Effect of wind direction and building disposition on gusty wind environment at high-rise building area

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Contents

1. Introduction

Urbanization → high-rise buildings ↗

→ influence the urban microclimate

→ increased wind speed around high-rise buildings (HRBs) is one of the most important micrometeorological effects (Oke, 1987)

So far any significant building wind impact is not assessed in high rise building environmental impact statement in Korea.

1. Introduction

327 typhoons affected Korea in the last 100 years and Typhoon induced wind damages are increasing (Typhoon White Book, 2011)

On 2nd September 2010, the strongest typhoon 'Kompasu' since 1995 hit Seoul, downing utility poles and trees, and shattering glasses in the building's windows.

Therefore, It is necessary to evaluate the gusty wind near high rise building area.

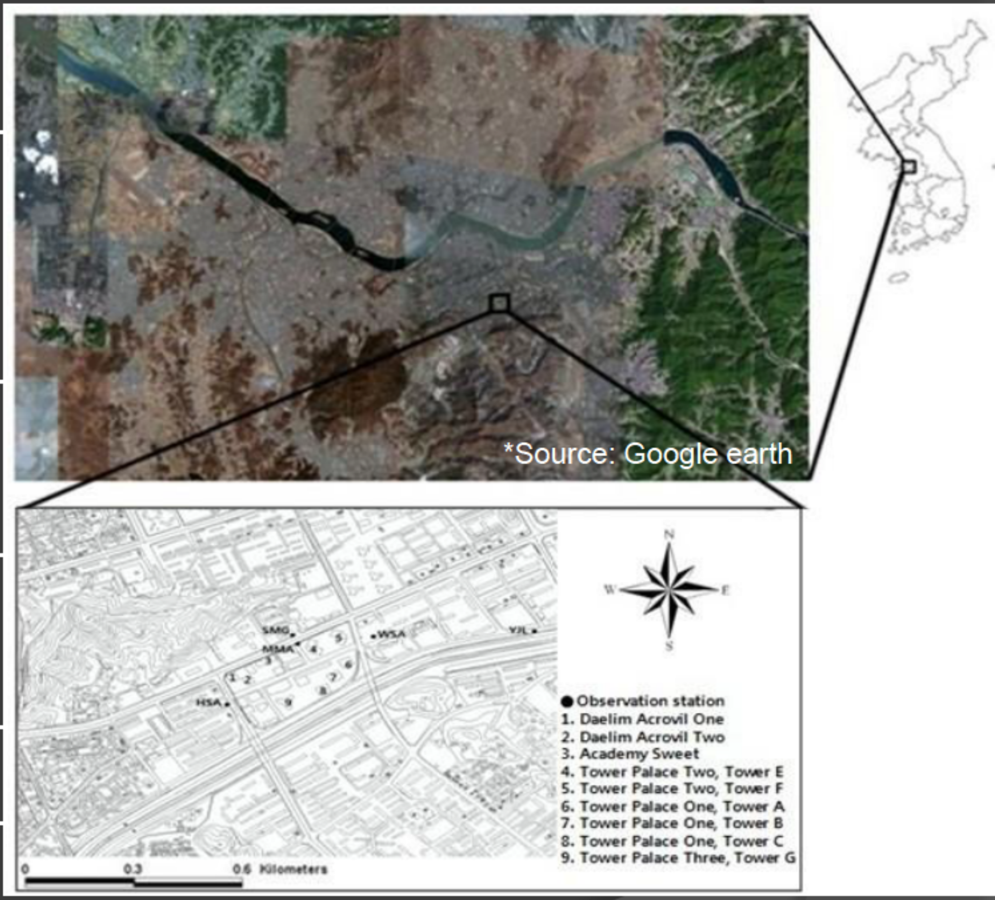
1. Introduction

Purpose:

To investigate the **wind characteristics** near high-rise building area under gusty wind conditions using numerical simulations.

