HIGH-ORDER LES FOR ATMOSPHERIC BOUNDARY-LAYER FLOWS

Erik Boström[1], Philipp Schlatter [1] & Dan S. Henningson [1]
[1] *Linné FLOW Centre, KTH Mechanics, Stockholm, Sweden*

In this talk we present a new numerical implementation of wall-modeled large-eddy simulation (LES) in a high-order Fourier/Chebyshev spectral code (SIMSON). The purpose of the work is to produce a simulation tool that accurately simulates the atmospheric boundary-layer flow inside and around wind farms where high resolution around the wind turbines is crucial and where roughness effects from the ground must be taken into account.

Our main code (see [2]) solves the incompressible Navier–Stokes equations in the velocity–vorticity (v, ω) formulation, in Fourier space over periodic stream- and span-wise directions with the Chebyshev-tau method; similar to that in the channel-flow study by Kim, Moin and Moser [5]. The original version of the code has been efficiently used for direct numerical simulation and wall-resolved LES to simulate low to moderate Reynolds number boundary-layer and channel flows at KTH Mechanics [3, 9].

We implement for our simulations, a wall model for the filtered velocities, using slip boundary conditions [4], whose friction coefficients are determined by modeling the wall-shear stress [8]. An example of such a simulation is shown in Fig. 1. below, which illustrates the fact that the boundary condition is indeed of Neumann/mixed type. Since we solve for the Fourier transformed v and ω, the wall (and free-stream) boundary conditions are implemented implicitly by applying the physical boundary conditions as a superposition of homogeneous and particular solutions to the second-order ordinary differential equations that are obtained after the time and horizontal space discretizations are applied.

Furthermore, we test different sub-grid-scale models and damping functions (e.g. [7]) for which the highly anisotropic nature of the grid and flow is taken into account and the modeled wall-shear-stress is smoothly matched.

The performance of the wall model together with the sub-grid-scale modeling strategies are tested and compared on standard test-cases such as a high Reynolds number channel flow [6] and the neutral atmospheric boundary-layer [1].

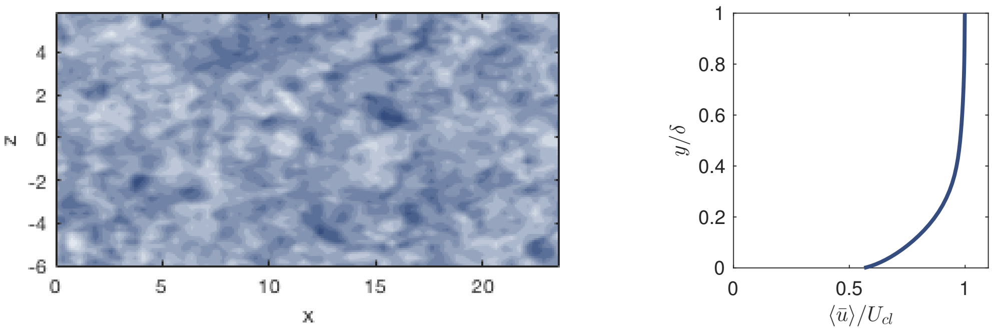

Figure 1. Wall modeled LES of an open channel flow of $Re = 10^9$, over the domain $[0, 8\pi] \times [0, 1] \times [-2\pi, 2\pi]$. (a) A $x - z$ cross-section of the u velocity field at $y/\delta = 0.089$ ($y^+ \approx 8.6 \times 10^5$). (b) The mean velocity profile of the filtered velocity $\bar{u}$. A wall model is imposed at the computational lower boundary at height $y = \Delta_y/2$, where Δ_y is the local filter width in the wall-normal direction.

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