Hong Kong Housing Authority

BEAM Plus NB v1.2 SA8c Microclimate Around Building

Air Ventilation Assessment Report

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Contents

1 Introduction

1.1 Background of Study

Ove Arup & Partners Hong Kong Ltd (Arup) was appointed as the environmental consultant by Hong Kong Housing Authority (HKHA) to carry out environmental studies of the Subsidised Sale Flats Development at Texaco Road (the Development) and to provide technical reports for supporting the BEAM-Plus v1.2 Credits SA8c - Microclimate Around Building – Air Ventilation Assessment.

All the methodology in this report is following the "Technical Circular No. 1/06 on Air Ventilation Assessments" jointly issued by the Housing, Planning and Lands Bureau (HPLB) and the Environment, Transport and Works Bureau (ETWB) on 19th July 2006, which is the prevailing technical circular for AVA.

1.2 Objective of the Study

The objective of the study is to assess the possible air ventilation performance of the proposed subsidised sale flats development under baseline and proposed scenarios with different development parameters.

2 Study Area

2.1 Characteristics of Project Area and Its Surrounding Areas

The Development is surrounded by urban clusters of Tsuen Wan East and Tai Wo Hau and the hilly topography of Kwai Chung West. To the southeast of the Project Area at some distance, is the slope topographies whose maximal altitude reaches around 200mPD.

The Development is located south to the intersection of Texaco Road and Tai Wo Hau Road with SKH Crown of Thorns Church & Kindergarten adjacent to the near northwest of the project site. Other nearest residential neighbourhoods include Wang Wah Building (in north), Tai Wo Hau Estate (northeast to south, clockwise), Kwai Yung Court (southeast behind Tai Wo Hau Estate), Sheung Chui Court (south-southwest), Wealthy Garden and East Asia Gardens (northwest to north). To the southwest to west of the Development on the other side of Texaco Road are several clusters of industrial buildings, such as Po Yip Building and Hing Yip Centre.

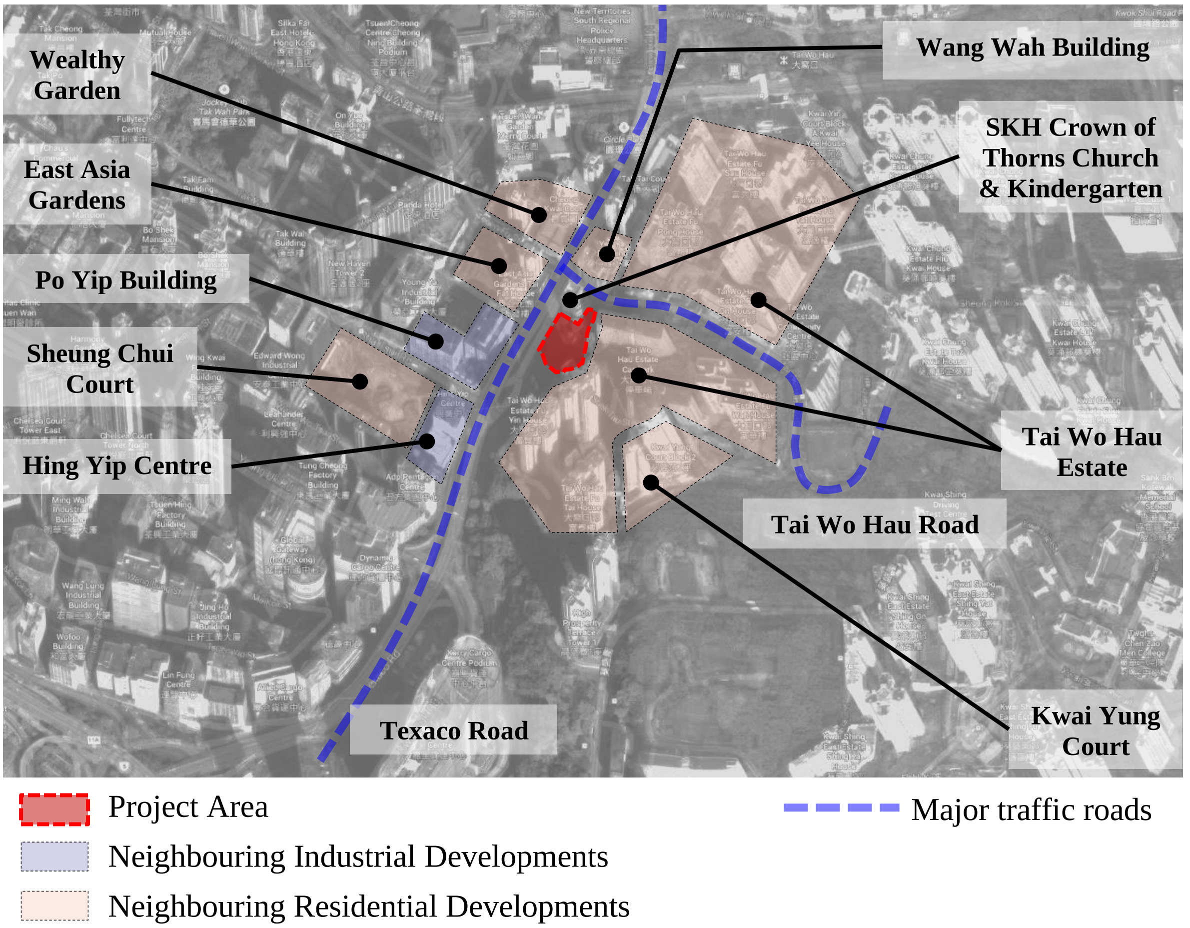


Figure 1 Location of the Project Site and its surrounding developments (Image Source: Google Map)

3 Site Wind Availability

Simulated RAMS data is adopted for the site wind availability in this study.

3.1 Wind Data from RAMS

As stipulated in the Technical Guide, the site wind availability would be presented by using appropriate mathematical models (e.g. RAMS simulation). Planning Department (PlanD) has set up a set of wind availability data of the Territory for AVA study, which could be downloaded at Planning Department Website[1].

The location of the Project Area falls within the location grid (x:069, y:53) in the RAMS information database. The wind availability data at 500mPD of location grid (x:069, y:53) is obtained to adopt in the AVA study.

The annual and summer wind roses for the study are shown in Figure 2 and Figure 3. The wind tunnel data shows that the majority of the wind comes from the northeast quarter under annual wind condition while the wind mainly comes from southeast and southwest quarter under summer wind condition.

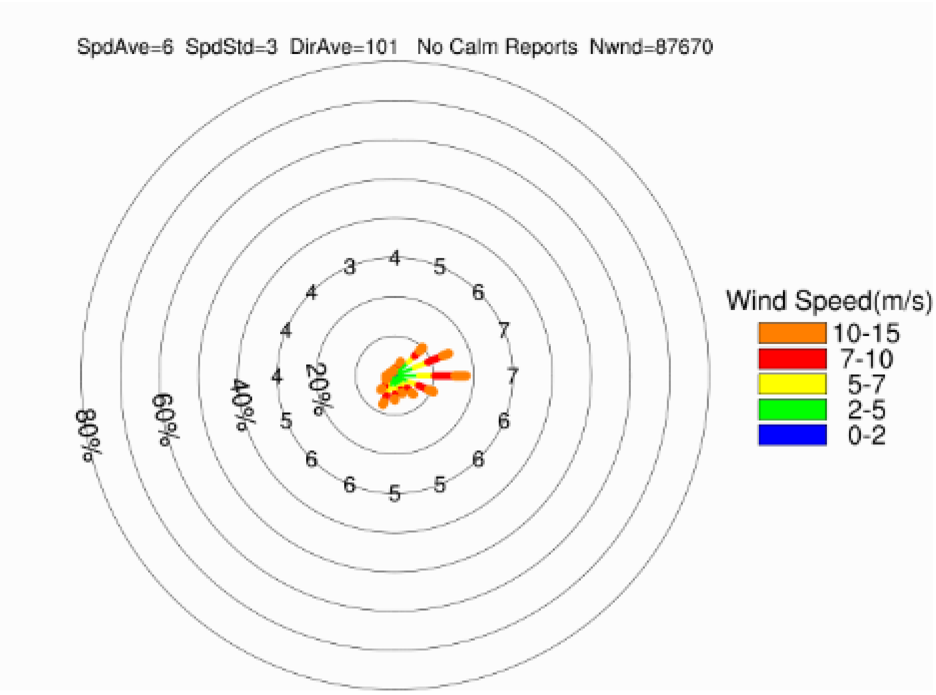


Figure 2 Wind rose for annual, non-typhoon wind

[1] http://www.pland.gov.hk/pland_en/info_serv/site_wind/site_wind/

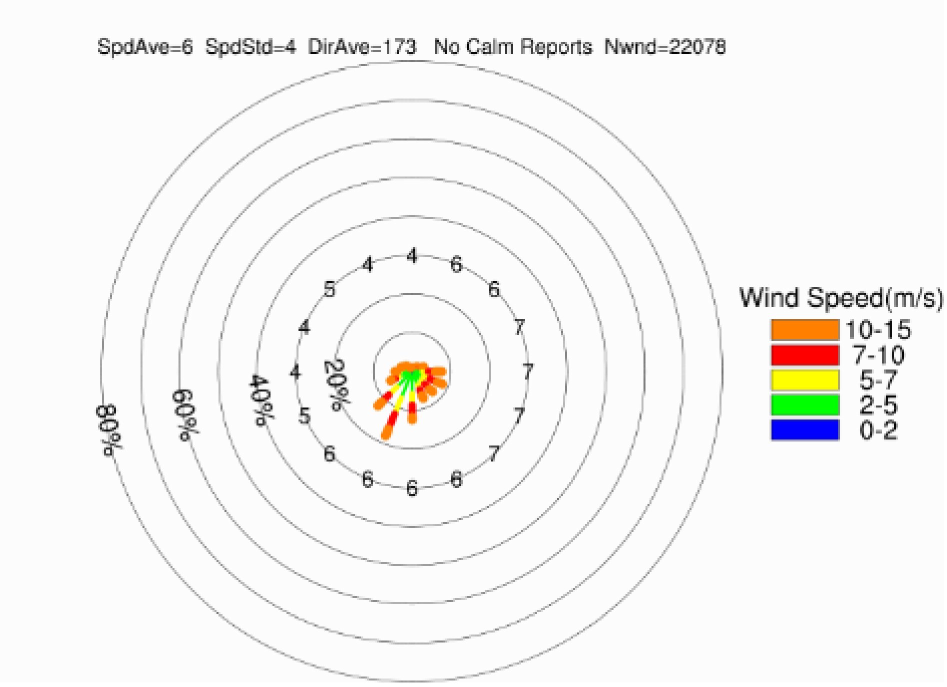


Figure 3 Wind rose for summer, non-typhoon wind

4 Qualitative Assessment of the Existing Wind Condition

With the consideration of the existing and committed developments near the Project Area, the wind environments under both annual and summer conditions are qualitatively assessed below based on the wind data presented in Section 3.

4.1 Under Annual Wind Condition

Under annual wind condition, the prevailing winds are mainly from northeast and southwest quarter. Various air paths are identified around the Project Area, such as Texaco Road Sha Tsui Road and Tai Wo Hau Road serve as major wind corridors, while Tai Ha Street, Sek Tau Street and Open Area 1 and Open Area 2 act as local air paths. The provision of the wind corridors and local air paths are interconnected together and form a network of air paths, which facilitates wind penetration to the Project Area (as shown in Figure 4).

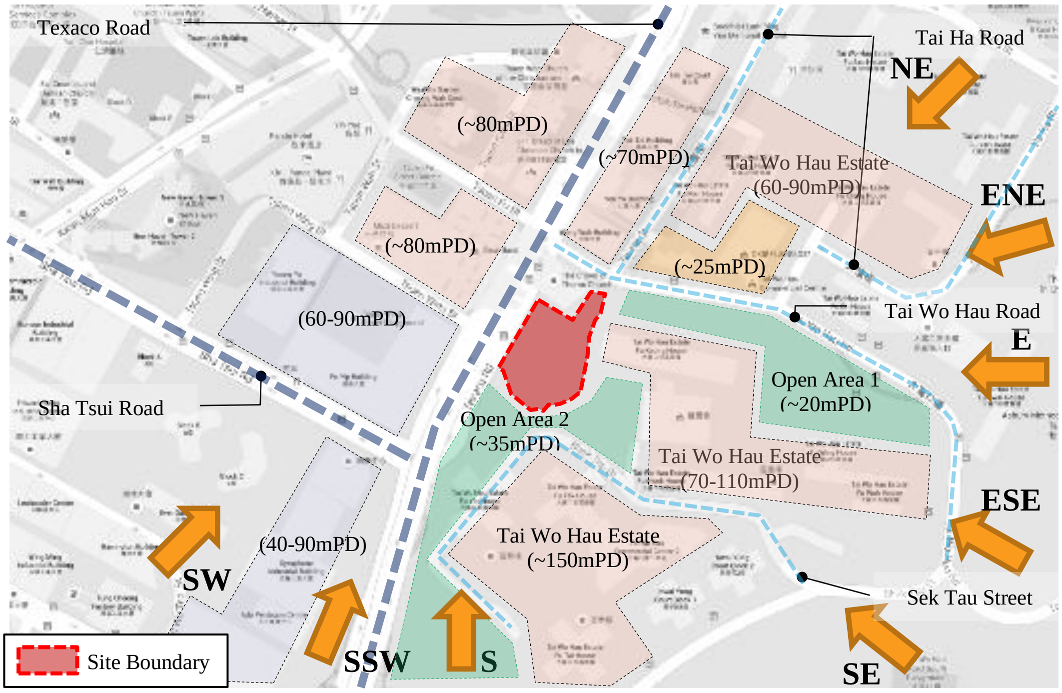


Figure 4 Wind condition under annual wind around the Project Site (image source: Google Map)

NE prevailing wind

The incoming wind would travel along Texaco Road and Tai Ha Street to reach the Project Site. The large building separations in Tai Wo Hau Estate also facilitate the NE incoming wind to reach the Project Site.

ENE and E prevailing wind

The incoming wind mostly would travel along Tai Wo Hau Road and Sek Tau Street. Open Area 1 allows the incoming wind from Tai Wo Hau Road to reach the Project Site while Open Area 2 facilitate the wind traveling along Sek Tau Street to reach the Project Site.

<u>ESE and SE prevailing wind</u>

The high rise Tai Wo Hau Estate southeast to the Project Site would shield some of the incoming wind, relatively calmer wind environment is expected. Part of the ESE and SE incoming wind would arrive the Project Site through Sek Tau Street and Open Area 2.

<u>S, SSW and SW prevailing wind</u>

The incoming winds would travel along the major wind corridor, Texaco Road, to reach the Project Site. The openness at the south provided by Open Area 2 would further facilitate the effect. For SSW and SW prevailing winds, part of the incoming wind would also travel along Sha Tsui Road to reach the Project Site.

4.2 Under Summer Wind Condition

For summer wind condition, the majority of the wind would come from southeast quarter and southwest quarter. Texaco Road and Sha Tsui Road still serve as major wind corridors and Open Area 1 and Open Area 2 are the wind entrances.

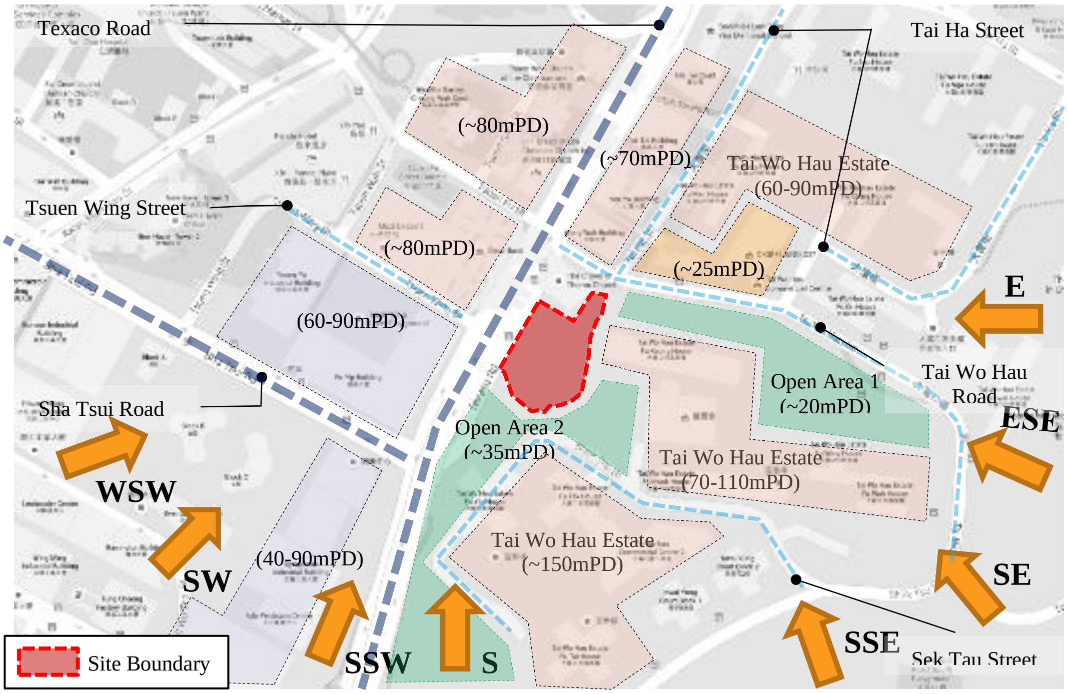


Figure 5 Wind condition under summer wind around the Project Site (image source: Google Map)

<u>E prevailing wind</u>

Similar to the previous section, the incoming wind mostly would travel along Tai Wo Hau Road and Sek Tau Street. Open Area 1 allows the incoming wind from Tai Wo Hau Road to reach the Project Site while Open Area 2 facilitate the wind traveling along Sek Tau Street to reach the Project Site.

<u>ESE and SE prevailing wind</u>

Similar to the previous section, the high rise Tai Wo Hau Estate southeast to the Project Site would shield some of the incoming wind and part of the ESE and SE incoming wind would arrive the Project Site through Sek Tau Street and Open Area 2.

SSE, S, SSW and SW prevailing wind

Similar to the previous section, the incoming winds would travel along the major wind corridor, Texaco Road, to reach the Project Site. The openness at the south provided by Open Area 2 would further facilitate the effect. For SSW and SW prevailing winds, part of the incoming wind would also travel along Sha Tsui Road to reach the Project Site.

WSW prevailing wind

Some of the incoming wind would travel along Sha Tsui Road and reach the Site at Texaco Road, and some incoming wind from Sha Tsui Road would be diverted by the industrial clusters to reach the Project Site through Tsuen Wing Street.

5 Methodology

5.1 Wind Directions and Profiles

As mentioned in Section 3, the RAMS wind data of location grid (x:69, y:53) is adopted for the site wind availability in this study.

5.1.1 Annual Prevailing Wind

Eight prevailing wind directions (highlighted in red colour in Table 1) are considered in this AVA Study which covers 80.6% of the total annual wind frequency. They are north-easterly (10.2%), east-north-easterly (15.1%), easterly (18.4%), east-south-easterly (10.8%), south-easterly (6.7%), southerly (6.2%), south-south-westerly (8.0%) and south-westerly (5.0%) winds.

Table 1 Annual Wind Frequency of the Wind Directions Considered in this Study

Wind Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	
Frequency	1.8%	4.0%	10.2%	15.1%	18.4%	10.8%	6.7%	4.9%	
Wind Direction	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
Frequency	6.2%	8.0%	5.0%	2.4%	2.3%	1.5%	1.3%	1.2%	80.4%

** The wind frequency showing in red colour represents the recommended wind direction for the CFD simulation.*

5.1.2 Summer Prevailing Wind

Eight prevailing wind directions (highlighted in red colour in Table 2) are considered in this AVA Study which covers 81.4% of the total summer wind frequency. They are east (8.0%), east-south-easterly (8.7%), south-easterly (7.6%), south-south-easterly (7.5%), southerly (12.7%), south-south-westerly (18.2%), south-westerly (20.7%) and west-south-westerly (5.7%) winds.

Table 2 Summer Wind Frequency of the Wind Directions Considered in this Study

Wind Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	
Frequency	1.0%	1.2%	1.8%	3.4%	8.0%	8.7%	7.6%	7.5%	
Wind Direction	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
Frequency	12.7%	18.2%	12.6%	6.1%	4.5%	3.1%	2.2%	1.1%	81.4%

** The wind frequency showing in red colour represents the recommended wind direction for the CFD simulation.*

5.1.3 Wind Profiles

The vertical discretization of the velocity profile was already approximated by a function of ground roughness and vertical height in the meso-scale modelling of RAMS data. There are 4 groups of data representing 4 quarters of all wind directions.

