Wind Engineering Joint Usage/Research Center
FY2020 Research Result Report

Research Field: Wind Disaster Mitigation
Research Year: FY2020
Research Number: 20203002
Research Theme: Integrated forecast of typhoon wind speed in urban area by meteorological and CFD models and field measurement
Representative Researcher: Shuyang CAO
Budget [FY2020]: 250000 Yen

*Figures can be included to the report and they can also be colored.
*Submitted reports will be uploaded to the JURC Homepage.

1. Research Aim

The fact that wind-related damage does not decrease in the past decades implies that the prediction of wind speed for a huge area does not sufficiently warn people of the wind risk. A typhoon usually travels several days before it lands in China or Japan since its birth. Typhoon-induced damage would be significantly mitigated if people could successfully predict the wind speed at a certain place or around a particular structure of concern. In order to achieve this purpose, people has to be able to 1) Predict the typhoon track and wind speed of meso-scale in real time; 2) Predict the wind speed of micro-scale at a certain point or around a particular structure in real time; and 3) optimize the simulation parameters in time by comparison with field measurements to achieve a better prediction of wind speed.
Towards this aim, as the first step, WRF-UCM models are applied to the simulation of strong urban wind fields in a typhoon in 2020.

2. Research Method

In the present study we first select an appropriate combination of the planetary boundary layer (PBL) and microphysics (MP) physical parameterization schemes by sensitivity tests on typhoon track and intensity, and then investigate the performances of UCMs under a fixed combination of physical parameterizations, aiming at finding out the better WRF-UCM combination for strong wind simulation in an urban area. More specifically, a 5-level nested WRF-UCM coupled simulation of spatial and temporal variations of wind speed in a real urban area is carried out during typhoon Lekima, from which the applications of WRF-UCM models to the simulation of a strong urban wind field are examined. Typhoon Lekima with a minimum pressure of 915 hPa and a maximum sustained wind speed of 62m/s was the strongest typhoon to strike China in 2019 and the third strongest typhoon landing in Zhejiang Province since 1949. A wide urban area was affected, causing a large amount of damage to urban infrastructures and buildings.
The simulation consists of two stages. The first stage contains the first three nested domains only, in which a sensitivity test of physical parameterized schemes is performed to select a combination of physical parameterized schemes that results in the best simulation of typhoon track and typhoon intensity. The second stage contains all 5-level nested domains in order to examine the performances of UCMs during a typhoon by utilizing the best physical parameterized scheme decided in the first-stage simulation. As shown in Table 1, 5 microphysics schemes (the Purdue Lin scheme, the WRF Single-Moment 5-class scheme, the Eta microphysics scheme, the WRF Single-Moment 6-class scheme and the Thompson scheme) and 3 UCMs (slab, single-layer and multi-layer UCMs) are tested.

Table1 Summary of model configurations

	Domain 01	Domain 02	Domain 03	Domain 04	Domain 05

Center Point	120.997E, 28.108N				
Horizontal grid distance	36Km	12Km	4Km	1.333Km	0.444Km
Dimension (XY)	150×150	240×240	240×240	210×210	210×210
Time step	72s	24s	8s	8/3s	8/9s
Calculation period (UTC time)	1200 Oct. 08 - 0600 Oct. 10, 2019			0600 Oct. 09 - 0000 Oct. 10, 2019	1800 Oct. 09 - 0000 Oct. 10, 2019
Map projection	Mercator				
Vertical coordinates	Terrain-following hydrostatic pressure vertical coordinate with 60 inhomogeneous vertical levels				
Time integration scheme	3^{rd}-order Runga-Kutta Scheme				
Spatial differencing scheme	6^{th}-order center differencing				
Longwave Radiation scheme	Rapid Radiative Transfer Model				
Shortwave Radiation scheme	Dudhia				
Surface Layer scheme	Monin-Obukhov Scheme				
Land Surface scheme	Noah Land Surface Model				
Planetary Boundary layer scheme	MYJ/ BouLac PBL			MYJ	
Cumulus Parameterization scheme	Kain-Fritsch			–	
Microphysics scheme	Lin/ WSM5/ ETA/ WSM6/ THOM			Lin	
Urban Canopy Model	–			SB-UCM/ SL-UCM/ ML-UCM	

3. Research Result

Figure 1 compared the simulated typhoon track with real typhoon track while Figure 2 compares the one-hour-mean wind speed profiles obtained by 3 models at different times. The simulated time-varying wind speed are compared with observation data to verify the accuracy of WRF-UCM in wind field simulation. The mean wind speed profiles, turbulence intensity profiles and self-power spectra of the simulated wind fields are compared to evaluate the effect of UCMs on WRF simulation of strong urban wind fields in a typhoon.

