AIR VENTILATION ASSESSMENT

WORKING PAPER

CFD Evaluation of Outdoor Air Ventilation for An Integrated Teaching Building Design

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1. Introduction

This study is to carry out Air Ventilation Assessment (AVA) to evaluate the proposed design in accordance with the methodology and requirements as stipulated under the category of Microclimate Around Buildings (SA8) of the BEAM Plus certification.

Two design cases, baseline and proposed schemes, are tested. The wind data of two cases are calculated by Computational Fluid Dynamics (CFD), and analyzed by inferential statistics. By carefully calculating, collecting, summarizing and analyzing the wind data, this study identifies the optimal design option with justifications to ensure that the microclimate around and adjacent to the proposed building has been adequately considered.

For subtropical climate, wind is beneficial. This report follows the ethos of “the more wind the better” (HKPD 2005). Proposed scheme is recommended to be the optimal design option. Based on the CFD simulation and statistical analysis of the study, on the whole, there is no stagnant area not flushed by breezes for the proposed scheme. By selecting the optimal design option, the requirements in APP-152 are satisfied.

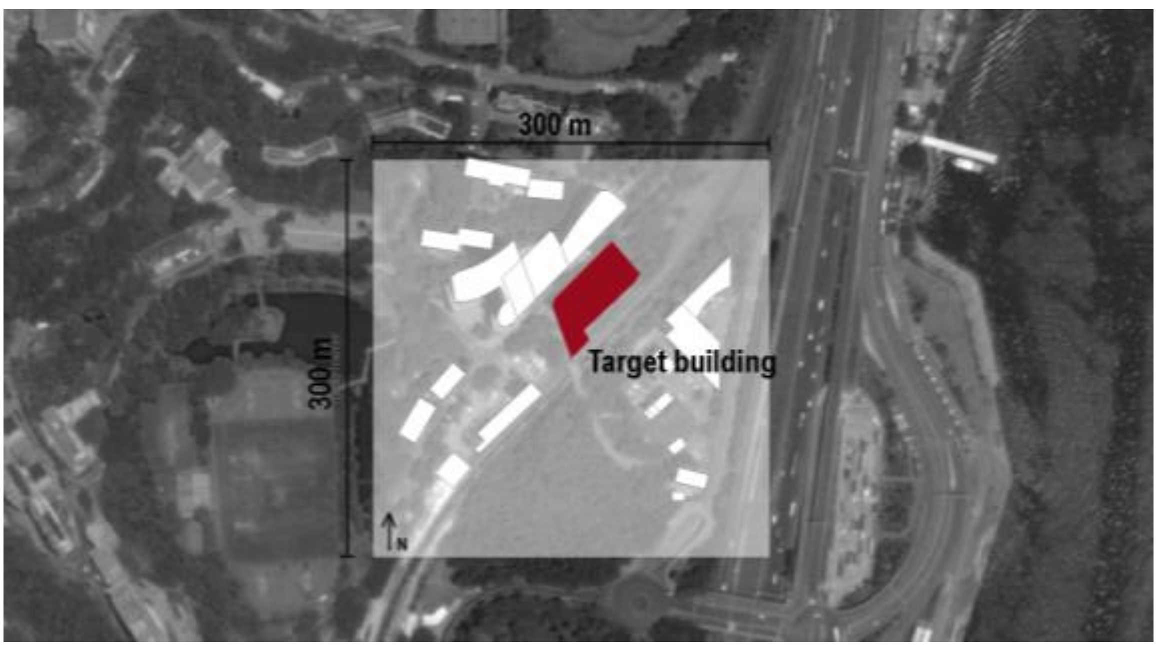
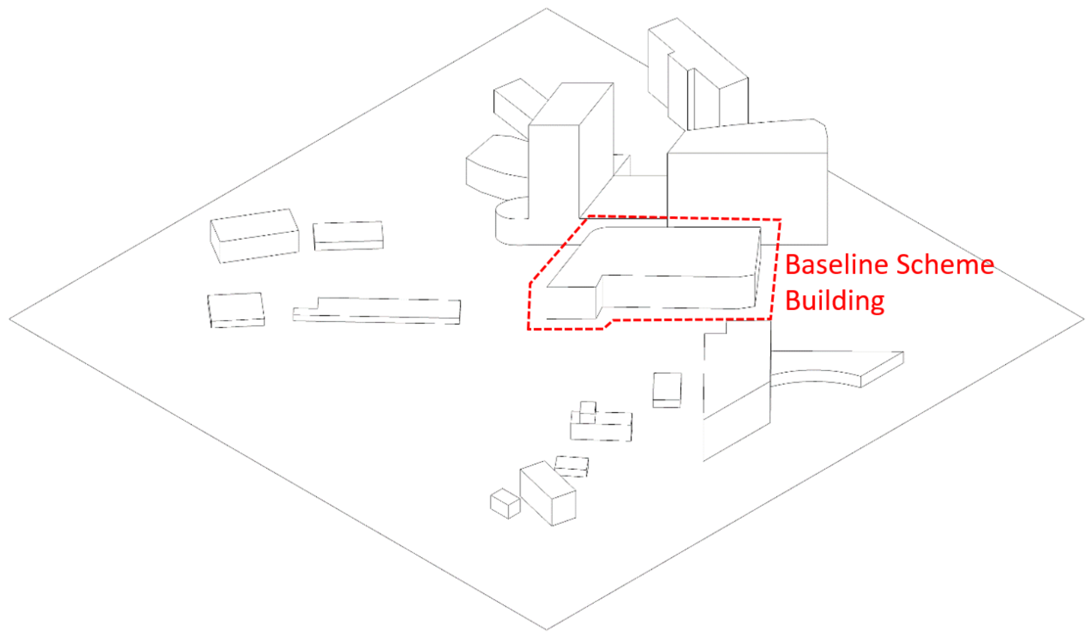


Figure 1 Site Plan, target building, and surrounding buildings

2. Summary of two design schemes

Two design schemes are introduced as following:

a) Baseline Scheme



b) Proposed Scheme

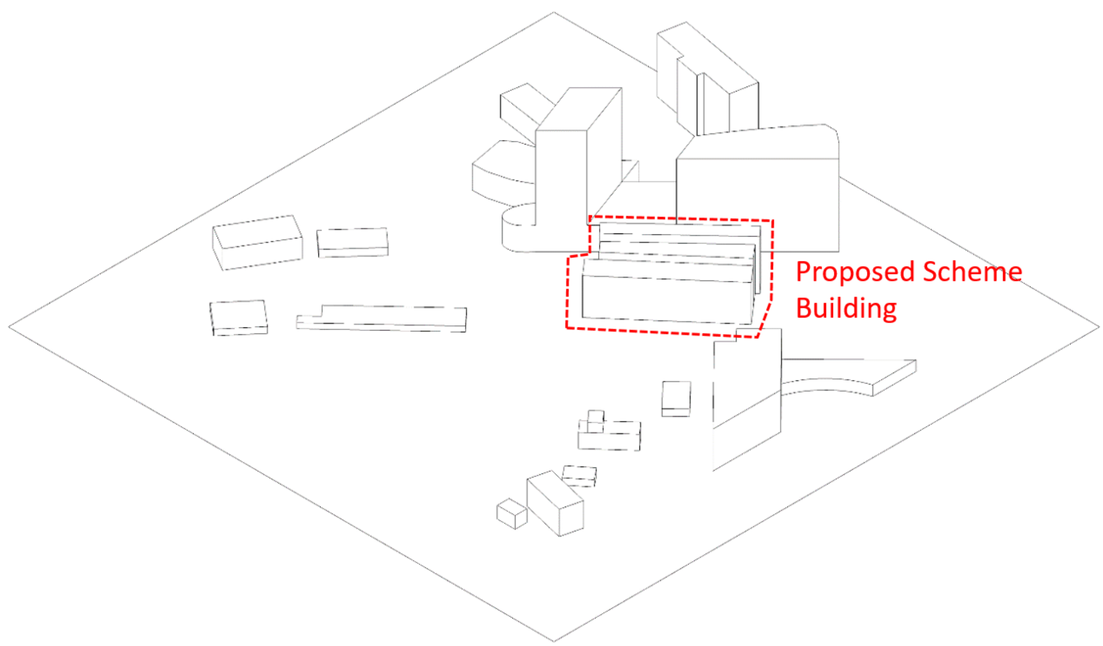


Figure 2 Baseline and proposed Schemes, highlighted by the red dash lines

3. CFD simulation

CFD simulations are conducted to calculate the wind data of the two design schemes. The simulations follow Architectural institute of Japan (AIJ) guidelines (Tominaga, Mochida et al. 2008) which was established especially for investigating the pedestrian wind environment around buildings. ANSYS CFD (Adopted for meshing: ICEM; Adopted for computational fluid dynamics simulation: Fluent) has been applied. The computational conditions will be described with details as follows.

3.1 Computational domain and models

The computational domains for both two scenarios are same: 700m x 700m x 200m (W x L x H), as shown in Figure 3. The blockage ratio is calculated as:

Blockage ratio = model volume / domain volume

Where the domain volume is 9.8 x 10^7 m^3, and the model volume is 237,753 m^3. Therefore, the blockage ratio is 0.24%, less than 3%.

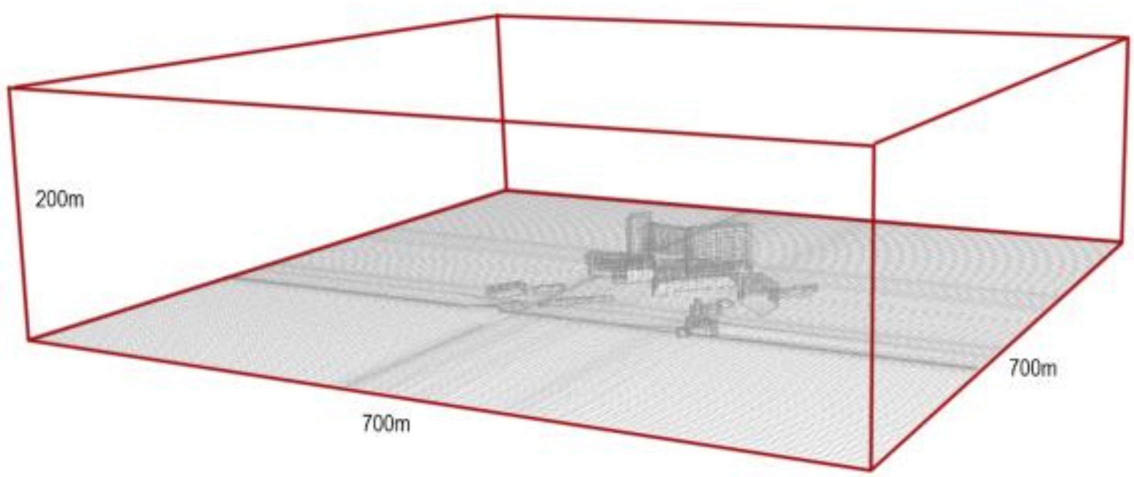


Figure 3 Computational domain size

Based on the AVA Technical Circular No. 1/06, the assessment area and surrounding area should include an area up to the perpendicular distance H and 2H respectively. H is the height of the tallest building on the project area. In this study, the values of H are 15 m and 25 m in the baseline and proposed schemes respectively. As shown in Figure 4, the surrounding area, i.e. modelling area, is 300m x 300m, larger than 2H.

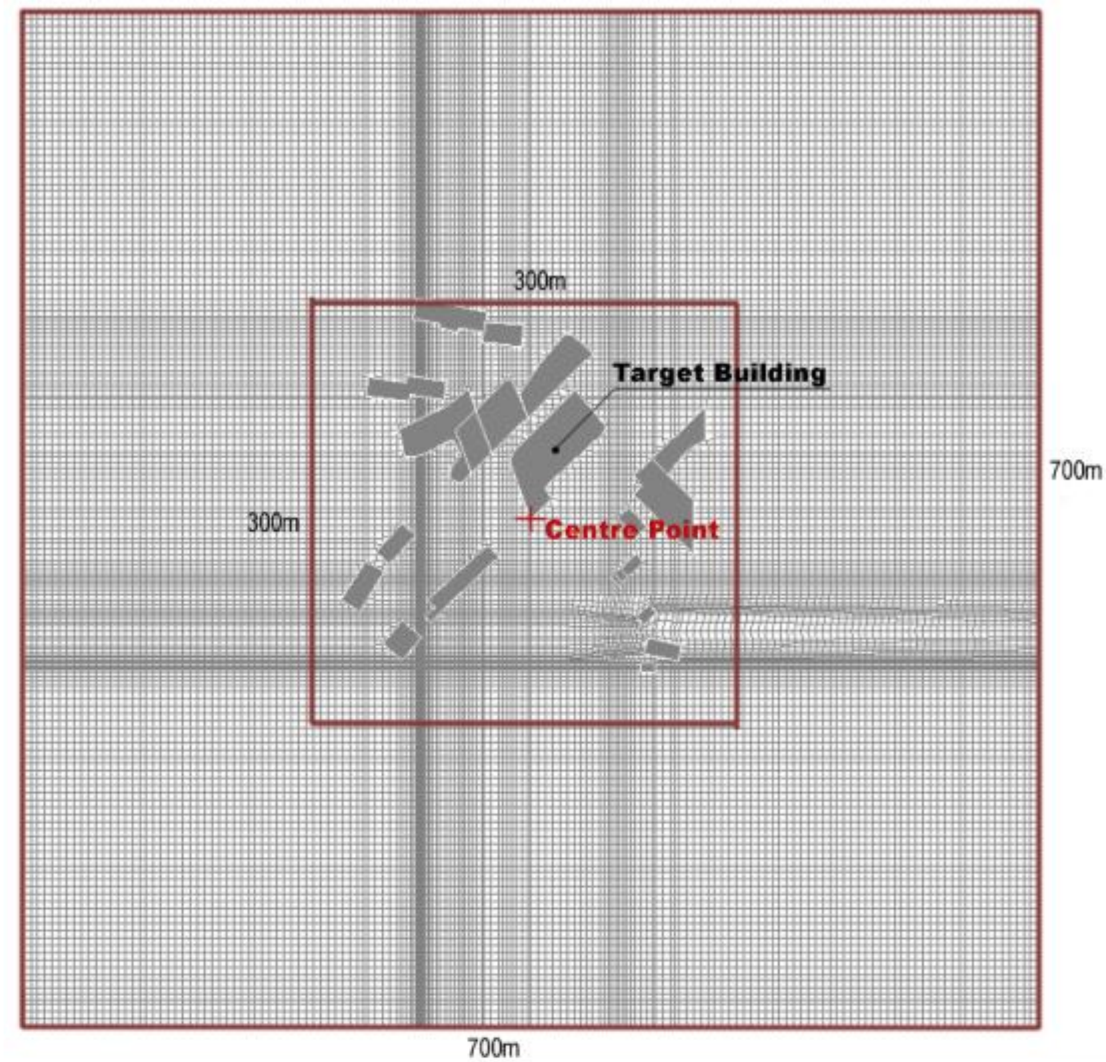


Figure 4 Domain area and surrounding area in the simulation

3.2 Grid arrangement

The computational domain is divided into about 2.2 – 2.5 million grid points. In general, fine grids are arranged within the 300m x 300m modelling area and coarse grids are arranged at other areas. Based on the AIJ guideline, three layers (layer height: 0.5m) are arranged below the evaluation height (the 4th layer, 2m above the ground). The maximum grid size ratio is set to 1.2.

3.3 Turbulence model and convergence

The turbulence model applied in this initial study is Reynolds-averaged Navier–Stokes (RANS) (Murakami, Ooka et al. 1999), κ-ω SST (Shear Stress Transport) model. Regarding the convergence criterion for the solution, the relevant recommendations from

AIJ and COST 14 (Frank 2006) guideline are followed in this study: “COST suggests that scaled residuals should be dropped 4 orders of magnitude. However, these values are largely dependent on flow configuration and boundary conditions, so it is better to check the solution directly using different convergence criteria.” In this study, the convergence criteria is 5 orders of magnitude.

