Scrutinizing the performance of under-resolved, model-free LBM simulations for attached and separated turbulent shear flows

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Abstract

The presentation is devoted to the predictive performance of a particular Lattice-Boltzmann model in turbulent shear flows. Attention is restricted to model-free (direct) simulations for a sequence of spatial resolutions in the range of 1-50 wall units.

Emphasis is given to a series of fundamental shear flows, ranging from a simple Taylor-Green vortex decay (Fig. 1 - left), to transitional flows (Fig. 1 - right) as well as attached and separated turbulent channel flows at different Reynolds numbers (Fig. 2). Performance is assessed by turbulence statistics, including two-point correlations and the related energy spectra or integral length scales, supplemented by conventional averages of mean velocity, wall shear as well as turbulence intensities.

Results display implicit turbulence modelling capabilities, which seem to inherently adapt to the resolution.

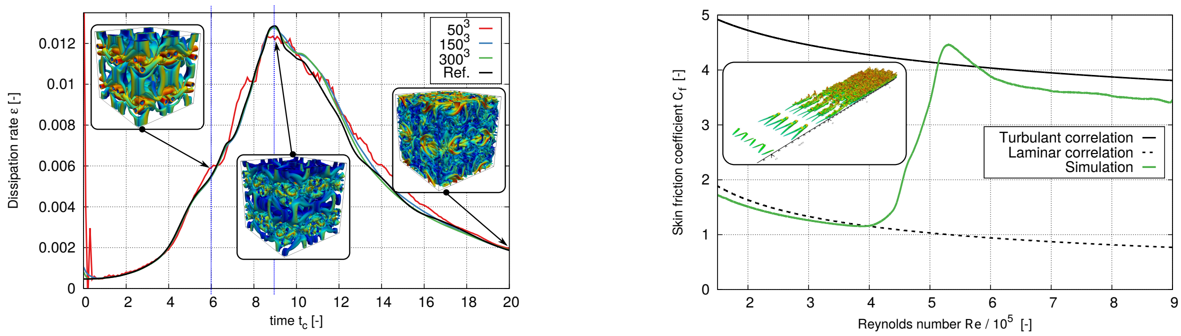

Fig. 1. Left: Model-free decay simulations of a Taylor-Green vortex (Re=1600); Resolution sensitivity of the predicted non-dimensional temporal evolution of the dissipation rate for a sequence of isotropic hexahedral grids (Ref. from [1]). Right: Model-free transition to turbulence simulations for a flat-plate boundary layer; Predicted skin-friction development.

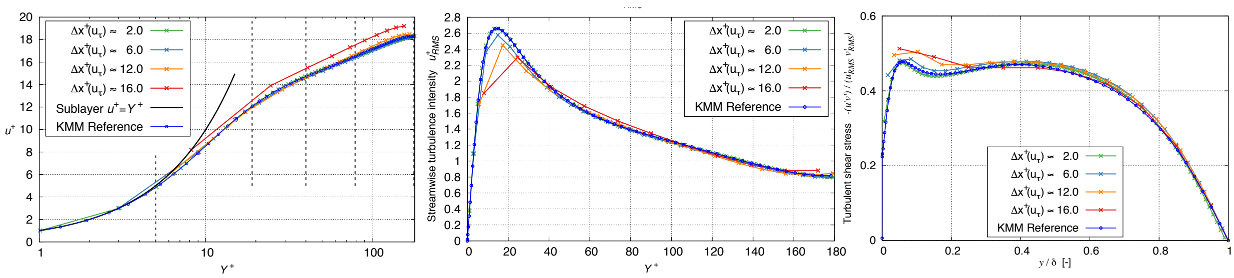

Fig. 2. Model-free simulation of a turbulent channel flow at Re_τ =180; Resolution sensitivity of the predicted non-dimensional streamwise mean velocity (left), streamwise turbulence intensity (centre) and turbulent shear stress (right) for a grid sequence ranging from typical DNS to typical RANS spatial resolution (KMM from [2]).

[1] W. M. van Rees, A. Leonard, D. I. Pullin, P. Koumoutsakos, J. Comput. Phys. 230 (2011), 2794-2805.

Ref. data from: http://www.as.dlr.de/hiocfd/spectral_Re1600_512.gdiag

[2] J. Kim, P. Moin, R. Moser, J. Fluid Mech. 177 (1987), 133-166.