Geophysical Research Abstracts, Vol. 9, 10079, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-10079

Laboratory study of surface boundary conditions for LES over a rough to-smooth transition

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A wind tunnel experiment was performed to test different LES surface boundary conditions downwind of a rough-to-smooth surface transition. Single and x-wire anemometers were used to obtain simultaneous high-resolution measurements of surface shear stress and wind velocity at nine positions downwind of the transition at $Re_\tau \approx 1.5 \times 10^4$. One-dimensional filtering, using Taylor's hypothesis, was used to obtain filtered velocity and surface shear stress. Substantial differences are found between the measured shear stress and the shear stress modeled using standard boundary conditions based on direct application of similarity theory (the log-law) with local fluctuating velocities. Those errors affect both the average value as well as the higher order statistics (variance and skewness) of the surface shear stress. In order to improve the prediction of the average surface shear stress we propose a simple new model based on a combination of two log laws. The first log law, which is recovered above the internal boundary layer height, corresponds to the upwind velocity profile; the other log law is adjusted to the downwind aerodynamic roughness and local surface shear stress, and it is recovered near the surface, in the equilibrium sublayer. In particular, the new model is also capable to predict the distribution of wind velocity downstream the transition. The performance of the new model is tested with our wind tunnel measurements and also with the field data of Bradley (1968). Compared with other existing simple analytical models, the proposed model shows improved predictions of both surface shear stress and velocity distributions at different positions downwind of the transition.