atmosphere

Supplementary material

An Investigation of the Quantitative Correlation between Urban Morphology Parameters and Outdoor Ventilation Efficiency Indices

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S1. Grid sensitivity analysis

In the present work, one case (shown in Figure S1a, BSC = 44%) is considered for the grid sensitivity analysis. This case is chosen because it has a symmetrical architectural layout, but it also has a clear channeling effect so that simulation results with different grid resolution. Three grids resolution are in particular generated by coarsening and refining the basic grid by about a factor of 1.5 in all the directions. The total grid number of coarse, basic and fine are respectively 464,468, 1,567,580 and 5,290,582. The minimum cell size δx, δy, δz are: 1.2m, 1.2m, 0.75m (Coarse grid), 0.8m, 0.8m, 0.5m (Basic grid), 0.5m, 0.5m, 0.33m (Fine grid). The vertical profiles of wind velocity along the lines at position P1 and P2 are shown in Figure S1b. The line starts from the ground to the top of the computational domain. No significant difference (less than 5%) between the three grids employed is obtained.

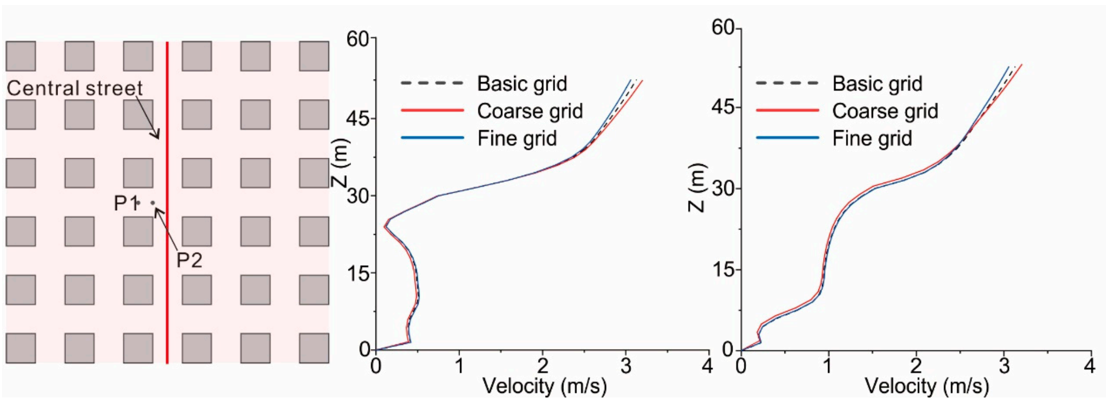


Figure S1. (a) Central street line and position P1, P2 located in the validation case, (b) Vertical wind profile line at P1, (c) Vertical wind profile line at P2.

Figure S2 shows the distribution of wind velocity along the central street line at the pedestrian level (z=2m). Similar to the vertical profiles shown in Figure S1, there is no significant change when using the finer grid. Therefore, in this study the Basic grid is employed for all the configurations investigated in this paper.

