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Development of a fast-response model for flow and dispersion within and above the urban canopy layer

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In the context of air pollution modelling there is an increasing demand for detailed yet fast simulations taking into account the complex structure of real urban morphometry.
Recently, a new modelling approach for describing the mean flow field inside and above the urban canopy has been proposed (Di Sabatino, et al., 2008). In this model the spatially-averaged flow field is described as a wind velocity profile satisfying a simplified stationary equation for the momentum balance between the urban canopy and the layer above. In this approach, the buildings within the canopy are represented as a canopy element drag formulated in terms of height-dependent morphological parameters f and p, which are the ratios of plan area and frontal area of buildings to the lot area, respectively. These morphological parameters represent an estimate of the building density and can be derived, by means of an average operation typically applied at the neighbourhood scale. The average operation is made possible by the detailed knowledge of urban geometry, which is nowadays available in digital format using image processing techniques known as Digital Elevation Models (Ratti et al., 2006).
In this paper we discuss the derivation and validation of the urban flow model and the extension of this modelling approach based on morphological parameters to a dispersion model for the concentration field. In particular, the computed wind velocity profile and the morphological parameters are used as input for a numerical model solving the Eulerian stationary advection-diffusion equation. The numerical dispersion model is applied to compute the spatially-averaged concentration of pollutant released from a point source in an array of cubes and the results are compared with those obtained from the Computational Fluid Dynamics (CFD) model FLUENT. The comparisons are carried out for different building densities, estimated by means of f and p and different source heights.
The morphologically based modelling approach is based on the integration of the equations on the neighbourhood scale without explicitly resolving the flow around individual buildings but still accounts for their effects. This allows to greatly reduce the computational costs with respect to CFD numerical simulations and, at the same time, to include the main physical mechanisms determining the flow and concentration fields, which are essentially related to the geometrical properties of the urban canopy. This makes these models suitable for the predictions of wind and concentrations over the neighbourhood scale in operational contexts such as air quality management at the urban scale. However, these models can also be exploited in conjunction with mesoscale and global dispersion models for climate change studies involving the effect of megacity sources.
References:
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