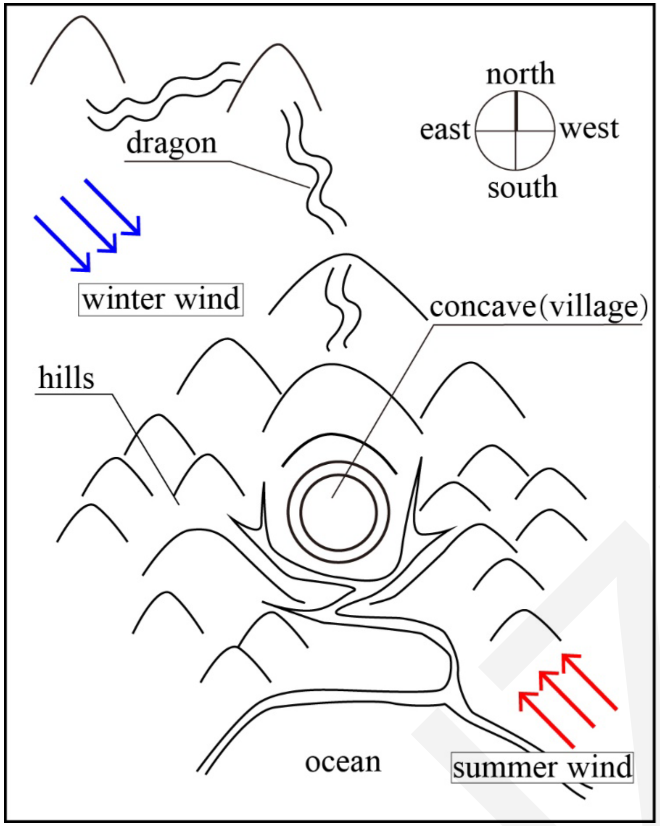
Journal of Zhejiang University-SCIENCE A

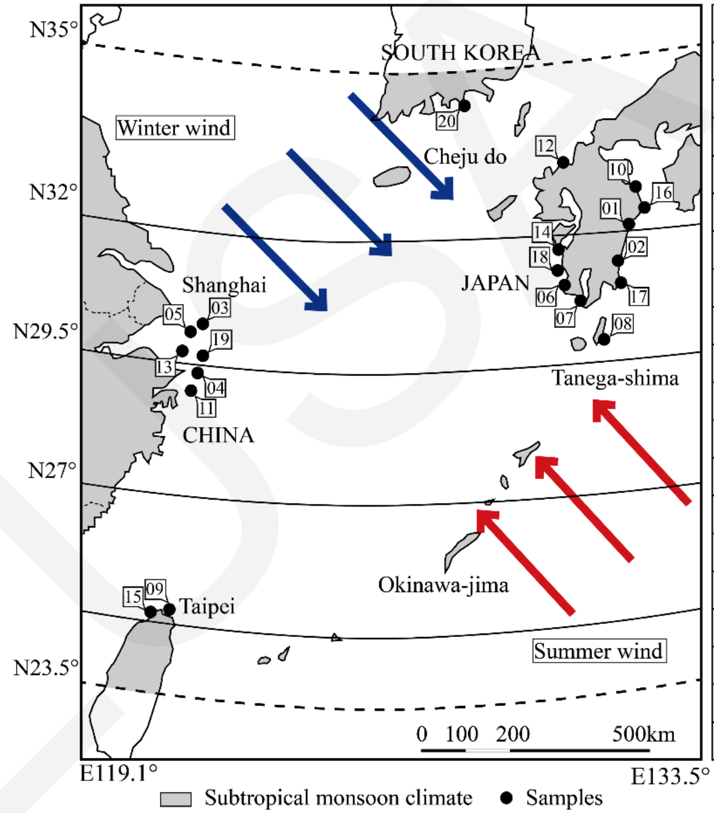
Wind suitability in site analysis of coastal concave terrains using computational fluid dynamics simulation: a case study in East Asia

Xiaoqing ZHU
Email:arc_zxq@163.com

Cite this as: Xiao-qing Zhu, Jian-tao Weng, Yi-qun Wu, Wei-jun Gao, Zhu Wang, 2017. Wind suitability in site analysis of coastal concave terrains using computational fluid dynamics simulation: a case study in East Asia. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 18(9):741-756.
http://dx.doi.org/10.1631/jzus.A1600313

