Parameterization of plume dispersion coefficient over rough surfaces

Chun-Ho Liu, Ziwei Mo and Zhangquan Wu

Department of Mechanical Engineering, The University of Hong Kong, Hong Kong

ABSTRACT:

Urban air quality is an important problem nowadays because of the close proximity of sources and receptors in dense environment. Gaussian plume models have been commonly employed in the industry for decades. They are handy tools to estimate air pollution impact for open-terrain configurations. However, their applications to urban environment should be cautiously in view of the complicated recirculating flows and turbulence generation mechanism around/over buildings. In particular, one of the key components in Gaussian plume models, dispersion coefficient, is usually determined empirically based on atmospheric stratification that might overlook the effect of rough urban surfaces, resulting in prediction uncertainty.

In this paper, we report our recent study of the transport processes over idealized rough surfaces (repeated rubs in crossflows) to simulate the flows and pollutant transport after a ground-surface, area source in crossflows over hypothetical urban areas. The effect of aerodynamic resistance (controlled by rib separation) on pollutant plume dispersion (measured by vertical dispersion coefficient σ_z) is critically examined. Firstly, analytical solution shows that σ_z is proportional to $x^{1/2}\times\delta^{1/2}\times f^{1/4}$, where x is the downwind distance after the pollutant source, δ the turbulent boundary layer (TBL) thickness, f (= $2u_\tau^2/U_\infty^2$) the friction factor, u_τ the friction velocity and U_∞ the free-stream TBL wind speed. Afterward, a complementary approach, using both wind-tunnel measurements and large-eddy simulation (LES) results, is used to verify the newly developed theoretical hypothesis. Although mild discrepancies are observed among various solutions (due to unaffordable scaling differences), the aforementioned proportionality is clearly depicted. The findings unveil the weakness of conventional practice, proposing a new parameterization of dispersion coefficient for pollutant plume dispersion over urban areas.

KEYWORDS: Air pollution modeling and impact on urban inhabitants

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