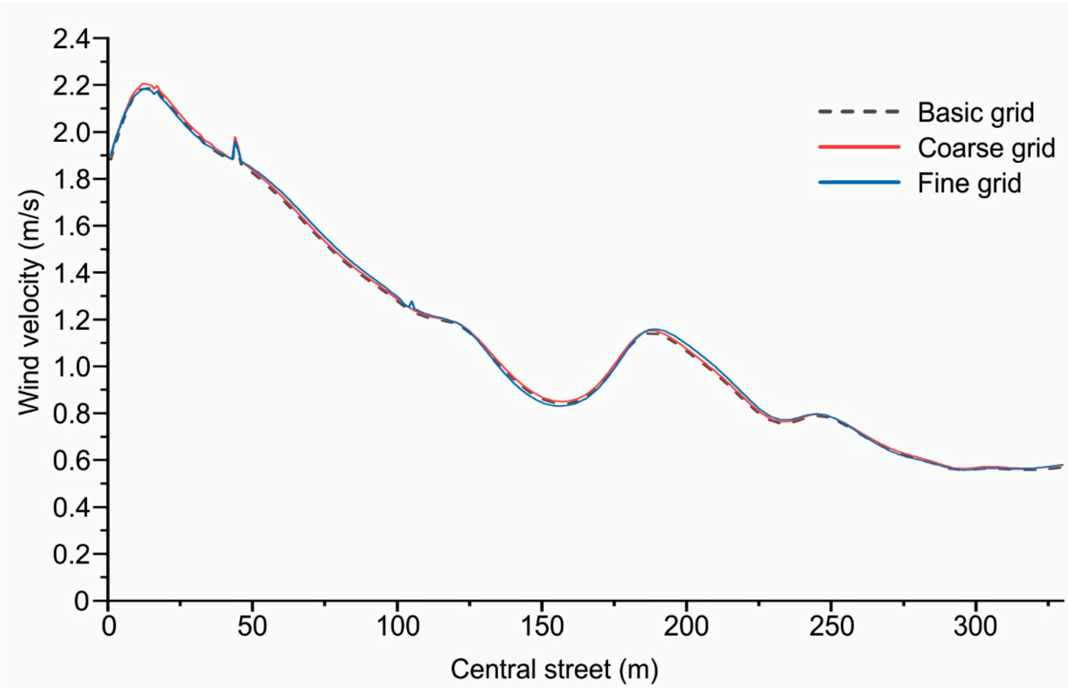


Figure S2. Distribution of wind velocity along the central street line at pedestrian level.

S2. Validation study

As recommended by AIJ (Tominaga et al., 2008), a validation study is performed in this paper by comparing CFD simulation results with wind-tunnel experiment of high-rise building in city blocks (Yoshie et al., 2005). The wind-tunnel experiment was carried at the Niigata Institute of Technology. The study model of high-rise building in city blocks is shown in Figure S3. The surrounding blocks are assumed to be 40m square and 10m high, while a high-rise building 25m square and 100m high (1:1:4) is located at the center of the domain. The surrounding blocks are assumed to be enclosed by two roads (each 10m wide) and roads 20m and 30m wide. The scale of the experimental model was 1/400 and the measuring height was 5mm above the ground of the wind tunnel (2m above ground in full-scale). 78 measuring points are arranged around the high-rise building to measure the wind velocity as shown in Figure S4a. The experimental results are measured by thermistor anemometer at wind direction θ=0° and θ=45°.

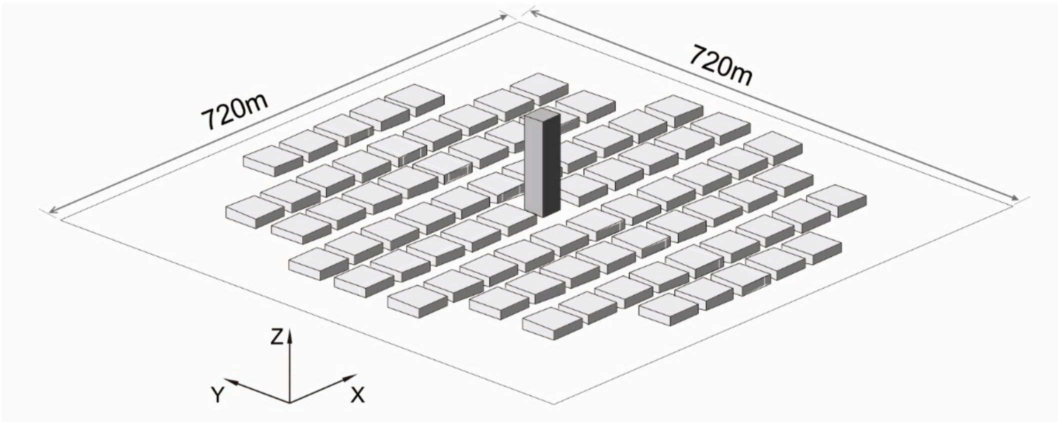


Figure S3. Validation model schematic of high-rise building in city-blocks.