Background

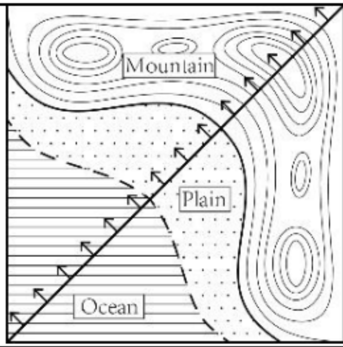
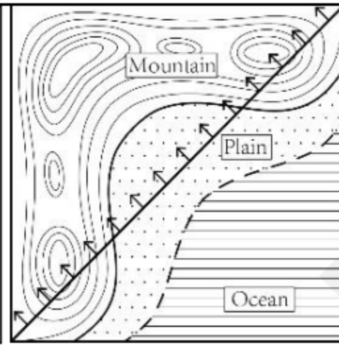
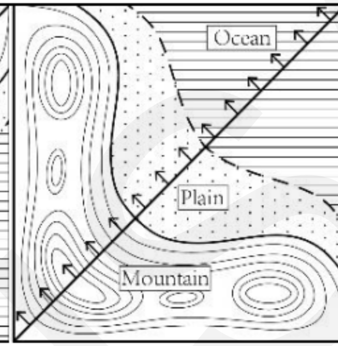
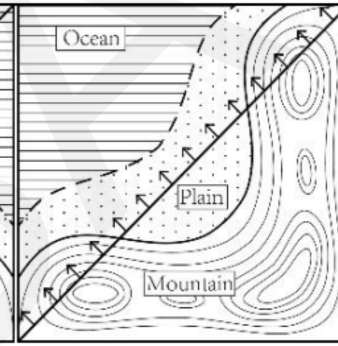
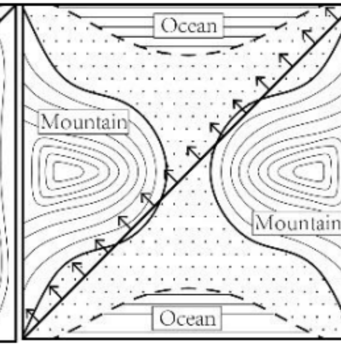




01	Kitauramachi Miyanoura	Japan
02	Oura	Japan
03	Yugengwan Village	China
04	Shaojiwan Village	China
05	Maojia	China
06	Kuchinomachi	Japan
07	Ei-chō	Japan
08	Wakizaki	Japan
09	Caoli	China
10	Himi	Japan
11	Duizhi village	China
12	Genkai	Japan
13	Yangangdun	China
14	Nishikata	Japan
15	Shihmen	China
16	Nobeoka	Japan
17	Kamae Oaza Hatozuura	Japan
18	Nakayashiki	Japan
19	Lizhangzhou	China
20	Yeongu 3-Gil	Korea

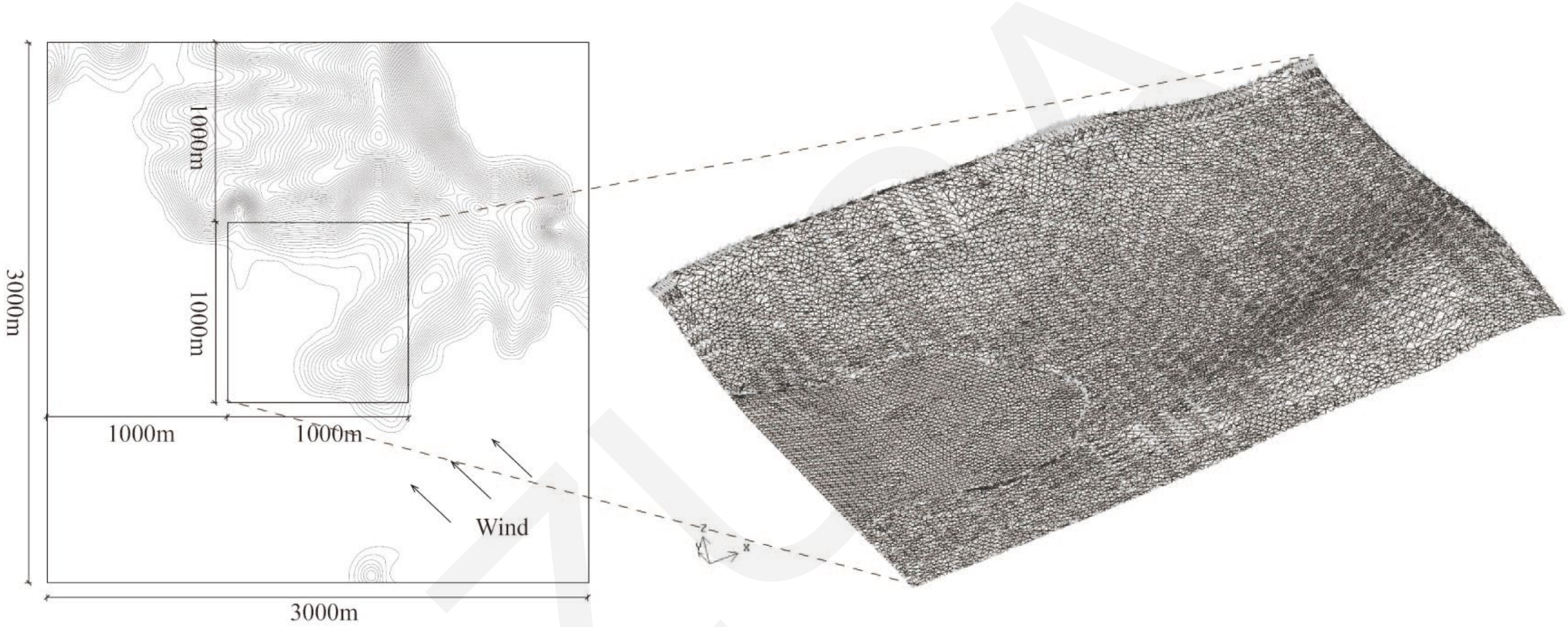
In most coastal concave terrains, a settlement is normally located on the north side, facing south. However, the modern construction pattern is quite rapid and a higher quality of living quality is demanded, including natural ventilation of individual buildings, a masterplan for external comfort, pollution dispersion and the use of wind loading calculations in structural design. So, it is necessary to assess the **outdoor wind environment**.