3.4 Boundary condition

For urban wind studies, the turbulence structures in the near wall region may not need to be fully resolved (Blocken, Stathopoulos et al. 2007). Instead, the logarithmic law boundary condition can be applied at the ground, top and wall surfaces.

3.5 Input wind profiles

The input wind profiles are set based on the data for the annual site wind availability, as recommended by Technical Circular No. 1/06. As highlighted in Table 1, the incoming prevailing wind directions are chosen, based on the requirement from Technical circular NO. 1/06: “*the probability of wind coming from the reduced set of directions should exceed 75% of the time in a typical reference year”*. The input vertical wind speed profile is set as:

$$V_{(h)} = V_{met} \cdot (\frac{h}{d_{met}})^a$$

Where a is the surface roughness factor (0.22) and V_{met} is the mean wind speed at infinity (d_{met}= 300 m) above the ground as shown in Table 1.

Table 1 Annual wind availability data on site. The chosen wind directions are highlighted

Wind directions (i)	Average Velocity at Infinity, m/s	Wind Probability (Pi)
0° (N)	4.629	3.1%
22.5°(NNE)	6.135	8.9%
45°(NE)	5.734	11.1%
67.5°(ENE)	5.394	9.9%
90°(E)	5.430	16.4%
112.5°(ESE)	5.550	10.9%
135°(SE)	5.690	6.3%
157.5°(SSE)	5.063	4.8%
180°(S)	5.020	5.1%
202.5°(SSW)	6.753	7.9%
225°(SW)	6.564	7.0%
247.5°(WSW)	3.813	2.4%
270°(W)	2.750	2.0%
292.5°(WNW)	3.269	1.3%
315°(NW)	3.300	1.5%
337.5°(NNW)	3.867	1.5%

Note: Total wind probability of the chosen wind directions: 75%.

4. Simulation result analysis

Based on Technical Circular No. 1/06 (TC 1/06), the wind data are collected and analyzed to clarify how different building typologies affect the surrounding pedestrian-level wind environment. A summary description of the pedestrian-level wind environment is presented using wind velocity contours and vectors of the modeling area (see Appendix II). To further evaluate the wind environments with two design schemes and identify the optimal design option, matched-pairs sample wind data were collected to statistically compare outdoor natural ventilation performance.

4.1 Test points

A total of 39 test points are selected at the pedestrian level (2m above the ground), as shown in Figure 5. As per TC 01/06, overall test points (O01-O27) are evenly distributed and positioned in the surrounding open space, where pedestrians frequently access. The special test points (P01-P12) are positioned in areas of strategic importance, i.e. Station Road.

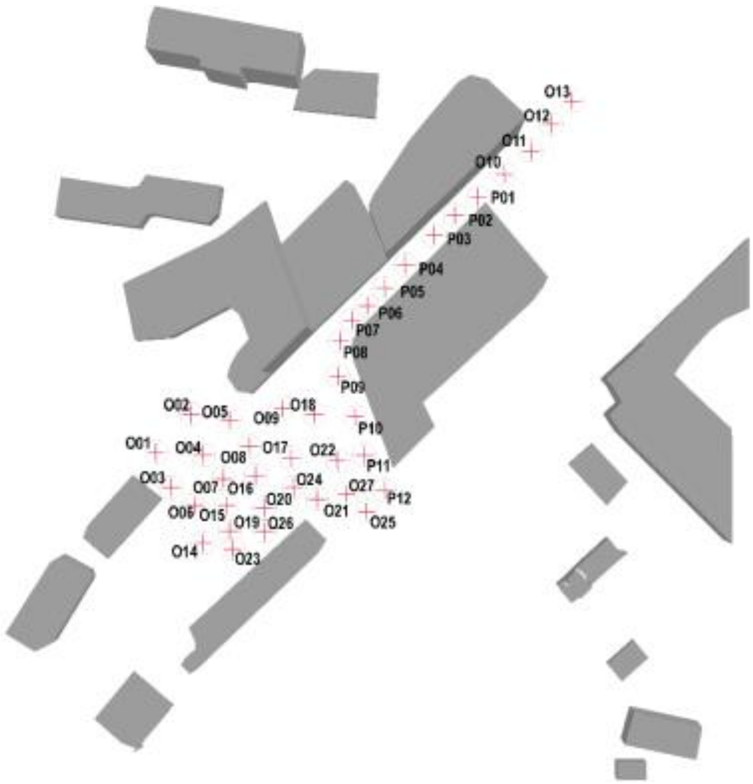


Figure 5. Test point locations (sample size n = 39)

4.2 Data analysis

In this report, both wind speed (V) and the velocity ratios (VR) are applied to evaluate the wind environment. For a particular wind direction, the wind velocity ratio (VR) of the test points is calculated as:

$$VR_{i,j} = \frac{V_{i,j}}{V_i}$$

Where $V_{i,j}$ is the j-th test point`s wind velocity at pedestrian level in a particular wind direction (i) and V_i is the averaged wind velocity at infinity in a particular wind direction (i) . The overall wind velocity ratio ($VR_{w,j}$) for each test point is calculated as:

$$VR_{w,j} = \sum_{i=1}^{8} P_i \cdot VR_{i,j}$$

Where P_i is the annual probability of winds approaching the study area from the wind direction (i), as shown in Table 1. The calculation results for $V_{i,j}$,$V_{w,j}$, $VR_{i,j}$, and $VR_{w,j}$ are appended (Appendix I), and $VR_{w,j}$ are plotted in Figure 6.

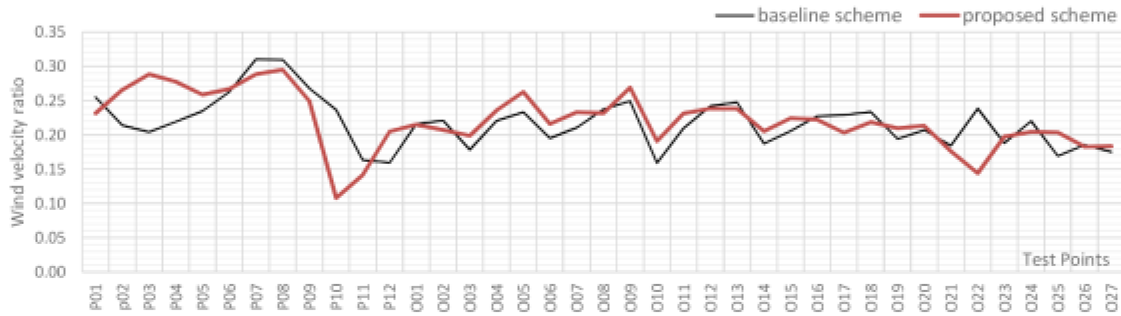


Figure 6 Comparison of wind velocity ratios ($VR_{w,j}$) collected from two design schemes

As shown in Figure 6, it is clear that the performances of two design schemes on the outdoor natural ventilation are similar, and averages of $VR_{w,j}$ in baseline and proposed schemes are same, 0.22. It could be explained as, even though the footprint area in the baseline scheme is larger than proposed scheme, the baseline scheme (15 m) is much lower than the proposed scheme (25 m).

Therefore, more than wind velocity ratio, we further compare the wind speed. The normal distribution fittings of $V_{w,j}$ for both two design schemes are conducted and presented in Figure 7. As shown in Figure 7, the annually averaged pedestrian-level wind speed ($V_{w,j}$) is larger than 1.0 m/s at the most of assessment area in both baseline and proposed schemes, and the performance of proposed scheme is slightly better than the baseline scheme. The average values of $V_{w,j}$ at baseline and proposed schemes are 1.65 m/s and 1.69 m/s respectively.

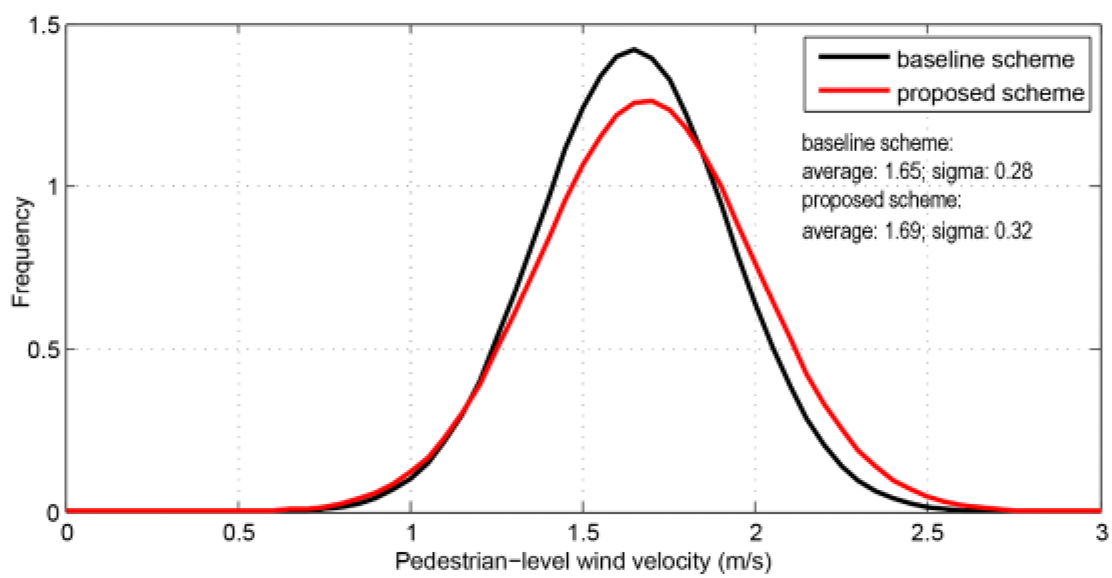


Figure 7 Normal distribution fittings of $V_{w,j}$ in baseline and proposed schemes. Confidence level: 95%

5. Conclusion

Based on the above analysis, both baseline and proposed schemes have limited negative effect on the surrounding wind environment. According to the normal distributions in Figure 7, the percentage of the low wind speed ($V_{w,j}$ < 1.0 m/s) is less than 5% in both two design schemes. It means that, on the whole, there is no stagnant area not flushed by breezes in two design schemes. The study can conclude that none of two design schemes studied would have any adverse air ventilation issues to the surroundings areas.

Proposed scheme is slightly better than baseline scheme, due to the comparison result in Figure 7. Compared with the baseline scheme, higher percentage of high wind speed and lower percentage of low wind speed is identified in the proposed scheme. Hence, the proposed scheme is recommended to be the optimal design option. By selecting the optimal design option, the requirements in APP-152 are satisfied.

References

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Frank, J. (2006). "Recommendations of the COST action C14 on the use of CFD in predicting pedestrian wind environment." Journal of Wind Engineering 108: 529-532.

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Appendix I

Table 2 Wind velocities ($V_{i,j}$) measured at test points in the baseline case

Test point (j)	$V_{1,j}$ NNE	$V_{2,j}$ NE	$V_{3,j}$ ENE	$V_{4,j}$ E	$V_{5,j}$ ESE	$V_{6,j}$ SE	$V_{7,j}$ SSW	$V_{8,j}$ SW	$V_{w,j}$
Frequency	9.20%	15.60%	13.00%	13.60%	9.00%	5.80%	7.00%	5.30%	75.00%
Reference V (m/s)	9.21	9.285	8.096	7.643	6.406	6.052	6.45	5.84	/
P01	1.51	3.64	3.85	2.88	0.70	1.14	2.46	1.99	2.01
p02	0.49	2.29	3.41	3.08	0.98	0.59	2.20	1.93	1.64
P03	0.19	1.35	3.13	3.14	1.78	1.09	1.85	1.96	1.52
P04	0.29	0.82	3.13	3.52	2.31	2.00	1.77	2.04	1.60
P05	0.26	1.06	3.23	3.66	2.43	2.27	2.00	2.15	1.71
P06	0.64	2.12	3.51	3.78	2.39	1.98	2.24	2.21	1.96
P07	1.39	3.26	4.01	4.04	2.35	1.41	3.08	2.79	2.36
P08	1.45	3.66	4.08	4.00	2.20	0.89	3.02	2.74	2.38
P09	1.42	2.75	3.31	3.62	2.59	2.28	1.71	1.46	2.04
P10	1.32	1.98	2.32	3.43	3.18	2.93	1.11	0.78	1.77
P11	1.13	1.22	1.35	2.80	2.24	1.98	0.32	0.64	1.22
P12	0.81	1.03	1.67	2.04	1.62	1.50	1.63	1.78	1.17
O01	1.41	1.37	2.54	3.62	2.87	2.46	0.09	1.00	1.62
O02	1.21	1.51	2.50	3.49	2.98	2.83	0.40	0.87	1.65
O03	1.18	1.29	2.07	2.89	2.06	1.75	0.87	0.58	1.35
O04	1.03	1.64	2.56	3.45	2.65	2.43	1.25	0.67	1.65
O05	0.74	1.87	2.67	3.48	2.87	3.02	0.59	1.50	1.73
O06	0.50	1.46	2.36	3.03	1.96	1.32	1.83	1.53	1.45
O07	0.36	1.79	2.47	3.16	2.33	2.02	1.59	1.30	1.57
O08	0.87	2.06	2.70	3.33	2.69	2.70	1.32	1.47	1.77
O09	1.20	2.43	3.09	3.30	2.31	2.55	1.15	2.07	1.89
O10	0.61	1.49	2.31	1.30	1.18	1.50	2.08	1.57	1.19
O11	2.57	3.63	1.96	0.51	1.87	2.46	1.97	1.22	1.64
O12	2.43	3.08	2.02	2.42	2.10	3.01	2.12	0.98	1.86
O13	2.07	2.98	2.45	2.96	1.73	3.09	2.13	0.81	1.90
O14	1.06	1.58	2.19	2.71	1.54	1.00	1.73	1.87	1.41
O15	1.11	1.75	2.34	2.92	1.99	1.47	1.70	1.67	1.55
O16	1.28	2.02	2.50	3.09	2.49	2.28	1.52	1.34	1.71
O17	1.66	2.16	2.44	2.86	2.53	2.37	1.39	1.39	1.73
O18	1.63	2.40	2.74	2.95	2.24	2.34	1.17	1.51	1.78
O19	1.27	1.69	2.20	2.71	1.68	1.13	1.73	1.79	1.47
O20	1.57	1.92	2.23	2.70	1.99	1.51	1.63	1.68	1.57
O21	1.51	2.13	2.10	2.52	1.67	1.03	0.88	1.33	1.43
O22	1.61	2.52	2.73	3.43	2.81	2.15	0.56	0.96	1.83
O23	1.36	1.68	2.06	2.56	1.57	1.13	1.72	1.73	1.42
O24	1.68	2.09	2.35	2.79	2.34	1.96	1.41	1.52	1.67
O25	0.95	1.00	1.58	2.44	1.82	1.47	1.77	1.70	1.24
O26	1.55	1.80	1.96	2.41	1.63	1.21	1.52	1.58	1.41
O27	1.17	1.59	1.70	2.69	1.92	1.36	0.92	1.27	1.33