2. study site

Location	Nearby tower palace, Dogok-dong, Gangnam-gu, Seoul
Annual mean air temperature of Seoul	12.5 ° C
Annual precipitation of Seoul	1450.5 mm
Land use type	Commercial-residential



The location of the study site

2. study site

Fallen Tree

Broken windows

Fallen observation tower

Wind damages at the study site during Typhoon 'Kompasu'（2nd September 2010）

3. Materials and methods

(1)Field observation

(2)Numerical simulation

(3)Validations

(4)Simulations for building wind characteristics

3. Materials and methods

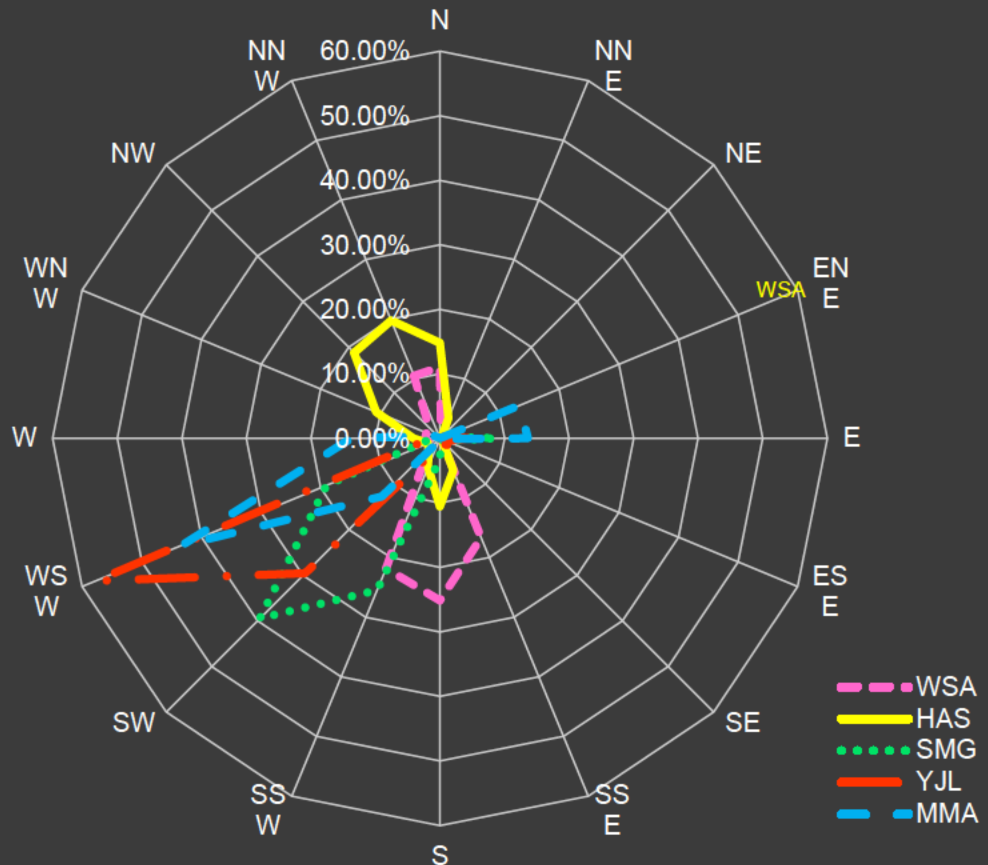
(1) Field observation

HSA	Hanshin apartment
WSA	Woosung apartment
SMG	Sookmyung girls' high school
MMA	Military mutual aid association
YJL	Yangjae stream left dike

The locations of five observation stations at the study area

3. Materials and methods

(1) Field observation



Percentage of wind direction when wind speed≥8m/s

Except the hanshin station, The rest four stations' prevailing gusty wind directions are from *south* to *west-southwest*.