Methodology

Type	I	II	II	IV	V
Description	Down-crosswind	Windward	Up-crosswind	Leeward	Crisscross
Diagrams					
Configuration with typical characteristics	Openings of coastal concave terrains are perpendicular to the wind direction ; open to the southwest.	Openings of coastal concave terrains are parallel to the wind direction; open to the southeast.	Openings of coastal concave terrains are perpendicular to the wind direction; open to the northeast.	Openings of coastal concave terrains are parallel to the wind direction; open to the northwest.	Openings of coastal concave terrains cross the wind direction; open to the north-south direction.
Location	Located mainly in the southwest corner of coastal islands.	Located mainly in the southeast corner of coastal islands.	Located mainly in the northeast corner of coastal islands.	Located mainly in the northwest corner of coastal islands.	Located mainly in the northwest corner of coastal islands.
Selected sampling sites	Kitauramachi Miyanoura, Japan; Oura, Japan; Yugengwan Village, China; Shaojiwan Village, China.	Maojia, China; Kuchinomachi, Japan; Ei-chō, Japan; Wakizaki, Japan.	Caoli, China; Himi, Japan; Duizhi village, China; Genkai, Japan.	Yangangdun, China; Nishikata, Japan; Shihmen, China; Nobeoka, Japan.	Kamae Oaza Hatozuura, Japan; Nakayashiki, Japan; Lizhangzhou, China; Yeongu 3-Gil, South Korea.

According to the direction of the opening of coastal concave terrains, a total of 20 sampling sites were selected and divided into five categories: down-crosswind, windward, up-crosswind, leeward and crisscross.