Table 3 Velocity ratios measured at test points in the baseline case

Test point (j)	$VR_{1,j}$ NNE	$VR_{2,j}$ NE	$VR_{3,j}$ ENE	$VR_{4,j}$ E	$VR_{5,j}$ ESE	$VR_{6,j}$ SE	$VR_{7,j}$ SSW	$VR_{8,j}$ SW	$VR_{w,j}$
Frequency	9.20%	15.60%	13.00%	13.60%	9.00%	5.80%	7.00%	5.30%	75.00%
Reference V (m/s)	9.21	9.285	8.096	7.643	6.406	6.052	6.45	5.84	/
P01	0.16	0.39	0.48	0.38	0.11	0.19	0.38	0.34	0.25
P02	0.05	0.25	0.42	0.40	0.15	0.10	0.34	0.33	0.21
P03	0.02	0.15	0.39	0.41	0.28	0.18	0.29	0.33	0.20
P04	0.03	0.09	0.39	0.46	0.36	0.33	0.27	0.35	0.22
P05	0.03	0.11	0.40	0.48	0.38	0.38	0.31	0.37	0.23
P06	0.07	0.23	0.43	0.49	0.37	0.33	0.35	0.38	0.26
P07	0.15	0.35	0.50	0.53	0.37	0.23	0.48	0.48	0.31
P08	0.16	0.39	0.50	0.52	0.34	0.15	0.47	0.47	0.31
P09	0.15	0.30	0.41	0.47	0.40	0.38	0.26	0.25	0.27
P10	0.14	0.21	0.29	0.45	0.50	0.48	0.17	0.13	0.24
P11	0.12	0.13	0.17	0.37	0.35	0.33	0.05	0.11	0.16
P12	0.09	0.11	0.21	0.27	0.25	0.25	0.25	0.31	0.16
O01	0.15	0.15	0.31	0.47	0.45	0.41	0.01	0.17	0.22
O02	0.13	0.16	0.31	0.46	0.46	0.47	0.06	0.15	0.22
O03	0.13	0.14	0.26	0.38	0.32	0.29	0.14	0.10	0.18
O04	0.11	0.18	0.32	0.45	0.41	0.40	0.19	0.12	0.22
O05	0.08	0.20	0.33	0.46	0.45	0.50	0.09	0.26	0.23
O06	0.05	0.16	0.29	0.40	0.31	0.22	0.28	0.26	0.20
O07	0.04	0.19	0.31	0.41	0.36	0.33	0.25	0.22	0.21
O08	0.09	0.22	0.33	0.44	0.42	0.45	0.20	0.25	0.24
O09	0.13	0.26	0.38	0.43	0.36	0.42	0.18	0.35	0.25
O10	0.07	0.16	0.29	0.17	0.18	0.25	0.32	0.27	0.16
O11	0.28	0.39	0.24	0.07	0.29	0.41	0.31	0.21	0.21
O12	0.26	0.33	0.25	0.32	0.33	0.50	0.33	0.17	0.24
O13	0.22	0.32	0.30	0.39	0.27	0.51	0.33	0.14	0.25
O14	0.11	0.17	0.27	0.35	0.24	0.17	0.27	0.32	0.19
O15	0.12	0.19	0.29	0.38	0.31	0.24	0.26	0.29	0.21
O16	0.14	0.22	0.31	0.40	0.39	0.38	0.24	0.23	0.23
O17	0.18	0.23	0.30	0.37	0.40	0.39	0.22	0.24	0.23
O18	0.18	0.26	0.34	0.39	0.35	0.39	0.18	0.26	0.23
O19	0.14	0.18	0.27	0.35	0.26	0.19	0.27	0.31	0.19
O20	0.17	0.21	0.28	0.35	0.31	0.25	0.25	0.29	0.21
O21	0.16	0.23	0.26	0.33	0.26	0.17	0.14	0.23	0.18
O22	0.17	0.27	0.34	0.45	0.44	0.36	0.09	0.17	0.24
O23	0.15	0.18	0.25	0.34	0.25	0.19	0.27	0.30	0.19
O24	0.18	0.23	0.29	0.36	0.37	0.32	0.22	0.26	0.22
O25	0.10	0.11	0.20	0.32	0.28	0.24	0.28	0.29	0.17
O26	0.17	0.19	0.24	0.32	0.25	0.20	0.24	0.27	0.19
O27	0.13	0.17	0.21	0.35	0.30	0.22	0.14	0.22	0.18

Table 4 Wind velocities ($V_{i,j}$) measured at test points in the proposed case

Test point (j)	$V_{1,j}$ NNE	$V_{2,j}$ NE	$V_{3,j}$ ENE	$V_{4,j}$ E	$V_{5,j}$ ESE	$V_{6,j}$ SE	$V_{7,j}$ SSW	$V_{8,j}$ SW	$V_{w,j}$
Frequency	9.20%	15.60%	13.00%	13.60%	9.00%	5.80%	7.00%	5.30%	75.00%
Reference V (m/s)	9.21	9.285	8.096	7.643	6.406	6.052	6.45	5.84	/
p1	0.98	2.91	3.53	2.73	1.76	1.27	2.29	0.66	1.80
p2	1.21	3.21	4.02	3.33	2.11	1.27	2.30	0.97	2.07
p3	1.56	3.65	4.11	3.49	2.36	1.60	2.28	1.12	2.25
p4	1.15	3.23	3.74	3.41	2.65	1.81	2.30	1.29	2.13
p5	0.94	2.96	3.50	3.22	2.61	0.59	2.67	1.60	1.98
p6	0.98	2.95	3.21	2.95	2.46	1.96	2.99	1.94	2.02
p7	1.32	3.39	3.27	2.92	2.30	2.50	3.29	2.44	2.18
p8	1.51	3.74	3.38	2.98	2.24	2.37	3.09	2.41	2.25
p9	1.14	3.25	3.01	2.78	2.11	1.84	1.99	1.84	1.91
p10	0.60	1.80	1.56	0.81	0.35	1.06	0.86	0.87	0.85
p11	0.95	1.68	1.80	1.47	0.92	2.09	0.57	1.05	1.08
p12	0.83	2.16	2.67	2.50	1.18	2.07	1.90	1.78	1.55
O01	1.17	1.51	2.78	3.38	2.85	2.59	0.08	0.81	1.62
O02	0.82	1.82	2.45	3.05	2.50	2.85	0.44	0.82	1.56
O03	1.17	1.72	2.28	2.89	2.49	2.21	0.77	0.59	1.50
O04	0.75	1.83	3.07	3.51	3.02	2.52	1.11	0.74	1.77
O05	0.42	2.95	3.33	3.59	3.07	2.70	0.79	1.51	1.99
O06	0.54	2.07	2.28	3.02	2.42	1.96	1.74	1.55	1.61
O07	0.63	2.24	2.56	3.20	2.71	2.35	1.71	1.29	1.74
O08	0.21	1.93	2.85	3.32	2.90	2.26	1.57	1.41	1.72
O09	0.46	3.28	3.35	3.45	2.94	1.82	1.49	2.09	2.04
O10	1.41	2.96	2.76	1.51	1.17	1.36	2.22	0.23	1.51
O11	3.03	4.26	2.31	0.99	1.64	2.32	2.21	0.60	1.85
O12	2.45	3.24	2.05	2.27	2.16	2.90	2.20	0.45	1.85
O13	2.07	3.04	2.41	2.75	1.86	2.91	2.04	0.28	1.85
O14	0.79	2.22	2.11	2.72	1.94	1.26	1.96	1.91	1.55
O15	0.63	2.38	2.28	2.92	2.36	2.10	1.91	1.70	1.68
O16	0.32	2.42	2.28	2.91	2.45	2.31	1.85	1.50	1.66
O17	0.64	1.97	2.08	2.65	2.27	1.91	1.72	1.52	1.51
O18	0.66	2.58	2.70	2.82	2.33	0.90	1.70	1.67	1.67
O19	0.73	2.27	2.15	2.70	2.03	1.53	1.99	1.83	1.58
O20	0.25	2.53	2.24	2.58	2.09	2.14	1.90	1.74	1.60
O21	0.93	2.13	1.98	1.79	1.47	2.15	1.19	1.44	1.34
O22	0.91	1.73	1.46	1.24	1.14	2.14	1.11	1.29	1.09
O23	0.54	2.21	2.08	2.55	1.83	1.30	1.97	1.79	1.49
O24	0.74	2.40	1.91	2.40	2.02	2.26	1.74	1.58	1.53
O25	0.90	2.16	2.61	2.44	1.22	2.00	1.93	1.75	1.54
O26	0.10	2.02	2.03	2.37	1.79	1.40	1.80	1.65	1.37
O27	0.94	1.98	2.32	2.12	1.29	2.11	1.35	1.40	1.39

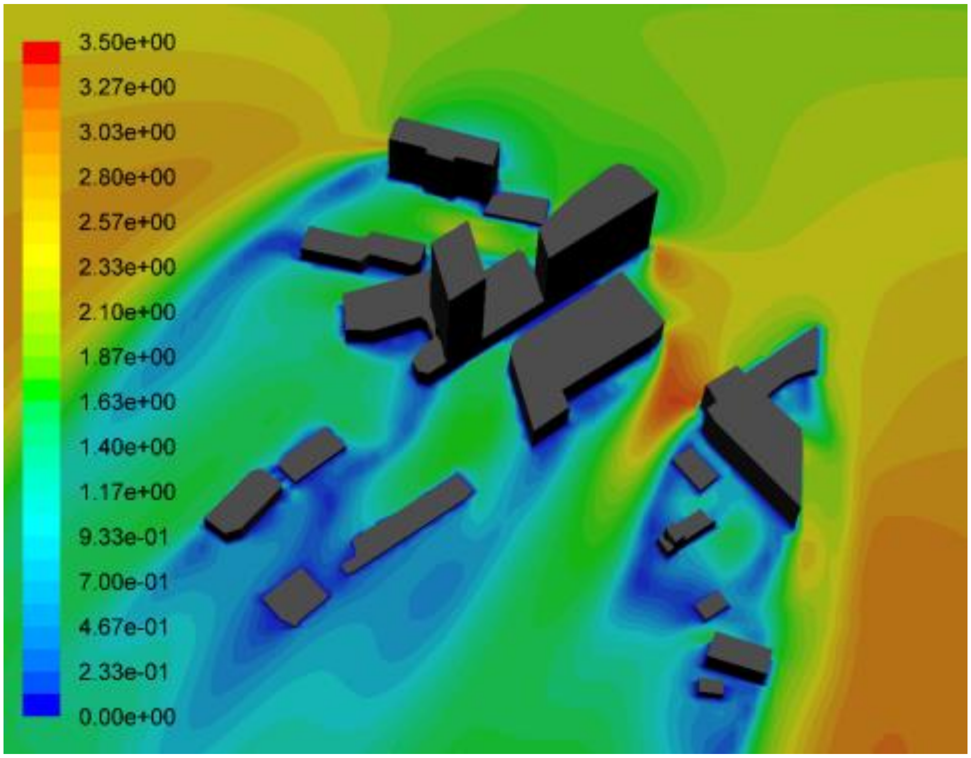
Table 5 Velocity ratios measured at test points in the proposed case

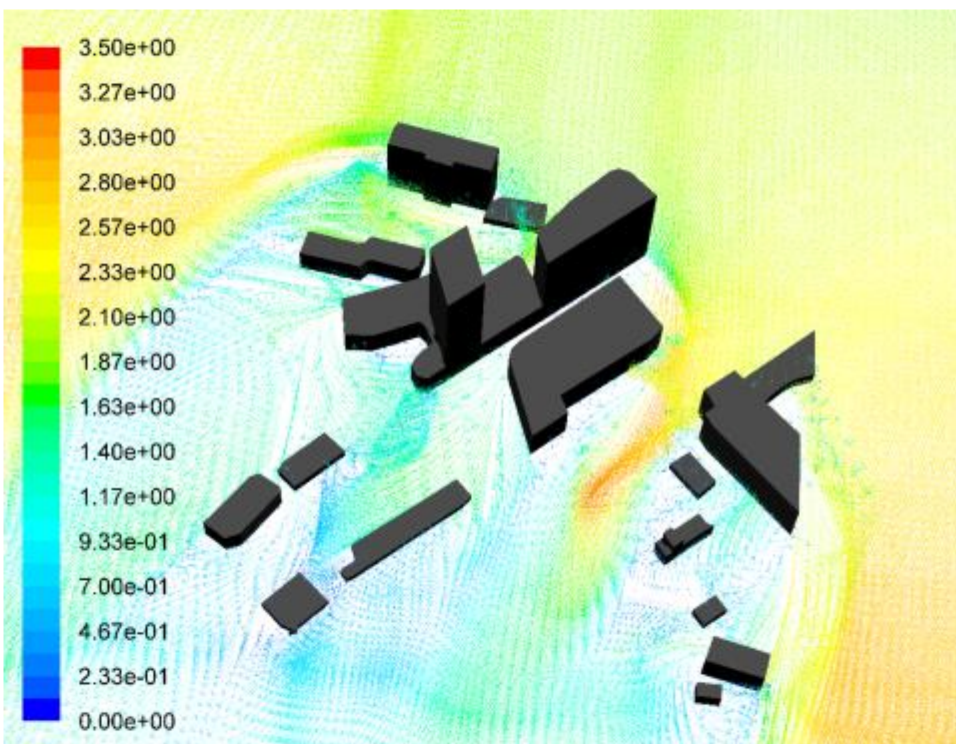
Test point (j)	$VR_{1,j}$ NNE	$VR_{2,j}$ NE	$VR_{3,j}$ ENE	$VR_{4,j}$ E	$VR_{5,j}$ ESE	$VR_{6,j}$ SE	$VR_{7,j}$ SSW	$VR_{8,j}$ SW	$VR_{w,j}$
Frequency	9.20%	15.60%	13.00%	13.60%	9.00%	5.80%	7.00%	5.30%	75.00%
Reference V (m/s)	9.21	9.285	8.096	7.643	6.406	6.052	6.45	5.84	/
p1	0.11	0.31	0.44	0.36	0.27	0.21	0.35	0.11	0.23
p2	0.13	0.35	0.50	0.44	0.33	0.21	0.36	0.17	0.27
p3	0.17	0.39	0.51	0.46	0.37	0.26	0.35	0.19	0.29
p4	0.12	0.35	0.46	0.45	0.41	0.30	0.36	0.22	0.28
p5	0.10	0.32	0.43	0.42	0.41	0.10	0.41	0.27	0.26
p6	0.11	0.32	0.40	0.39	0.38	0.32	0.46	0.33	0.27
p7	0.14	0.37	0.40	0.38	0.36	0.41	0.51	0.42	0.29
p8	0.16	0.40	0.42	0.39	0.35	0.39	0.48	0.41	0.29
p9	0.12	0.35	0.37	0.36	0.33	0.30	0.31	0.31	0.25
p10	0.07	0.19	0.19	0.11	0.05	0.18	0.13	0.15	0.11
p11	0.10	0.18	0.22	0.19	0.14	0.34	0.09	0.18	0.14
p12	0.09	0.23	0.33	0.33	0.18	0.34	0.30	0.30	0.20
O01	0.13	0.16	0.34	0.44	0.44	0.43	0.01	0.14	0.21
O02	0.09	0.20	0.30	0.40	0.39	0.47	0.07	0.14	0.21
O03	0.13	0.19	0.28	0.38	0.39	0.37	0.12	0.10	0.20
O04	0.08	0.20	0.38	0.46	0.47	0.42	0.17	0.13	0.24
O05	0.05	0.32	0.41	0.47	0.48	0.45	0.12	0.26	0.26
O06	0.06	0.22	0.28	0.40	0.38	0.32	0.27	0.27	0.22
O07	0.07	0.24	0.32	0.42	0.42	0.39	0.27	0.22	0.23
O08	0.02	0.21	0.35	0.43	0.45	0.37	0.24	0.24	0.23
O09	0.05	0.35	0.41	0.45	0.46	0.30	0.23	0.36	0.27
O10	0.15	0.32	0.34	0.20	0.18	0.22	0.34	0.04	0.19
O11	0.33	0.46	0.29	0.13	0.26	0.38	0.34	0.10	0.23
O12	0.27	0.35	0.25	0.30	0.34	0.48	0.34	0.08	0.24
O13	0.22	0.33	0.30	0.36	0.29	0.48	0.32	0.05	0.24
O14	0.09	0.24	0.26	0.36	0.30	0.21	0.30	0.33	0.21
O15	0.07	0.26	0.28	0.38	0.37	0.35	0.30	0.29	0.22
O16	0.03	0.26	0.28	0.38	0.38	0.38	0.29	0.26	0.22
O17	0.07	0.21	0.26	0.35	0.35	0.32	0.27	0.26	0.20
O18	0.07	0.28	0.33	0.37	0.36	0.15	0.26	0.29	0.22
O19	0.08	0.24	0.27	0.35	0.32	0.25	0.31	0.31	0.21
O20	0.03	0.27	0.28	0.34	0.33	0.35	0.29	0.30	0.21
O21	0.10	0.23	0.24	0.23	0.23	0.35	0.18	0.25	0.18
O22	0.10	0.19	0.18	0.16	0.18	0.35	0.17	0.22	0.14
O23	0.06	0.24	0.26	0.33	0.29	0.21	0.31	0.31	0.20
O24	0.08	0.26	0.24	0.31	0.32	0.37	0.27	0.27	0.20
O25	0.10	0.23	0.32	0.32	0.19	0.33	0.30	0.30	0.20
O26	0.01	0.22	0.25	0.31	0.28	0.23	0.28	0.28	0.18
O27	0.10	0.21	0.29	0.28	0.20	0.35	0.21	0.24	0.18

