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Large Eddy Simulations of Flow and Scalar Exchanges over Urban Terrain to Improve Urban Canopy Model Parameterizations

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Understanding of the physical processes modulating transport of momentum and scalars over urban terrain is essential for parameterizing these processes in coarser geophysical models. Since passive scalars are advected with the flow, broad similarity is expected between momentum and scalar transport. However, unlike momentum, which is dominated by form drag over very rough walls, scalar transport must occur through the viscous exchanges at the solid-fluid interface, which might result in transport dissimilarity. To examine these similarities and differences of momentum and passive scalar exchanges over large three-dimensional roughness elements, a suite of large-eddy simulations (LES) is conducted.

The LES is first validated, and the importance of matching the Reynolds number of the simulations to real-world values is underscored. Analyses of the results show that the turbulent components of the transport of momentum and scalars within the canopy and roughness sublayers are quite similar. However, strong dissimilarity is noted between the dispersive fluxes. The dispersive components are also found to be a significant fraction of the total fluxes within and below the roughness sublayer, and hence it is important to model their contribution correctly. Current Urban Canopy Models do not distinguish between these two components and thus new exchange schemes are needed in these models. Moreover, increasing frontal density induces a general transition in the flow from a rough boundary layer type to a mixed-layer-like type, which is found to have contrasting effects on momentum and scalar transport that also need to be accounted for.