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Large-Eddy Simulation on Plume Dispersion within Regular Arrays of Cubic Buildings

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There is a potential problem that hazardous and flammable materials are accidentally or intentionally released into the atmosphere, either within or close to populated urban areas. For the assessment of human health hazard from toxic substances, the existence of high concentration peaks in a plume should be considered. For the safety analysis of flammable gas, certain critical threshold levels should be evaluated. Therefore, in such a situation, not only average levels but also instantaneous magnitudes of concentration should be accurately predicted. However, plume dispersion is an extremely complicated process strongly influenced by the existence of buildings. In complex turbulent flows, such as impinging, separated and circulation flows around buildings, plume behaviors can be no longer accurately predicted using empirical Gaussian-type plume model. Therefore, we perform Large-Eddy Simulations (LES) on turbulent flows and plume dispersions within and over regular arrays of cubic buildings with various roughness densities and investigate the influence of the building arrangement pattern on the characteristics of mean and fluctuation concentrations.

The basic equations for the LES model are composed of the spatially filtered continuity equation, Navier-Stokes equation and transport equation of concentration. The standard Smagorinsky model (Smagorinsky, 1963) that has enough potential for environment flows is used and its constant is set to 0.12 for estimating the eddy viscosity. The turbulent Schmidt number is 0.5. In our LES model, two computational regions are set up. One is a driver region for generation of inflow turbulence and the other is a main region for LES of plume dispersion within a regular array of cubic buildings. First, inflow turbulence is generated by using Kataoka's method (2002) in the driver region and then, its data are imposed at the inlet of the main computational region at each time step. In this study, the cubic building arrays with λf=0.16, 0.25 and 0.33 are set up (λf: the building frontal area index). These surface geometries consist of 20$\times$6, 25$\times$7 and 28$\times$9 arrays in streamwise and spanwise directions, respectively. Three cases of plume source located at the ground surface behind the building in the 6th, 7th and 8th row of the building array are tested.

It is found that the patterns of the dispersion behavior depending on roughness density are successfully simulated and the spatial distributions of mean and fluctuating concentrations are also captured within and over the building arrays in comparison with the wind tunnel experiments conducted by Bezpalcová (2008).