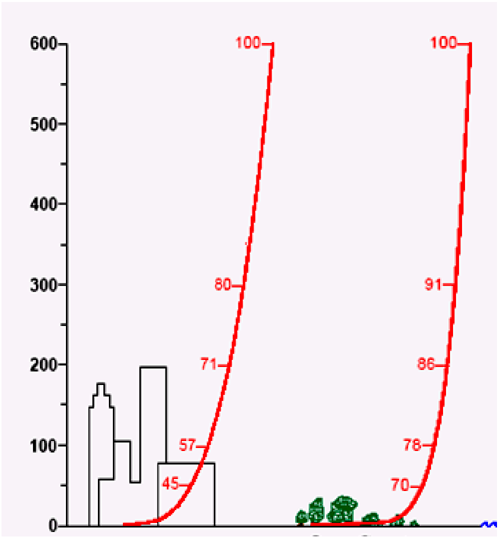


Figure 6 Example of the various wind profiles against different topographies

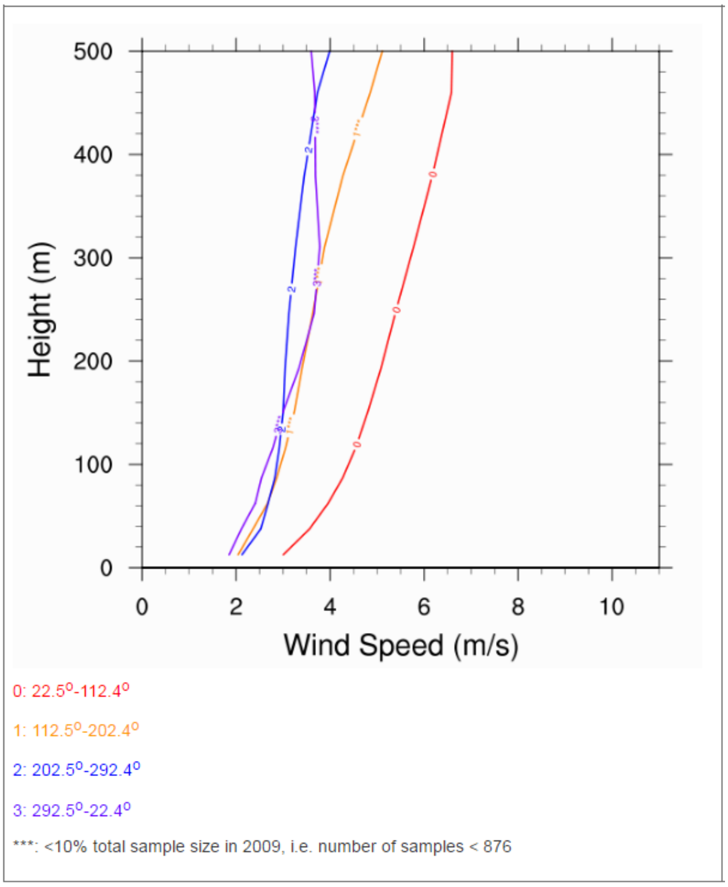


Figure 7 RAMS wind profiles for the location grid (x:069, y:053)

5.2 Technical Details of CFD Simulations

The AVA methodology as stipulated in the Technical Circular and Technical Guide is used for this study. The following sections describe the details of the study methodology.

5.2.1 Project Assessment and Surrounding Areas

With reference to the Technical Guide, the areas of evaluation and assessment should include all area within the Project Area, as well as a belt up to 1H, where H is the height of the tallest building of the Proposed Development, around the site boundary.

Under the two development scenarios, the tallest building of the potential development is around H≈135m. Notwithstanding, in order to capture a more representative wind profile of the surrounding area of the Project Site, the Surrounding Area are proposed to extend beyond 2H from the Project Site Boundary. High rise industrial development such as Kerry Cargo Centre, Dynamic Cargo Centre and high rise residential development Tai Kwai Tin Court, are thus included into the model. The neighbouring elevated structures, Texaco Road Flyover are also modelled in the study. The Assessment and Surrounding Areas are indicated in Figure 8, and the modelled elevated structures for the study are shown in Figure 9.

The model takes information of the surrounding buildings and site topography provided by Planning Department. The size of the CFD model for this Study is approximately 2700m (L) x 2700m (W) x 1600m (H) as shown in Figure 8.

Figure 8 Project Area, Assessment Area, Surrounding Area and Computational Domain for the Study

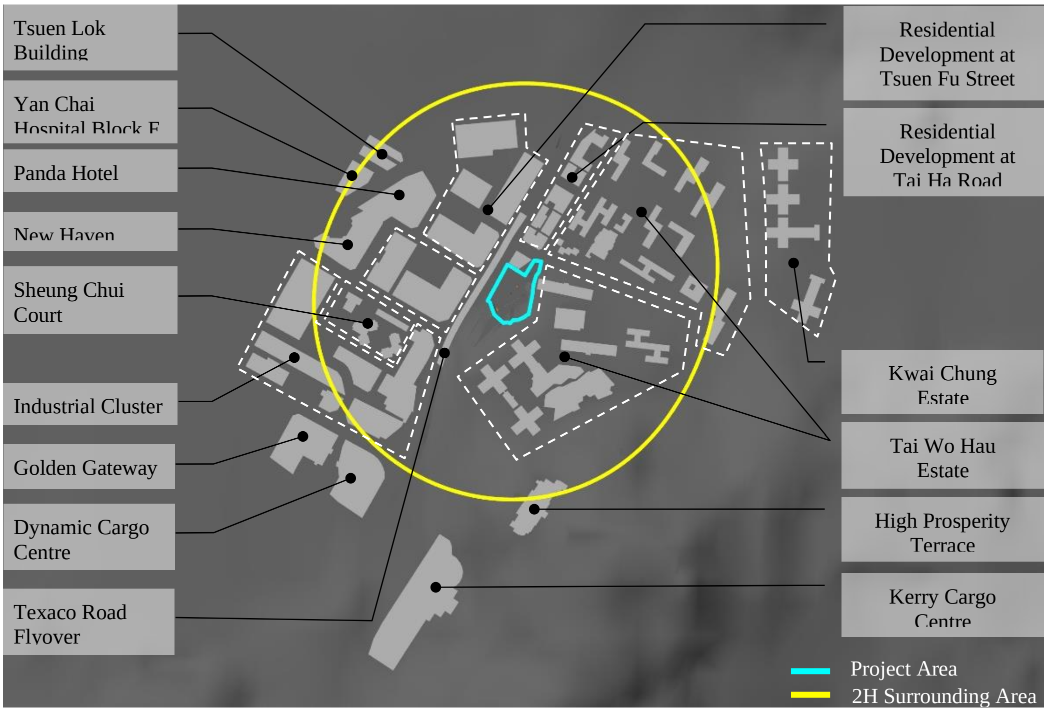


Figure 9 Modelled Elevated Structures and Surroundings

5.2.2 Assessment Tool

Computational Fluid Dynamics (CFD) technique is utilized for the AVA Initial Study. Well recognised commercial CFD packages ANSYS ICEM-CFD and STAR-CCM+ are used, where both software are widely used in the industry for AVA studies. With the use of three-dimensional CFD method, the local airflow distribution can be visualised in detail. The air velocity distribution within the flow domain, being affected by the site-specific design and the surrounding buildings, is simulated under the prevailing wind conditions in a year.

5.2.3 Mesh Setup

Body-fitted unstructured grid technique is used to fit the geometry to reflect the complexity of the development geometry. A prism layer of 3m above ground (totally 6 layers and each layer is 0.5m) is incorporated in the meshing so as to better capture the approaching wind. The expansion ratio is 1.3 while the maximum blockage ratio is 3%.

Finer grid system is applied to the most concerned area based on preliminary judgement, while coarse grid system is applied to the area of surrounding buildings for better computational performance while maintaining satisfactory result.

5.2.4 Turbulence Model

As highlighted in recent academic and industrial research literatures by CFD practitioners, the widely used standard k - ε turbulence model technique may not adequately model the effects of large scale turbulence around buildings and ignores the wind gusts leading to the relatively poor prediction in the recirculation regions around building. Therefore in this CFD simulation, realizable $k - \varepsilon$ turbulence modelling method is applied. This technique provides more accurate representation of the levels of turbulence that can be expected in an urban environment.

5.2.5 Calculation Method

The Segregated Flow model solves the flow equations in a segregated manner. The linkage between the momentum and continuity equations adopted the predictor-corrector approach. A collocated variable arrangement and a Rhie-and-Chow-type pressure-velocity coupling combined with a SIMPLE-type algorithm. A higher order differencing scheme is applied to discretize the governing equations. The convergence criterion is set to 0.0005 on mass conservation. The calculation will repeat until the solution satisfies this convergence criterion.

The prevailing wind direction as mentioned in Section 5.1.1 and Section 5.1.2 are set to inlet boundary of the model with wind profile as detailed in Section 0. The downwind boundary is set to pressure with value of atmospheric pressure. The top and side boundaries are set to symmetry. In addition, to eliminate the boundary effects, the model domain is built beyond the Surrounding Area as required in the Technical Circular.

5.2.6 Summary

Based on previous sections, the detail parameters are summarized below.

	CFD Model
Physical Model Scale	Real model, 1:1 scale
Model details	Only include Topography, Buildings blocks, Streets/Highways, no landscape is included
Domain	2700m(L) x 2700m(W) x 1600m(H)
Assessment Area	Up to 280m from the Project Area
Surrounding building Area	Up to 560m from the Project Area
Grid Expansion Ratio	The grid should satisfy the grid resolution requirement with maximum expansion ratio = 1.3
Prismatic layer	Prism layer must cover pedestrian level at least 3m, spacing recommend 0.5m for the first 3m above ground level
Inflow boundary Condition	Incoming wind profile approximated as described in Section
Outflow boundary	Pressure boundary condition with dynamic pressure equal to zero
Wall boundary condition	Logarithmic law boundary
Solving algorithms	Rhie and Chow SIMPLE for momentum equation Hybrid model for all other equations
Blockage ratio	< 3%
Convergence criteria	Below 0.5×10^{-3}

5.3 AVA Indicator

The Wind Velocity Ratio (VR) as proposed by the Technical Circular was employed to assess the ventilation performances of the Proposed Development and surrounding environment. Higher VR implies better ventilation. The calculation of VR is given by the following formula:

$$VR = \frac{V_p}{V_\infty}$$

V_∞= the wind velocity at the top of the wind boundary layer (assumed to be the mean wind speed of the approaching wind flow measured at an elevation equivalent to 500mPD in this study).

V_P= the wind velocity at the pedestrian level (2m above ground) after taking into account the effects of buildings.

The higher the value of VR, the less is the impact due to buildings on wind availability.

The Average VR is defined as the weighted average VR with respect to the percentage of occurrence of all considered wind directions. This gives a general idea of the ventilation performance at the considered location at both annual and summer wind condition.

5.3.1 Assessment Parameter

CFD simulations were conducted to study the wind environment. As specified in the Technical Circular, indicator of ventilation performance should be the VR, defined as the ratio of the wind velocity at the pedestrian level (2m above ground) to the wind velocity at the top of the wind boundary layer. Site spatial average velocity ratio (SVR) and a Local spatial average velocity ratio (LVR) should be determined.

Table 3 Terminology of the AVA Initial Study

Terminology	Description
Velocity Ratio (VR)	The velocity ratio (VR) represents the ratio of the air velocity at the measurement position to the value at the reference points.
Site spatial average velocity ratio (SVR)	The SVR represent the average VR of all perimeter test points at the site boundary which identified in the report.
Local spatial average velocity ratio (LVR)	The LVR represent the average VR of all points, i.e. perimeter and overall test points at the site boundary which identified in the report.

5.4 Studied Scenarios

In this study, there are two scenarios – namely Baseline Scenario, Proposed Scenario.

5.4.1 Baseline Scenario

Baseline Scenario presents a residential development at a site area of about 4,626 m^2 and maximum building height of 135 mPD. The building is in a L-shape. The three-dimensional model of Baseline Scenario is shown in Figure 11 to Figure 14.