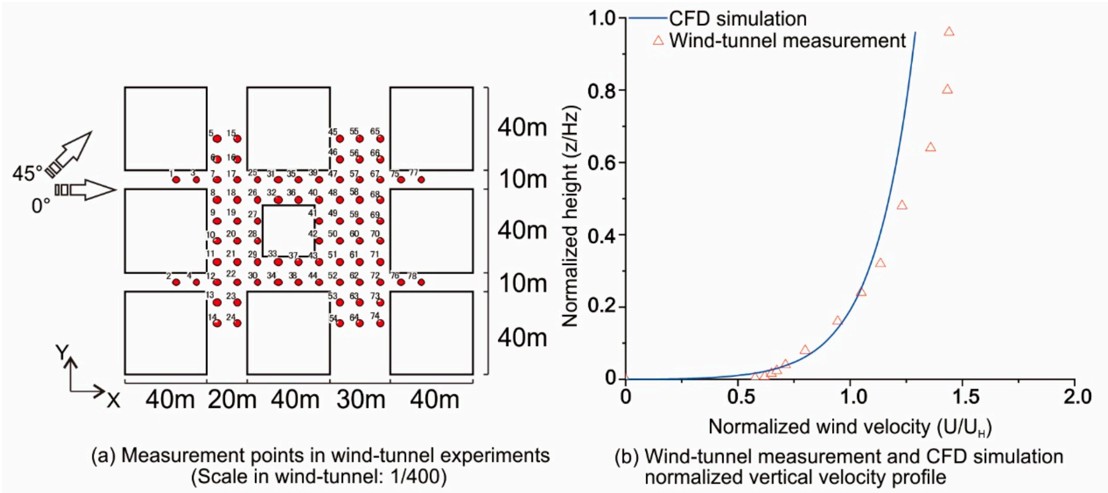


Figure S4. (a) Measuring points in wind-tunnel experiment, (b) normalized wind velocity profiles of the CFD simulation and wind-tunnel experiment.

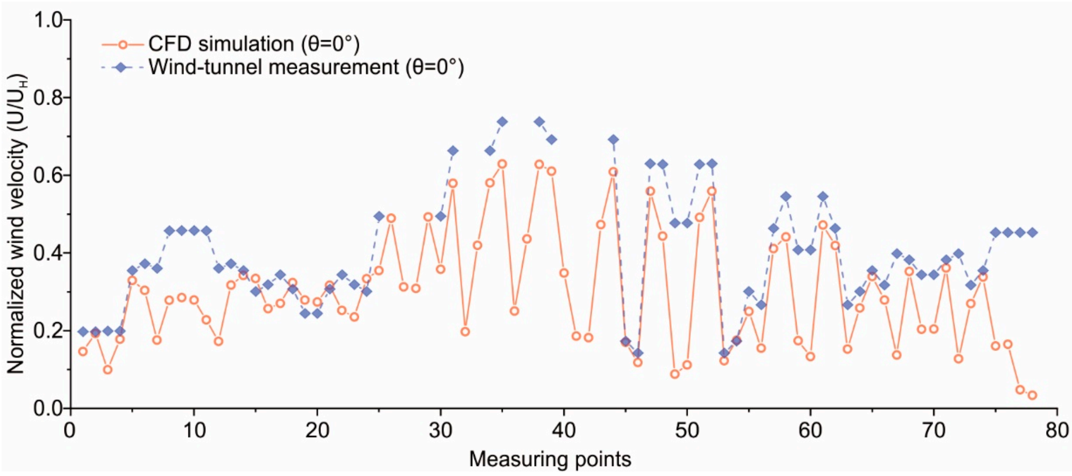
For the validation study, the CFD simulation is carried out in full-scale. The boundary conditions and solver settings presented in Section 2 of this paper are employed here. Details are shown in Table S1.

