Geophysical Research Abstracts
Vol. 15, EGU2013-11111, 2013
EGU General Assembly 2013

Large Eddy Simulations to determine the role of dispersive stresses in the urban canopy layer

Andreas Christen (1,2), Marco Giometto (2), and Marc Parlange (2)

(1) University of British Columbia, Geography / Atmospheric Science Program, Vancouver, Canada (andreas.christen@ubc.ca), (2) École Polytechnique Fédérale de Lausanne, Laboratory of Environmental Fluid Mechanics, Lausanne, Switzerland

Urban-scale weather and air pollution forecasting models need to realistically predict conditions in the urban canopy layer (UCL) - the atmosphere in-between buildings where people live and most activities take place. Nevertheless, for performance reasons, forecasting models cannot resolve every detail of the flow field around individual buildings and obstacles in a city. In common urban canopy parameterizations (UCPs), exchange processes between the UCL and the overlying atmosphere - including momentum transfer - are simplified to one-dimensional bulk flow representations, where the time-averaged flow field is also horizontally averaged over a larger spatial subset of the urban canopy. In the spatial averaging process of RANS equations, additional covariance terms arise in the time-averaged momentum balance, called 'dispersive stresses'. Physically, a dispersive stress can be explained as spatial correlation between the mean horizontal flow and mean vertical flow around buildings at a given height layer. Due to lack of knowledge on the role of dispersive fluxes, they are neglected in all current UCPs and transfer formulations. Only limited CFD studies for idealized cubical arrays show that dispersive fluxes are relevant and important to properly describe the overall momentum transfer in those specific rigid canopies.

The current contribution determines the role of dispersive stresses to the overall momentum transfer for a more realistic urban canopy by means of large eddy simulation (LES). LES takes into account the unsteadiness that characterizes canopy layer flows, offering indisputably superior performances in predicting momentum exchange with respect to traditional methods, in particular when the effects of canopy elements play a major role. LES also showed to be able to properly represent the flow in areas of strong separation and in wakes, features that are strongly present in urban canopies, where most RANS and URANS models fail due to their under-prediction of turbulent kinetic energy and turbulent fluxes. In the current simulation, we adopt a Cartesian grid approach with cyclic boundary conditions, the subgrid terms are parameterized adopting a Lagrangian scale-dependent dynamic model and the urban morphometry is taken into account through a discrete, direct-forcing, immersed boundary approach which has the numerical advantage, over other techniques, of not introducing stiff forcing terms in the equations.

Simulations are run for neutral flow conditions with different morphometries, informed by light-detection and ranging data of the morphometry of a real suburban surface in Vancouver, Canada for which long-term tower-based turbulence and flux measurements exist as a benchmark dataset. Different resolutions are tested in order to validate the LES subgrid model and results are averaged over $800T$ where T is the turnover time for the characteristic eddy shed by the given morphometry. The vertical profiles of dispersive stress and horizontally averaged Reynolds stress are computed and compared. The statistical analysis of the time averaged flow field is done using spatial quadrant analysis, which allows determination of scale and space fraction of regions effectively contributing to the overall dispersive stress.