IMPACT OF ATMOSPHERIC SPATIAL-TEMPORAL RESOLUTION ON STORM SURGE SIMULATION AND RELATED DAMAGE CHANGE - CASE STUDY ON 2018 TYPHOON JEBI -

Yuji Araki, Kyoto University, Pacific Consultants Co., LTD., Japan, yuuji.araki@tk.pacific.co.jp
Takuya Miyashita, Kyoto University, Japan, miyashita.takuya.4w@kyoto-u.ac.jp
Tomoya Shimura, Kyoto University, Japan, shimura.tomoya.2v@kyoto-u.ac.jp
Toshitaka Baba, Tokushima University, Japan, baba.toshi@tokushima-u.ac.jp
Tetsuya Takemi, Kyoto University, Japan, takemi.tetsuya.8r@kyoto-u.ac.jp
Keita Fujiwara, Kyoto University, Japan, fujiwara.keita.7p@kyoto-u.ac.jp
Nobuhito Mori, Kyoto University, Japan, mori@oceanwave.jp

INTRODUCTION

Typhoon intensity is projected to increase in the future due to climate change (IPCC AR6). Accordingly, future storm surge height can increase, resulting in an expected urban damage increase. It is important to know the relation between typhoon intensity and expected direct and indirect damages because of the estimation of the cost-benefit ratio for infrastructure investment. In order to make appropriate infrastructure design or upgrades, it is necessary to have an accurate understanding of the relation between the storm surge intensity and its expected damage changes as a function of typhoon characteristics.

This study aims to estimate storm surge height, inundation, and related damage based on a high-resolution numerical weather prediction model. The target typhoon is Jebi, which caused severe damage along the coastal area of Osaka in 2018, and the target area is Osaka Bay, Japan. The sensitivity to storm surge height is examined by numerical simulation under various meteorological conditions. The fragility function is then used to estimate the amount of inundation damage. We compare the storm surge simulation accuracy and the amount of inundation damage due to the meteorological conditions.

TYPHOON DATA AND STORM SURGE SIMULATION

The pressure and wind speed field of 2018 Typhoon Jebi were simulated using the WRF model (Fujiwara et al. 2022). The wind and pressure fields were given by the WRF model having two domain nesting (low-resolution domain: d01, high-resolution domain: d02). The domain 1 was simulated a wide area with a horizontal 5-km resolution and 60-minute time interval, and the domain 2 with 1-km resolution and 10-minute time interval, was simulated around Osaka. This study compared the effect of input typhoon's time resolution into the storm surge model.

The wind and pressure fields from the WRF model were prepared for storm surges in three different methods. Case A uses d01 data only, Case B interpolated d01 every 10 minutes linearly and d02 data, and Case C interpolated d01 every 10 minutes by new tracking of typhoon center algorism and d02 data. In Case C, we introduced moving spatial-temporal interpolation considering the movement of the typhoon. Figure 1 shows the example of differences between Case B and Case C. Case C detected the center of the typhoon from 2 timestep typhoons and interpolated to every 10 minutes considering the movement.

The storm surge simulation was conducted JAGURUS (Baba et al., 2015) using 4 domain nesting from 2,430 m to 90 m resolution. JAGRUS model is a nonlinear shallow water equation which is originally developed to simulate the propagation and inundation of tsunamis. We extended it to apply storm surge simulation by considering the pressure term induced by sea level pressure change and the wind stress term. The bathymetry of storm surge simulation was given by GEBCO in offshore and by the Japan Cabinet Office's high-resolution data. The detail information on the location and height of dikes in Osaka Bay was also given by the Japan Cabinet Office dataset.

Figure 2 shows the spatial distribution of maximum storm surge height in domain 1 and domain 4 simulated using JAGURUS and Case C. Also, the tide level observation point at Osaka is shown. The storm surge height in the inner part is relatively higher.

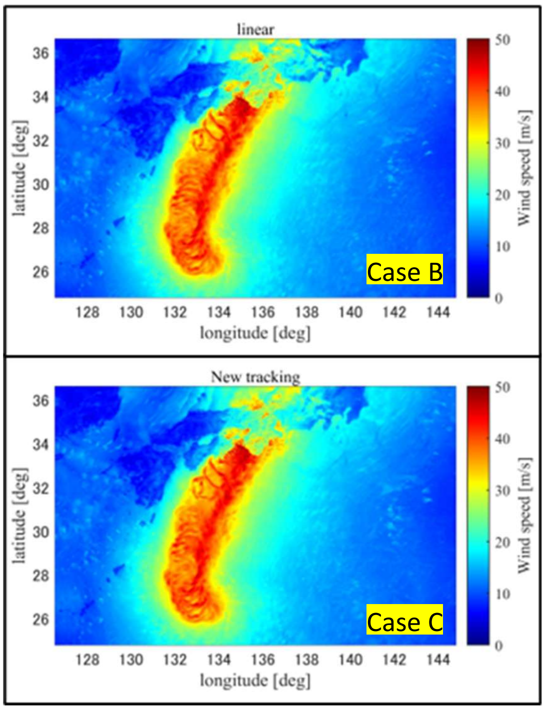

Figure 1 - Image of interpolation using maximum wind speed in each grid through time series (upper: liner interpolation, lower: new tracking interpolation)