3. Materials and methods

(2) Numerical simulation

Target area

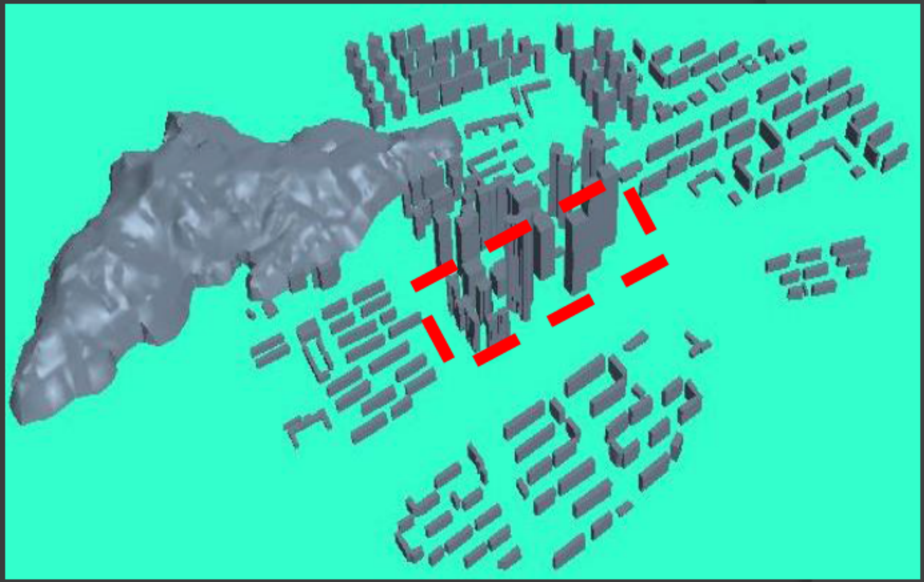
Area for simulation

Domain of study site and target area

3. Materials and methods

(2) Numerical simulation

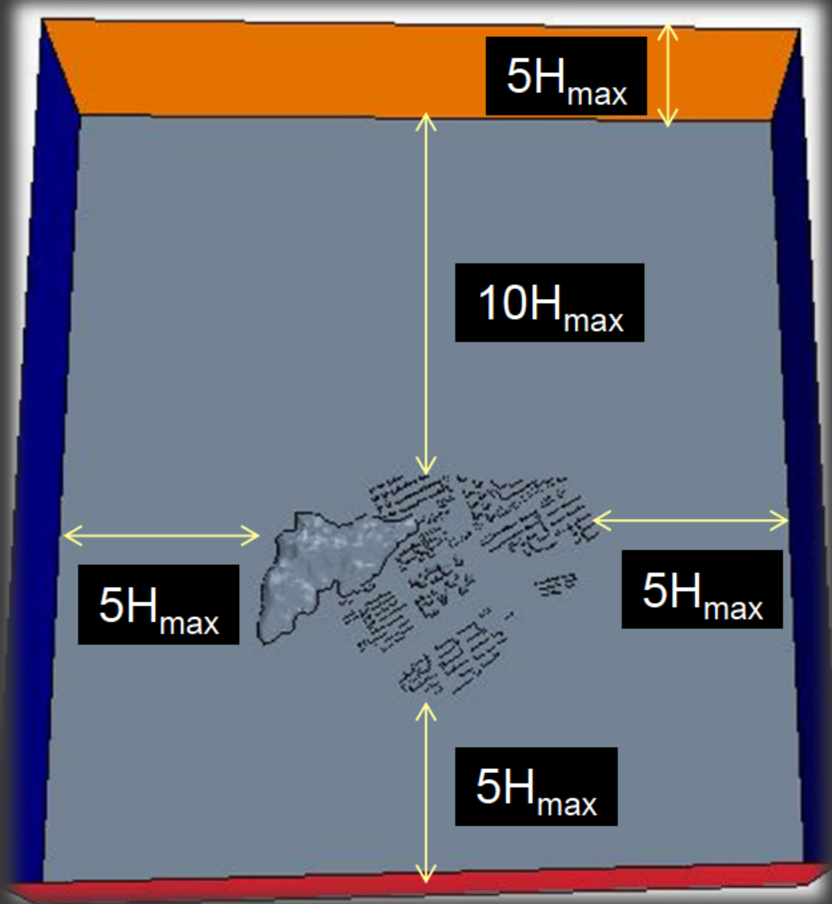
2D domain of study site



3D domain of study site

3. Materials and methods

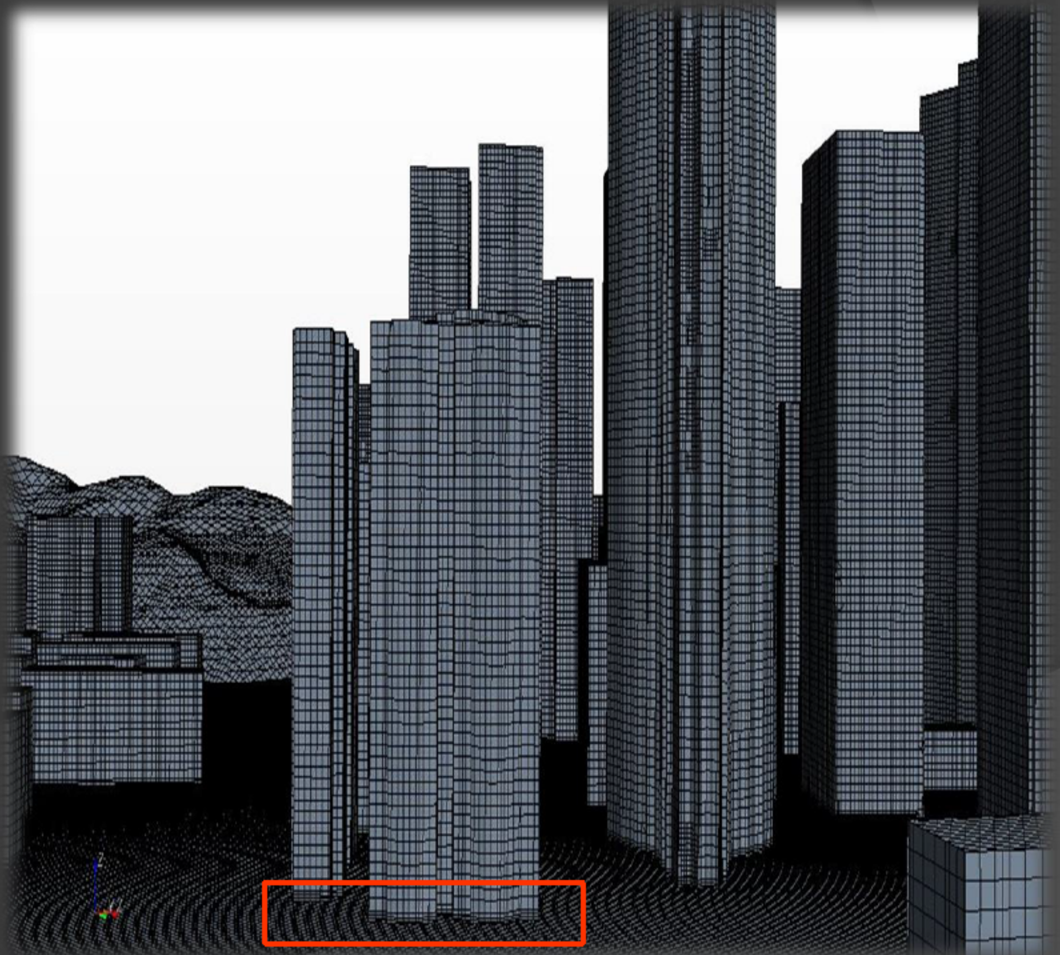
(2) Numerical simulation



Domain setting

(Hmax : the height of highest building)

Domain size: 4.8 * 5.4 * 1.5 km^3



Mesh discretization

3. Materials and methods

(2) Numerical simulation

Boundary conditions of all simulations

Turbulence model	Standard k-ε model
State	Steady state
Pressure correction algorithm	SIMPLE
Domain Setting	Inlet: Velocity Inlet Outlet: Pressure Outlet Bottom: Non-slip Top & Side: Symmetry Plane
Inlet Wind Profile	$U_{(Z)} = U_{(G)} * (Z/Z_{(G)})^{\alpha}$ $k = 1.5(U*I)^2$ $\varepsilon = C_{\mu}^{0.5} * k * (\Phi Uz / \Phi z)$

I :Turbulence intensity
K:Turbulence kinetic energy
Z_G :Observation height
C_μ: Constant in the standard k- ε model
U: Mean wind velocity
Ḱ :Von Kámán constant

ε :Dissipation rate of k
$U_{(G)}$:Wind velocity at the observation height
u^*: Friction velocity
v_T :Eddy(or turbulent) viscosity
α: Roughness coefficient

3. Materials and methods

(3) Validation

- Validation of wind profile power law $U_{(Z)} = U_{(G)} * (Z/Z_{(G)})^{\alpha}$

  Roughness coefficient：α=0.25, 0.28, 0.33

- Validation of the wind environment under strong typhoon condition

- Select YJL station data as reference data

3. Materials and methods

(4) Simulations for building wind characteristics

After establishment of the model with the proper roughness coefficient（α）, simulations were conducted under three conditions to discuss the building wind characteristics :