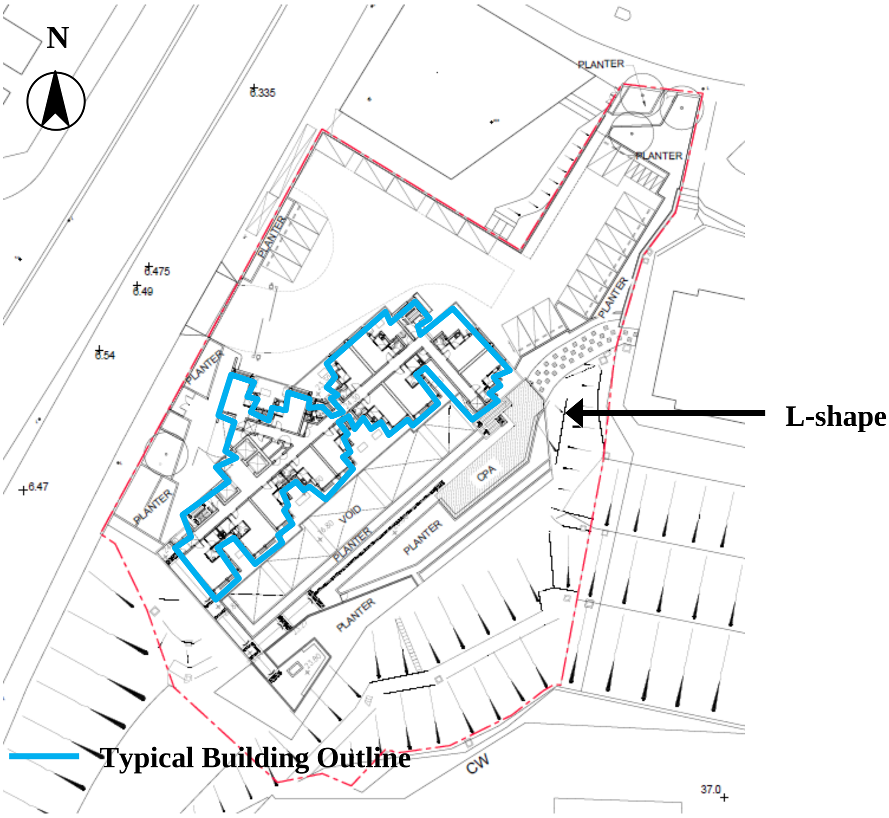


Figure 10 Building Layout of Baseline Scenario

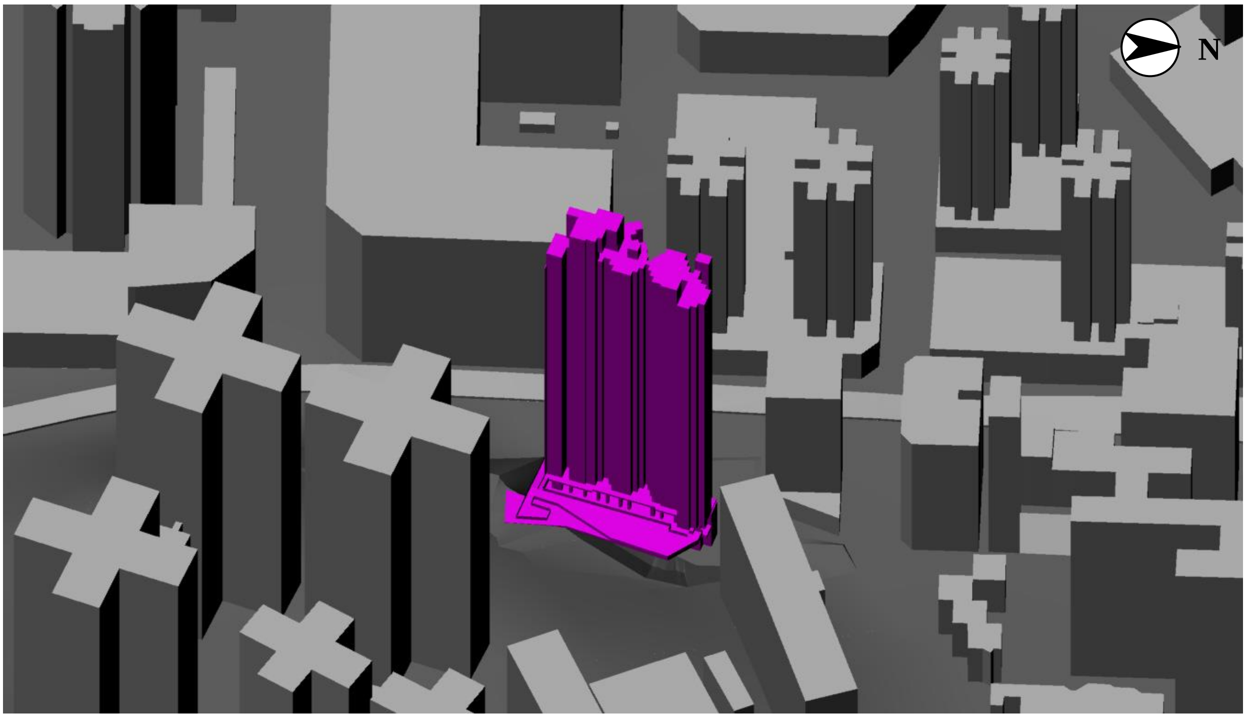


Figure 11 Model of Baseline Scenario, Easterly View

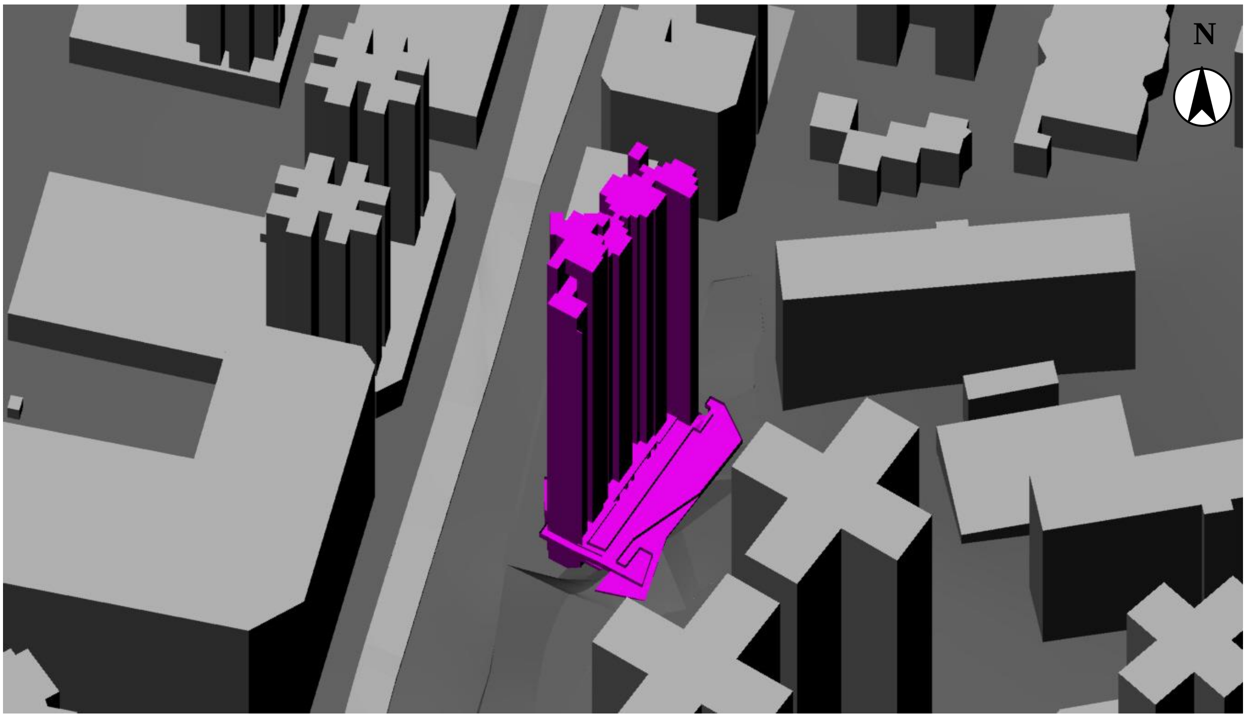


Figure 12 Model of Baseline Scenario, Southerly View

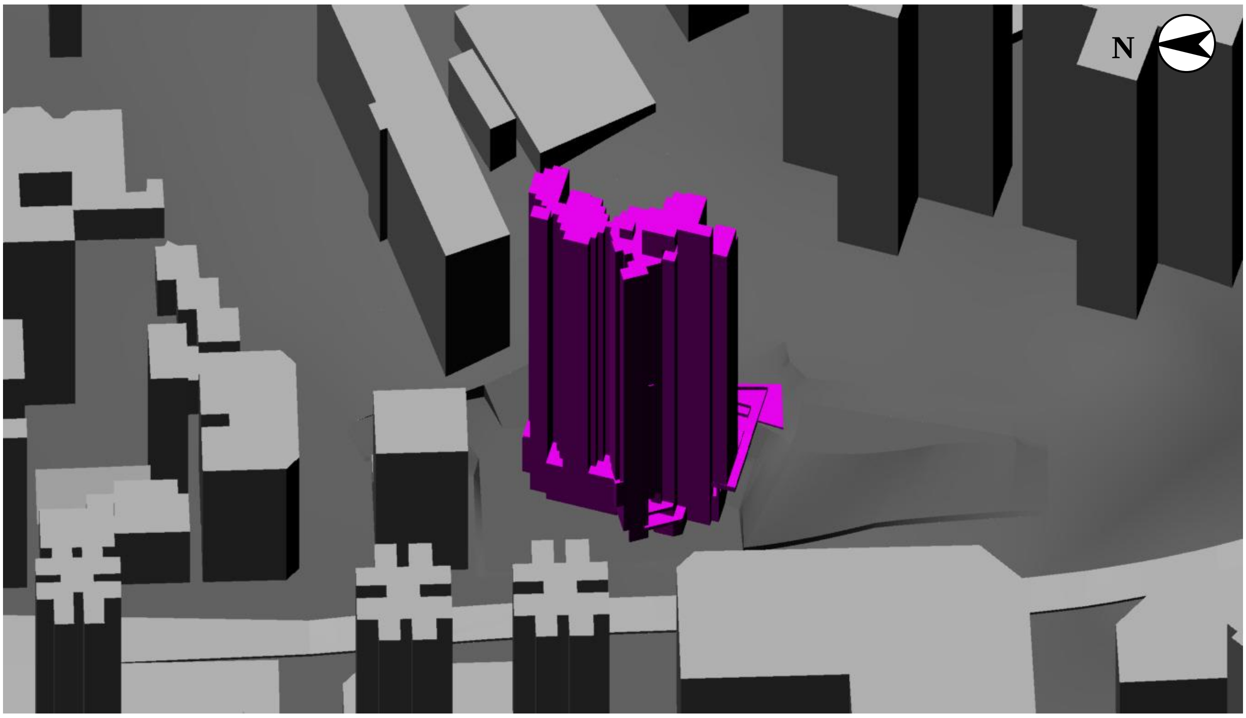


Figure 13 Model of Baseline Scenario, Westerly View

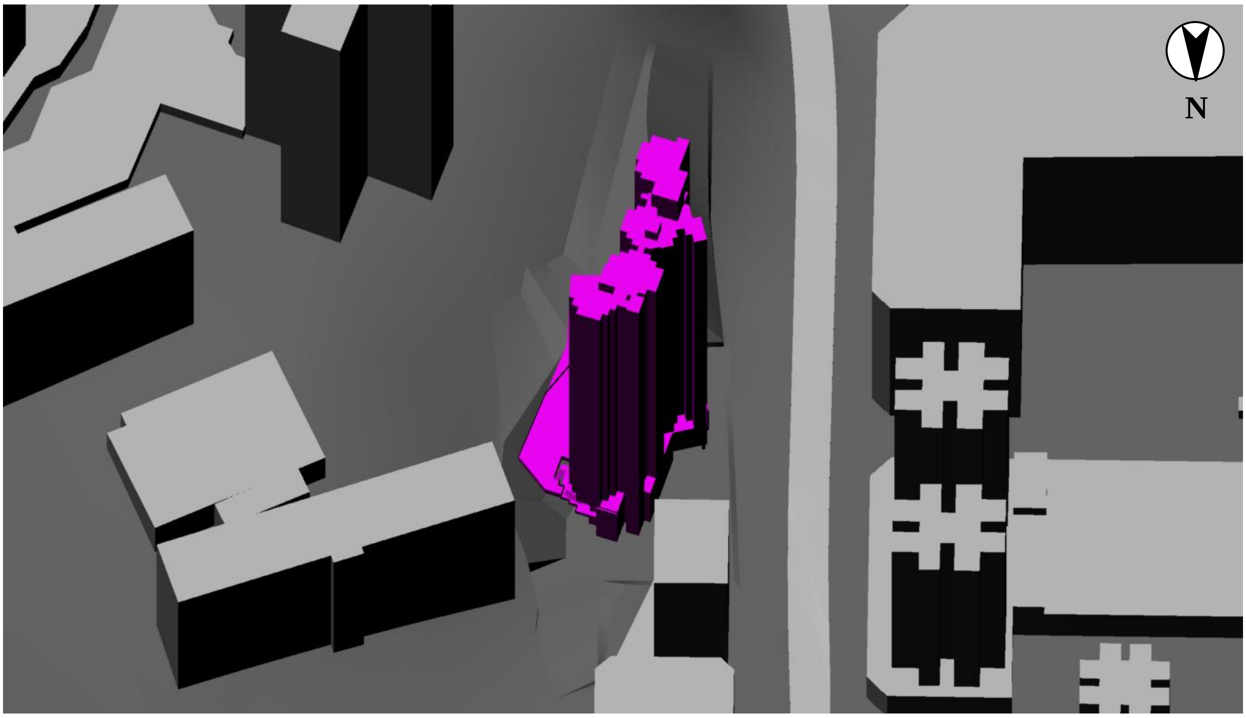
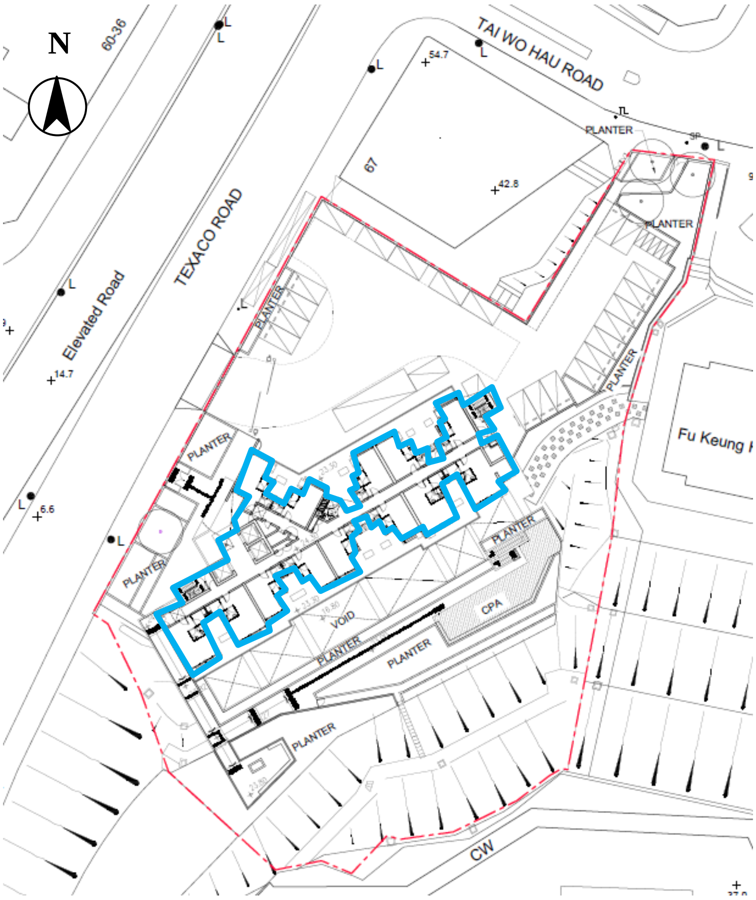


Figure 14 Model of Baseline Scenario, Northerly View

5.4.2 Proposed Scenario

Proposed Scenario presents a residential development at the identical site area of about 4,626 m^2 and maximum building height of 135 mPD. The building is slightly oriented to the east while two flats are relocated. The three-dimensional model of Proposed Scenario is shown in Figure 16 to Figure 19.



Typical Building Outline

Figure 15 Building Layout of Proposed Scenario

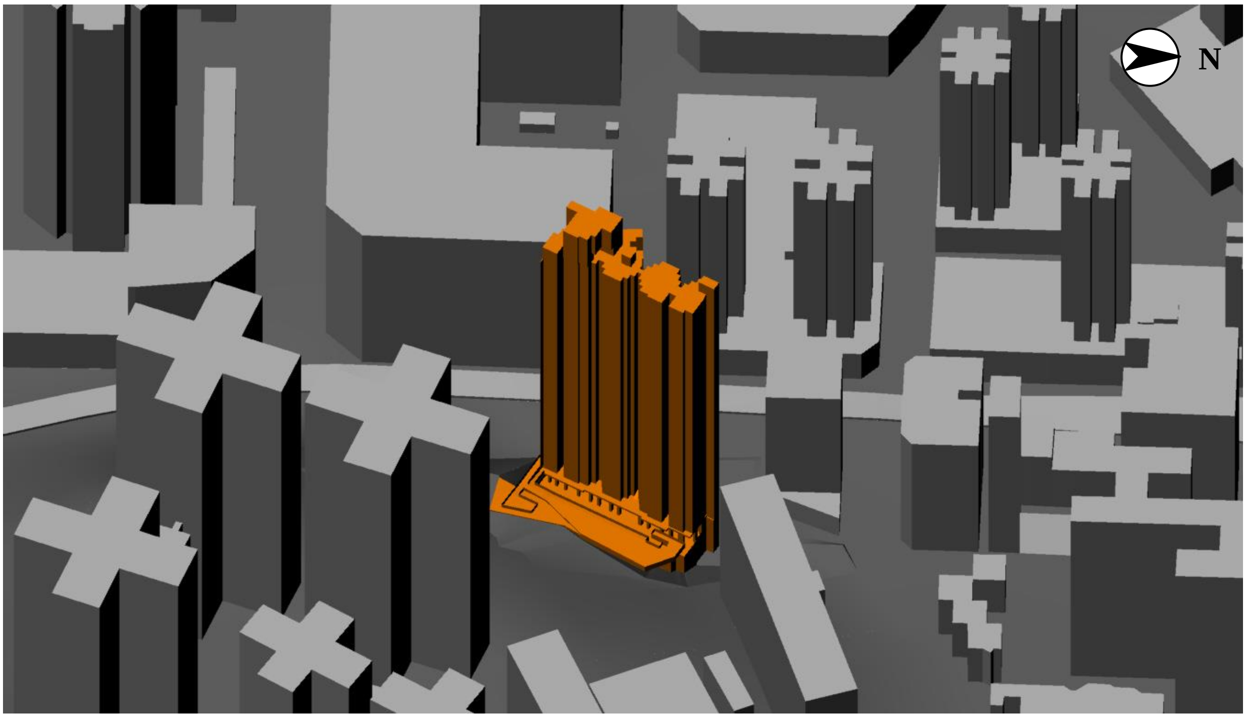


Figure 16 Model of Proposed Scenario, Easterly View

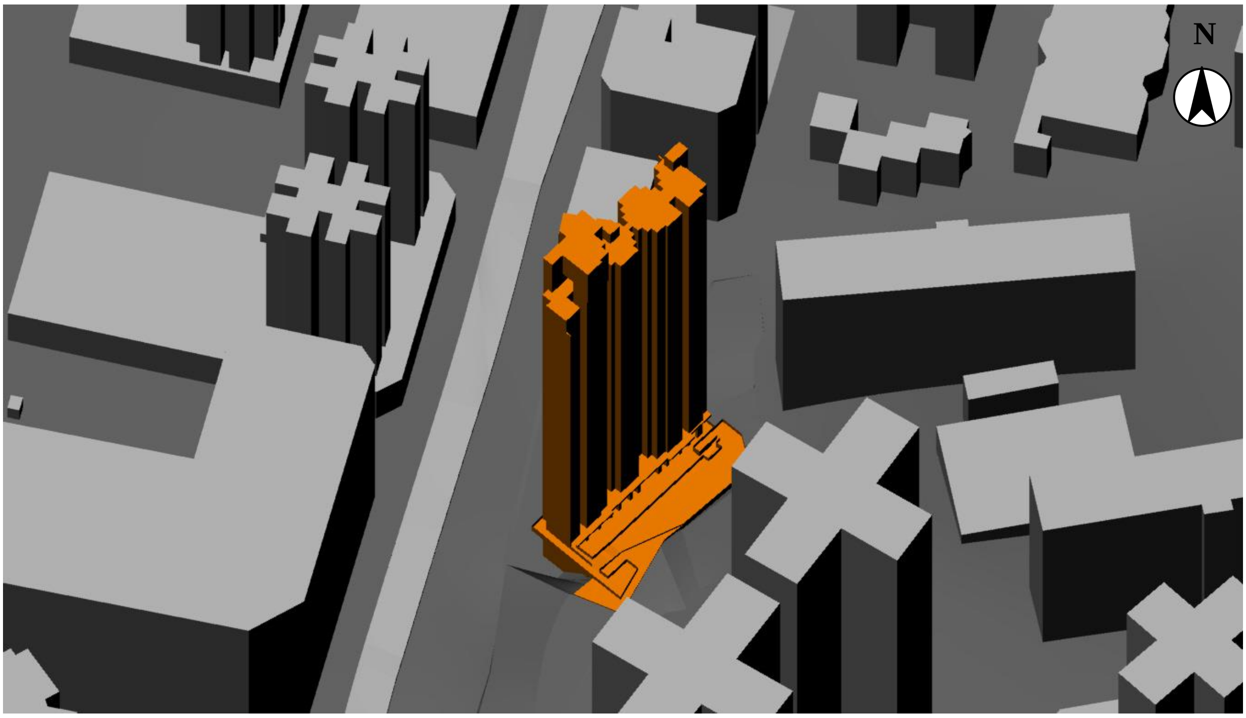


Figure 17 Model of Proposed Scenario, Southerly View

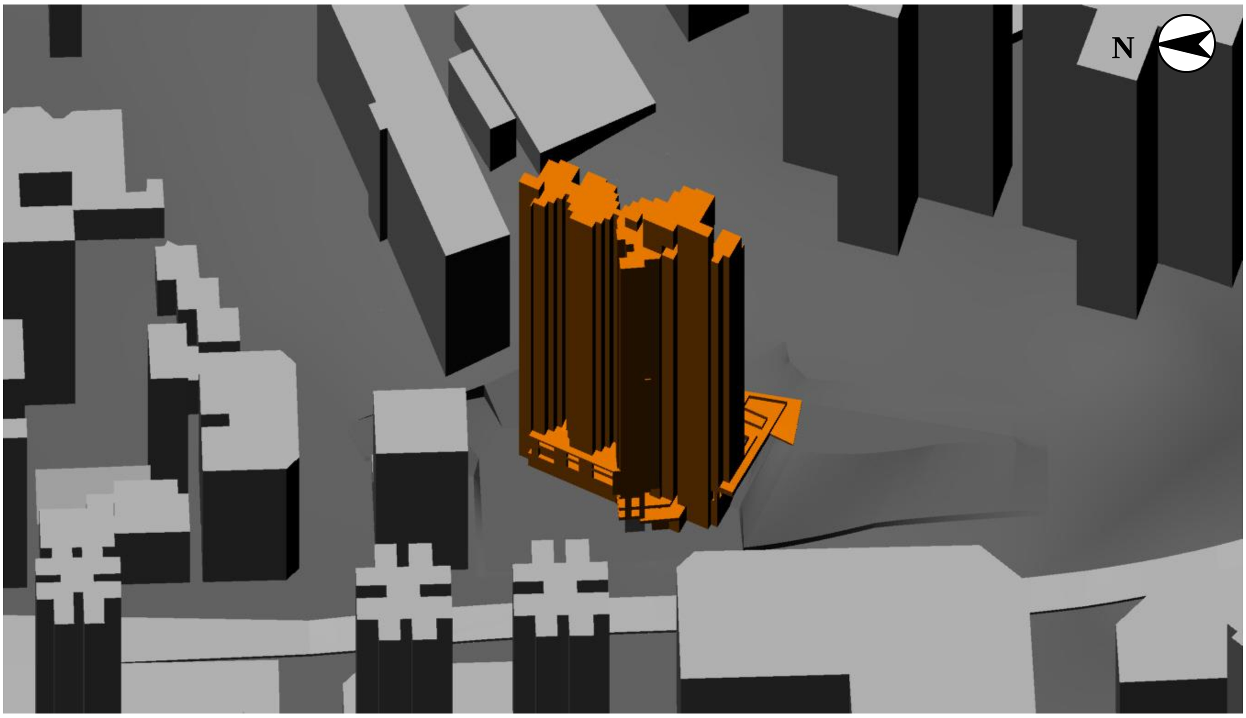


Figure 18 Model of Proposed Scenario, Westerly View

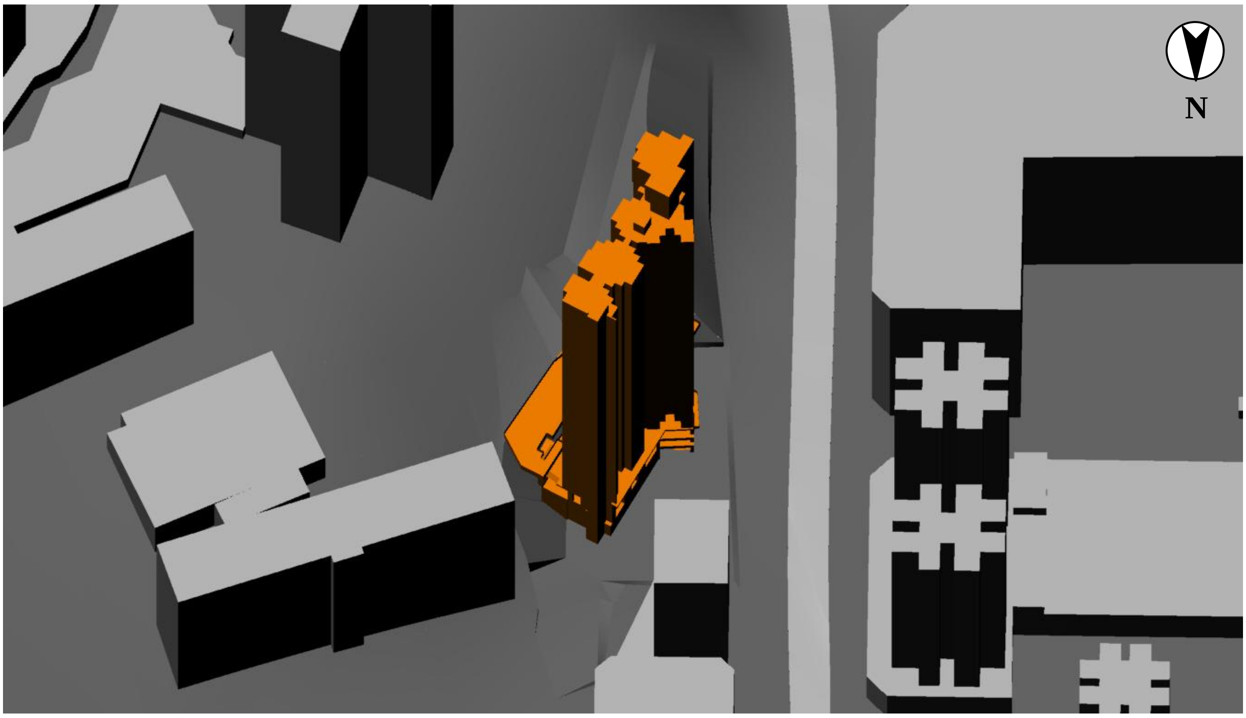


Figure 19 Model of Proposed Scenario, Northerly View

5.5 Test Point Location

Test points are evenly placed along the site boundary and within the assessment area of the potential development to determine the ventilation performance. There are three types of test points in the study:

5.5.1 Perimeter Test Points

Perimeter test points are the points positioned at the boundary of the Project Area. In accordance with the Technical Circular, perimeter points (**Blue spots**) are positioned at interval of around 15m along the site boundary. The site boundaries for the 2 Scenarios are identical, namely P points (30 points) for comparison of Baseline Scenarios and Proposed Scenario. The test point locations are shown in Figure 20.

5.5.2 Overall Test Points

Overall test points are those points evenly positioned in the open area, on the streets and places where pedestrian frequently access within the assessment area, namely O points. 67 overall test points (**Red spots**) are selected and shown in Figure 21.