Appendix II

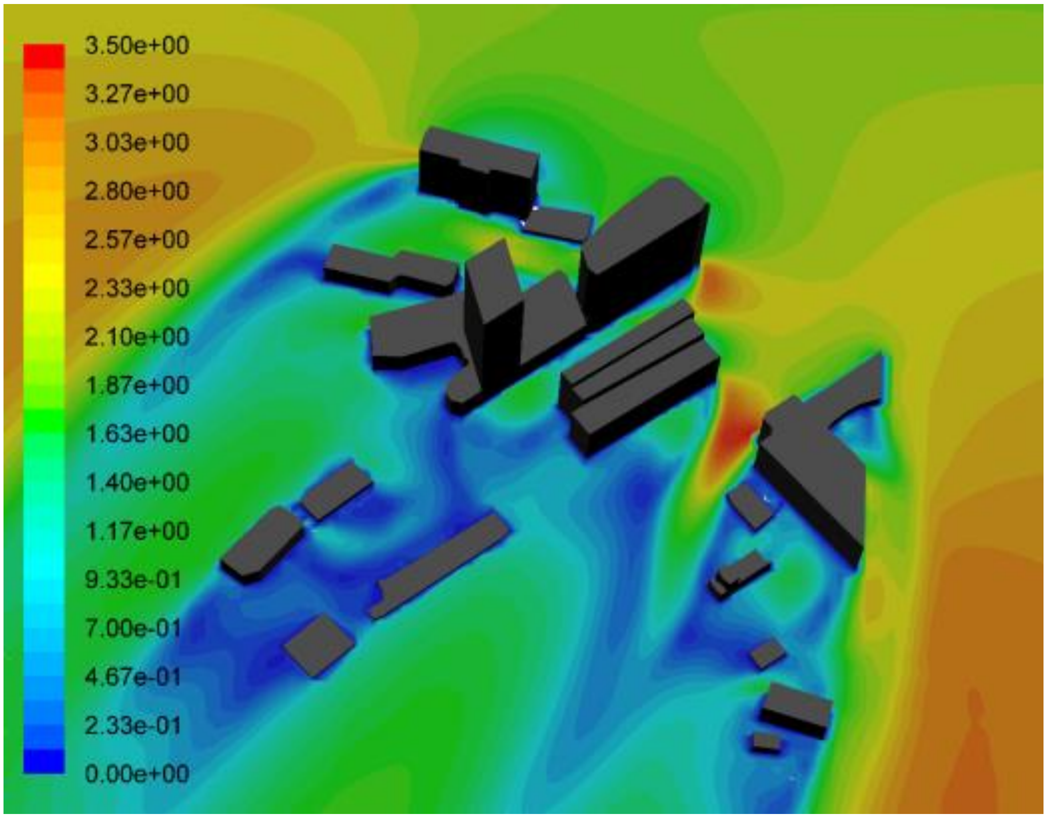
Contours and vectors of wind velocity

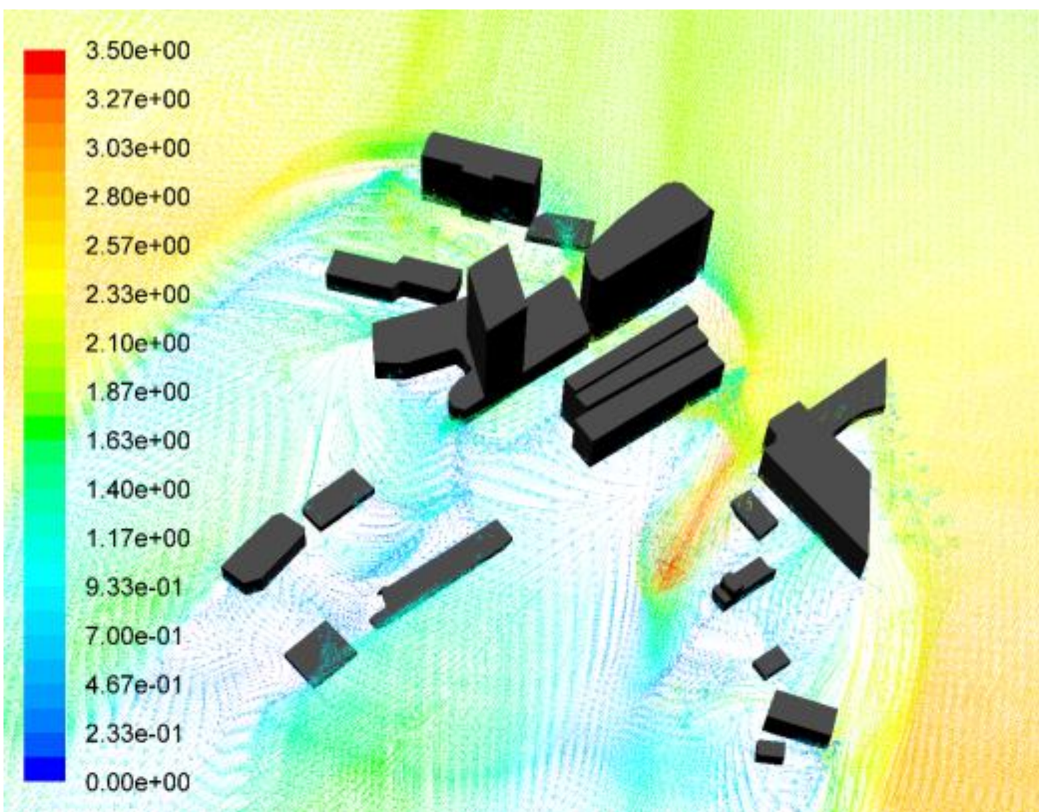
Wind direction: NNE 22.5 (Baseline case)



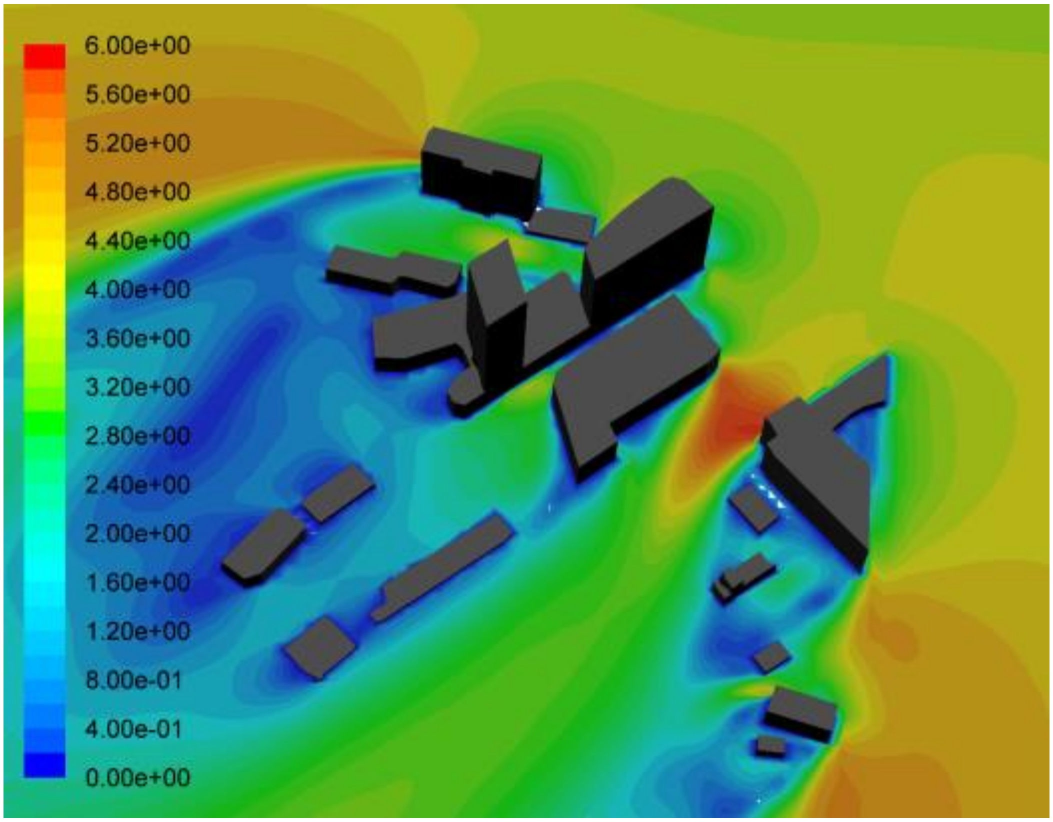


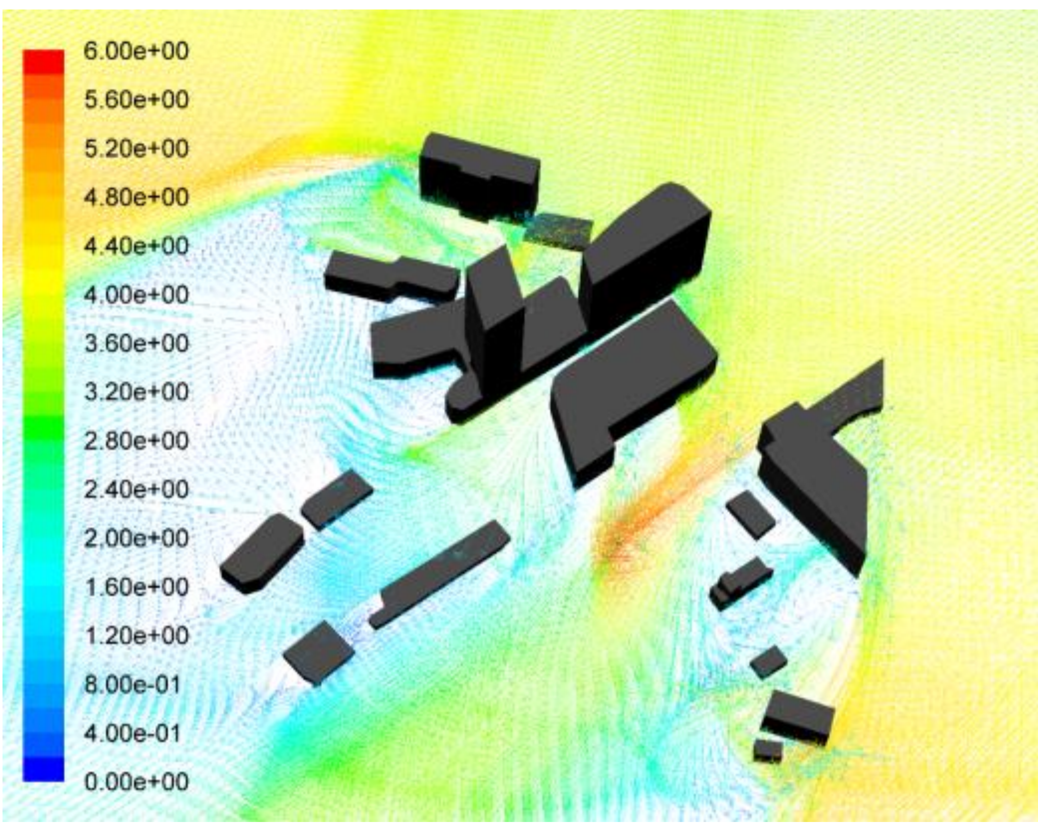
Wind direction: NNE 22.5 (Proposed case)