① Effect of wind direction

② Effect of building density

③ Effect of building height

4. Results

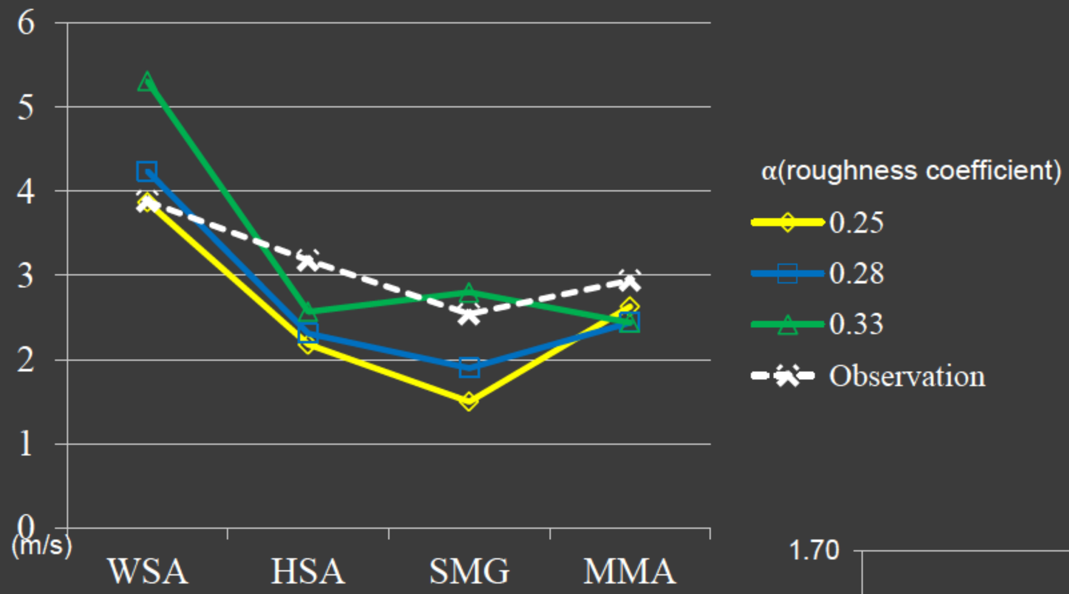
(1) validation between observation and simulation results

Beaufort Level, mean wind speed and standard deviation(σ) of YJL

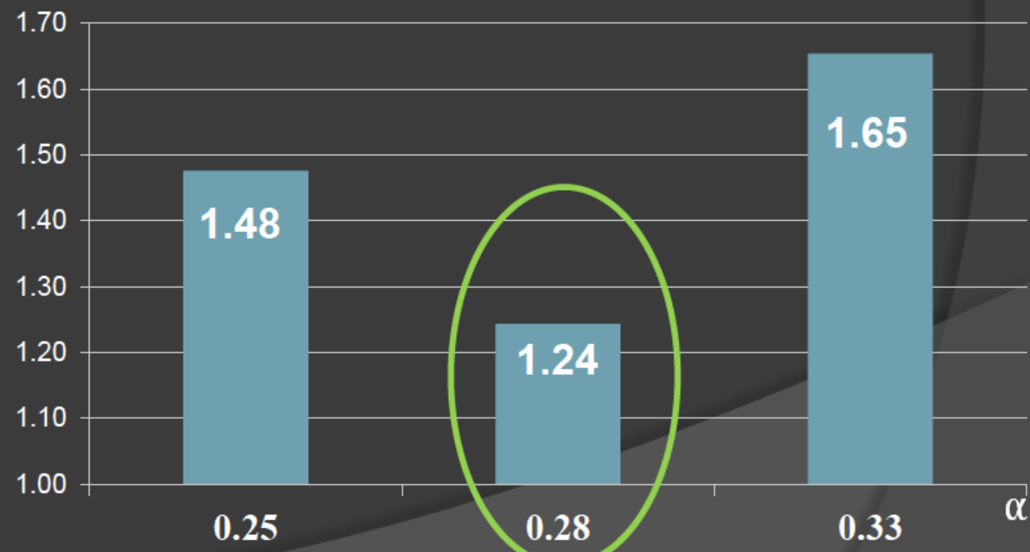
Beaufort Level			YJL	
Level	Range of wind speed (m/s)	Frequency ratio at YJL (%)	Mean wind speed	σ
1	0-0.3	6.2	0.24	0.06
2	0.3-1.6	29.5	0.88	0.37
3	1.6-3.4	34.1	2.47	0.52
4	3.4-5.5	21.6	4.30	0.58
5	5.5-8.0	7.3	6.41	0.66
6	8.0-10.8	1.2	8.92	0.72
7	10.8-13.6	0.1	11.71	0.74
8	13.6-17.2	0.0	14.82	1.07
9	17.2-20.8	0.0	19.17	1.21
10	20.8-24.5	0.0	22.57	0.83
Average standard deviation				0.68

