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Understanding the impact of varying geometry level of detail in multi-direction urban RANS simulations tailored for urban air-mobility viability.

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Wind flow predictions in realistic urban areas are sensitive to a wide range of governing parameters such as building resolution, wind incidence, urban morphology, and underlying topography to list a few. In this study, we quantify the impact of the level of detail (LoD) of the urban built environment and the inflow direction (θ) on wind-safety for urban-air mobility using a Reynolds-Averaged Navier-Stokes (RANS) simulation framework. To isolate the effect of LoD and θ, we chose the TU Delft campus (radius of ~ 1 km) and the city of Den Haag (radius of ~ 1.5 km) as representative urban environments that contain a variety of urban fabric and incident wind conditions.

The simulation framework consists of steady state Reynolds-Averaged Navier-Stokes simulations using a second-order accurate finite volume formulation that solves the governing equations using the SIMPLE algorithm at 5-degree resolution (i.e., 72 θ's over a 360-degree range) with a reference wind velocity of 5 m/s at 10 m above the ground. In addition to varying the inflow wind direction, we also compare two LoD's, specifically, LoD1.2 (lower quality of building resolution, industry standard for wind engineering simulations) and LoD2.2 (higher quality of building resolution), resulting in a total of 288 simulations.

First, we assessed the effect of θ resolution on the prediction capabilities of the wind-rose weighted directionally-averaged peak wind velocities (U_a) and found that when compared to the 5-degree resolution cases with 10-, 15-, and 20-degree resolution, there is a selection bias on how accurately high-wind regions are predicted. Specifically, when the U_a is computed using 5- and 15-degree resolution, there is a better agreement as opposed to the 10- and 20-degree resolution case. These results suggest that even with a minimum resolution of 10-degree's (for θ) the peak U_a locations can be subject to a selection bias for both, simple and relatively complex wind-roses. Next, we studied the effect of varying LoD's and found that LoD2.2 shows substantially different peak U_a regions when compared to LoD1.2. Directly comparing these two LoDs, we find that minimally LoD2.2 should be used for cases where peak U_a are of interest at approximately 10-20 m height above the ground which are of most interest in terms of urban air mobility.

This work represents a systematic review of the effect of wind incidence direction and level of detail on the flow prediction capabilities in realistic urban environments. We anticipate that our findings will be useful to urban planners and engineers working to improve the air-quality, wind comfort, and explore the possibilities of UAV's as a potential mode of last mile mobility within the urban-air space, to list a few.