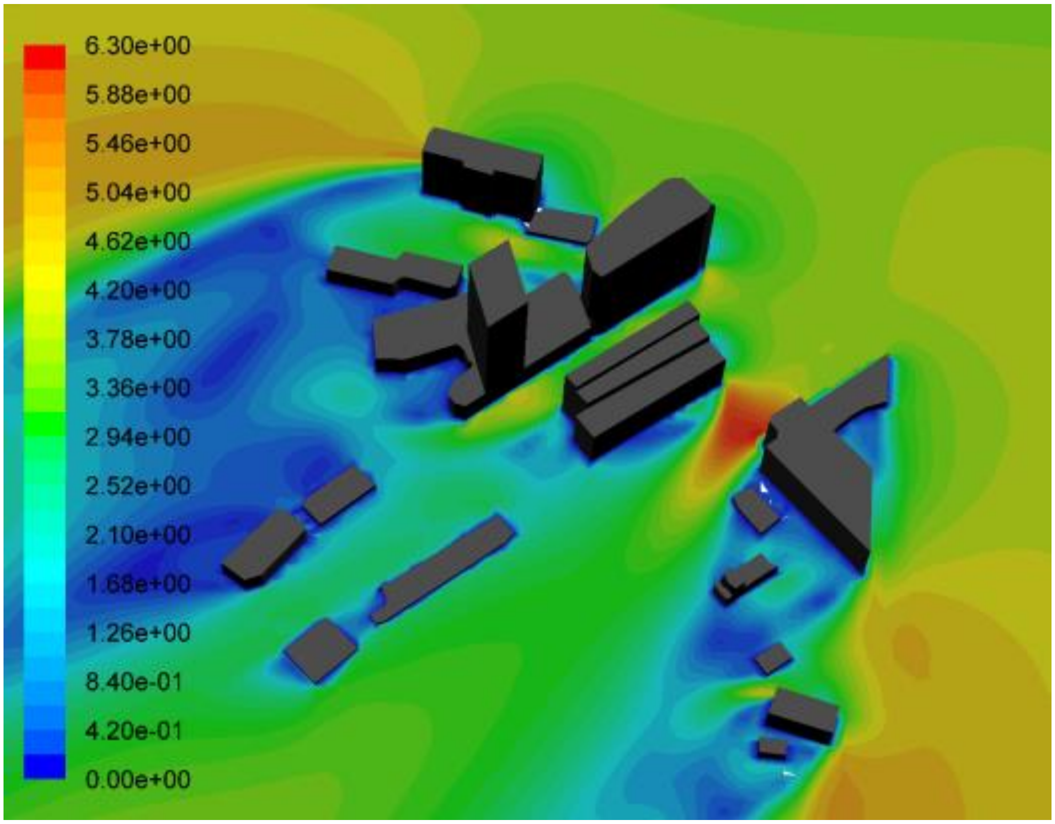


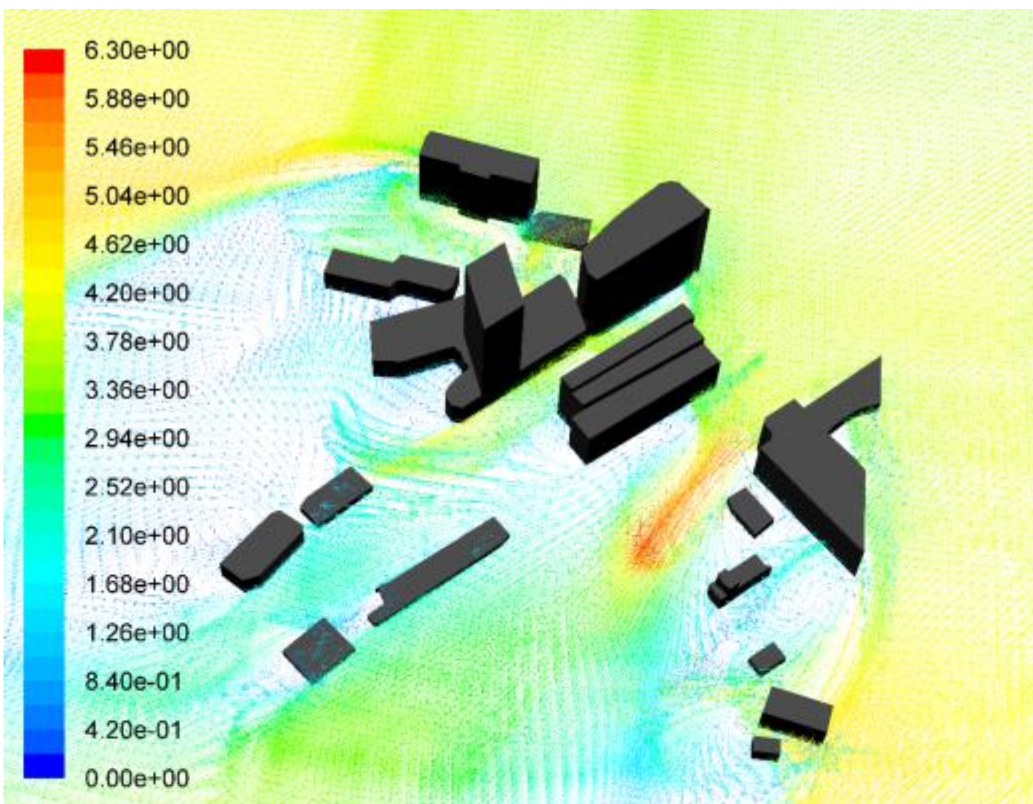
Wind direction: NE 45 (Baseline case)



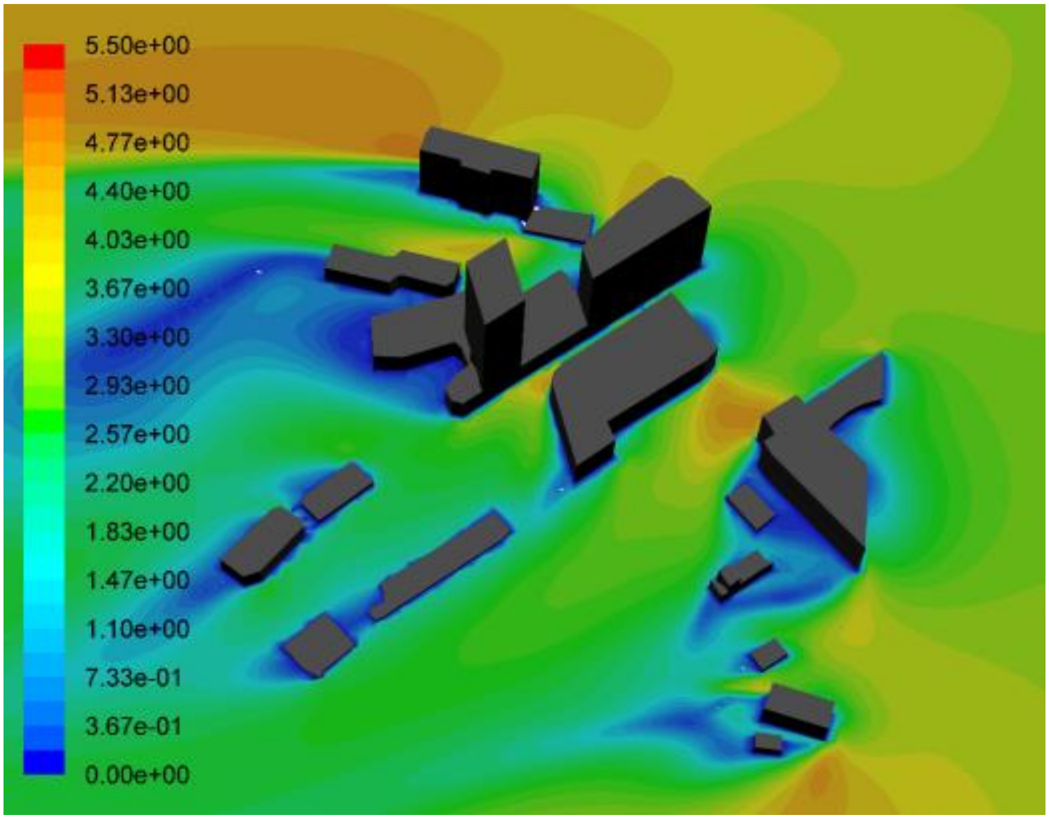


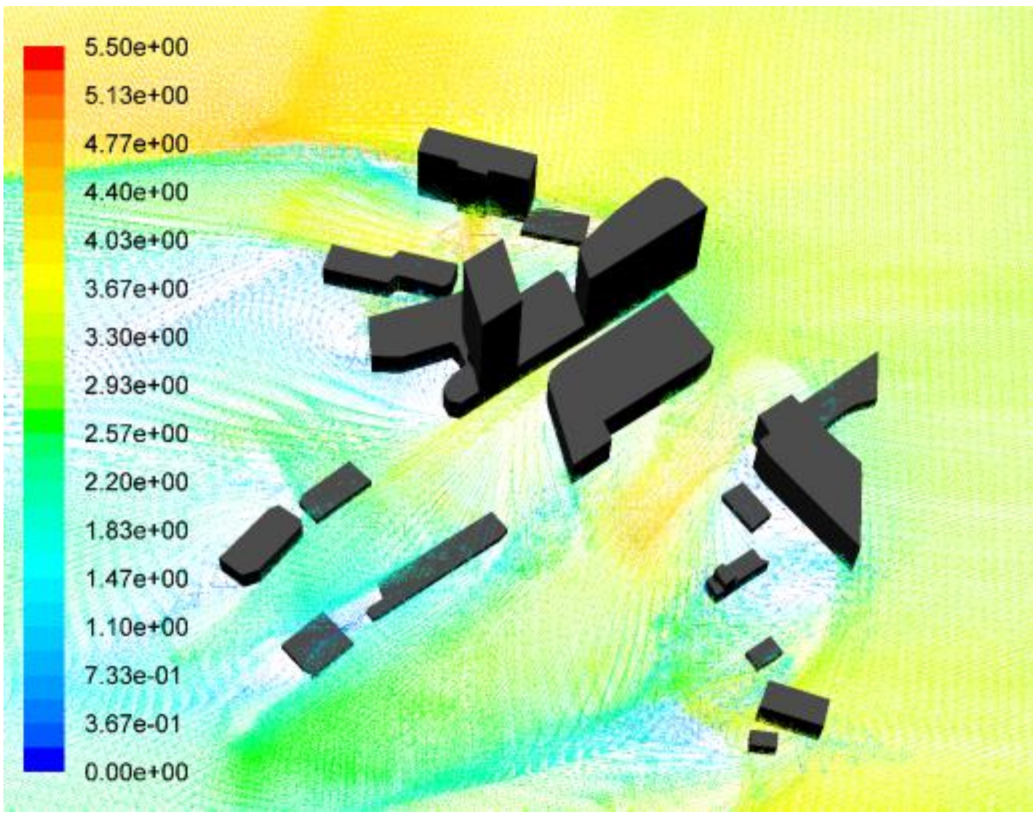
Wind direction: NE 45 (Proposed case)



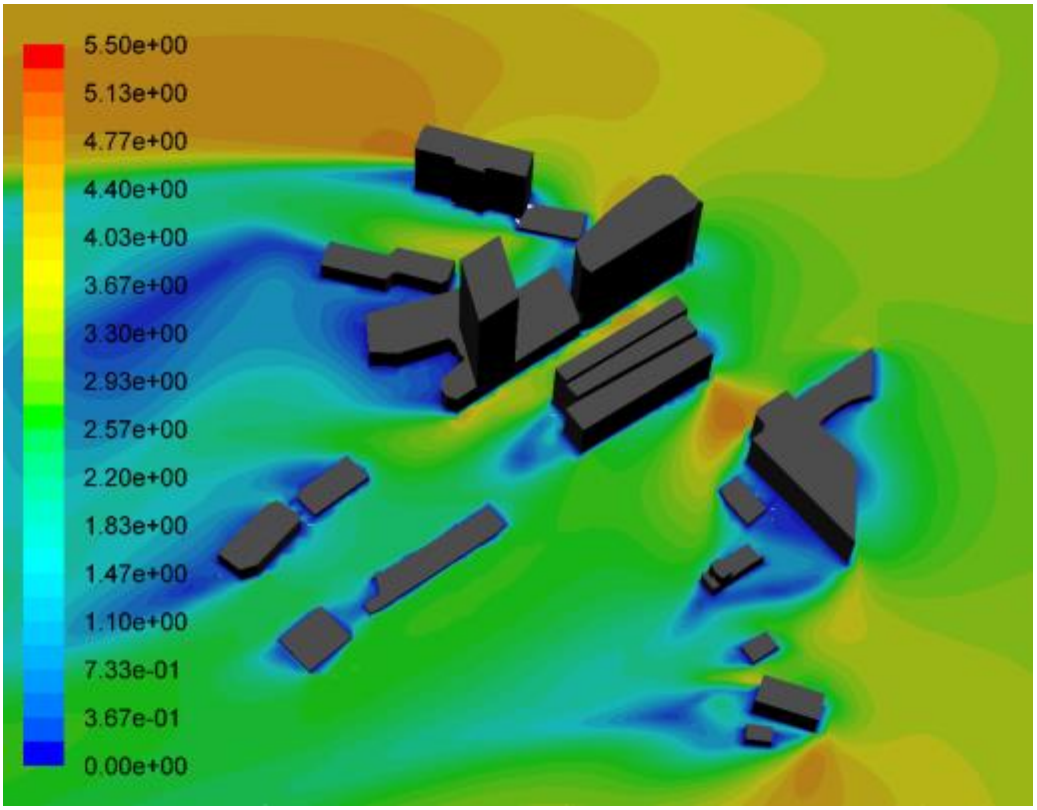


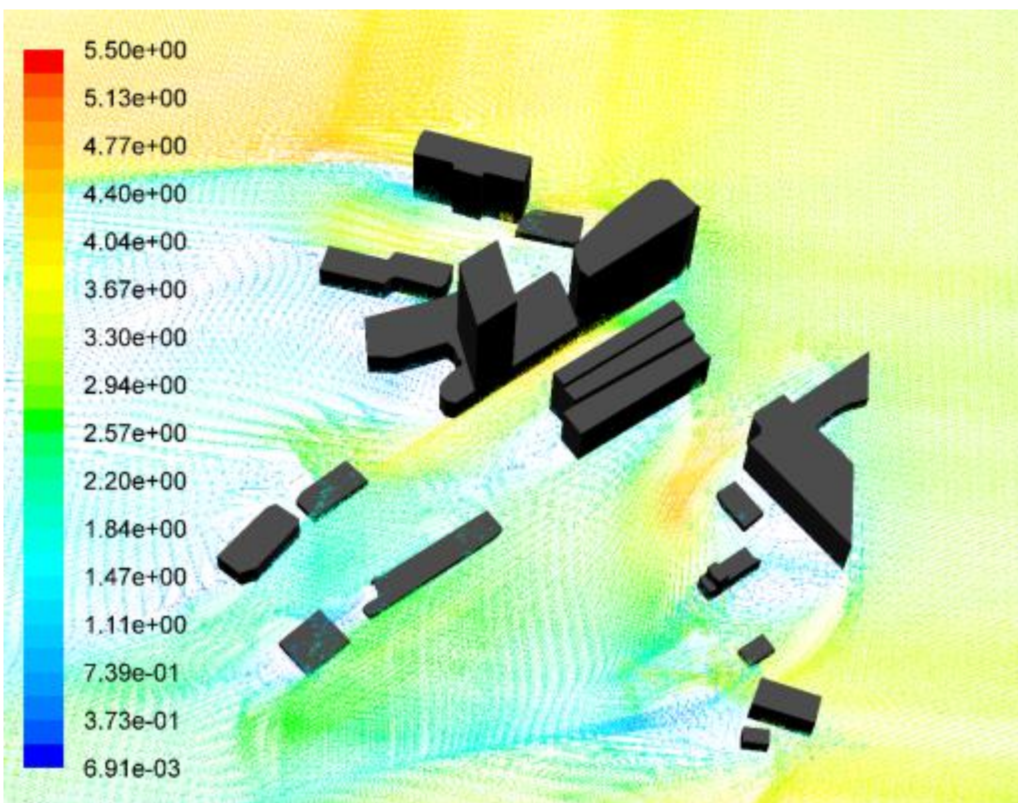
Wind direction: ENE 67.5 (Baseline case)