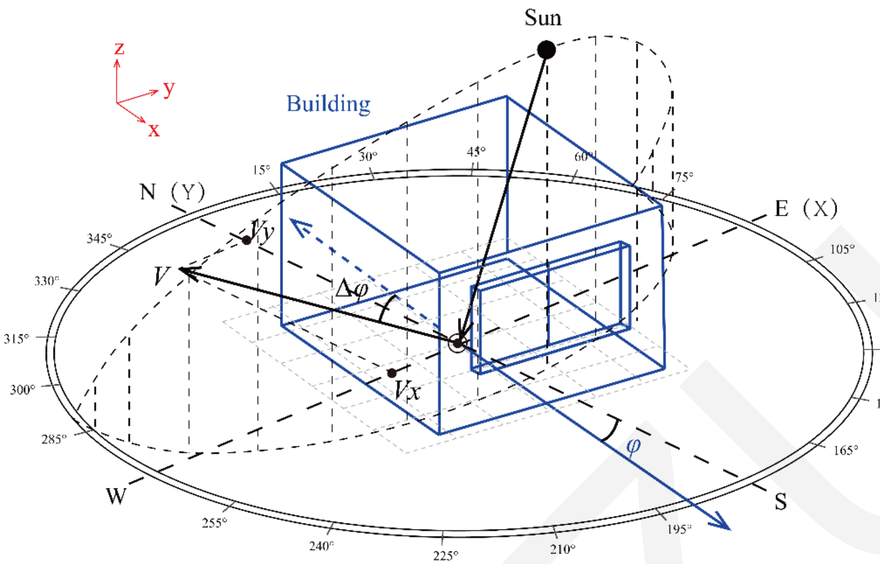
Methodology

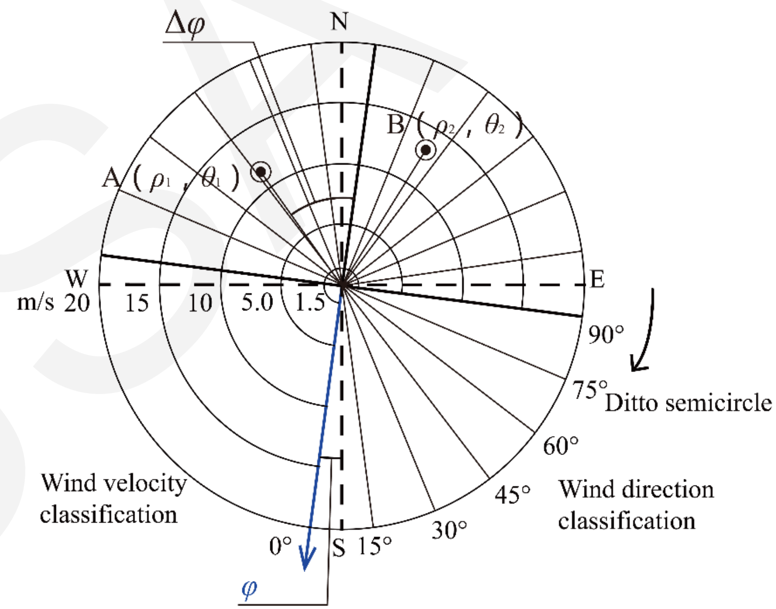


FLUENT was used for developing a wind simulation model. CFD grids with high precision were required to generate simulated wind fields in coastal concave terrains.

This simulation took summer as the main evaluation season for investigating external comfort, pollutant diffusion and natural ventilation conditions in these regions. The wind in the final simulated conditions was set as the prevailing wind in each case.