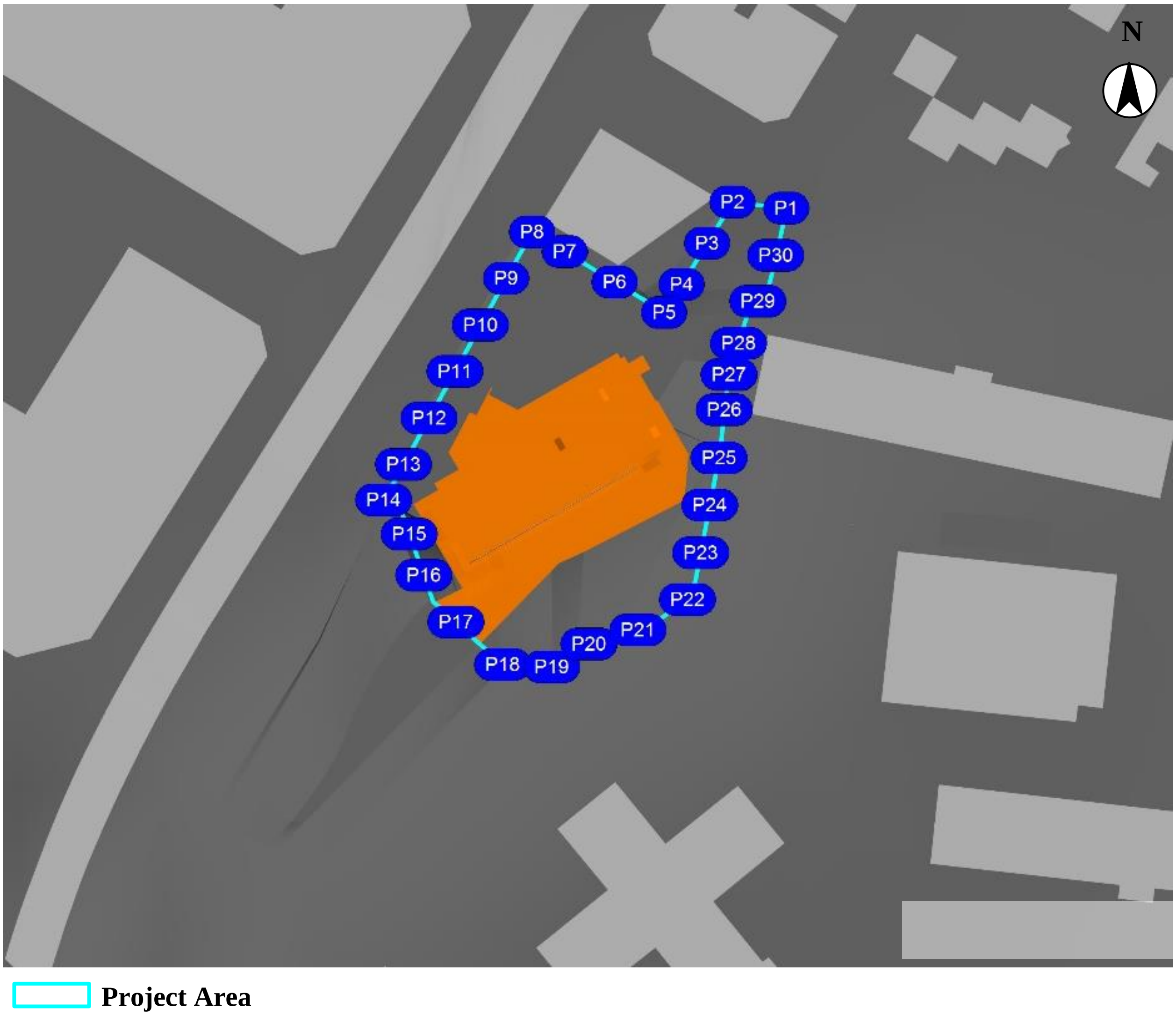


Figure 20 Location of Perimeter Test Points

Figure 21 Location of Overall Test Points

6 Qualitative Assessment

This section discussed on the anticipated air ventilation performance under the Proposed Scenario as compared with Baseline Scenario. Both Proposed and Baseline Scenarios have the same site area of about 4,626 m^2 and building height of 135 mPD, however they are different in terms of size of the site orientation and flat locations.

As shown in *"Studied Scenarios"* section above, the typical floors of Baseline Scenario are in L-shape, and the scenario is slightly orientated to the north as compared to the Proposed Scenario. Also, the covered landscape areas at 2/F and 3/F podia are enclosed. As a result, it is expected that the Baseline Scenario would block more S and SE winds to enter Tsuen Kwai Street, Tsuen Fu Street, Tsuen Fu Street Garden and northern part of Texaco Road, as compared with Proposed Scenario.

The Proposed Scenario is slightly orientated to the east while the typical floors are no longer in L-shape, which would facilitate more S and SE winds to arrive some focus areas. In addition, stronger downwash effect from the Proposed Scenario enhances the ventilation performance of surrounding areas under SW and WSW winds. Moreover, the covered landscape areas at 2/F and 3/F podia are semi-enclosed, which enhance the permeability of the Development site.

In short, it is expected that the Proposed Scenario would generally enrich the wind environments of surrounding areas as compared with Baseline Scenario due to the relatively smooth building shape, optimized building orientation and lager permeability of the Development site.

7 Quantitative Assessment

Quantitative assessment has been conducted comparing among Baseline Scenario and Proposed Scenarios using computational fluid dynamics.

7.1 Overall Ventilation Performance

Annual Condition

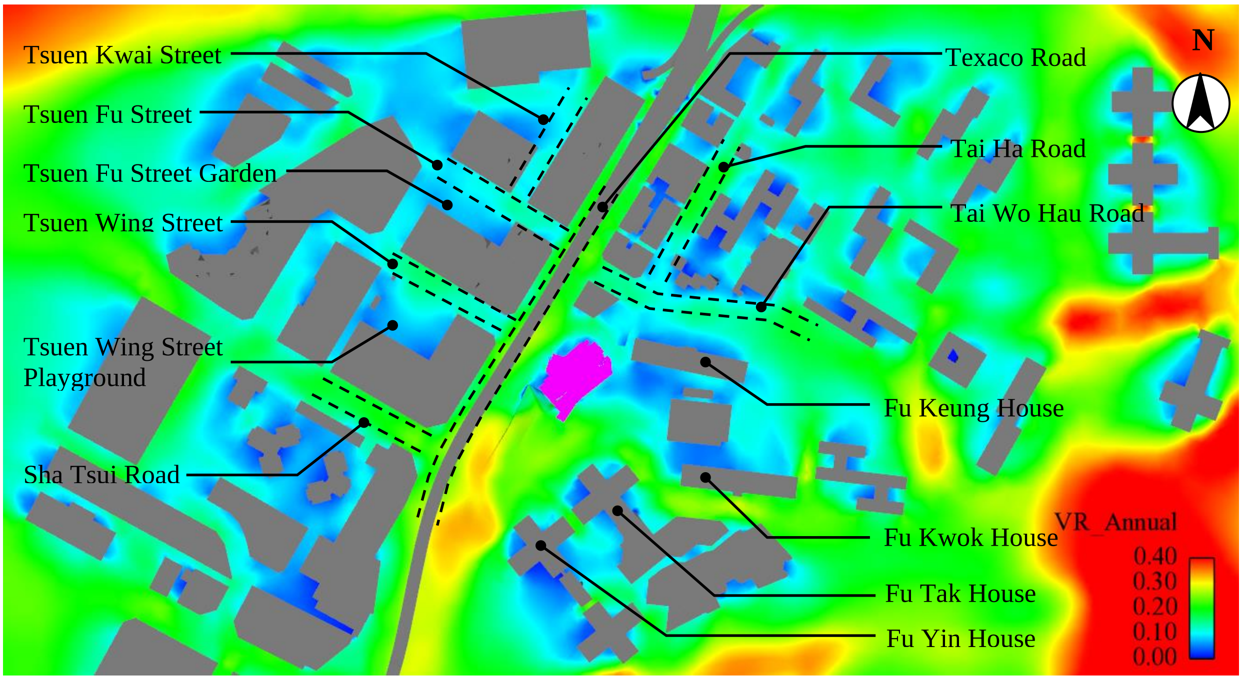


Figure 22 Average annual VR contour plots for Baseline Scenario

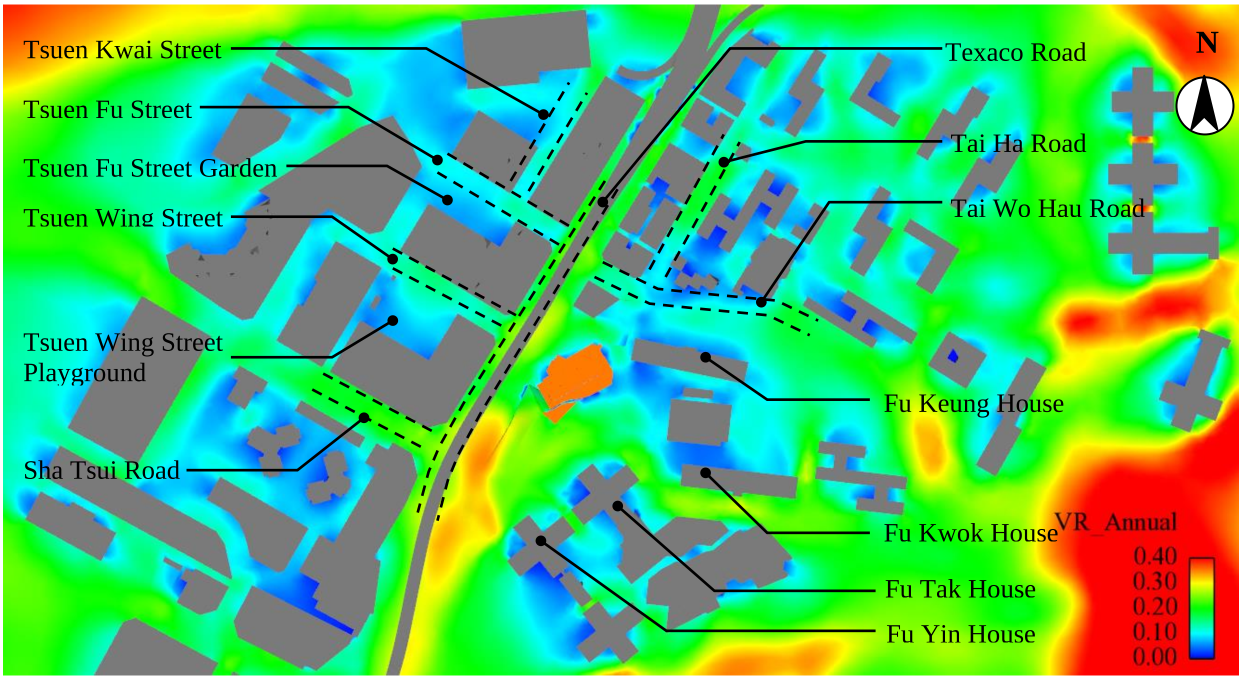


Figure 23Average annual VR contour plots for Proposed Scenario

Table 4 SVR and LVR under Annual Condition

	Baseline Scenario	Proposed Scenario
SVR	0.12	0.12
LVR	0.12	0.13

Under annual condition, Proposed Scenario achieved a slightly higher LVR as compared with Baseline Scenario. This suggests that Proposed Scenario achieved slightly better ventilation performance at the immediate surroundings of the Development Site as compared to Baseline Scenario.

Both Proposed and Baseline Developments could help to capture the high-level wind towards the pedestrian level. The higher LVR of the Proposed Scenario is mainly due to relatively smooth building shape, optimized building orientation and lager permeability of the Development Site. The ventilation performance of the nearby focus areas is enhanced, including Texao Road, Tsuen Wing Street, Sha Tsui Road and Fu Tak House. Detailed discussion is presented in the “Focus Area” section.

Summer Condition

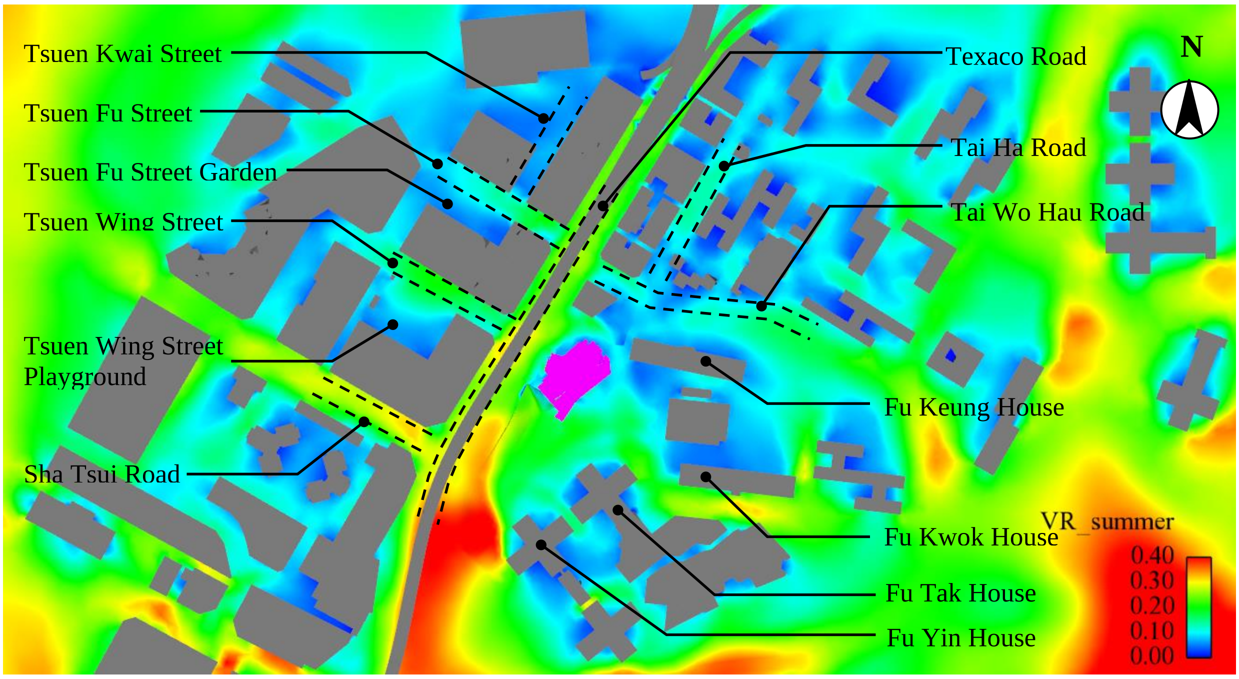


Figure 24 Average summer VR contour plots for Baseline Scenario

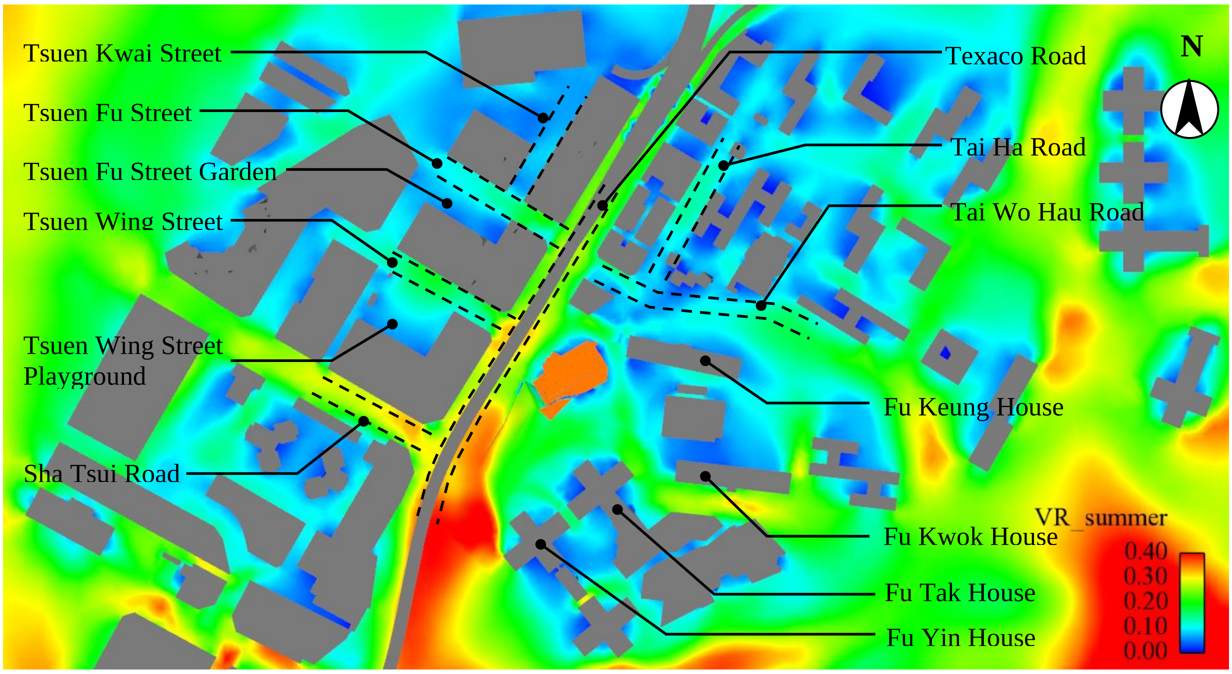


Figure 25 Average summer VR contour plots for Proposed Scenario

Table 5 SVR and LVR under Summer Condition

	Baseline Scenario	Proposed Scenario
SVR	0.12	0.12
LVR	0.13	0.13

Under summer condition, Proposed Scenario has the same SVR and LVR as the Baseline Scenario, hence it would be expected that the overall ventilation performance at the immediate and local surroundings of the Development site are similar under both scenarios.

Similar to the annual condition, the Development Site of Proposed Scenario is slightly orientated to the east, which enhances the ventilation performance at some focus areas since it allows more S and SE winds to flow along the Development Site. Moreover, the stronger downwash effect from the Proposed Scenario helps to capture the incoming wind towards the pedestrian level and enhance the ventilation performance at the Sha Tsui Road and Fu Yin House, under SW wind. Detailed discussion is presented in the "Focus Area" section.

7.2 Focus Area

Various Focus Areas with frequent pedestrian access and within major activity zones were defined, as shown in Figure 26.

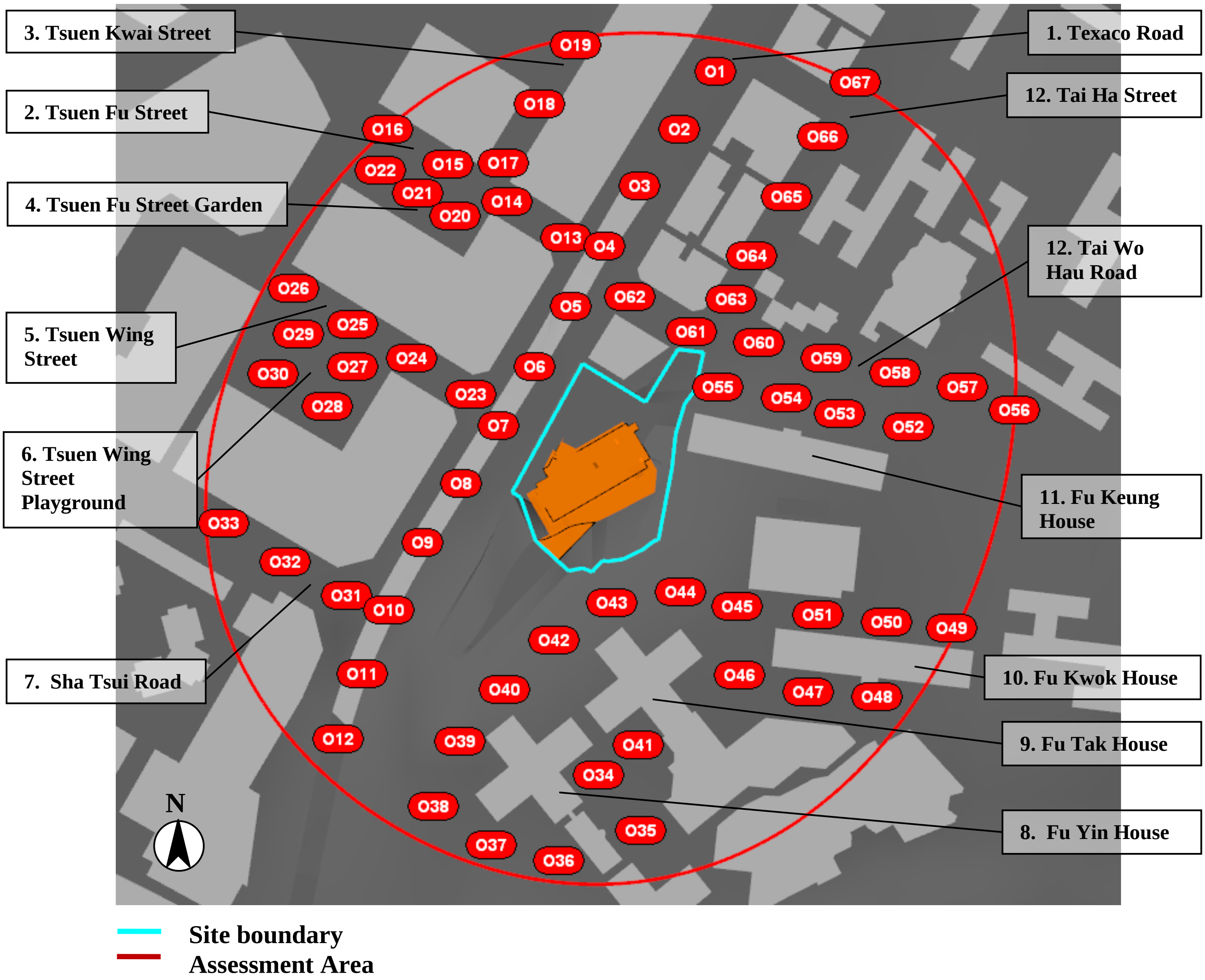


Figure 26 Focus Area Location

The average VR for the Focus Areas under annual and summer conditions respectively are presented below.