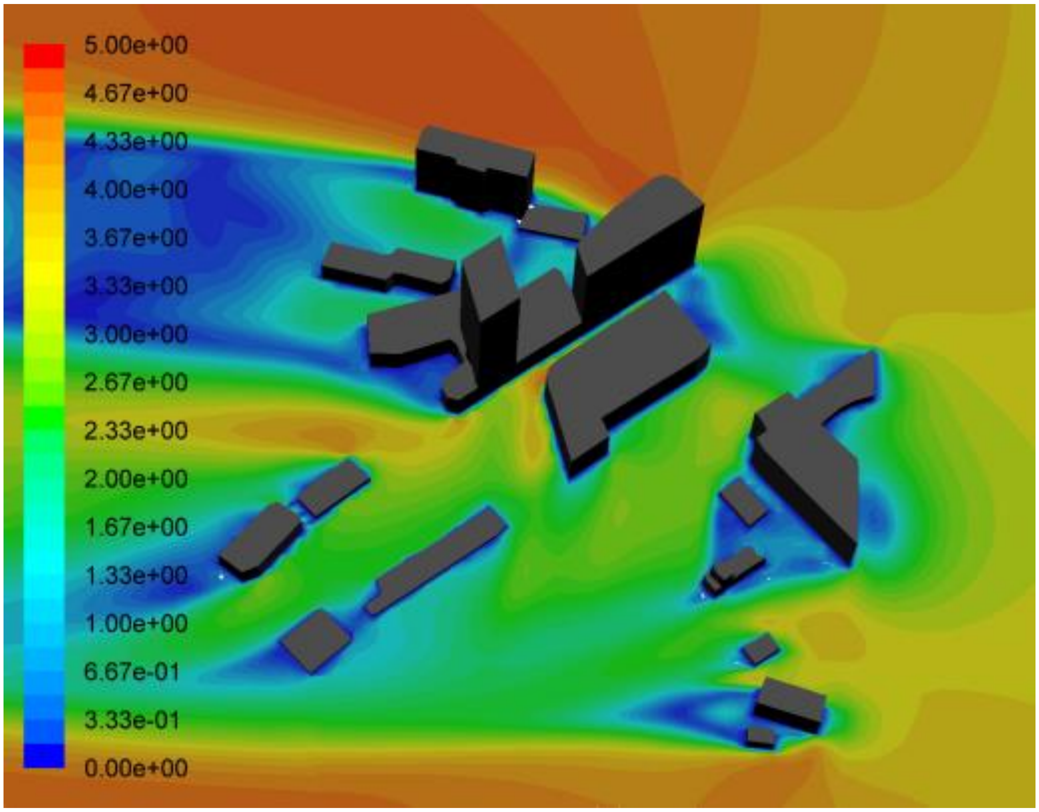


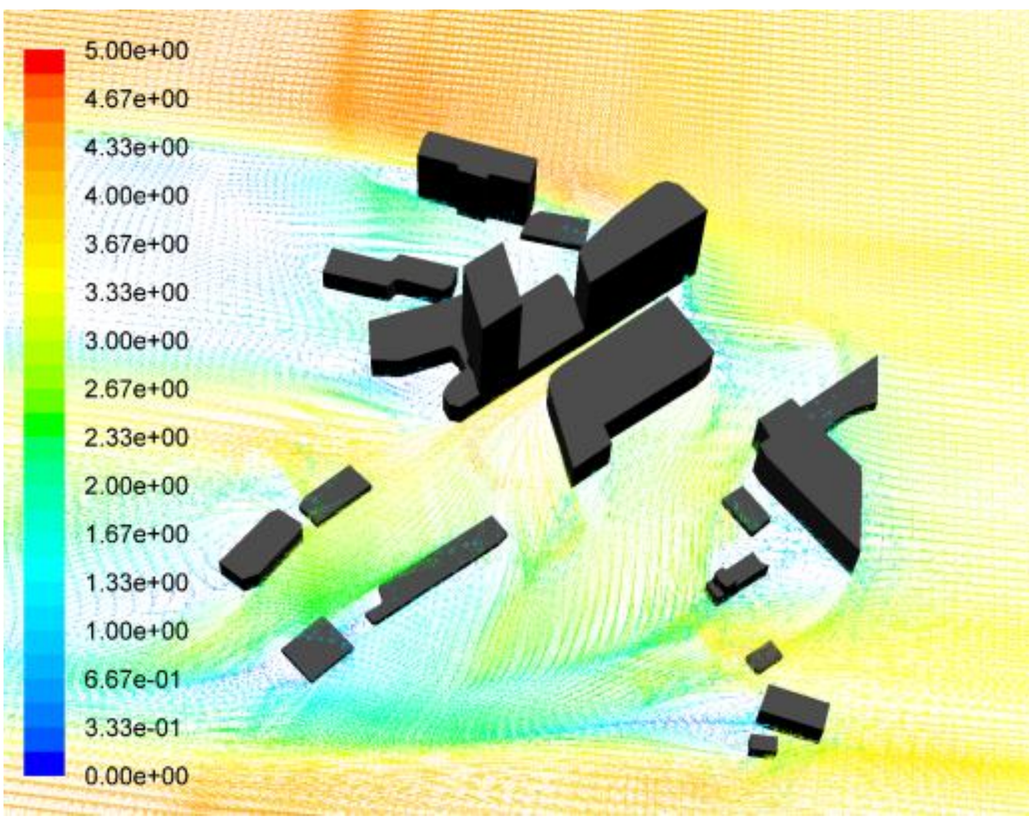
Wind direction: ENE 67.5 (Proposed case)



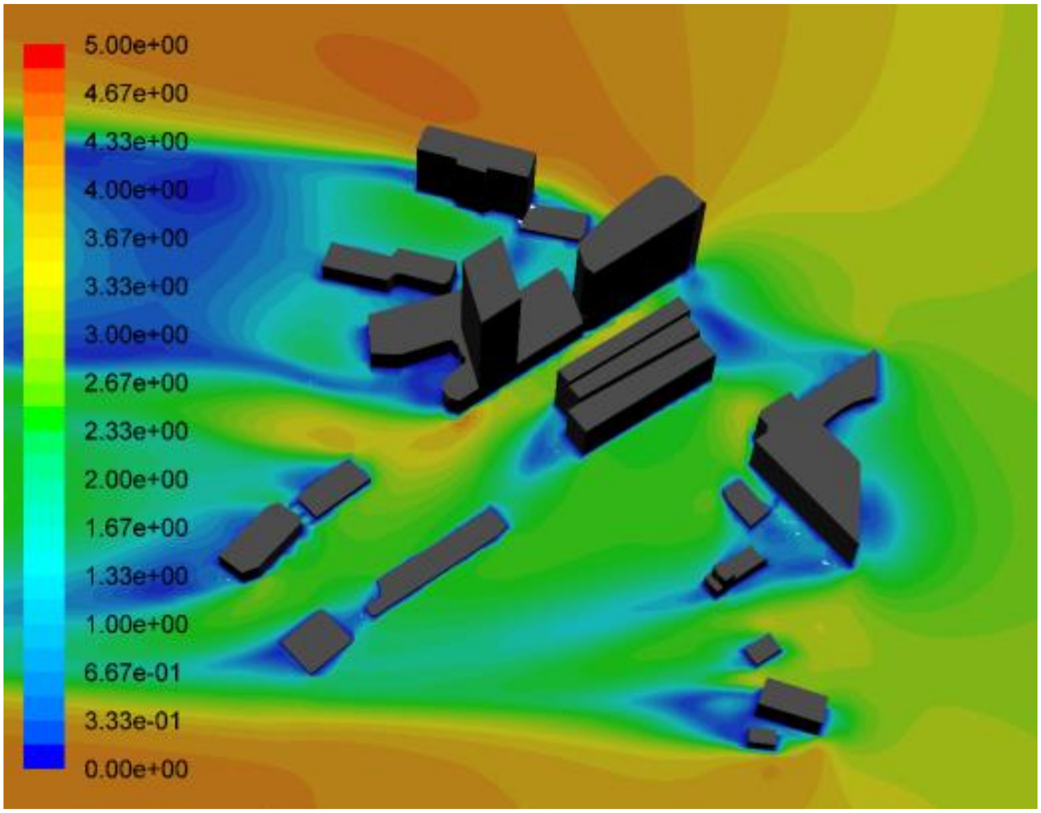


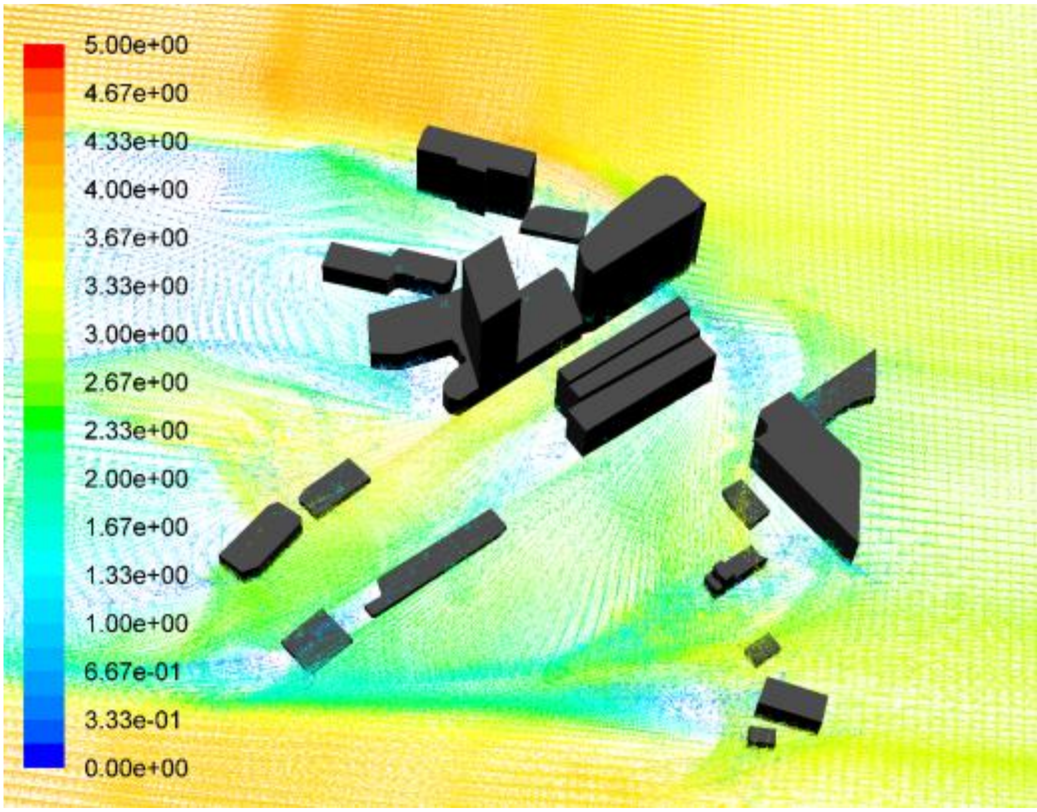
Wind direction: E 90 (Baseline case)



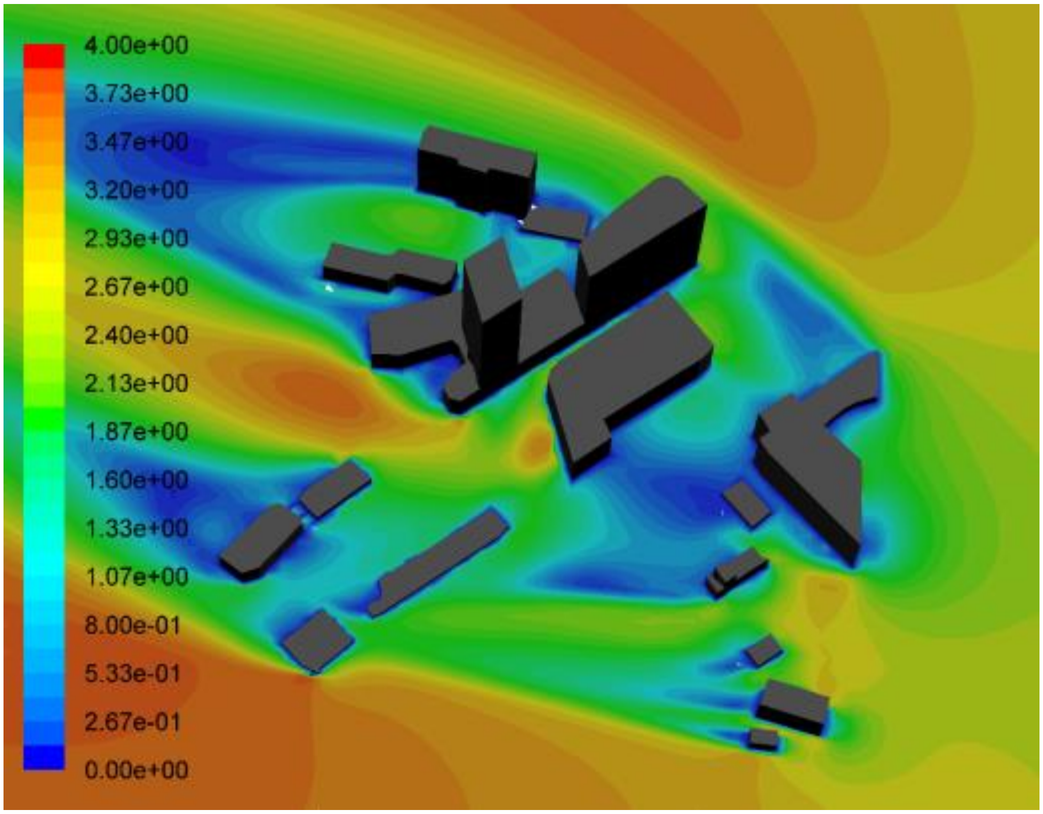


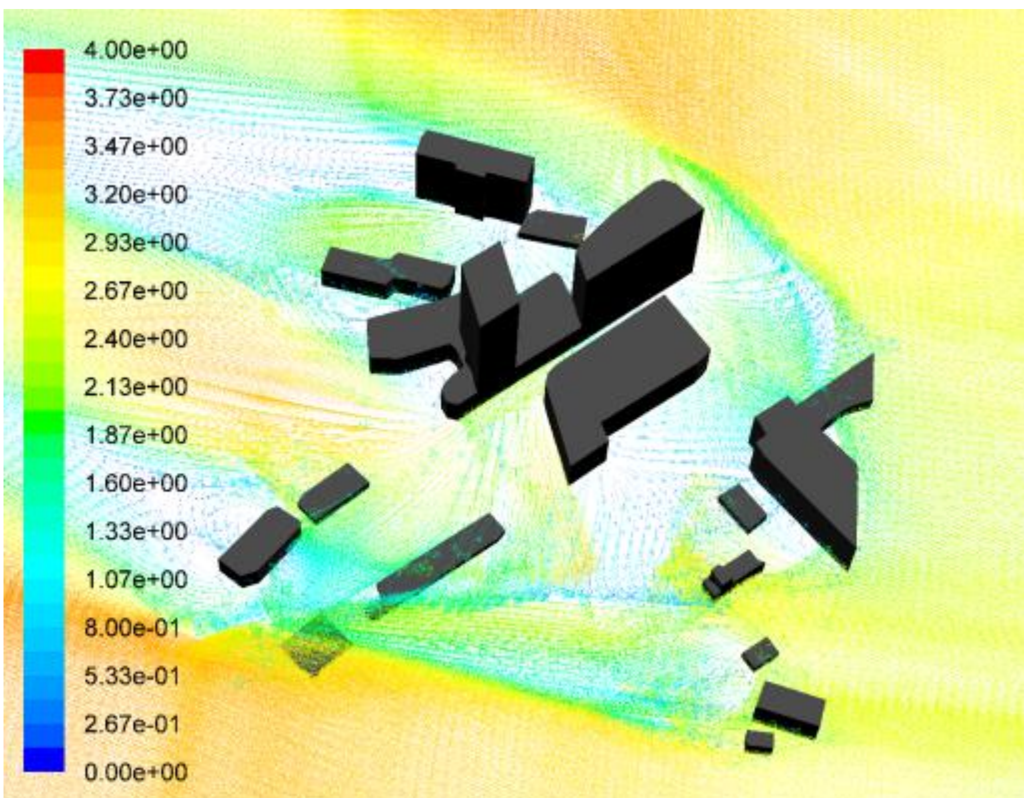
Wind direction: E 90 (Proposed case)



