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Turbulent Plume Dispersion over Two-dimensional Idealized Urban Street Canyons

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Human activities are the primary pollutant sources which degrade the living quality in the current era of dense and compact cities. A simple and reasonably accurate pollutant dispersion model is helpful to reduce pollutant concentrations in city or neighborhood scales by refining architectural design or urban planning. The conventional method to estimate the pollutant concentration from point/line sources is the Gaussian plume model using empirical dispersion coefficients. Its accuracy is pretty well for applying to rural areas. However, the dispersion coefficients only account for the atmospheric stability and streamwise distance that often overlook the roughness of urban surfaces. Large-scale buildings erected in urban areas significantly modify the surface roughness that in turn affects the pollutant transport in the urban canopy layer (UCL). We hypothesize that the aerodynamic resistance is another factor governing the dispersion coefficient in the UCL. This study is thus conceived to study the effects of urban roughness on pollutant dispersion coefficients and the plume behaviors.

Large-eddy simulations (LESs) are carried out to examine the plume dispersion from a ground-level pollutant source over idealized 2D street canyons in neutral stratification. Computations with a wide range of aspect ratios (ARs), including skimming flow to isolated flow regimes, are conducted. The vertical profiles of pollutant distribution for different values of friction factor are compared that all reach a self-similar Gaussian shape. Preliminary results show that the pollutant dispersion is closely related to the friction factor. For relatively small roughness, the factors of dispersion coefficient vary linearly with the friction factor until the roughness is over a certain level. When the friction factor is large, its effect on the dispersion coefficient is less significant. Since the linear region covers at least one-third of the full range of friction factor in our empirical analysis, urban roughness is a major factor for dispersion coefficient. The downstream air quality could then be a function of both atmospheric stability and urban roughness.