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Multilayer urban canopy modelling and mapping for traffic pollutant dispersion at high density urban areas

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Traffic emission is one of the major sources for air pollution in dense urban areas, and its dispersion is highly limited due to closely packed buildings especially near pedestrian level. The heterogeneity of urban morphology makes it challenging to model the flow dynamics and pollutant dispersion by CFD and wind tunnel, which require high computational cost. To assist quick urban design and planning process, the semi-empirical morphological method is an alternative solution, and has been broadly documented. But, most of semi-empirical models assume uniform building height, which is contradictory to real urban areas. For example, the standard variance of building height normalized by average building height is up to 1.8 in Hong Kong and 2.7 in Singapore. To address above issues, this study developed a semi-empirical multilayer urban canopy model (UCM). The theory of dividing the urban canopy into multiple layers is firstly introduced to include the impact of building height variance on pollutant dispersion, followed by governing equations based on mass conservation for the modelling of pollution dispersion within urban canopy layer. To validate this UCM model, results in several cases with uniform and non-uniform building height distributions were compared with CFD simulation. The validation study indicates that the new multilayer model performs well to model the vertical pollutant transport, and modelling results can mostly follow the trend of the CFD simulations. The assumption of zero pollutant concentration over the modeled canopy and no horizontal pollutant transfer has increasingly negligible influence with increasing urban densities. The present paper conducted two case studies in metropolitan areas in Singapore and Hong Kong to illustrate how to implement this multilayer urban canopy model in the planning practice. With an in-house GIS team using available data, this multilayer semi-empirical model provides planners a way to understand air pollutant dispersion in high-density urban areas.