Annual Condition

Table 6 Focus Area Results under Annual Condition

Focus Area		Test Points	Average Hourly Mean Wind Speed (m/s)	
			Baseline	Proposed
1	Texaco Road	O1 – O12	0.17	0.18
2	Tsuen Fu Street	O13 – O16	0.09	0.09
3	Tsuen Kwai Street	O17 – O19	0.09	0.09
4	Tsuen Fu Street Garden	O20 – O22	0.07	0.06
5	Tsuen Wing Street	O23 – O26	0.12	0.13
6	Tsuen Wing Street Playground	O27 – O30	0.08	0.07
7	Sha Tsui Road	O31 – O33	0.17	0.18
8	Fu Yin House	O34 – O40	0.12	0.12
9	Fu Tak House	O41 – O46	0.13	0.14
10	Fu Kwok House	O47 – O51	0.13	0.13
11	Fu Keung House	O52 – O55	0.09	0.08
12	Tai Wo Hau Road	O56 – O62	0.12	0.11
13	Tai Ha Street	O63 – O67	0.12	0.12

Under annual condition, only half of the focus areas achieved similar VR values which indicates that their ventilation performance is not quite similar among the scenarios. The two scenarios result in quite different ventilation performance in focus areas.

At Tsuen Wing Street, Proposed Scenario achieved higher VR as compared with Baseline Scenario due to larger permeability of the Development site. The semi-enclosed design of the 1/F and 2/F podia allows more winds to penetrate the Development Site to achieve better ventilation performance.

At southern part of the Texaco Road, Sha Tsui Road and Fu Tak House, Proposed Scenario also achieved higher VR as compared with Baseline Scenario since the stronger downwash effect from the Proposed Scenario helps to capture the incoming wind towards the pedestrian level and enhance the ventilation performance under SW and WSW winds.

At Tsuen Wing Street Playground and Tsuen Fu Street Garden, Proposed Scenario achieved lower VR as compared with Baseline Scenario since the Baseline Scenario is orientated to the north. The Baseline Scenario diverts more SSW and SW winds to the Tsuen Wing Street Playground, as well as more E wind to the Tsuen Fu Street Garden.

Under Baseline Scenario, higher VR is achieved at Tai Wo Hau Road and Fu Keung House due to the downwash effect helps to capture the incoming wind towards the pedestrian level and enhance the ventilation performance under NE and ENE winds.

Summer Condition

Table 7 Focus Area Results under Summer Condition

Focus Area		Test Points	Average Hourly Mean Wind Speed (m/s)	
			Baseline	Proposed
1	Texaco Road	O1 – O12	0.22	0.23
2	Tsuen Fu Street	O13 – O16	0.11	0.12
3	Tsuen Kwai Street	O17 – O19	0.05	0.06
4	Tsuen Fu Street Garden	O20 – O22	0.05	0.06
5	Tsuen Wing Street	O23 – O26	0.15	0.15
6	Tsuen Wing Street Playground	O27 – O30	0.08	0.08
7	Sha Tsui Road	O31 – O33	0.23	0.24
8	Fu Yin House	O34 – O40	0.14	0.15
9	Fu Tak House	O41 – O46	0.12	0.12
10	Fu Kwok House	O47 – O51	0.13	0.13
11	Fu Keung House	O52 – O55	0.09	0.08
12	Tai Wo Hau Road	O56 – O62	0.11	0.10
13	Tai Ha Street	O63 – O67	0.09	0.09

Similar to the annual condition, the VR at nearly half of the focus areas is generally similar among two scenarios only under summer condition, which indicates that the two different scenarios result in quite different ventilation performance in focus areas.

At Sha Tsui Road, Fu Yin House and southern part of Texaco Road, the Proposed Scenario achieved higher VR as compared with Baseline Scenario since stronger downwash effect from the Proposed Scenario helps to capture the incoming wind towards the pedestrian level and enhance the ventilation performance under SW wind.

At Tsuen Kwai Street, Tsuen Fu Street, Tsuen Fu Street Garden and Texaco Road, the orientation of Development Site of Proposed Scenario allows more S and SE winds to arrive the aforementioned areas, hence the VR is slightly higher as compared with Baseline Scenario.

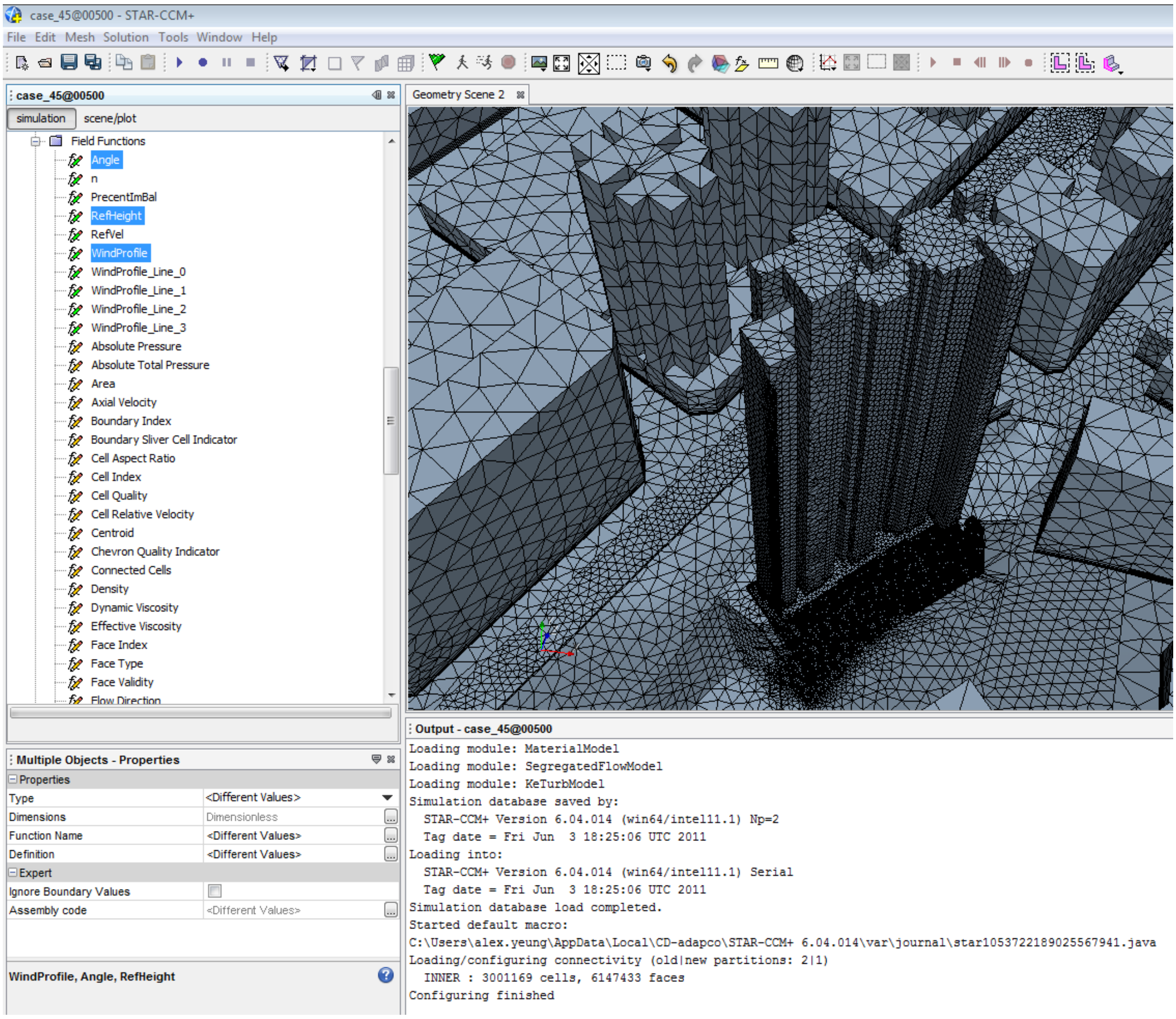
Under Baseline Scenario, higher VR is achieved at Tai Wo Hau Road and Fu Keung House since the greater downwash effect from the Baseline Scenario and enclosed 2/F and 3/F podia enhance the ventilation performance, under ENE wind. Moreover, the Development site is slightly orientated to the north, which allows more S and SSW winds to arrive the focus areas.

8 Conclusion

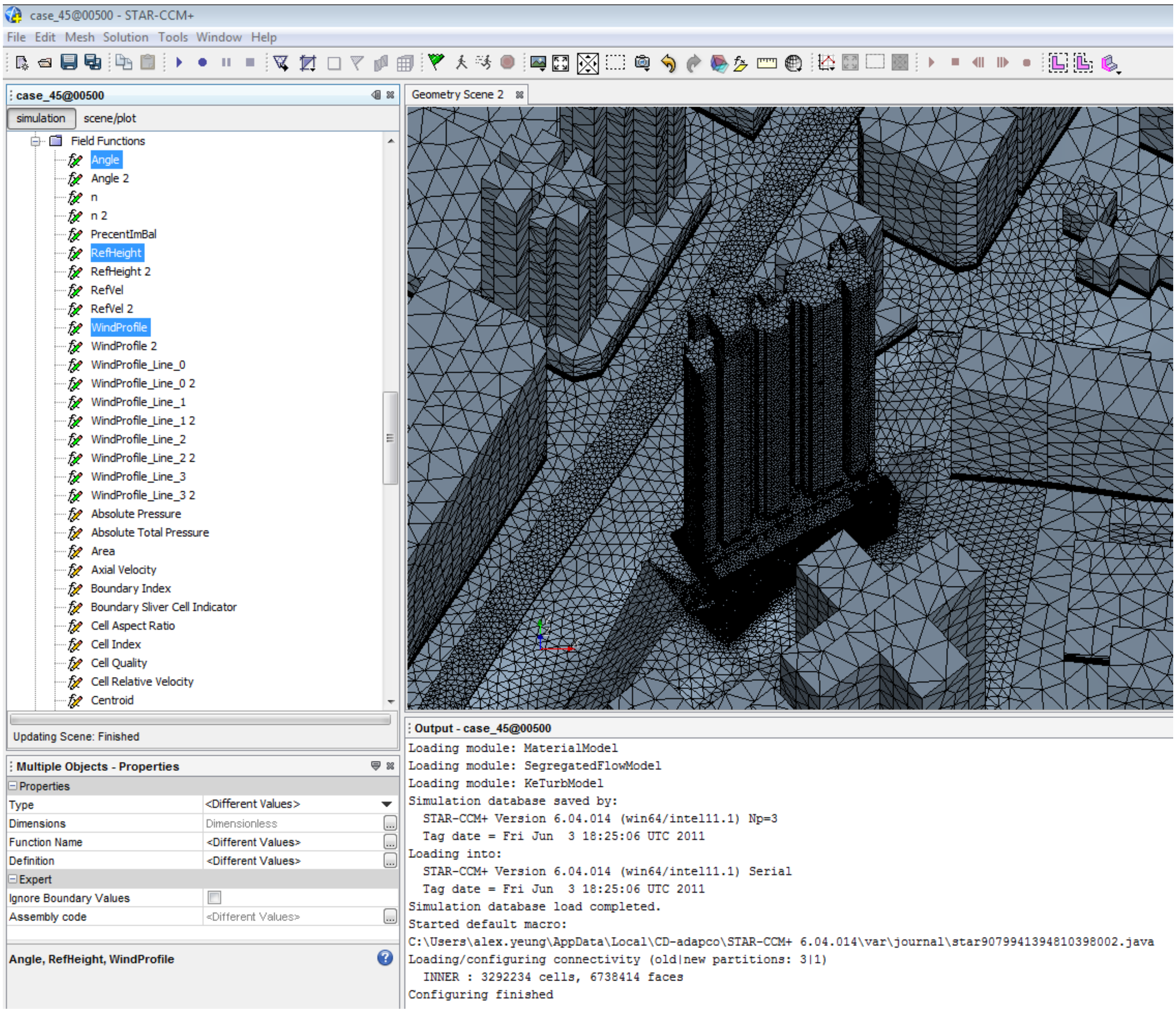
Under annual condition, the SVR and LVR of Baseline and Proposed Scenarios are the same. Under summer condition, the SVR of two scenarios are the same while the LVR of Proposed Scenario is slightly greater than the Baseline Scenario, which shows that the overall ventilation performance at the immediate and local surroundings of the Development Site is slightly better under Proposed Scenario.

As compared with Baseline Scenario, the Proposed Scenario is slightly orientated to the east while the covered landscape areas at 2/F and 3/F podia are semi-enclosed, which would facilitate more S and SE winds to arrive some focus areas. In addition, stronger downwash effect from the Proposed Scenario enhances the ventilation performance of surrounding areas under SW and WSW winds. As a result, the Proposed Scenario will result in better surrounding wind performance as compared to the Baseline Scenario. This credit shall be achieved.

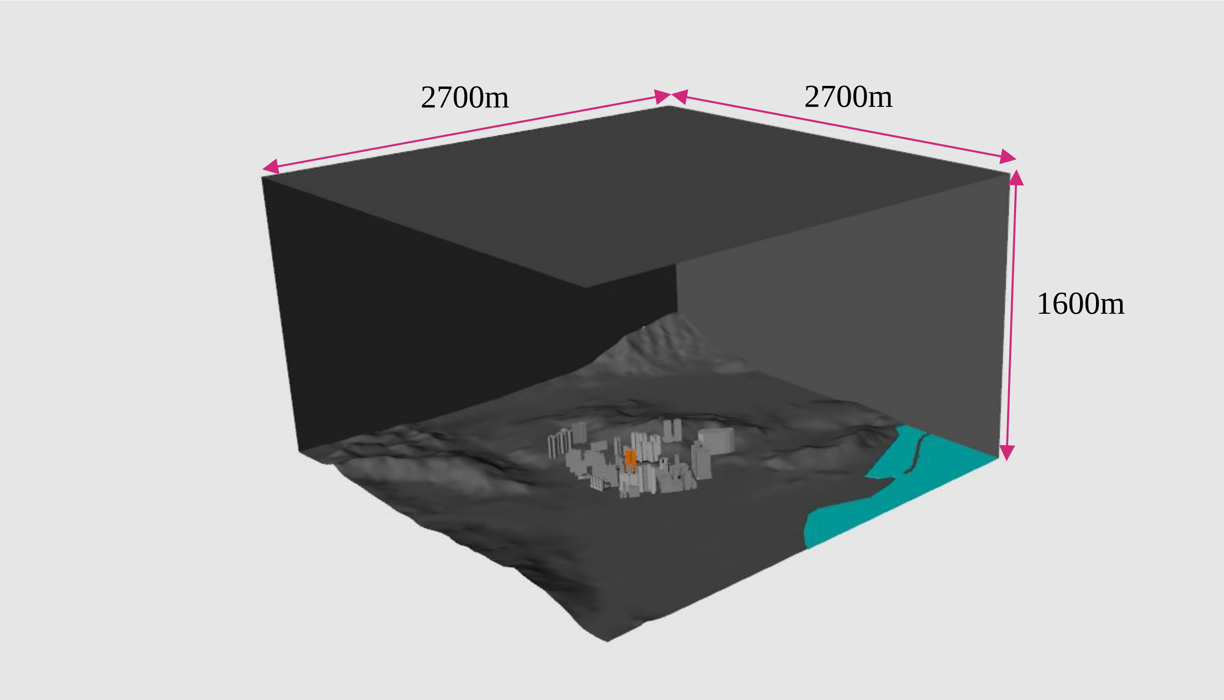
Appendix A – Input Parameter



Baseline


case_45@00500 - STAR-CCM+
File Edit Mesh Solution Tools Window Help
case_45@00500
simulation
scene/plot
Field Functions
Angle
Angle 2
n
n 2
PrecentImBal
RefHeight
RefHeight 2
RefVel
RefVel 2
WindProfile
WindProfile 2
WindProfile_Line_0
WindProfile_Line_0 2
WindProfile_Line_1
WindProfile_Line_1 2
WindProfile_Line_2
WindProfile_Line_2 2
WindProfile_Line_3
WindProfile_Line_3 2
Absolute Pressure
Absolute Total Pressure
Area
Axial Velocity
Boundary Index
Boundary Sliver Cell Indicator
Cell Aspect Ratio
Cell Index
Cell Quality
Cell Relative Velocity
Centroid
Updating Scene: Finished
Multiple Objects - Properties
Properties
Type
<Different Values>
Dimensions
Dimensionless
Function Name
<Different Values>
Definition
<Different Values>
Expert
Ignore Boundary Values
Assembly code
<Different Values>
Angle, RefHeight, WindProfile
Geometry Scene 2
Output - case_45@00500
Loading module: MaterialModel
Loading module: SegregatedFlowModel
Loading module: KeTurbModel
Simulation database saved by:
STAR-CCM+ Version 6.04.014 (win64/intel11.1) Np=3
Tag date = Fri Jun 3 18:25:06 UTC 2011
Loading into:
STAR-CCM+ Version 6.04.014 (win64/intel11.1) Serial
Tag date = Fri Jun 3 18:25:06 UTC 2011
Simulation database load completed.
Started default macro:
C:\Users\alex.yeung\AppData\Local\CD-adapco\STAR-CCM+ 6.04.014\var\journal\star9079941394810398002.java
Loading/configuring connectivity (old|new partitions: 3|1)
INNER : 3292234 cells, 6738414 faces
Configuring finished

Proposed



Computation Domain

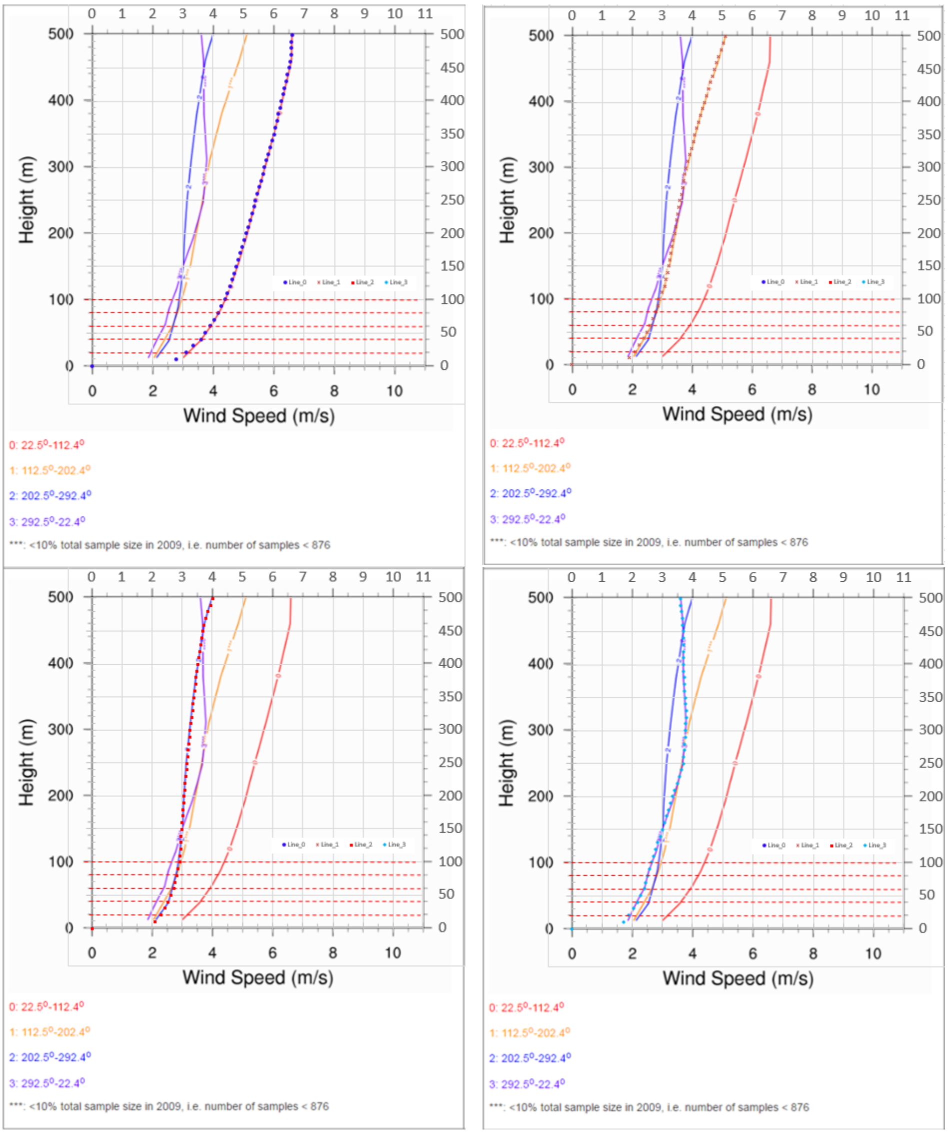
WindProfile_Setting.java - SciTE

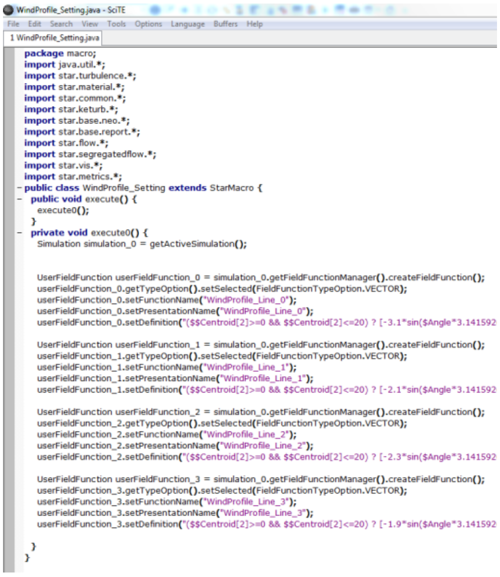
File Edit Search View Tools Options Language Buffers Help