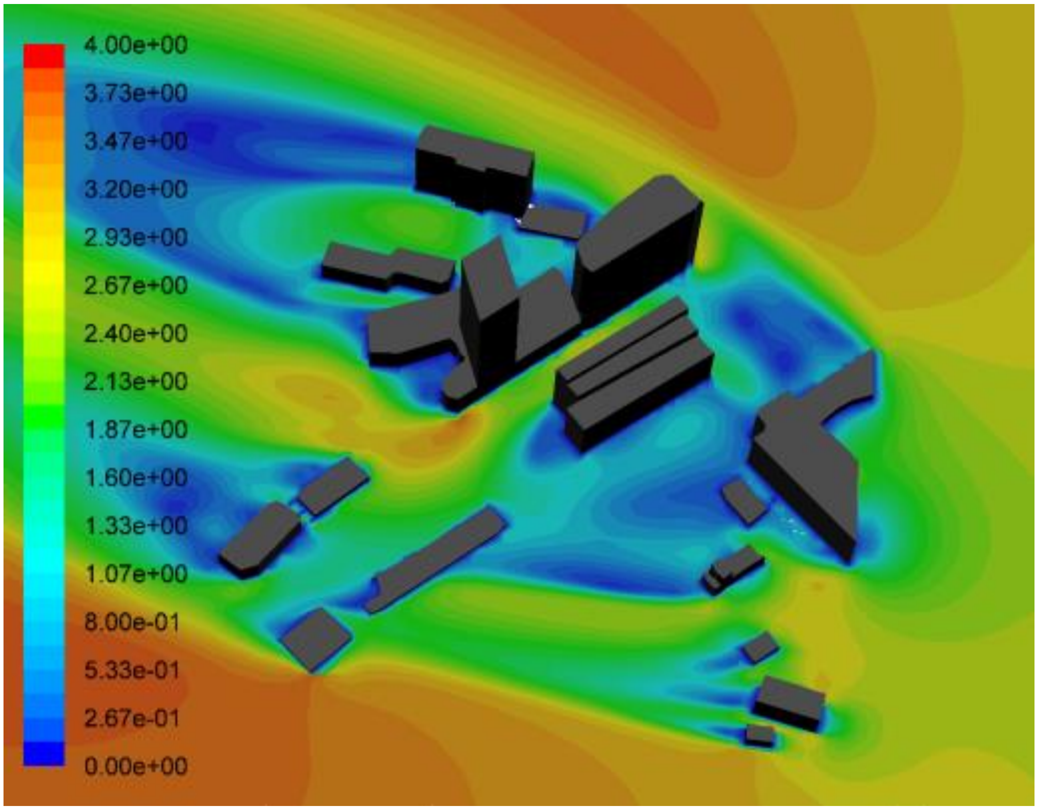


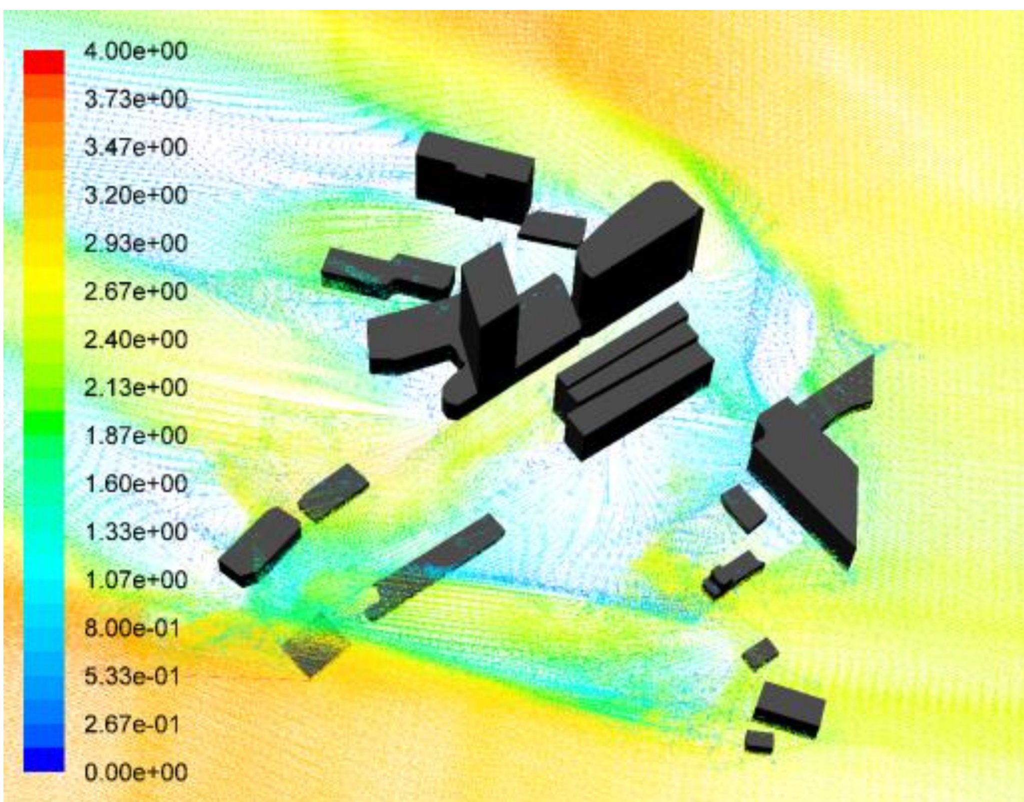
Wind direction: ESE 112.5 (Baseline case)



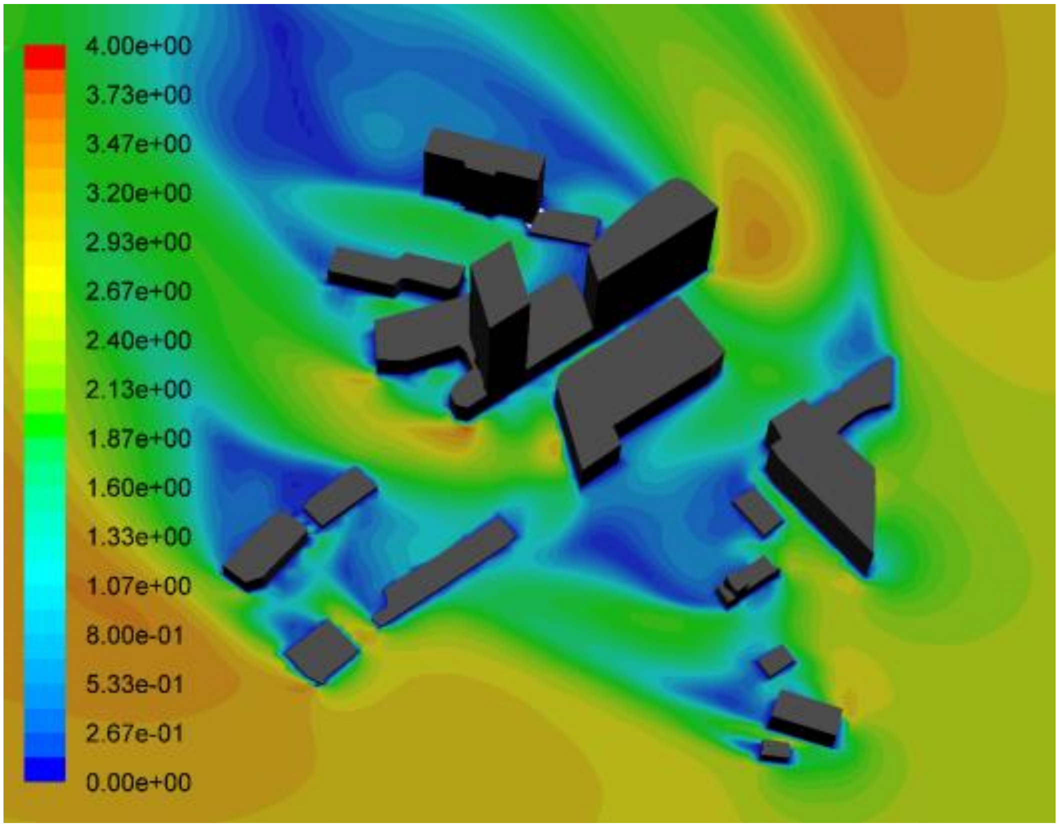


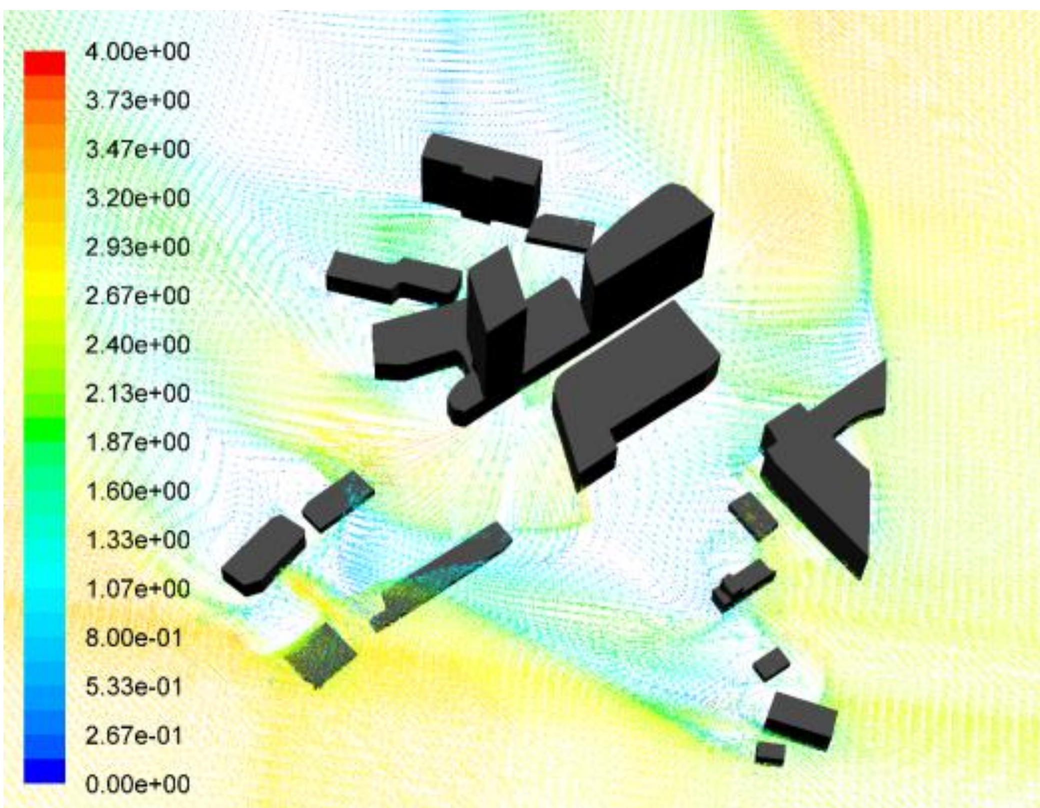
Wind direction: ESE 112.5 (Proposed case)



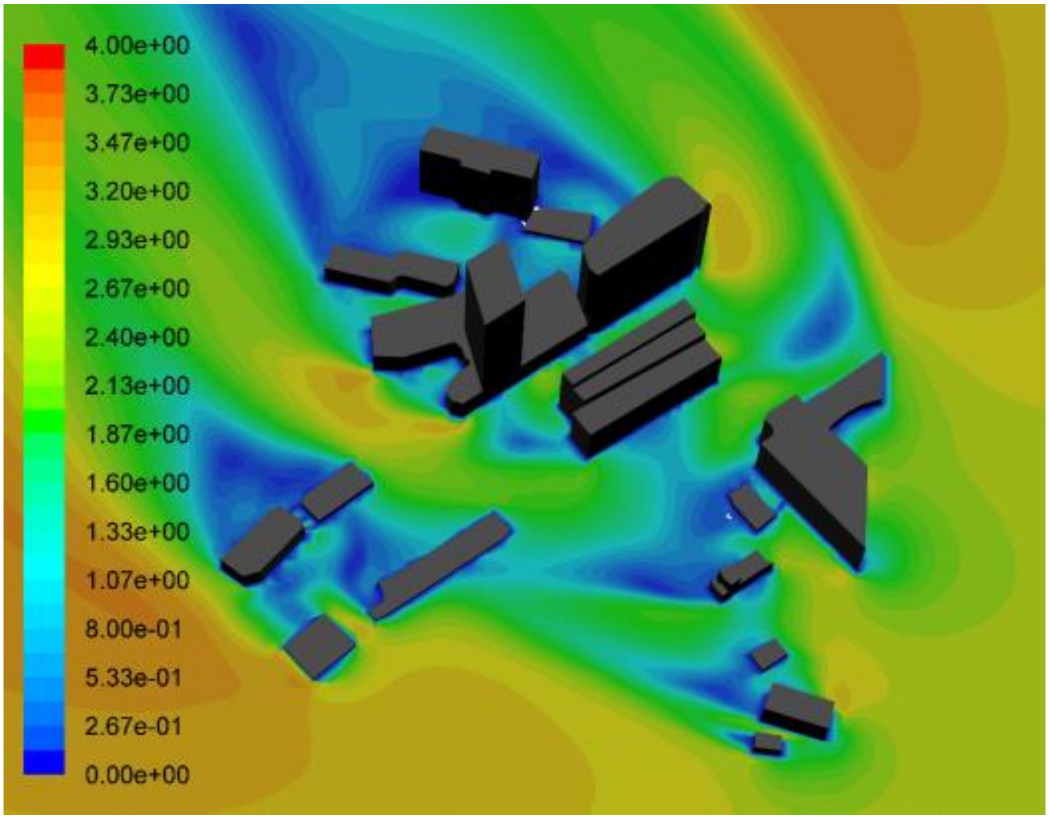


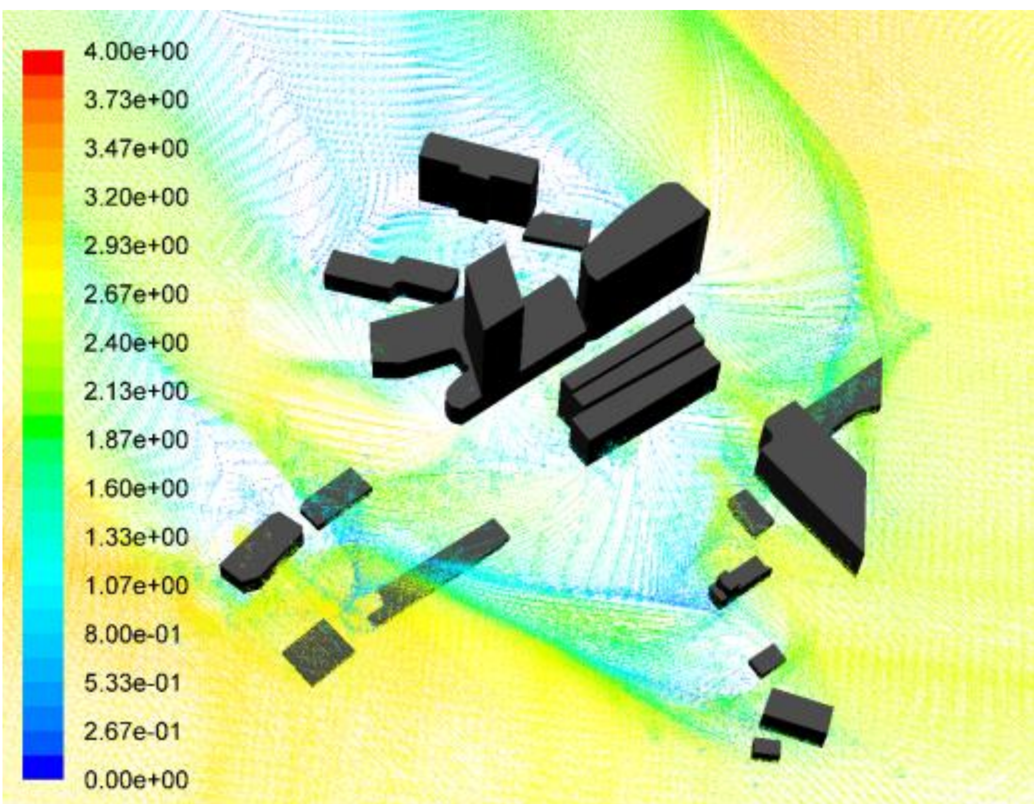
Wind direction: SE 135 (Baseline case)



