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CFD MODELING OF THE NEAR-FIELD POLLUTANT DISPERSION IN URBAN SETTINGS: COMBINED EFFECTS OF THE SOURCE LOCATION AND PLANAR HETEROGENEITIES

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ABSTRACT

Diverse building structures and arrangements are being introduced due to the fast pace of urbanization, which could negatively impact the air quality and how the exhaust gases from rooftop sources are dispersed throughout the built area. Therefore, defining a series of systematic studies is essential to explore and identify the effects of the unique urban morphologies on turbulent mixing and pollutant diffusion and to further improve the practices of operating and designing the exhaust stacks and fresh air intakes. In this regard, a series of CFD studies in idealized but systematically irregular block arrays are conducted to investigate the physics of scalar transport in the presence of urban heterogeneities. This approach is an intermediary between the studies in actual geometries with case-specific outcomes and studies in idealized and regular arrangements with missing impacts of the nonuniformities available in urban areas. The ANSYS CFX code was used to solve the 3D steady Reynolds-averaged Navier-Stokes (RANS) equations on a building-scale high-resolution grid. The validity of the implemented turbulence model, numerical algorithm, modeling techniques, and the grid generation scheme is evaluated using the Mock Urban Setting Tests (MUST) high-quality dispersion dataset. Passive and neutrally buoyant scalar is considered as the pollutant to be emitting from two types of rooftop source locations within an array of 7 by 7 cubical blocks: one with no structure upstream to solely investigate the complicated interactions of turbulent flows with the urban morphologies, and one located at the center of the array to account for more realistic situations in which dispersion is affected by urban features available upstream and downstream. The potential synergy of the pollutant source location, wind direction, planar urban density, and horizontal heterogeneity are studied through 24 generic cases. In order to account for the planar heterogeneity effects, two array arrangements of regular (reference cases) and staggered are considered, along with three different planar densities of loosely packed, regularly packed, and tightly packed. Furthermore, two inflow wind directions of perpendicular (0˚) and oblique (45˚) to the obstacles disposition direction are tested in all the selected cases in this research. In addition to the qualitative analysis of the simulation results, the effects of the urban morphologies on the dispersion field are also quantitatively evaluated using two nondimensionalized indicators of velocity ratio (V_R) and normalized concentration (C^*).