Methodology

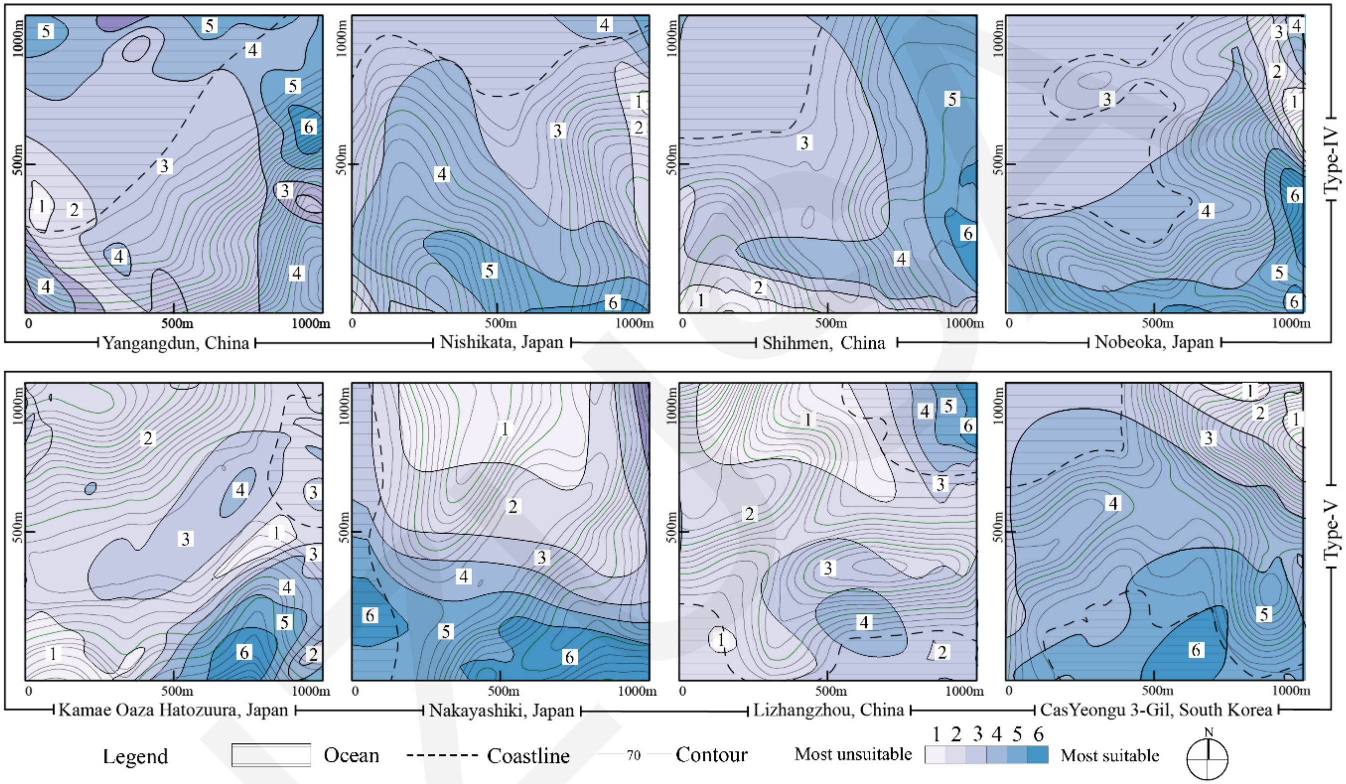




To effectively assess the external comfort and natural ventilation of wind environments, the two non-dimensional variables, wind velocity and wind direction, were integrated to form a new dimensionless parameter named wind suitability (WS):

$$WS = \mathrm{INT}\left(\sqrt{(V'^2 + D'^2)/2}\right).$$

Results



After simulating typical cases, an evaluation chart of wind suitability could be obtained. The wind suitability results indicated that the coastal con-cave terrains could directly influence the layout of wind fields. Buildings could achieve the best wind environment if they were located on the windward slopes. In these areas, the wind suitability was highest.

Discussion

Correlations analysis between wind suitability and terrain factors

	Slope gradient		Slope direction		Altitude		Wind suitability	
	Correlation coefficient	Sig. (2-tailed)	Correlation coefficient	Sig. (2-tailed)	Correlation coefficient	Sig. (2-tailed)	Correlation coefficient	Sig. (2-tailed)
Slope gradient	1.000	—	-0.057	0.001	0.458	0	-0.435	0
Slope direction	-0.057	0.001	1.000	—	-0.001	0.937	-0.011	0.520
Altitude	0.458	0	-0.001	0.937	1.000	—	-0.968	0
Wind suitability	-0.435	0	-0.011	0.520	-0.968	0	1.000	—

1. Correlations of <0.05 (2-tailed) were considered statistically significant.
2. There were 800 measuring points.

Altitude, slope gradient and slope direction are the three main numeric variables representing terrain characteristics. The correlation between wind suitability and altitude was the most significant, with a correlation coefficient of -0.968. So altitude was the main terrain factor determining wind suitability.

Discussion

In this paper, after the calculation of SPSS, we obtained the logistic regression model of preferable wind conditions deduced from SPSS analysis as follows:

$$P_p = 1/\left(1+\exp\left(-1363.64+0.87x_1+0.41x_2+33.92x_3\right)\right).$$

The logistic regression model of undesirable wind conditions was deduced from SPSS analysis as follows:

$$P_i = 1/\left(1+\exp\left(897.25-0.87x_1-0.54x_2-26.89x_3\right)\right).$$

We used the data of the 20 cases to check the formulas, and the total correct rates of fitting were about 75%. Therefore, these formulas can provide a rough probability of preferable and undesirable wind conditions in the area.

Conclusion

- In conclusion, we recommend the selection of residential building sites with bay openings facing the direction of the prevailing wind and that the opposite direction should be avoided.

- Correlation analysis suggested that wind suitability is significantly correlated with terrain factors. The correlation between wind suitability and altitude was the most significant, followed by the slope gradient. There was no strong association between slope direction and wind suitability.

- Guidelines for the wind environment were proposed based on the distribution rules of measuring points of the wind field. In types I, II, III, we suggested choosing areas where the altitude was 0~10 m and the slope gradient was 20~30°, and for types IV and V, areas where the altitude was 40~50 m and the slope gradient 30~40°. When it comes to direction, site selection varies among the different types. Overall, in types I, II and III, it was better to use areas where the slope direction was 90~180°, while in types IV and V, 225~315° was recommended.
- Formulas to estimate probabilities of preferable and undesirable wind conditions were introduced, to give a broad evaluation of wind environments. But if detailed results are needed, we suggest using the evaluation model for wind suitability.