Extreme Winds in Urban Districts during Typhoon Jebi (2018)

By: Dr. Tetsuya Takemi, Associate Professor
Disaster Prevention Research Institute (DPRI), Kyoto University, Japan

Typhoon Jebi (2018) made landfall in the Osaka Bay area, Japan and caused significant damages to buildings and houses, trees, power lines, and so on. The maximum instantaneous wind measured at the meteorological observatory in Osaka reached 47.4 m s^{-1}, the third record in the history of the observatory.

This report documents the damages in an urban district of Osaka City, Japan and the results of the numerical analysis on extreme winds in the densely built, urban district.

1. Introduction

Typhoon Jebi (2018) developed in the western North Pacific in August 2018 and obtained the lifetime minimum central pressure of 915 hPa. After obtaining this intensity, Typhoon Jebi maintained its intensity while moving northward. On September 4th, Typhoon Jebi finally made landfall on the islands of Shikoku and Honshu, crossing over the Osaka Bay, and spawned storm surges/high waves around the bay areas as well as strong winds over the inland areas. Kansai International Airport (KIX) established on a reclaimed island in the Osaka Bay in 1994 was seriously damaged by storm surge. Furthermore, a large number of points observed extreme winds, which caused severe damages to houses/buildings, trees/forests, power lines, etc.

Typhoon Jebi took a track very similar to Typhoon Nancy (1961) and Muroto Typhoon (i.e., Daini-Muroto Typhoon) in 1934. In Osaka City, the 1st, 2nd, and 3rd highest record of instantaneous wind speed is 60.0 m s^{-1} in September 1934 (Muroto), 50.6 m s^{-1} in September 1961 (Daini-Muroto), and 47.4 m s^{-1} in September 2018 (Jebi), respectively. In Kyoto City, the maximum instantaneous wind speed during Typhoon Jebi was 39.4 m s^{-1}, which is the 2nd highest record since the observation started in 1915 (the 1st record in Kyoto City is 42.1 m s^{-1} in September 1934). This suggests that this typhoon has been the most threatening windstorm in the area. Considering the time period spanning from 1934 to 2018, the influences of both urbanization and global warming should be taken into account to assess the disaster risks by typhoons.

2. Damages by strong winds in the Namba area, Osaka City

In the Namba area, one of the business district in Osaka City, severe damages to houses, structures, trees along streets and in parks, occurred. Figure 1 shows damage to an old wooden house in the Namba area.

Figure 1: damage to an old house in Osaka City.

There were also damages to roofs, walls, signboards, etc. of buildings and houses. A large number of trees along the streets and in parks in Osaka City sustained severe damages.

Figure 2 shows the damages to trees along the Midousuji Street, a major street in Osaka City.

Figure 2: Damages to trees on the Midousuji street.

3. Numerical analysis of strong winds in Osaka City

After the severe damages incurred in urban districts, quantitative estimations of winds in the areas were necessary. However, it is very difficult to quantitatively estimate strong winds in urban districts, due to absence of observations within urban districts, and because of the inability to simulate airflows in urban districts with only a numerical weather prediction model. Explicit representations of urban buildings and structures are critically important to reproduce airflows within urban districts.

The idea in this study is to combine the advantages of a numerical weather prediction model and a turbulence model (large-eddy simulation model; LES) to quantitatively estimate the wind speeds in the business district of Osaka City. The weather prediction model can reproduce actual meteorological situations including Typhoon Jebi (2018), while the LES model can incorporate the actual buildings and structures and hence reproduce turbulent airflows within actual urban districts. The framework of this analysis is presented in Figure 3.

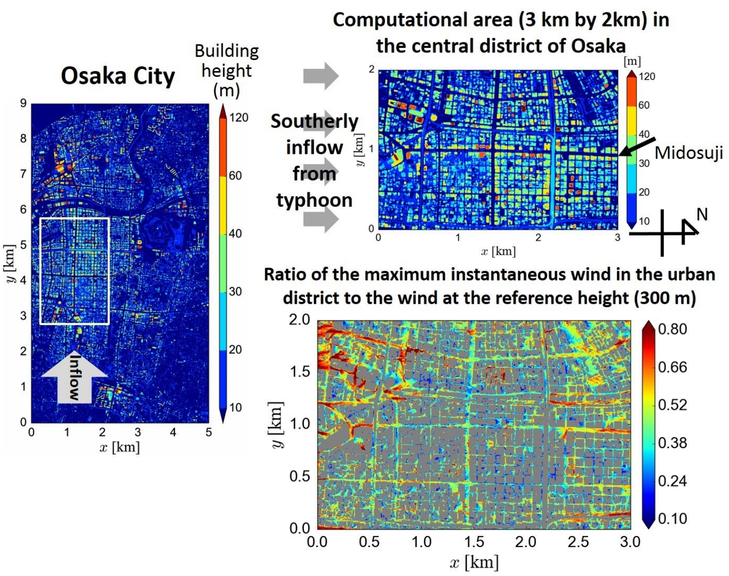

Figure 3: Conceptual framework of the numerical analysis of strong winds in urban districts.

The LES model was able to simulate fluctuating, turbulent airflows within the business district of Osaka City. By referring to the simulated wind speeds by the weather model and quantifying the wind speeds simulated by the LES model, the maximum wind speeds in some areas within the district analyzed here were estimated to be 60 - 70 m s^{-1}, owing to the downward transport of strong winds at higher levels above the urban canopy (Figure 4).

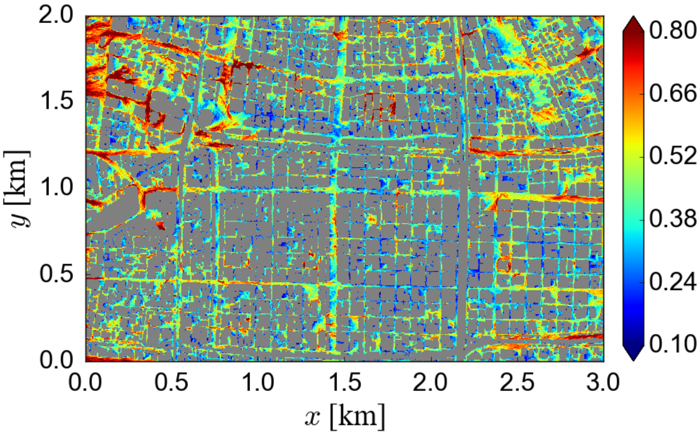

Figure 4: The spatial distribution of the maximum instantaneous wind speed at the 10-m height from the time series of the wind speed at each grid point in a business district of Osaka City.

4. Implications

The turbulent airflows and the maximum wind gusts within the actual business district of Osaka City were successfully estimated by combining the meteorological simulations and building-resolving turbulent airflow simulations. Wind speeds were highly variable, depending on the arrangement and vertical extent of surrounding buildings and structures. From this study, emphasize is placed on the critical importance to understand the risk of strong winds hidden in urban districts by conducting similar analyses on various metropolitan areas. Considering the ongoing re-shaping of metropolitan areas and the increasing number of high-rise buildings in Japan and the possible impacts of future climate change on the intensification of typhoons, it is necessary to understand emerging risks of strong winds in urban districts.

References

Takemi, T., T. Yoshida, S. Yamasaki, and K. Hase, 2019: Quantitative estimation of strong winds in an urban district during Typhoon Jebi (2018) by merging mesoscale meteorological and large-eddy simulations. *SOLA*, **15**, 22-27, doi:10.2151/sola.2019-005.