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Pollutant Plume Dispersion over Hypothetical Urban Areas based on Wind Tunnel Measurements

Ziwei Mo and Chun-Ho Liu
Department of Mechanical Engineering, The University of Hong Kong, Hong Kong (ziwei.mo@gmail.com)

Gaussian plume model is commonly adopted for pollutant concentration prediction in the atmospheric boundary layer (ABL). However, it has a number of limitations being applied to pollutant dispersion over complex land-surface morphology. In this study, the friction factor (f), as a measure of aerodynamic resistance induced by rough surfaces in the engineering community, was proposed to parameterize the vertical dispersion coefficient (σ_z) in the Gaussian model. A series of wind tunnel experiments were carried out to verify the mathematical hypothesis and to characterize plume dispersion as a function of surface roughness as well. Hypothetical urban areas, which were assembled in the form of idealized street canyons of different aspect (building-height-to-street-width) ratios (AR = 1/2, 1/4, 1/8 and 1/12), were fabricated by aligning identical square aluminum bars at different separation apart in cross flows. Pollutant emitted from a ground-level line source into the turbulent boundary layer (TBL) was simulated using water vapour generated by ultrasonic atomizer. The humidity and the velocity (mean and fluctuating components) were measured, respectively, by humidity sensors and hot-wire anemometry (HWA) with X-wire probes in streamwise and vertical directions. Wind tunnel results showed that the pollutant concentration exhibits the conventional Gaussian distribution, suggesting the feasibility of using water vapour as a passive scalar in wind tunnel experiments. The friction factor increased with decreasing aspect ratios (widening the building separation). It was peaked at AR = 1/8 and decreased thereafter. Besides, a positive correlation between σ_z/x^n (x is the distance from the pollutant source) and $f^{1/4}$ (correlation coefficient r^2 = 0.61) was observed, formulating the basic parameterization of plume dispersion over urban areas.