Table S1. The calculation conditions utilized in the CFD simulation.

Calculation conditions	Solver settings
Computational domain	1080m*1920m*525m;
Grid resolution	about 2 million hexahedral cells;
Turbulence model	Standard k–ε turbulence model;
Algorithm for pressure-velocity	SIMPLE;
Scheme for advection terms	Second-order discretization for convection terms and the viscous terms;
Boundary conditions	Inflow: Boundary condition presented by Richards and Hoxey (1993); Outflow: Zero gradient condition; Ground and block surfaces: Non-slip wall; Top and lateral surfaces: Symmetry;

Because the CFD simulation and the wind-tunnel experiment are in different scales, for better comparison between them, the height is normalized by the total height of computational domain (H_Z), the wind velocity is normalized by the inflow wind velocity (U_H) at the height of the central high-rise building (H). The inflow wind velocity profiles of the CFD simulation and wind-tunnel experiment are presented in Figure S4b. The normalized inflow wind velocity of the CFD simulation well agrees with the experimental one, especially at relatively lower heights.

Figure S5 compares numerical and experimental results at the measuring points for the wind directions θ=0° and θ=45°. Qualitatively wind tunnel and CFD profiles have the same behavior. To assess the overall model performance, several statistical parameters have been calculated, namely the normalized mean square error NMSE, the fraction of predictions within a factor of two of observations FAC2, the fractional bias FB and the correlation coefficient R. The commonly accepted values for 'state of the art' model performance are: [39]: NMSE ≤ 1.5; FAC2 ≥ 0.5; −0.3 ≤ FB ≤ 0.3. Results of the statistical analysis presented in Table S2 show a quite satisfactory model performance in terms of the essential features of the mean velocity, supporting the use of the chosen CFD set-up for the simulations of all the configurations investigated in this paper.



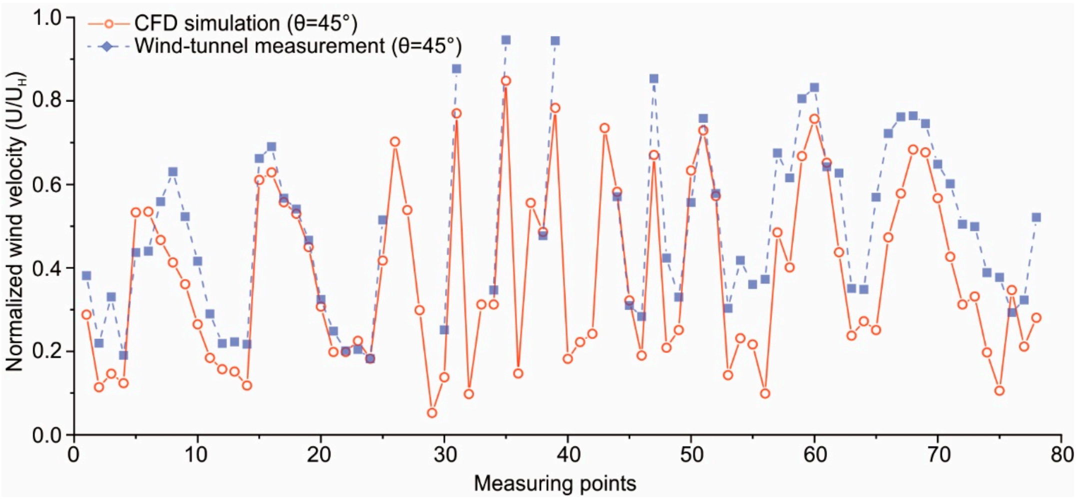


Figure S5. Comparison of numerical and experimental results for wind direction θ equal to (a) 0°, (b) 45°.

Table S2. Results of the statistical analysis for the normalized wind velocity.

Statistical parameter	Wind direction θ=0°	Wind direction θ=45°
NMSE	0.20	0.11
FAC2	0.83	0.88
FB	0.31	0.25
R	0.73	0.90