4. Results

validation between observation and simulation results



Observation and simulation wind speeds based on α at four points



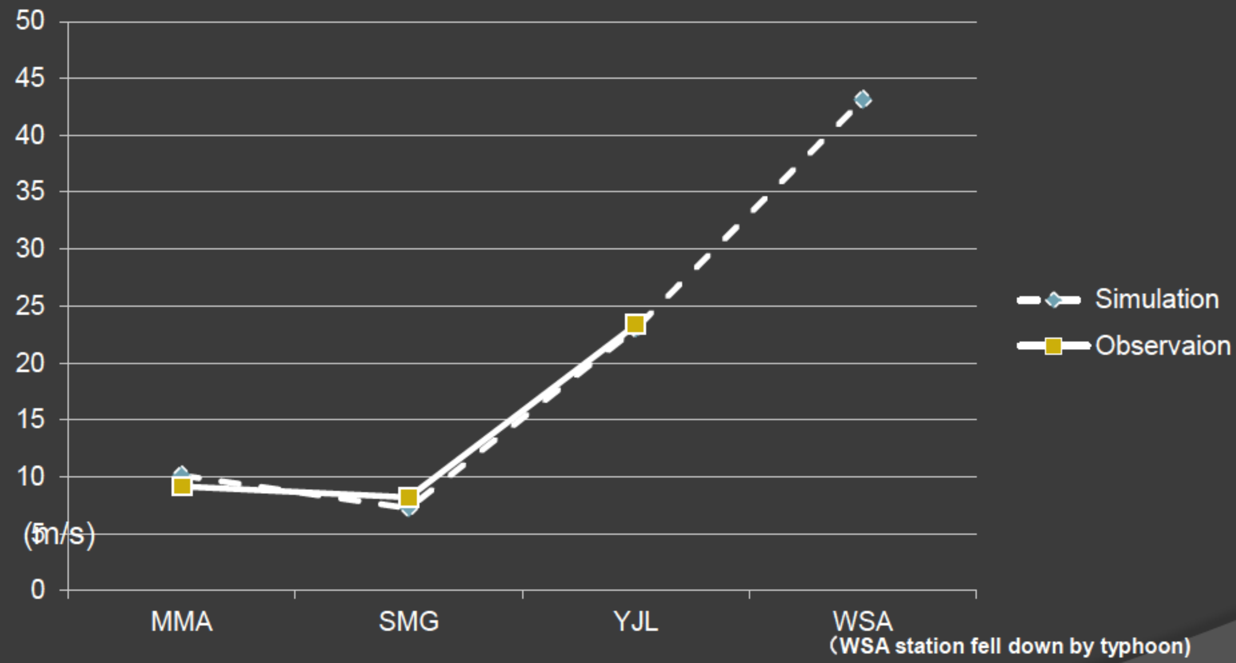
Standard deviation of the observation and simulated wind speed based on α

4. Results

validation under the typhoon condition

The maximum wind data at YJL station which is 23.36 m/s at 176.6° was selected as the reference data.

The simulation result has a high accuracy under the typhoon condition.



Comparison between simulation and observation data (9/2/2010 7:00)

4. Results

The effect of wind direction on wind environment

The maximum wind speed of HRB and surrounding area in each wind direction

Wind direction	High rise building area $_{max}$	Surroundings $_{max}$
165°	48.6 (Point1)	48.6 (Point2)
180°	48.6 (Point3)	**54.7** (Point4)
195°	**50.8** (Point5)	44.5 (Point6)
210°	44.1 (Point7)	37.0 (Point8)
225°	46.2 (Point7)	31.9 (Point9)
240°	46.1 (Point7)	31.0 (Point2)
255°	44.5 (Point10)	38.8 (Point2)