1 WindProfile_Setting.java

```
package macro;
import java.util.*;
import star.turbulence.*;
import star.material.*;
import star.common.*;
import star.keturb.*;
import star.base.neo.*;
import star.base.report.*;
import star.flow.*;
import star.segregatedflow.*;
import star.vis.*;
import star.metrics.*;
public class WindProfile_Setting extends StarMacro {
  public void execute() {
    execute0();
  }
  private void execute0() {
    Simulation simulation_0 = getActiveSimulation();
```

Domain Settings




WindProfile_Setting.java - SciTE

File Edit Search View Tools Options Language Buffers Help

1 WindProfile_Setting.java

```
package macro;
import java.util.*;
import star.turbulence.*;
import star.material.*;
import star.common.*;
import star.keturb.*;
import star.base.neo.*;
import star.base.report.*;
import star.flow.*;
import star.segregatedflow.*;
import star.vis.*;
import star.metrics.*;
public class WindProfile_Setting extends StarMacro {
  public void execute() {
    execute0();
  }
  private void execute0() {
    Simulation simulation_0 = getActiveSimulation();


    UserFieldFunction userFieldFunction_0 = simulation_0.getFieldFunctionManager().createFieldFunction();
    userFieldFunction_0.getTypeOption().setSelected(FieldFunctionTypeOption.VECTOR);
    userFieldFunction_0.setFunctionName("WindProfile_Line_0");
    userFieldFunction_0.setPresentationName("WindProfile_Line_0");
    userFieldFunction_0.setDefinition("($$Centroid[2]>=0 && $$Centroid[2]<=20) ? [-3.1*sin($Angle*3.141592

    UserFieldFunction userFieldFunction_1 = simulation_0.getFieldFunctionManager().createFieldFunction();
    userFieldFunction_1.getTypeOption().setSelected(FieldFunctionTypeOption.VECTOR);
    userFieldFunction_1.setFunctionName("WindProfile_Line_1");
    userFieldFunction_1.setPresentationName("WindProfile_Line_1");
    userFieldFunction_1.setDefinition("($$Centroid[2]>=0 && $$Centroid[2]<=20) ? [-2.1*sin($Angle*3.141592

    UserFieldFunction userFieldFunction_2 = simulation_0.getFieldFunctionManager().createFieldFunction();
    userFieldFunction_2.getTypeOption().setSelected(FieldFunctionTypeOption.VECTOR);
    userFieldFunction_2.setFunctionName("WindProfile_Line_2");
    userFieldFunction_2.setPresentationName("WindProfile_Line_2");
    userFieldFunction_2.setDefinition("($$Centroid[2]>=0 && $$Centroid[2]<=20) ? [-2.3*sin($Angle*3.141592

    UserFieldFunction userFieldFunction_3 = simulation_0.getFieldFunctionManager().createFieldFunction();
    userFieldFunction_3.getTypeOption().setSelected(FieldFunctionTypeOption.VECTOR);
    userFieldFunction_3.setFunctionName("WindProfile_Line_3");
    userFieldFunction_3.setPresentationName("WindProfile_Line_3");
    userFieldFunction_3.setDefinition("($$Centroid[2]>=0 && $$Centroid[2]<=20) ? [-1.9*sin($Angle*3.141592

  }
}
```

Wind Profiles Settings

Appendix B – Output Summary

Overall_NE_Point.dat - SciTE

File Edit Search View Tools Options Language Buffers Help

1 Overall_NE_Point.dat

VR_NE	X	Y	Z	I	J	K
4.42662e-001	6.19500e+001	1.43690e+002	9.70000e+000	N/A	N/	
4.18834e-002	4.62100e+001	1.18150e+002	9.25000e+000	N/A	N/	
2.92114e-001	2.89500e+001	9.36900e+001	8.90000e+000	N/A	N/	
3.37999e-001	1.36200e+001	6.79000e+001	8.56000e+000	N/A	N/	
3.05970e-001	-1.05000e+000	4.16900e+001	8.21000e+000	N/A	N	
2.96619e-001	-1.63800e+001	1.59000e+001	8.02000e+000	N/A	N	
3.83644e-001	-3.19300e+001	-9.87000e+000	8.06000e+000	N/A		
3.80647e-001	-4.83900e+001	-3.49500e+001	8.00000e+000	N/A		
3.83238e-001	-6.50500e+001	-6.03100e+001	8.61000e+000	N/A		
2.51394e-001	-7.96500e+001	-8.98100e+001	8.36000e+000	N/A		
1.54919e-001	-9.11100e+001	-1.17540e+002	6.41000e+000	N/A		
1.95386e-001	-1.01740e+002	-1.45600e+002	9.96000e+000	N/A		
3.04922e-002	-3.05000e+000	7.16900e+001	8.37000e+000	N/A	N	
6.39984e-002	-2.87200e+001	8.72100e+001	8.35000e+000	N/A	N	
1.21576e-001	-5.42000e+001	1.03040e+002	8.35000e+000	N/A	N	
1.99923e-001	-7.99900e+001	1.18360e+002	8.36000e+000	N/A	N	
2.16451e-001	-3.00500e+001	1.03690e+002	8.53000e+000	N/A	N	
2.07772e-001	-1.43500e+001	1.29250e+002	8.83000e+000	N/A	N	
1.50276e-001	1.35000e+000	1.54820e+002	8.99000e+000	N/A	N/	
1.04231e-001	-5.10500e+001	8.06900e+001	8.08000e+000	N/A	N	
1.32784e-001	-6.70500e+001	9.06900e+001	8.09000e+000	N/A	N	
2.17006e-001	-8.30500e+001	1.00690e+002	8.12000e+000	N/A	N	
2.11055e-001	-4.40500e+001	3.69000e+000	7.83000e+000	N/A	N	
1.28939e-001	-6.97200e+001	1.92100e+001	7.60000e+000	N/A	N	
1.61294e-001	-9.50500e+001	3.36900e+001	7.45000e+000	N/A	N	
1.45808e-001	-1.21050e+002	4.96900e+001	7.50000e+000	N/A	N	
5.16023e-002	-9.50500e+001	1.56900e+001	7.70000e+000	N/A	N	
9.06515e-002	-1.06050e+002	-1.31000e+000	7.94000e+000	N/A		
8.55397e-002	-1.18530e+002	2.95200e+001	7.58000e+000	N/A	N	
5.78700e-002	-1.29530e+002	1.25200e+001	7.85000e+000	N/A	N	
1.17720e-001	-9.80500e+001	-8.33100e+001	7.31000e+000	N/A		
1.38417e-001	-1.24230e+002	-6.86700e+001	7.65000e+000	N/A		
7.98980e-002	-1.51050e+002	-5.23100e+001	7.53000e+000	N/A		
2.45593e-001	1.09500e+001	-1.61310e+002	3.89200e+001	N/A	N	
2.62180e-001	2.92400e+001	-1.85090e+002	3.95300e+001	N/A	N	
9.77309e-002	-6.05000e+000	-1.98310e+002	3.90900e+001	N/A		
5.51810e-002	-3.52400e+001	-1.91410e+002	3.54900e+001	N/A		
6.83677e-002	-6.01200e+001	-1.74640e+002	3.05100e+001	N/A		

Baseline

Overall_E_Point.dat - SciTE

File Edit Search View Tools Options Language Buffers Help

1 Overall_E_Point.dat

VR_E	X	Y	Z	I	J	K
2.95010e-002	6.19500e+001	1.43690e+002	9.70000e+000	N/A	N/	
2.00990e-002	4.62100e+001	1.18150e+002	9.25000e+000	N/A	N/	
1.38303e-001	2.89500e+001	9.36900e+001	8.90000e+000	N/A	N/	
1.42449e-001	1.36200e+001	6.79000e+001	8.56000e+000	N/A	N/	
4.44905e-002	-1.05000e+000	4.16900e+001	8.21000e+000	N/A	N	
2.81442e-001	-1.63800e+001	1.59000e+001	8.02000e+000	N/A	N	
2.66612e-001	-3.19300e+001	-9.87000e+000	8.06000e+000	N/A		
5.80702e-002	-4.83900e+001	-3.49500e+001	8.00000e+000	N/A		
4.10559e-001	-6.50500e+001	-6.03100e+001	8.61000e+000	N/A		
5.17243e-001	-7.96500e+001	-8.98100e+001	8.36000e+000	N/A		
4.31335e-001	-9.11100e+001	-1.17540e+002	6.41000e+000	N/A		
4.34466e-001	-1.01740e+002	-1.45600e+002	9.96000e+000	N/A		
4.18518e-002	-3.05000e+000	7.16900e+001	8.37000e+000	N/A	N	
6.31784e-002	-2.87200e+001	8.72100e+001	8.35000e+000	N/A	N	
3.48743e-002	-5.42000e+001	1.03040e+002	8.35000e+000	N/A	N	
4.67650e-002	-7.99900e+001	1.18360e+002	8.36000e+000	N/A	N	
1.73304e-002	-3.00500e+001	1.03690e+002	8.53000e+000	N/A	N	
8.88069e-002	-1.43500e+001	1.29250e+002	8.83000e+000	N/A	N	
2.90516e-002	1.35000e+000	1.54820e+002	8.99000e+000	N/A	N/	
5.40032e-002	-5.10500e+001	8.06900e+001	8.08000e+000	N/A	N	
4.67913e-002	-6.70500e+001	9.06900e+001	8.09000e+000	N/A	N	
2.90633e-002	-8.30500e+001	1.00690e+002	8.12000e+000	N/A	N	
2.51743e-001	-4.40500e+001	3.69000e+000	7.83000e+000	N/A	N	
7.86112e-002	-6.97200e+001	1.92100e+001	7.60000e+000	N/A	N	
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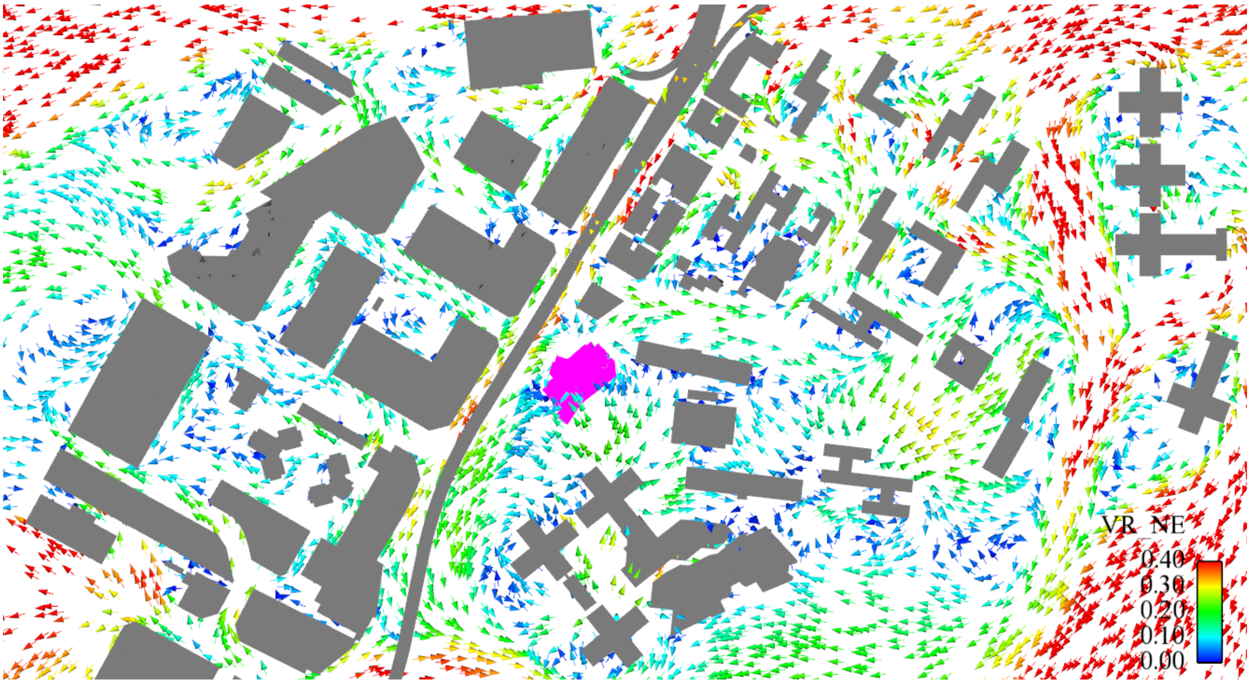
1.56880e-001	-9.50500e+001	1.56900e+001	7.70000e+000	N/A	N	
9.72073e-002	-1.06050e+002	-1.31000e+000	7.94000e+000	N/A		
1.45560e-001	-1.18530e+002	2.95200e+001	7.58000e+000	N/A	N	
3.96713e-002	-1.29530e+002	1.25200e+001	7.85000e+000	N/A	N	
4.10709e-001	-9.80500e+001	-8.33100e+001	7.31000e+000	N/A		
3.80159e-001	-1.24230e+002	-6.86700e+001	7.65000e+000	N/A		
3.35377e-001	-1.51050e+002	-5.23100e+001	7.53000e+000	N/A		
5.31424e-002	1.09500e+001	-1.61310e+002	3.89200e+001	N/A	N	
1.10506e-001	2.92400e+001	-1.85090e+002	3.95300e+001	N/A	N	
5.48363e-002	-6.05000e+000	-1.98310e+002	3.90900e+001	N/A		
9.33655e-002	-3.52400e+001	-1.91410e+002	3.54900e+001	N/A		
7.36560e-002	-6.01200e+001	-1.74640e+002	3.05100e+001	N/A		

