Geophysical Research Abstracts
Vol. 15, EGU2013-1976, 2013
EGU General Assembly 2013

Plume Dispersion over Idealized Urban–liked Roughness with Height Variation: an LES Approach

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Human activities (e.g. vehicular emission) are the primary pollutant sources affecting the health and living quality of stakeholders in modern compact cities. Gaussian plume dispersion model is commonly used for pollutant distribution estimate that works well over rural areas with flat terrain. However, its major parameters, dispersion coefficients, exclude the effect of surface roughness that unavoidably prone to error handling the pollutant transport in the urban boundary layer (UBL) over building roughness. Our recent large-eddy simulation (LES) has shown that urban surfaces affect significantly the pollutant dispersion over idealized, identical two-dimensional (2D) street canyons of uniform height. As an extension to our on-going effort, this study is conceived to investigate how rough urban surfaces, which are constructed by 2D street canyons of non-uniform height, modify the UBL pollutant dispersion .

A series of LESs with idealized roughness elements of non-uniform heights were performed in neutral stratification. Building models with two different heights were placed alternatively in the computational domain to construct 2D street canyons in cross flows. The plume dispersion from a ground-level passive pollutant source over more realistic urban areas was then examined. Along with the existing building-height-to-street-width (aspect) ratio (AR), a new parameter, building-height variability (BHV), is used to measure the building height unevenness. Four ARs (1, 0.5, 0.25 and 0.125) and three BHVs (20%, 40% and 60%) were considered in this study.

Preliminary results show that BHV greatly increases the aerodynamic roughness of the hypothetical urban surfaces for narrow street canyons. Analogous to our previous findings, the air exchange rate (ACH) of street canyons increases with increasing friction factor, implying that street-level ventilation could be improved by increasing building roughness via BHV. In addition, the parameters used in dispersion coefficient estimates are related to the friction factor in the way similar to that of uniform street canyons, i.e. they are linear functions of friction factor when the roughness is small and become insensitive to friction factor thereafter over very rough surfaces. It is thus suggested that aerodynamic resistance is the key factor affecting the air quality in urban areas. Moreover, the friction factor could be used to parameterize the dispersion coefficients over different roughness elements.