PROBABILISTIC FORECASTING SYSTEM OF STORM SURGE USING A STOCHASTIC TYPHOON MODEL

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INTRODUCTION

This paper presents a newly developed real time probabilistic forecasting system of storm surge at an arbitrary target location when a typhoon is formed and approaches to the location. Such probabilistic information may be essential for business or public entities along the coast who need to make appropriate decision to what extent they should break their daily operations and prepare for the upcoming coastal hazard.

DESCRIPTION OF THE SYSTEM

Developed system, based on Monte Carlo simulation, consists of two parts: (i) generation of a number of virtual typhoons; and (ii) storm surge prediction for each typhoon. In the first part, virtual typhoons are generated by the stochastic typhoon model (STM) (Higaki and Tajima, 2020). This STM is based on the higher-order auto-regression model. At arbitrary time after the typhoon formation, the time history of observed paths and central pressure are used as input data for this auto-regression model to account for its time history. Starting from this time, STM computes the future time variation of paths and central pressure of the typhoon, which reflect statistical characteristics of the past data. Other forecasted data, if available, can also be incorporated so that statistical characteristics of the generated typhoons agree with those forecasted data.

In the second part, time-varying storm surge at the specified location is computed for each of generated typhoons. Here, the storm surge model also requires high computational efficiency so that a number of storm surge computations for each virtual typhoon can be done on a real time basis. In order to achieve this requirement, the present system applied the non-linear regression model based on Recurrent Neural Network (RNN) (Igarashi and Tajima, 2021). Among various RNNs, this study applied a long short-term memory. The model inputs the time-series data of typhoon paths and central pressure, and outputs time-varying storm surge height at the target location. A number of training data were obtained by the storm surge model based on a non-linear shallow water equation (NLSW) with spatio-temporal variation of wind velocity components and atmospheric pressures specified by an empirical typhoon model. The observed typhoon data and a number of virtual typhoons generated by STM were used for these training data.

RESULTS AND DISCUSSIONS

Paths of virtual typhoons generated by STM reasonably represented the observed path and the one forecasted by Japan Meteorological Agency (JMA) for the case of Typhoon Hagibis, which caused storm surge along Tokyo Bay in 2019 (Fig. 1(a)). Furthermore, RNN-based storm surge model showed good predictive skills of the time to time storm surge height at the inner part of Tokyo bay (Fig. 1(b)), computed by a storm surge model based on NLSW for various virtual typhoons, which were not used for the training of RNN model.

Fig. 2 shows the exceedance probability of the forecasted peak storm surge of 1,000 virtual typhoons for the case of Hagibis. Different colors indicate the difference of the time, up to which observed data was used as input data. Forecasts at three different time are reasonably consistent with each other, and observed peak storm surge height is plotted within the range of there curves of exceedance probability. Not only the peak value, this system can obtain time-varying probability of storm surge height. More details of the developed system and potential usage of the outcomes of this system will be presented and discussed at the conference.

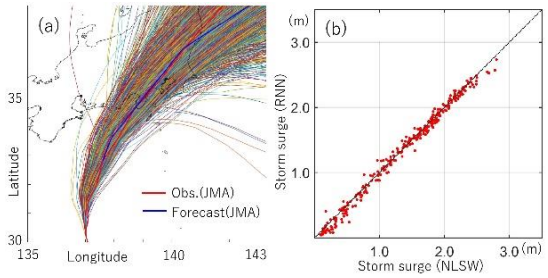

Figure 1 (a) Paths of generated virtual typhoons for the case of Hagibis with paths observed and forecasted by JMA. (b) Comparisons of time to time storm surge height between models based on RNN and NLSW.

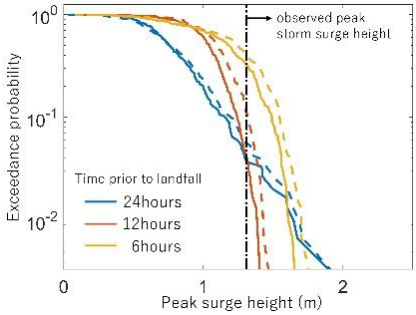

Figure 2 Exceedance probability of peak surge height for the case of Hagibis. Color difference indicates the different time of forecast. Line type indicates the results of different storm surge models, RNN (solid) and NLSW (dashed).

REFERENCES

Higaki, Y. & Y. Tajima (2020): Study on the applicability of a stochastic typhoon model for probabilistic forecasting of storm surge induced by a typhoon, Coast. Eng. J., doi:10.1080/21664250.2020.1828015

Igarashi, Y. & Y. Tajima (2021): Application of recurrent neural network for prediction of the time-varying storm surge, Coast. Eng. J., doi:10.1080/21664250.2020. 1868736