Figure 3 shows the simulated time series of storm surge heights at the observation point. The black line is observed surge at the same point. The peak of Case A (d01) is 1.68m, which is a large underestimating. On the other hand, the peaks of Case B (linear interpolation) and Case C (new tracking interpolation) are over 2.0m. Comparing Case B and C, the peak surge height of Case C is higher and has significantly improved the accuracy. According to these results, we can see that calculation accuracy becomes much better by using typhoon data with high resolution in both time and space, and the new tracking interpolation method (Case C) could improve the accuracy of linear interpolation (Case B). Additionally, the peak surge height in Case C is still underestimated because simulated meteorological data by WRF was underestimated slightly compared with observation. We suppose the peak time of Case A is better than others because the meteorological data delayed almost 1 hour compared with observation, and that couldn't express the detail of the typhoon by using every 60-minute typhoon data, so it's coincident.

ESTIMATION OF TOTAL DAMAGE

We estimated inundation damage using simulated maximum storm surge height and the fragility function by Hirai et al. (2020). The estimated inundation damage is shown in Figure 4. The black line is the baseline fragility function. The color lines show the difference of 3 cases (A-C). The damage amount of Case C was almost 28 billion JPY (almost 1.8 million USD). The maximum storm surge height of Case A (the yellow line) was 1.62m, so if we didn't interpolate typhoon data, we might underestimate approximately 72%. As same as the maximum storm surge height, the ratio of the amount of inundation damage is approximately 71%. We can see that the effect of the interpolation method and the resolution in both time and space is large to the amount of inundation damage. The expected damage for Case C is lower as an amount of inundation damage. According to the fragility function, the amount of inundation damage is not monotonical to the surge height and rapidly increases if a high storm surge height is caused, especially higher than 3.0m.

CONCLUSIONS

This study examined to estimate storm surge height, inundation, and related damage based on a high-resolution numerical weather prediction model. The new pressure and wind interpolation fields were also proposed. The conclusions we obtained in this study are,

1. The calculation accuracy becomes much better by using typhoon data with high resolution in both time and space, and the new tracking interpolation method could improve the accuracy than linear interpolation.
2. If we didn't interpolate typhoon data, we might underestimate maximum storm surge height approximately 72%. As same as the maximum storm surge height, the ratio of amount of inundation damage is approximately 71%.
3. The effect of interpolation method, and the resolution in both time and space is large to amount of inundation damage.

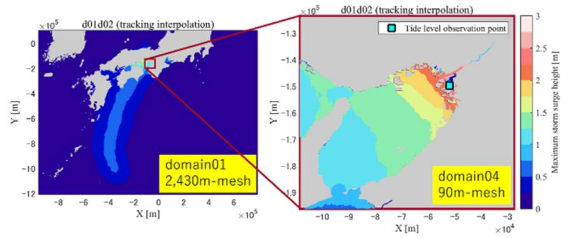

Figure 2 - Maximum storm surge height in each calculation grids and the location of tide level observation point (■)

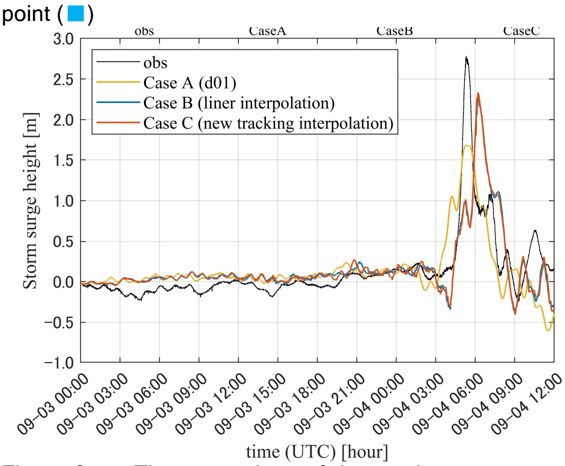

Figure 3 - The comparison of time series storm surge height by the difference of interpolation method of input typhoon data (black line: timeseries of observed storm surge height, color lines: timeseries of simulated storm surge heights)

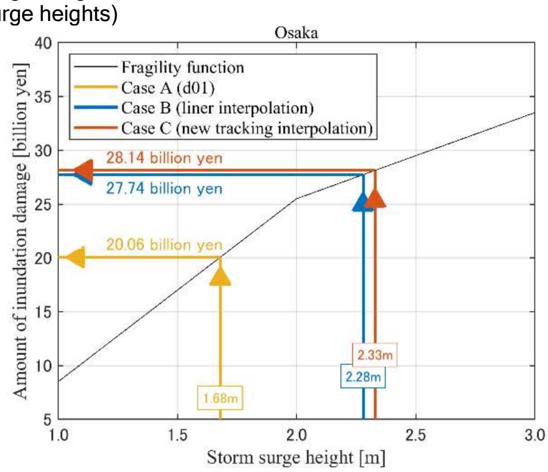

Figure 4 - The estimation of amount inundation damage using the fragility function (black line) by maximum storm surges in each case (color lines)

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