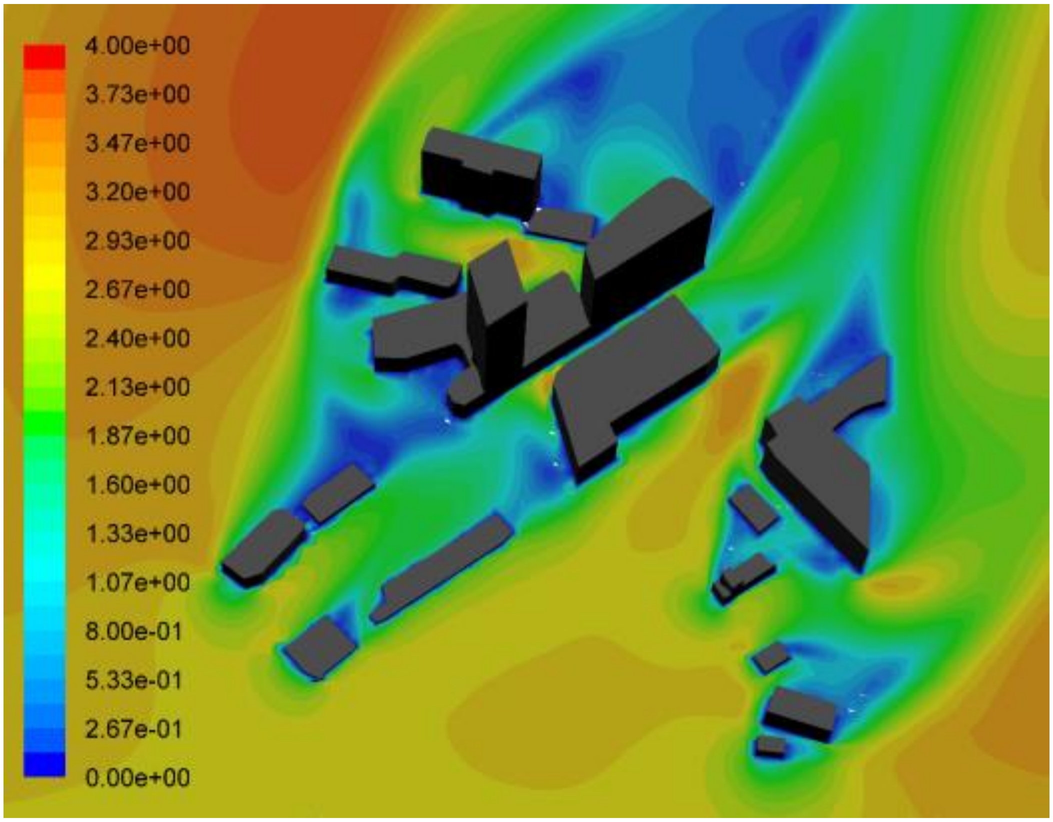


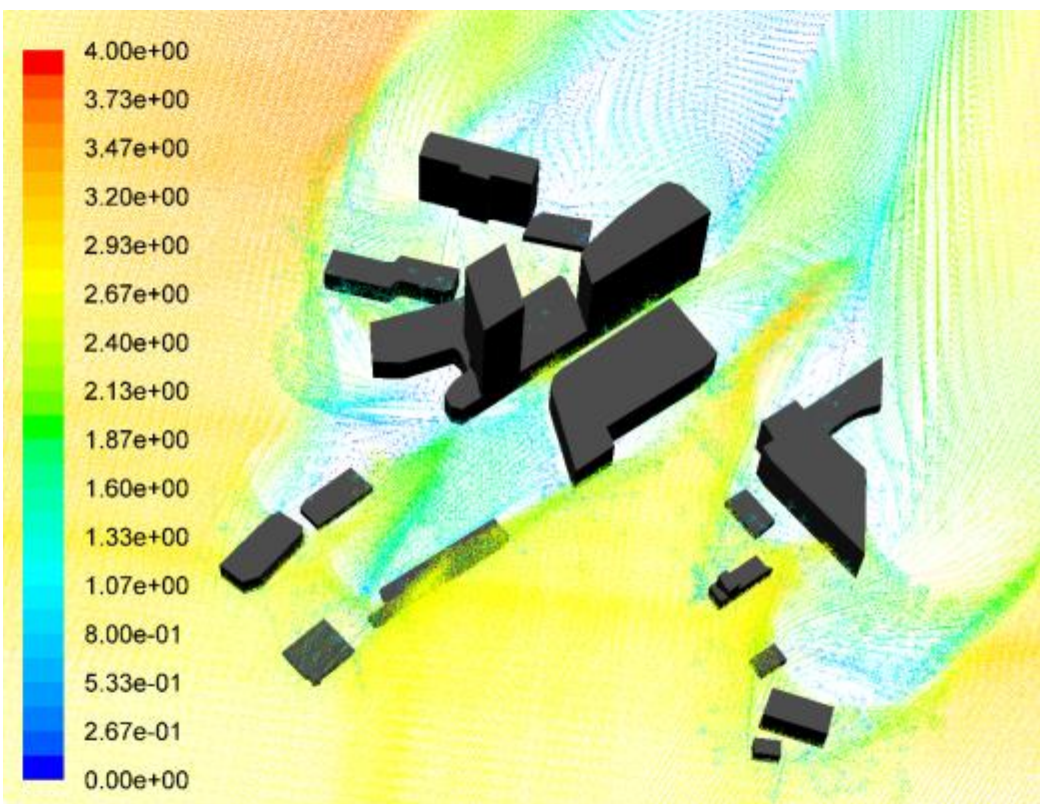
Wind direction: SE 135 (Proposed case)



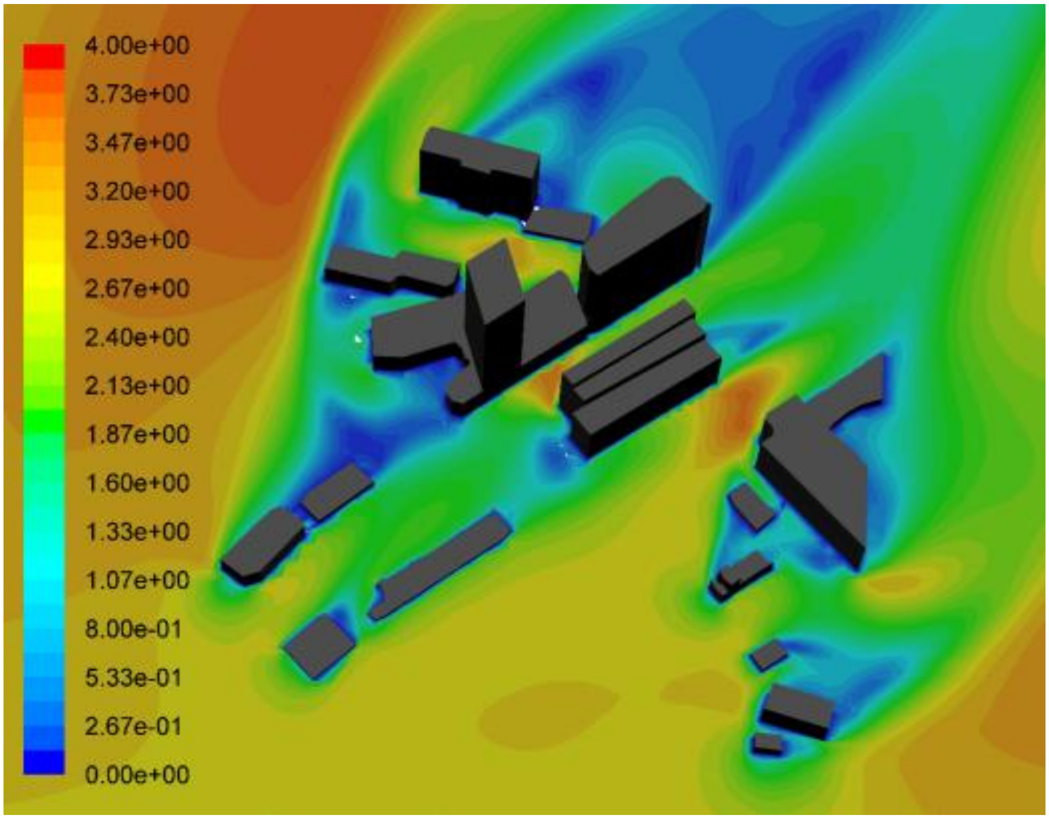


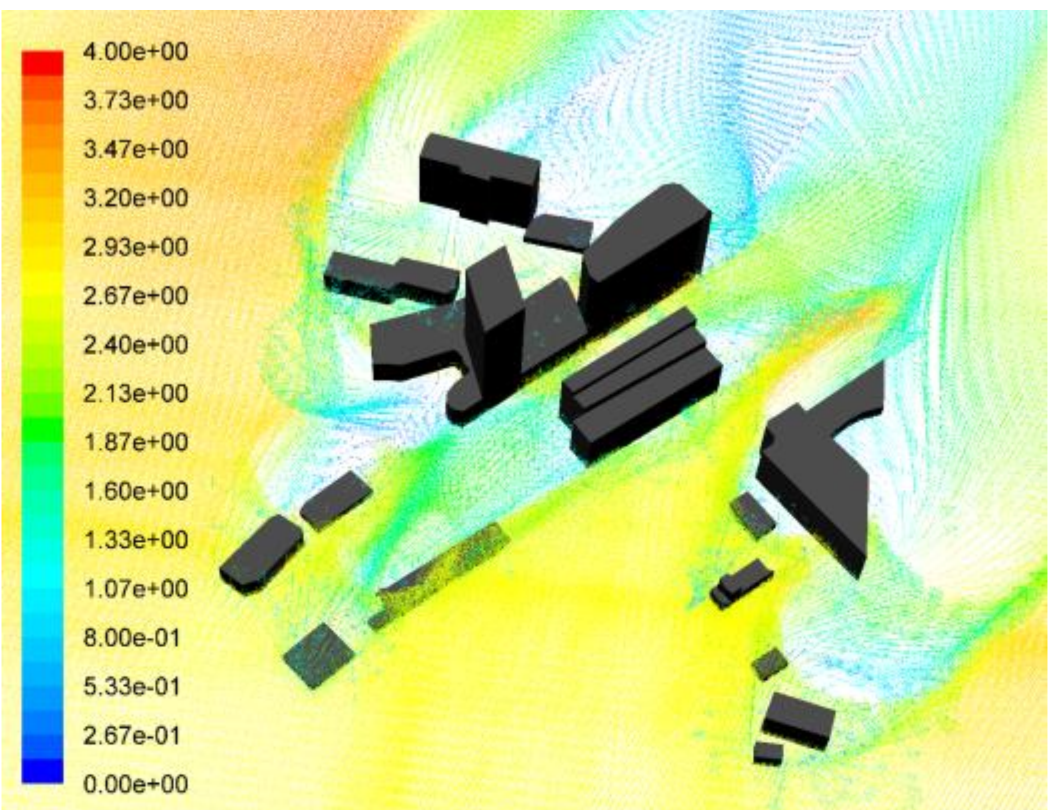
Wind direction: SSW 202.5 (Baseline case)



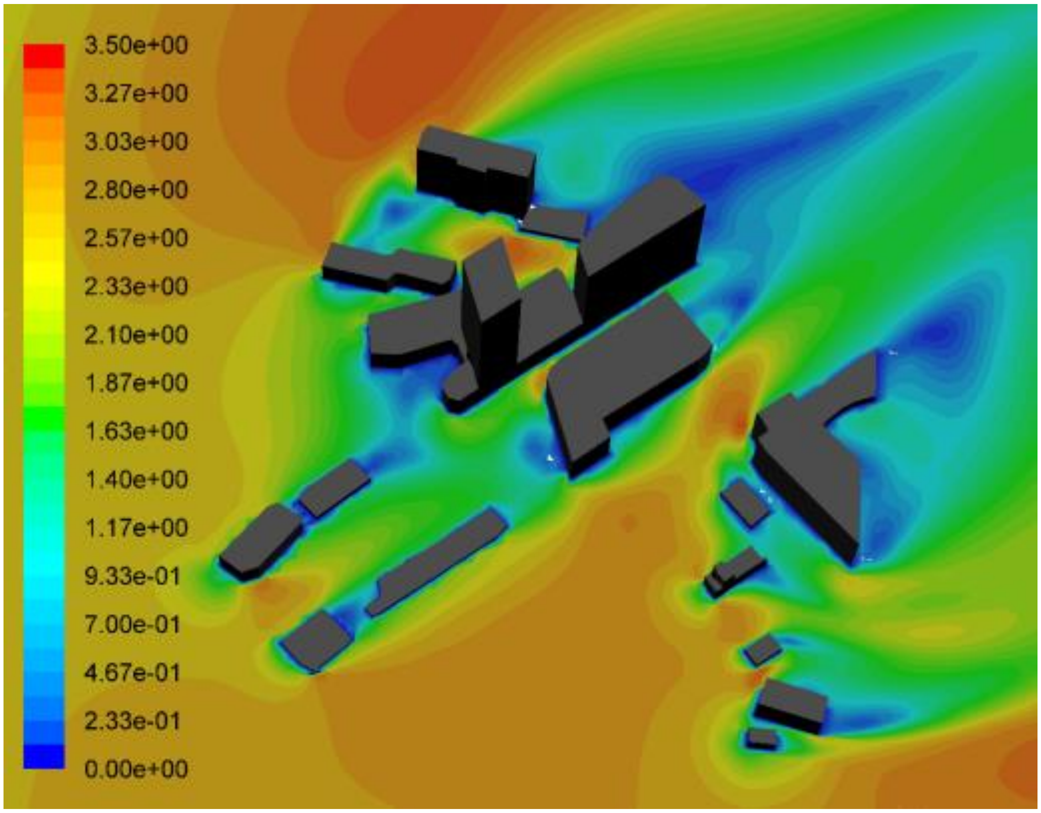


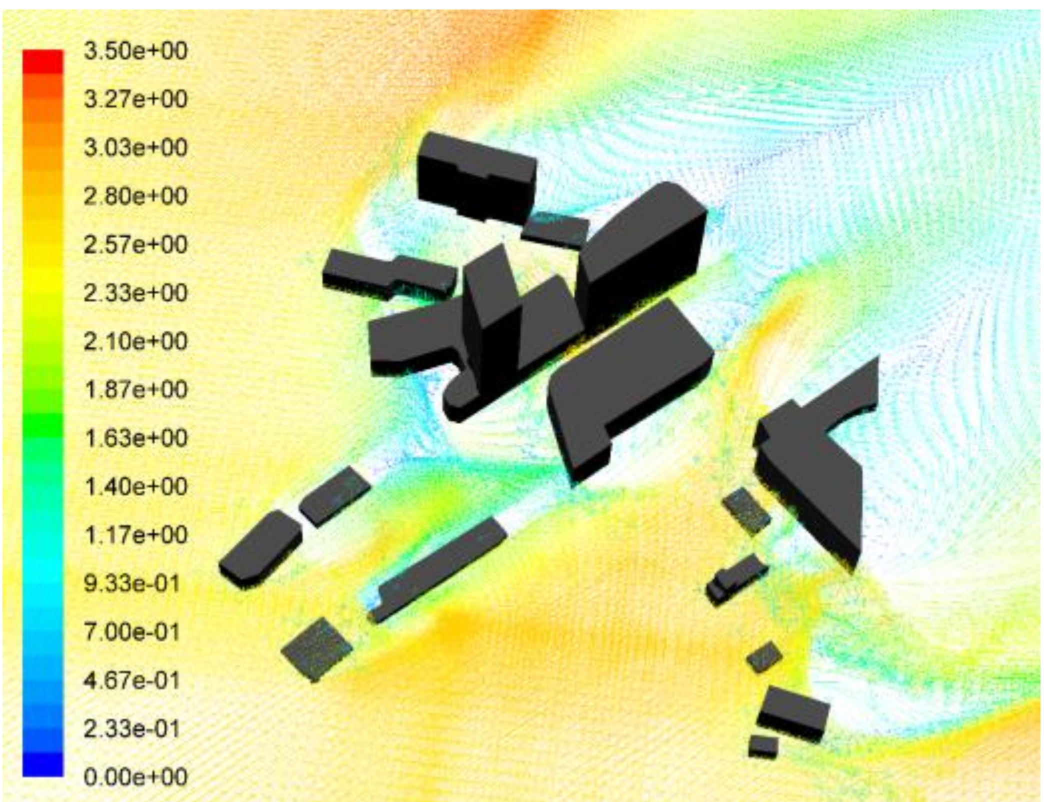
Wind direction: SSW 202.5 (Proposed case)





Wind direction: SW 225 (Baseline case)





Wind direction: SW 225 (Proposed case)