsys3D simulations (b) a magnified contour plot of the corresponding vorticity field in the wake of the actuator line, performed using the OpenFOAM package)