1) MYJ scheme combined with the LIN, WSM5 or THOM microphysical model better restores the typhoon track while the MYJ scheme combined with Lin, WSM5 or WSM6, lead to satisfactory results of typhoon intensity from a statistical point of view.

2) The WRF-UCM model can be used to restore the typhoon wind fields for wind engineering purposes, especially for the high-wind-speed periods after typhoon landfall.

3) ML-UCM effectively reflects the interference effect of various urban land-use types on wind flow. Comparing simulation results with observation data shows that ML-UCM improves the simulation results of the wind field within the atmospheric boundary layer. This is proved by the fact that both the mean-wind-speed profiles and turbulence-intensity profiles of typhoon wind fields obtained using ML-UCM are closer to the observed values than the results of the other two models. However, due to WRF model restrictions, neither turbulence intensity nor power spectrum can be perfectly simulated.

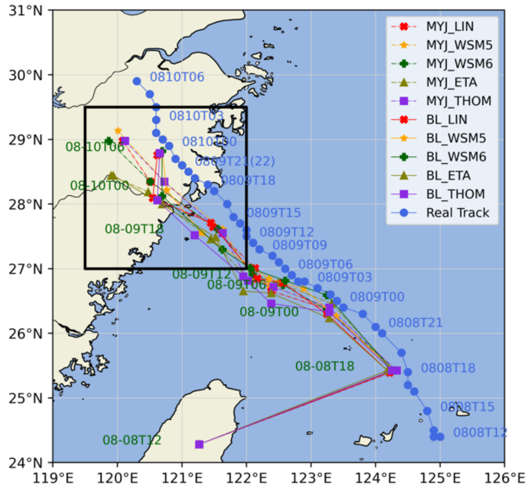


Fig. 1 Comparison of the simulated typhoon track with observations

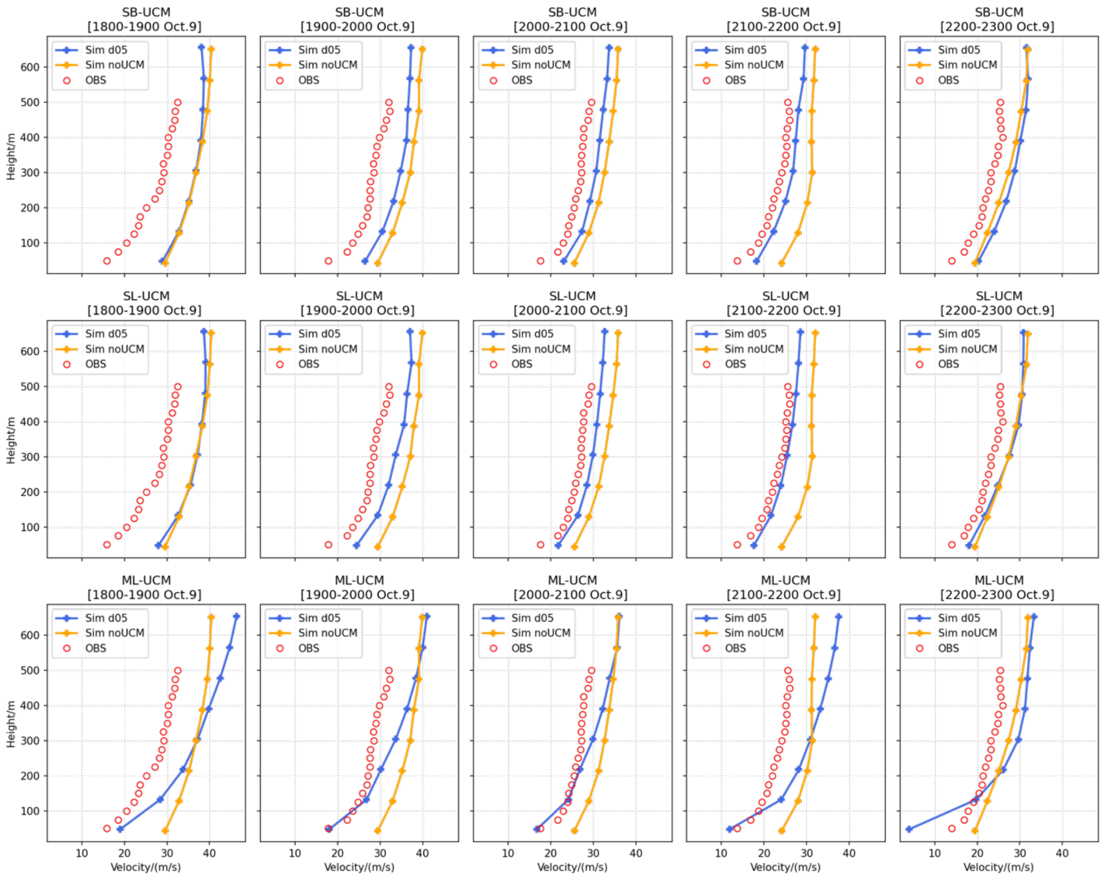


Fig.2 Comparison of the one-hour-mean wind speed profiles obtained by 3 models

4. Published Paper etc.

[Underline the representative researcher and collaborate researchers]

[Published papers]

1. No paper published. (In submission)

[Presentations at academic societies]

1. No presentation.

[Published books]

1. No book published

[Other] Intellectual property rights, Homepage etc.
No

5. Research Group
1. Representative Researcher
Shuyang CAO

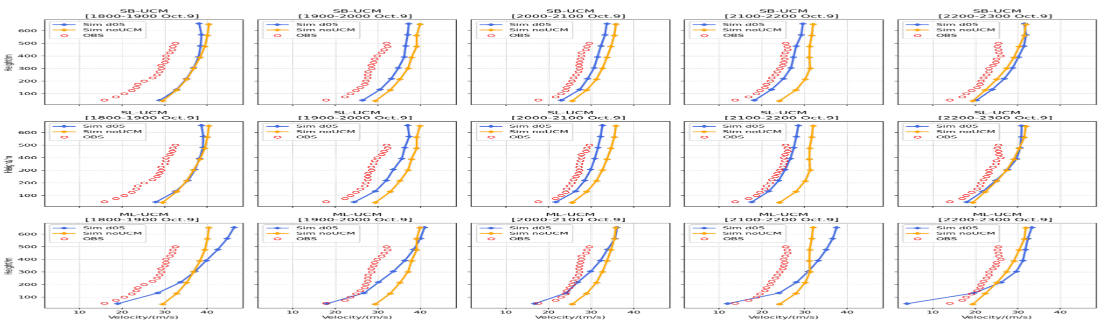
2. Collaborate Researchers
1. Yuxin Zhang
2. Lin Zhao
2. Jinxin Cao

6. Abstract (half page)

Research Theme
Representative Researcher (Affiliation)
Summary・Figures

