PSEUDO GLOBAL WARMING EXPERIMENTS OF BEACH MORPHOLOGICAL CHANGE: CASE STUDY IN NIIGATA COAST CAUSED BY TYPHOON LUPIT (2021)

Kota Ohizumi, CTI Engineering Co., Ltd., k.oizumi3025@gmail.com
Ryota Nakamura, Niigata University, r-nakamura@eng.niigata-u.ac.jp
Daichi Katayama, Niigata University, f22e028a@mail.cc.niigata-u.ac.jp
Shu Ito, Niigata University, ito.eng0123@gmail.com
Kunihiko Ishibashi, Niigata University, ishibashik@eng.niigata-u.ac.jp
Shigeru Kato, Toyohashi University of Technology, s-kato@ace.tut.ac.jp

INTRODUCTION

Extreme external forces such as associated with strong cyclones have often caused severe coastal erosions. Numerical simulation models have been employed for evaluating these coastal morphological changes (Roelvink et al., 2009). However, few studies focused on the morphological response caused by tropical cyclones under expected climate change. In this study, field surveys and numerical simulations were conducted to evaluate morphological changes caused by typhoon Lupit (2021) on Niigata coast. PGW (Pseudo Global Warming) methods under the SSP scenarios of IPCC AR6 were used to simulate morphological responses under expected climate change.

STUDY AREA

Fig. 1 shows various information such as typhoon track, observed stations, and simulated ranges in the study area. Niigata coast has long been noted for its coastal erosion problem mainly because high wave events have occurred in winter season. Therefore, the countermeasures to coastal erosion have been carried out by constructing detached breakwaters. However, authors confirmed from the previous studies that erosion trend still clearly occurred during high wave events

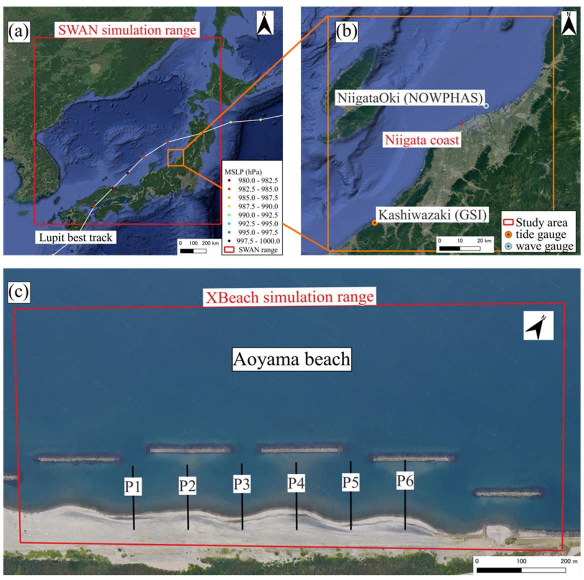

Figure 1 - Study area on Aoyama beach in Niigata coast

(Ohizumi et al., 2022; Ito et al., 2022; Ito et al., 2021). In this study, we focused the morphological change before and after the passages of the typhoon at Aoyama beach with detached breakwaters (Ito et al., 2022).

METHODOLOGY

Fig. 2 shows the numerical model configuration in this study. Based on the dates of the surveys conducted, numerical simulation period was set from August 7 to August 13 in 2021. Firstly, WRF (Skamarock et al., 2008) simulated wind boundary condition. Next, SWAN (Booji et al., 1999) simulated wave field by using the simulated wind forcing fields by WRF. Finally, XBeach (Roelvink et al., 2009) simulated morphological change based on the field survey data and the simulated wave boundary condition. In addition, XBeach simulation used Surfbeat (XB-SB) and Non-hydrostatic (XB-NH) modes.

After quantitative evaluation of hindcast simulation, PGW experiments were conducted in WRF using 26 GCMs multi-model ensembles. The PGW method used is the same as in the previous studies (Nakamura et al., 2016, 2021). Here, Fig. 3 shows PGW fields under SSP5-8.5 and SSP3-7.0 used by WRF simulation. The PGW fields were constructed with considering the difference between present (2015-2024) and future (2081-2100) climate of sea surface temperature (SST), air temperature (AT), relative humidity (RH), and geopotential height (GPH).