Proposed

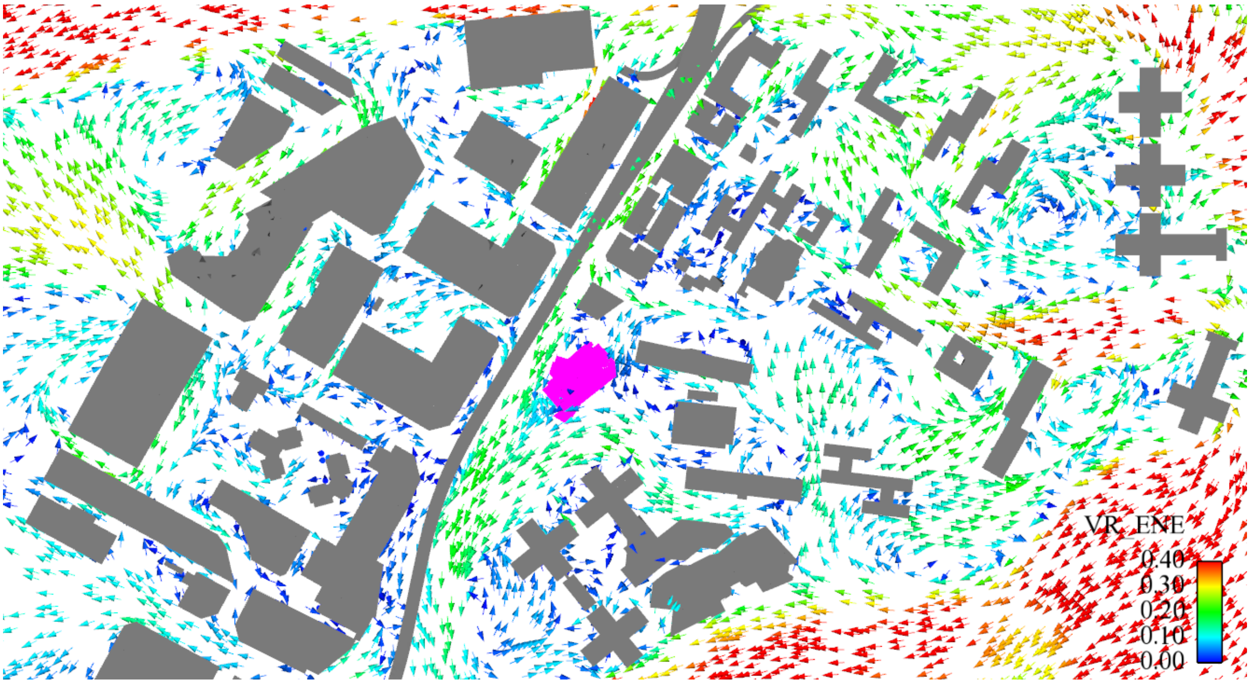
Appendix C – Vector Plots

Baseline

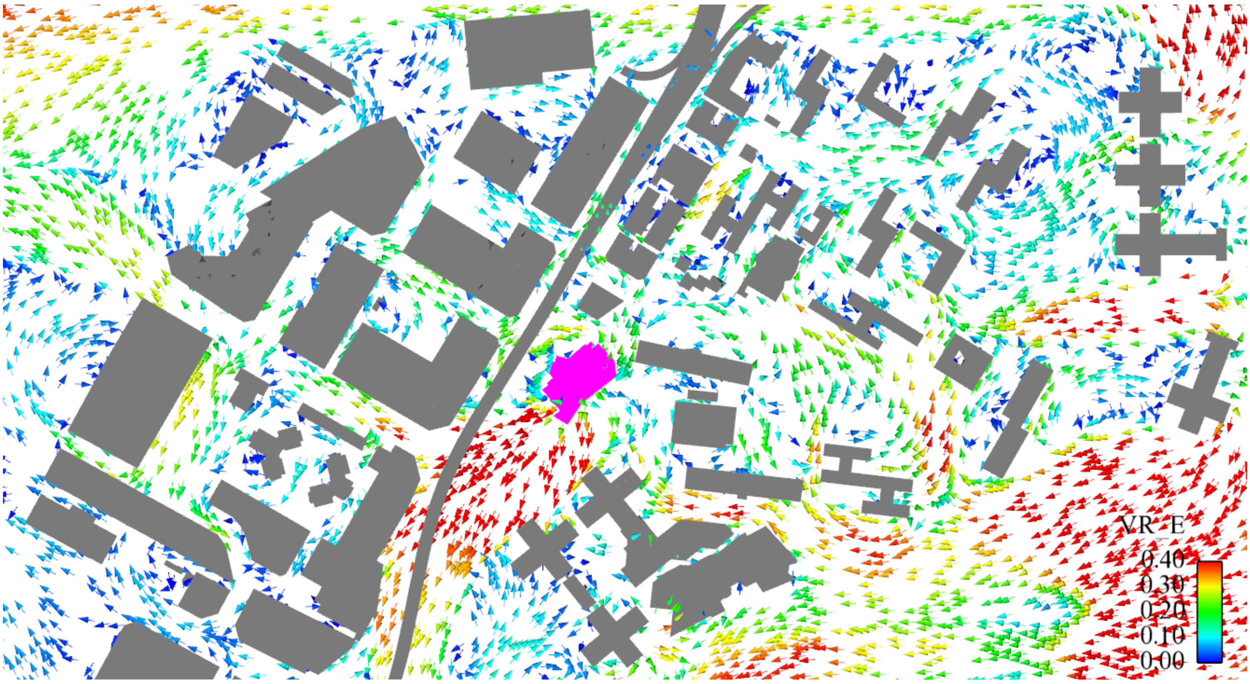
NE wind



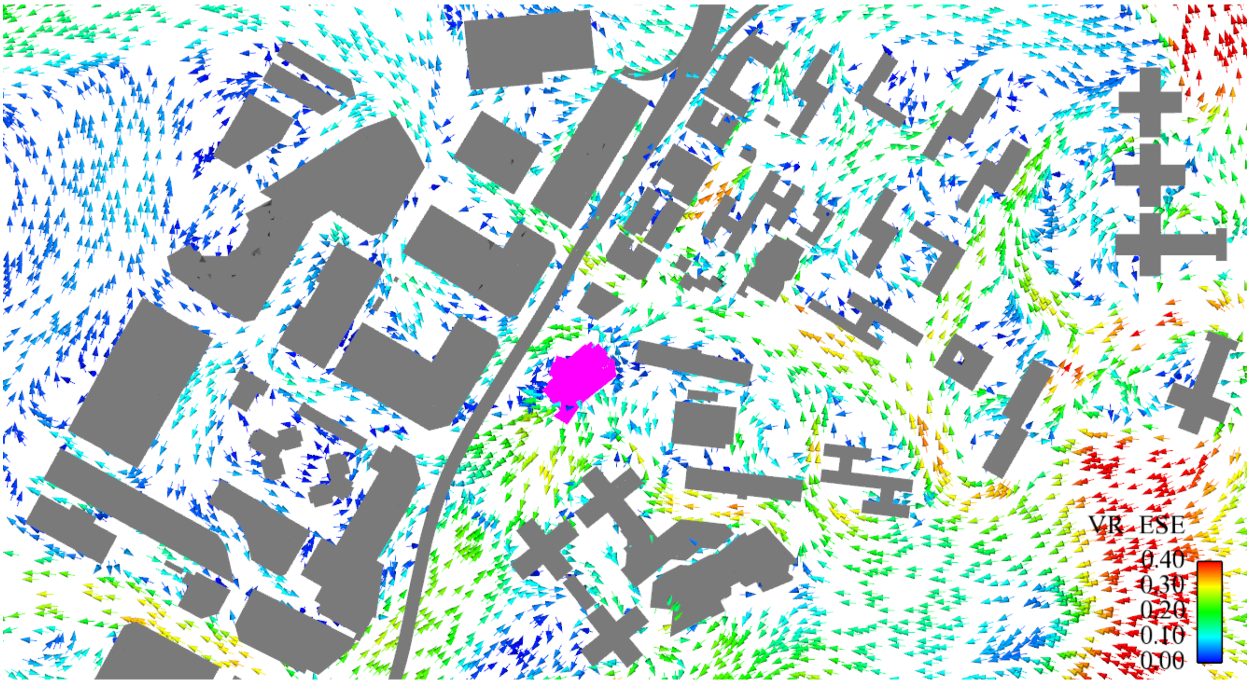
ENE wind



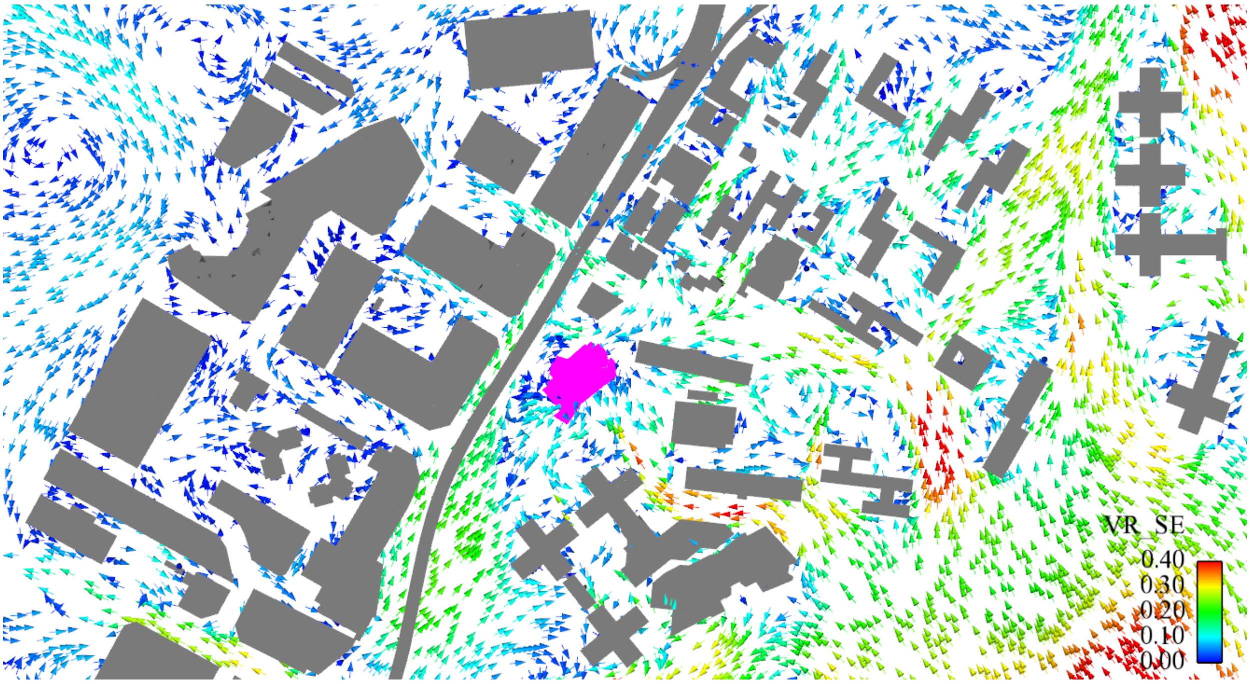
E wind



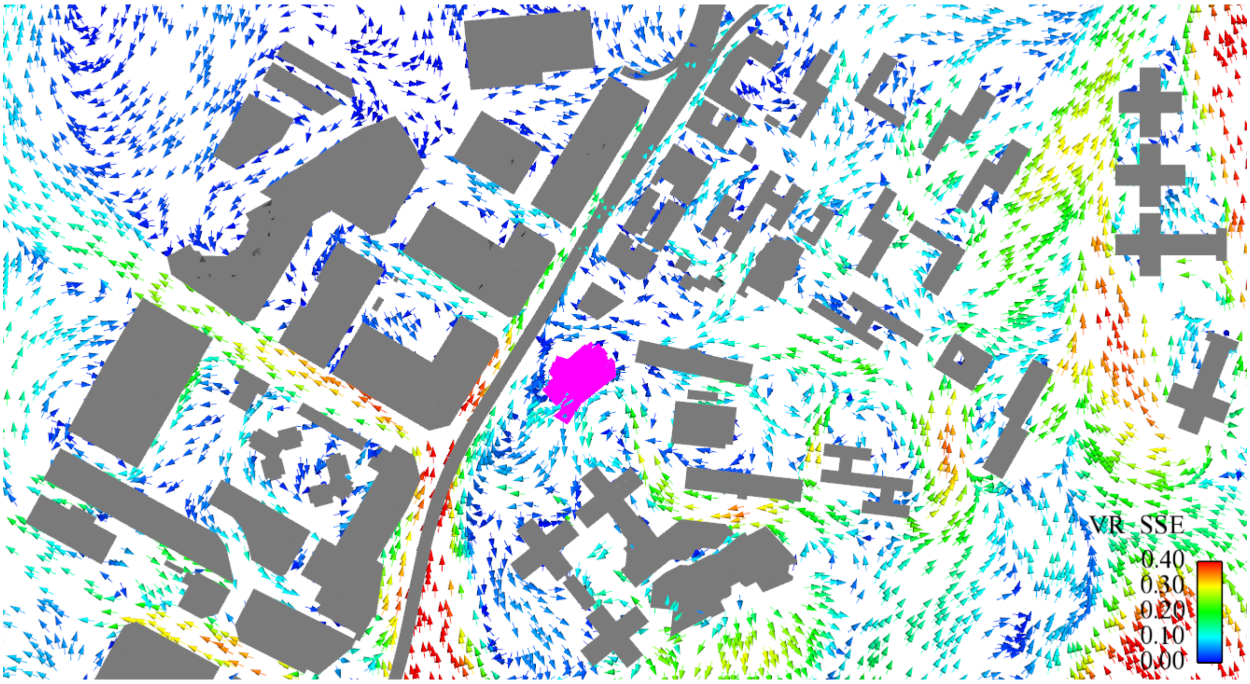
ESE wind



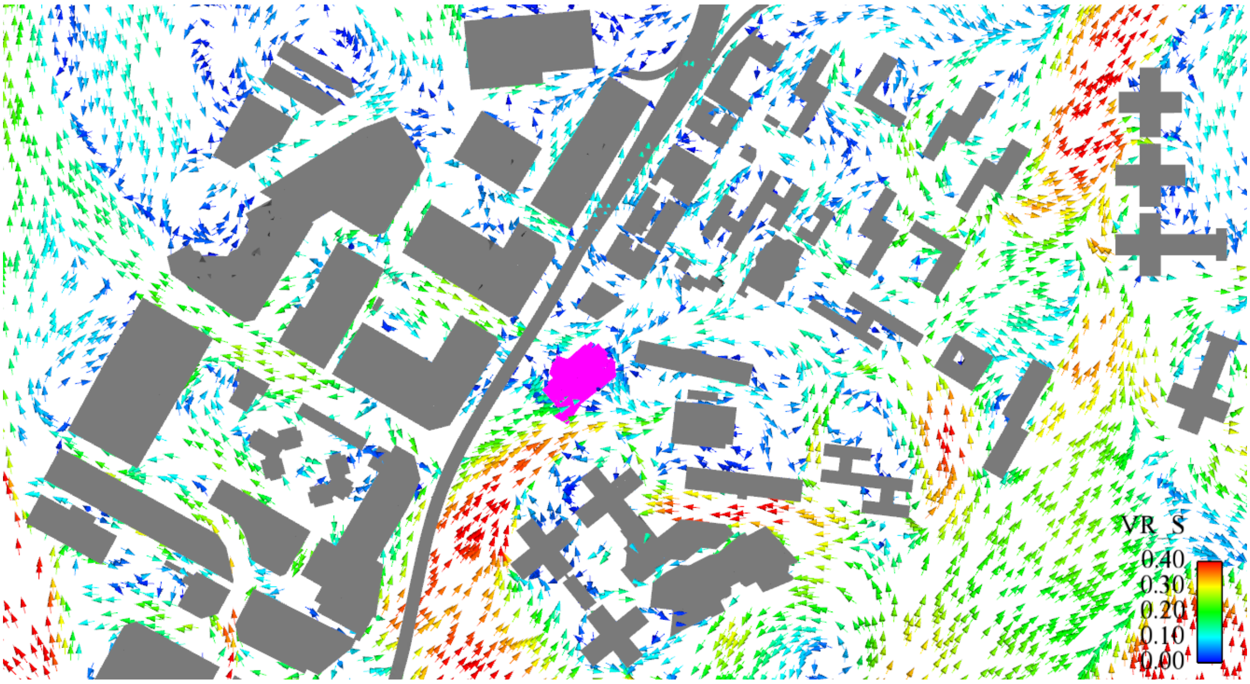
SE wind



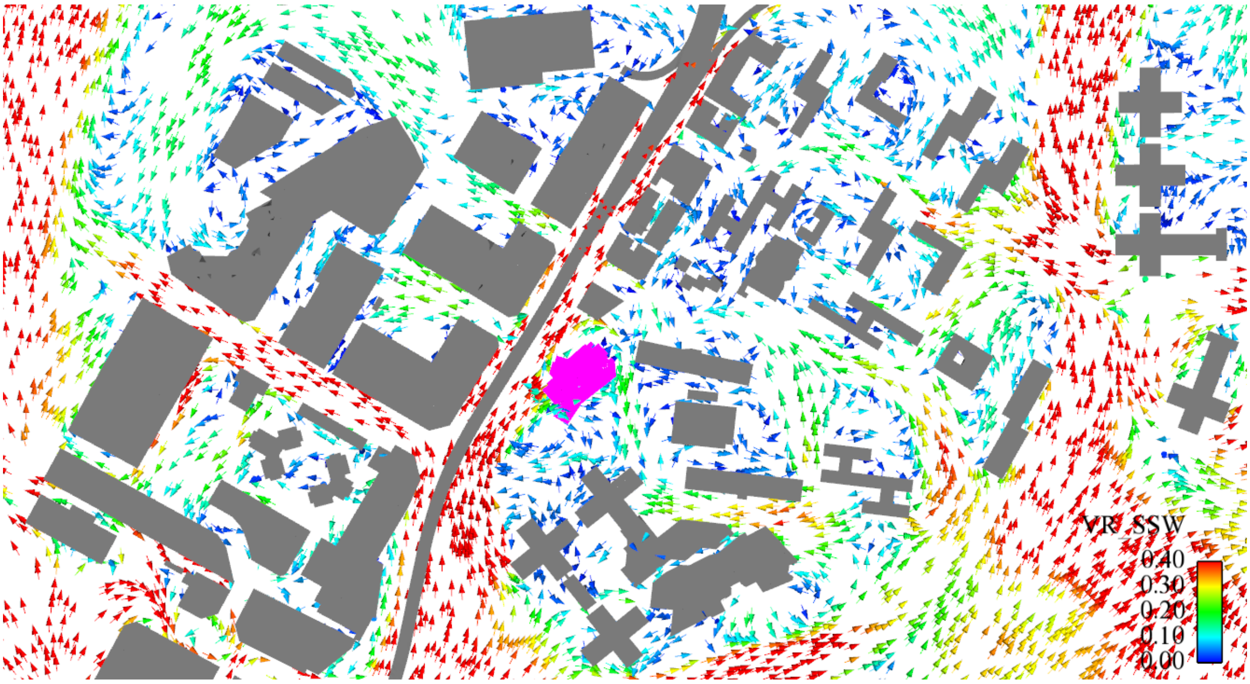
SSE wind



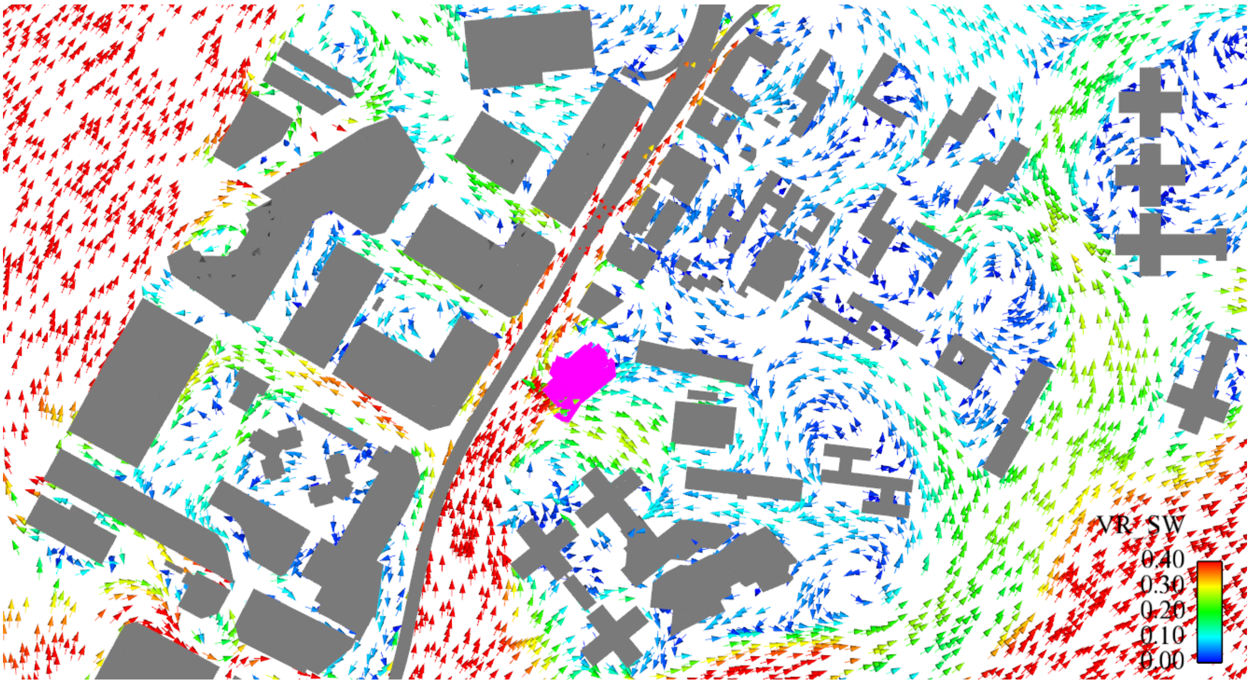
S wind



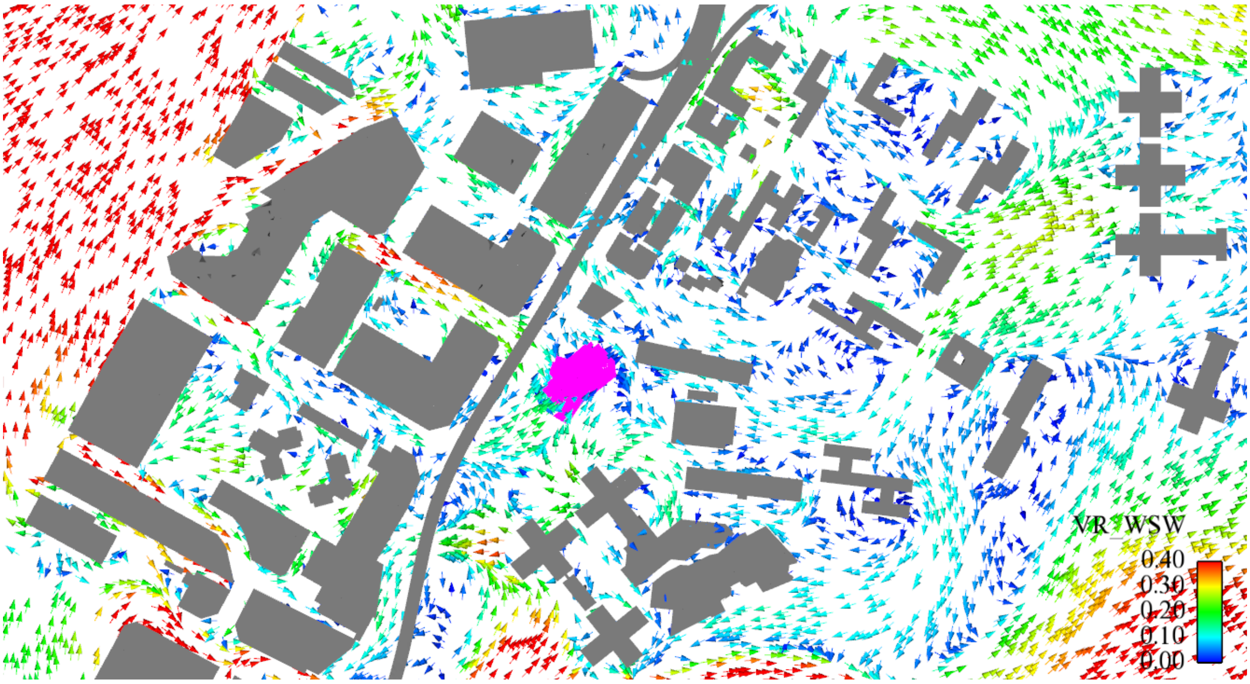
SSW wind



SW wind

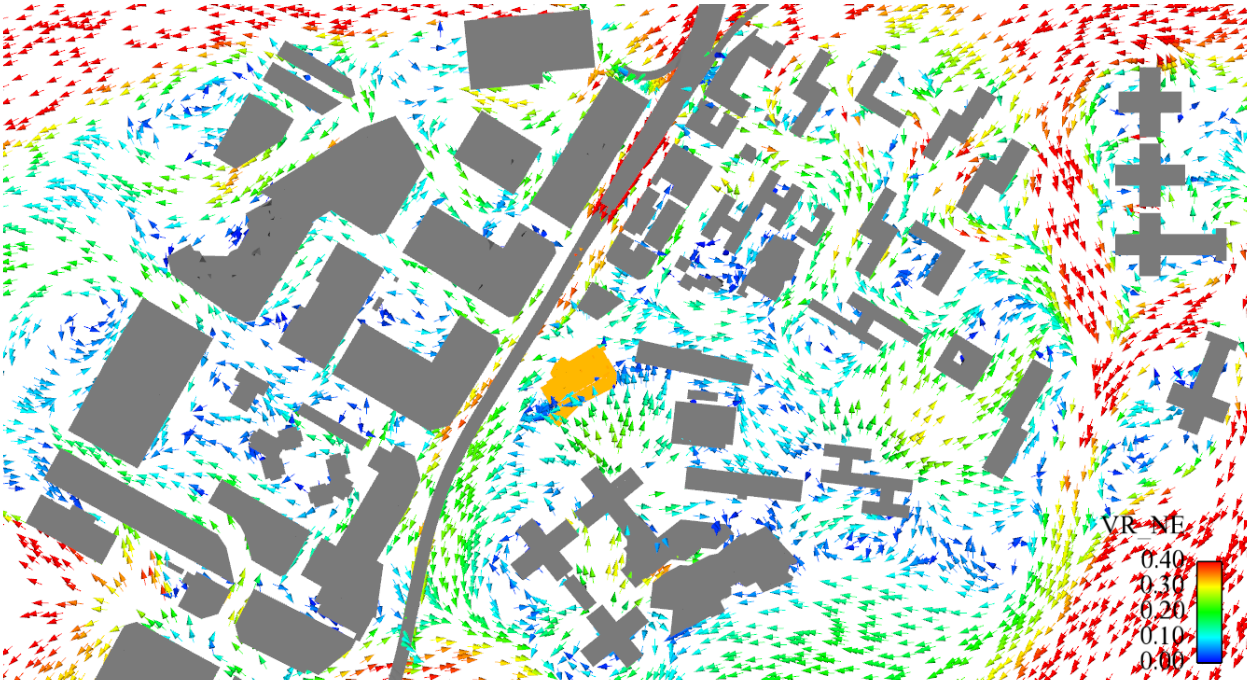


WSW wind

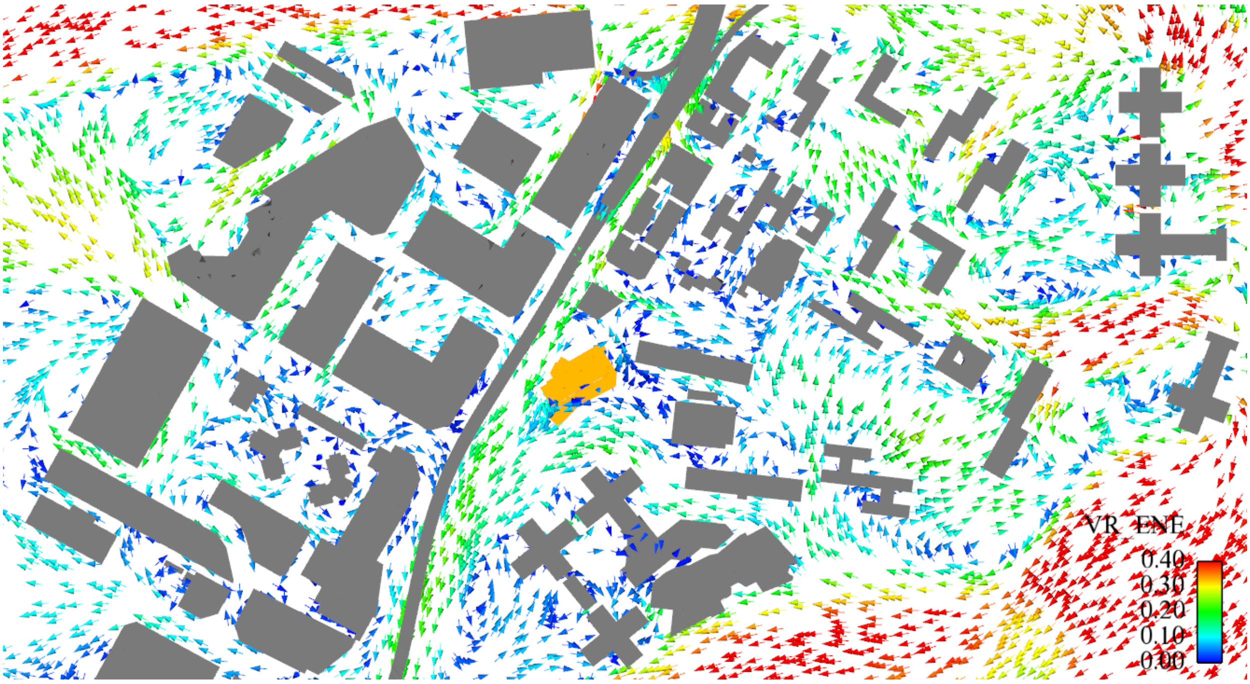