Integrated forecast of typhoon wind speed in urban area by meteorological and CFD models and field measurement
Yuxin Zhang, Shuyang Cao, Lin Zhao, Jinxin Cao (Tongji University, Shanghai, China)

Summary
Typhoon-induced damage would be significantly mitigated if people could successfully predict the wind speed at a certain place or around a particular structure of concern. Towards this aim, as the first step, WRF-UCM models are applied to the simulation of strong urban wind fields in a typhoon in 2020. In this study, WRF-UCM coupled models are adopted to simulate an urban wind field during the landfall of a strong typhoon. Sensitivity analysis is first carried out in order to obtain the best typhoon track simulation, based on which the PBL scheme of Mellor-Yamada-Janjic (MYJ) and the Microphysics model of Purdue Lin (Lin) are chosen for successive WRF-UCM simulations. A World Urban Data Analysis and Portal Tool (WUDAPT) based Local Climate Zone (LCZ) classification map is drawn to replace and supplement the default underlying surface data to execute WRF-UCM coupled simulations. The simulated time-varying wind speed and wind direction are compared with observation data to examine the accuracy of the WRF-UCM simulation. The mean wind speed and turbulence intensity profiles and power spectra of simulated wind fields are further studied to evaluate the applicability of different UCMs to the simulations of the typhoon wind field in an urban area. It is shown that coupling suitable UCM into the WRF model can improve urban typhoon wind field simulation, and utilizing multi-layer UCM (ML-UCM) for high wind speed and slab UCM (SB-UCM) or single-layer UCM (SL-UCM) for moderate wind speed periods achieves better results.



Comparison of one-hour-mean wind speed profiles with observations