Large-eddy simulations of turbulent flow over urban areas of Osaka, Japan

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Urban turbulent boundary-layer flows are strongly perturbed by the roughness elements mounted on the ground surface; however, the flows are primarily driven by large-scale forcing at higher levels. Knowledge of the complex interactions between the urban surface roughness and the boundary-layer processes is not merely important for improved urban canopy parameterisations (UCPs), it is also desired for developing optimised schemes towards the downscaling of mesoscale meteorological perturbations. Using large-eddy simulation (LES) and wavelet analysis, results relevant to both aspects are presented for realistic urban areas in Osaka, Japan. For the former, time-averaged Eulerian statistics show that the inertial sub-layer, wherein close-to-constant Reynolds shear stresses are often expected, may not be always clearly identified compared to idealised roughness arrangements; nonetheless well-defined logarithmic wind profiles are established allowing the formulation of the surface aerodynamics parameters (z_0 and d) in terms of the surface roughness features. To complement existing UCP schemes, the parameterisation of z_0 and d using machine learning is investigated. For the latter, the turbulence statistics exhibit a great dependence on height: wavelet-analysis results show that the turbulence eddies are much more fluctuated at lower heights; by contrast, the eddies away from the surface layers are well organized on different scales, suggesting that the downscaling of mesoscale perturbations needs to be treated differently according to the vertical heights that the perturbations would be incorporated in the urban computational fluid dynamics (CFD) models. The potential of applying wavelet analysis, which may allow signals to be coupled in a manner admitting both the multiscale nature and the unsteadiness of large-scale forcing, is discussed.

Keywords: Wavelet analysis, Urban canopy parameterization, Urban-mesoscale coupling, Boundary-layer turbulence