Proposed

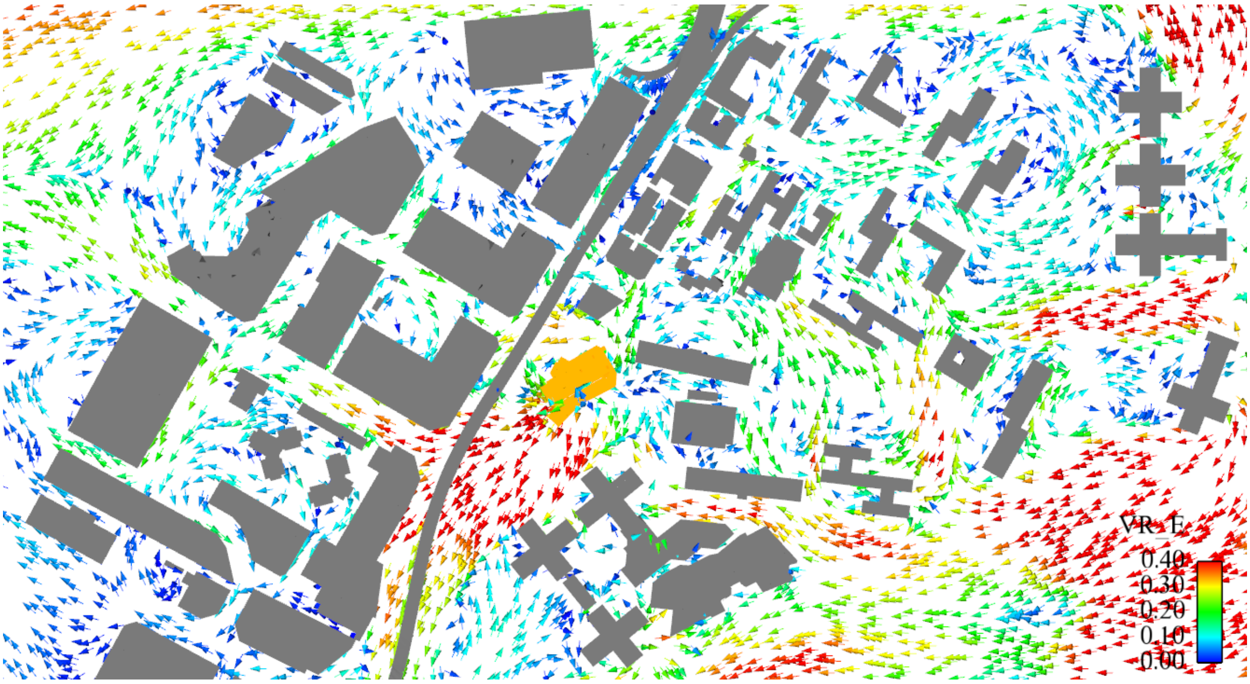
NE wind



ENE wind



E wind



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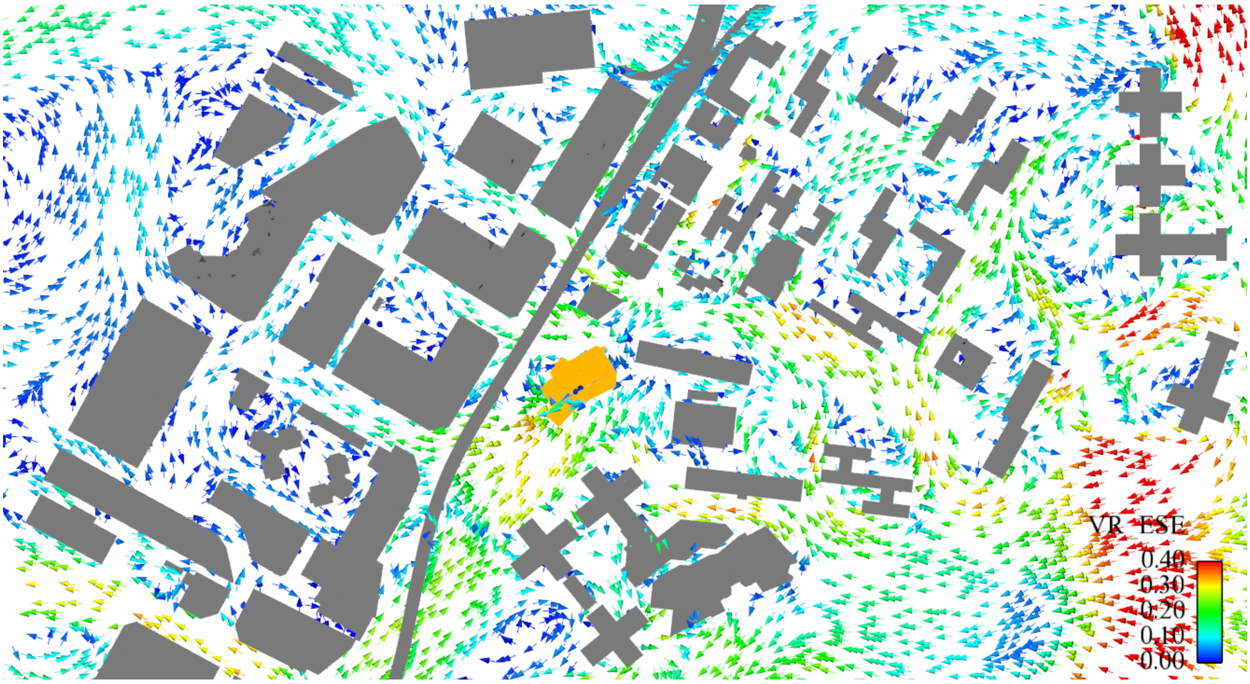

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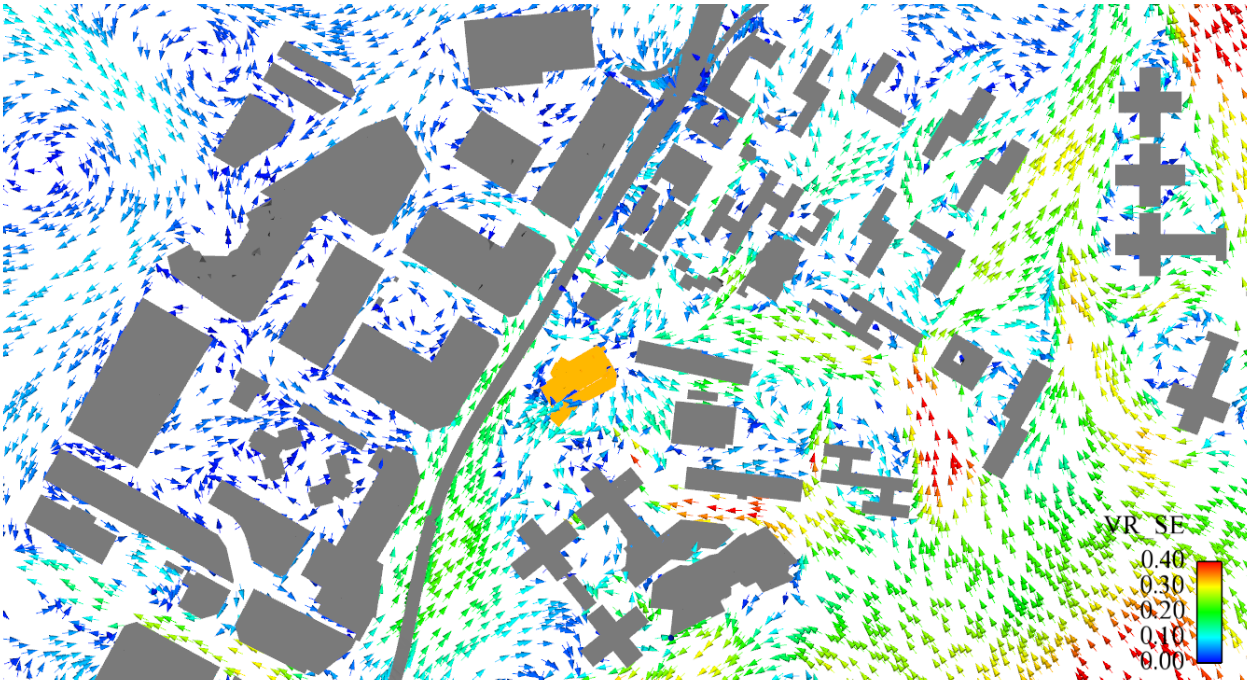

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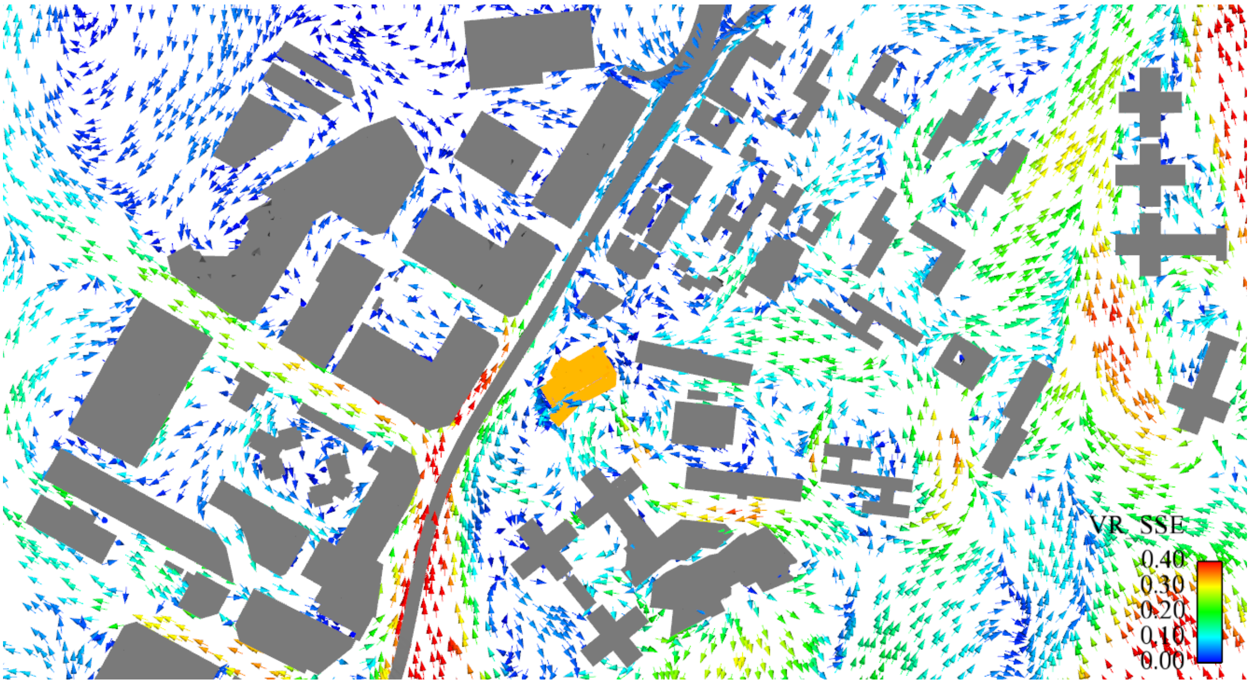

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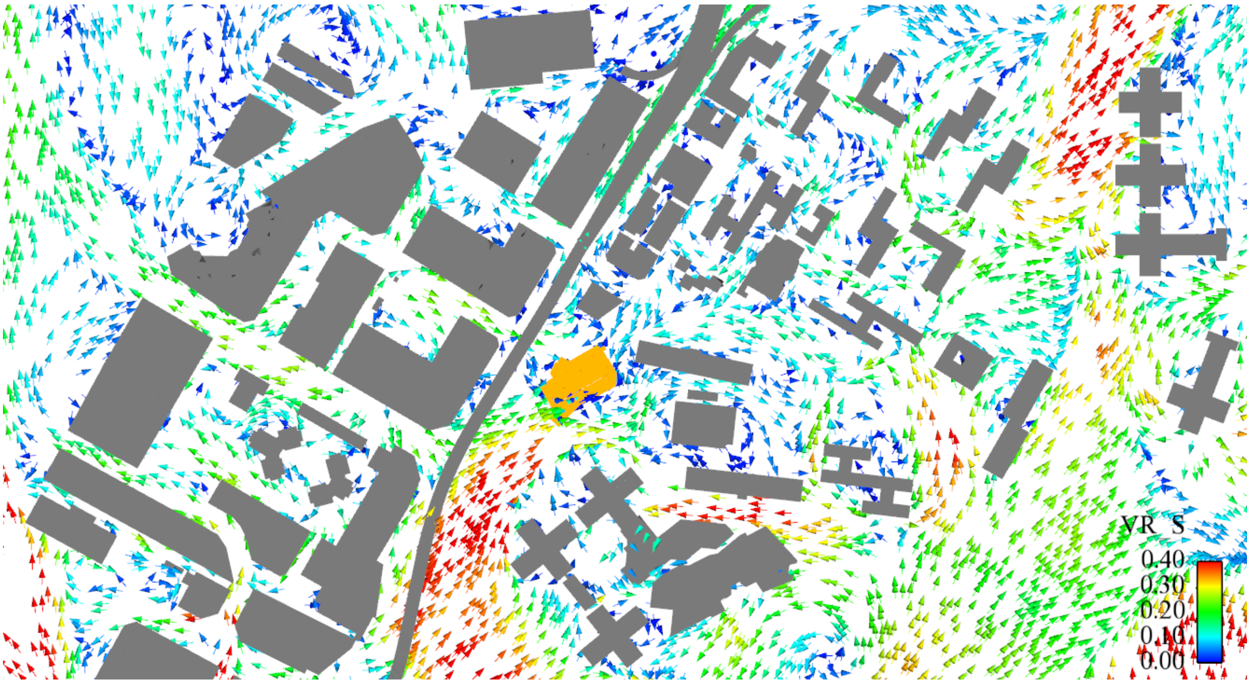
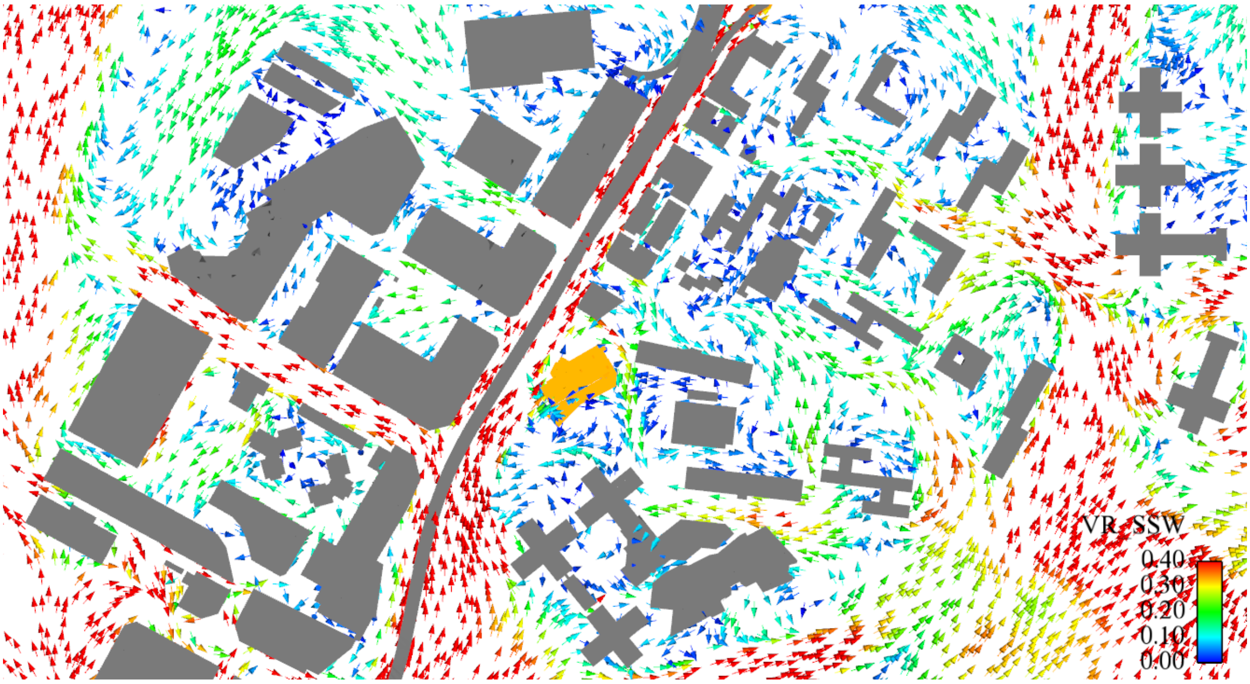
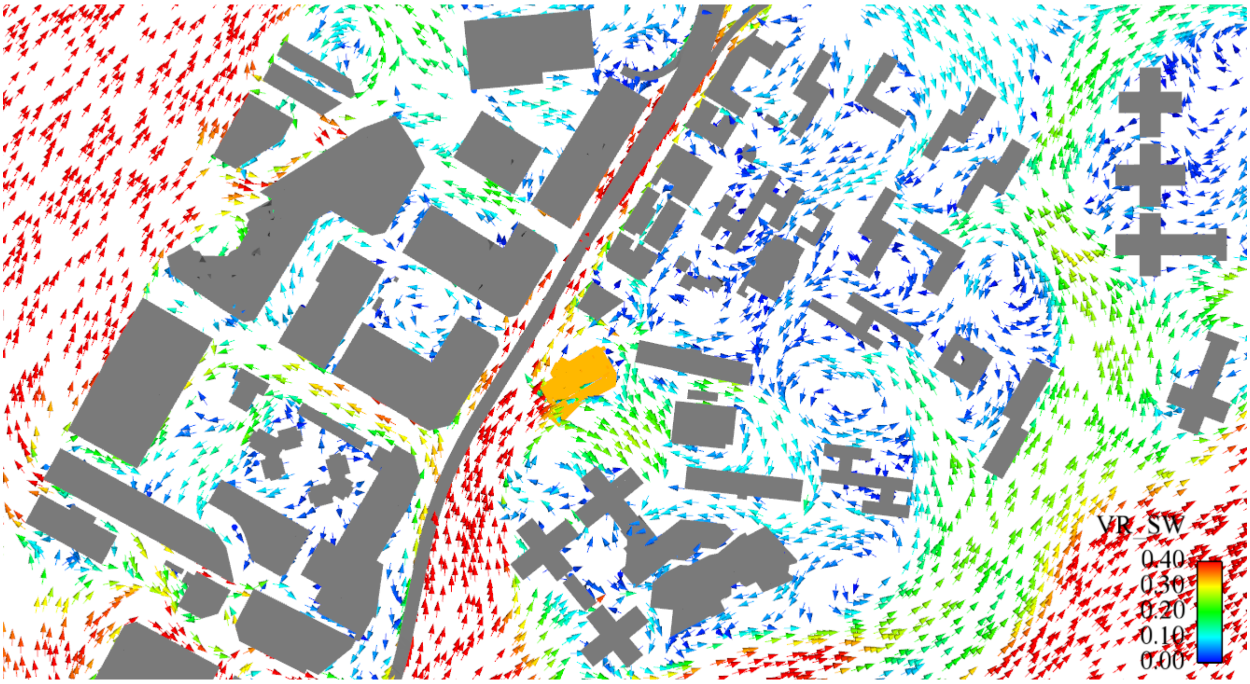


SSW wind



SW wind



WSW wind