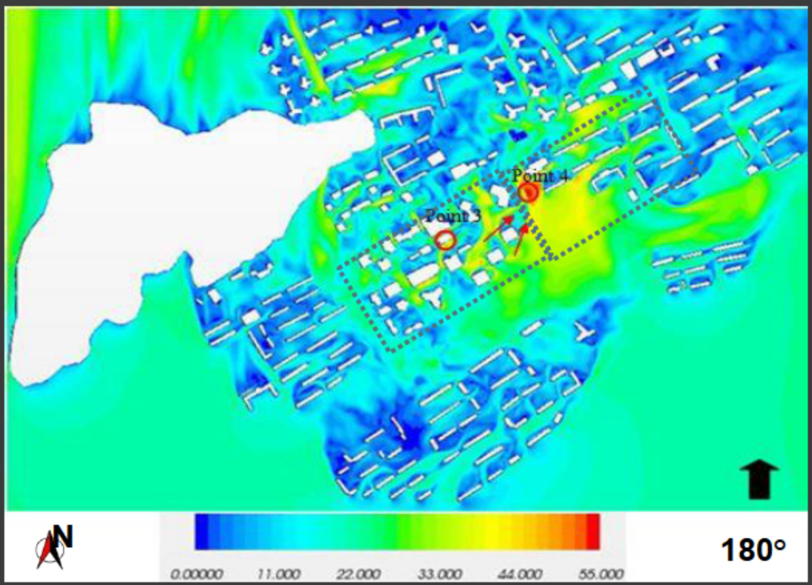
The location of maximum wind speed in each wind direction

（Point：max wind speed point）

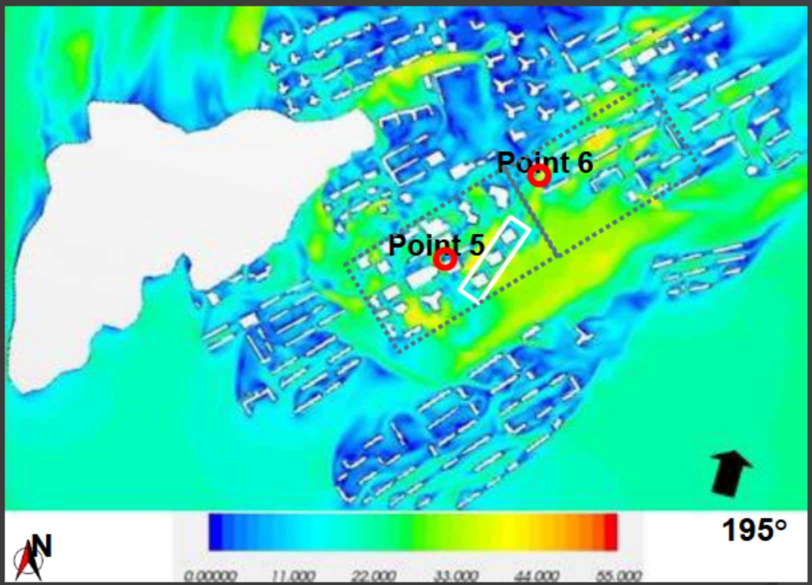
4. Results

The effect of wind direction on wind environment

When the wind comes from 180 (south), the max speed with 54.7 m/s(point 4) at the surrounding area is higher than 48.6 m/s (point 3) at the HRB area.



Wind environment(wind direction 180°, 2m above ground)



Wind environment(wind direction 195°, 2m above ground)

The maximum wind speed reached 50.8m/s (Point 5) at the corner of a relatively low-rise building (54m) surrounded by HRBs, and maximum wind speed of 44.5m/s (Point 6) at surrounding area were recorded at 195°.

Summary

(1) Not only high rise building area but also adjacent areas, especially the corners of leeward side are dangerous and susceptible to building wind damage in certain directions.

The wind direction factor should be the primary consideration in the wind environment assessment.

(2) Changing building density ⟶ barely reduce the maximum wind speed of the surrounding area of HRBs .

Compared with the HRB area and its adjacent area, the most dangerous place is almost twice of the highest building's height away from the HRB area.

(3) Changing building height ⟶ validly decrease the wind speeds both at HRBs area and its surrounding area.

(4) Compared with decreasing the building density, changing the building height is more effective in decreasing wind speed.