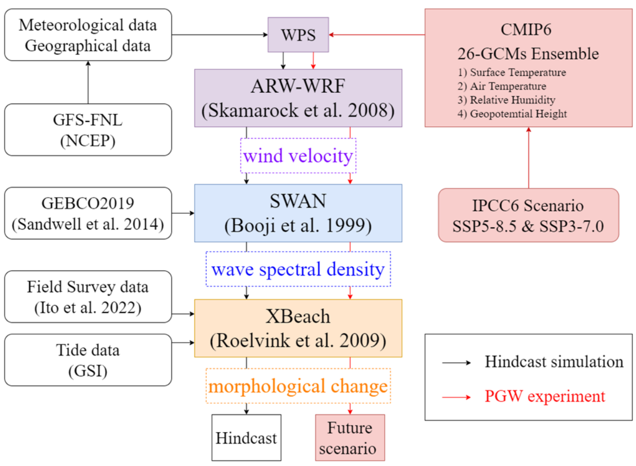

Figure 2 - Numerical model configuration

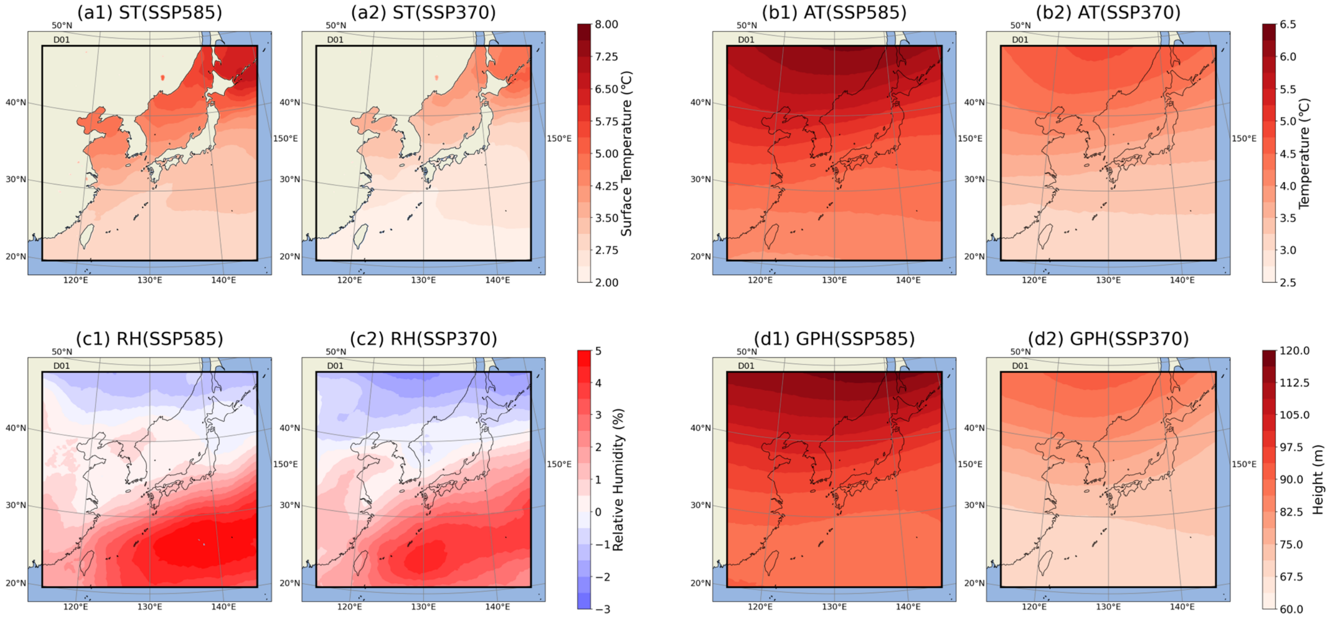

Figure 3 - PGW fields under SSP5-8.5 and SSP3-7.0 of ST(a), AT(b), RH(c), and GPH(d)

RESULTS
The typhoon track and the minimum sea level pressure (MSLP) simulated by WRF were in good agreement with the best track information (Fig. 4 (a)). Further, SWAN simulated the wave field well as the correlation coefficient (R) and the root mean squared error (RMSE) of significant wave height (Hs) were 0.833 and 0.459 m, respectively (Fig. 4 (b)).

Then, we validated the simulated results of XBeach (Fig. 5) by confirming Brier Skill Score (BSS) for cross-shore lines (Sutherland et al., 2004). As a result, the BSS for each cross-section line (P1-P6) indicated that XB-NH agreed better with the results of field survey than XB-SB (Fig. 6). Indeed, the average of BSS in all lines (P1-P6) was 0.5206 for XB-NH and -0.5977 for XB-SB, respectively. Therefore, XB-NH was employed for evaluating the morphological changes under future conditions.

DISCUSSIONS
Figure 7 shows the difference of bed level between present and future simulations. The future simulation indicated that Hs increases with increasing typhoon strength (Fig. 4). As a result, the severe erosion near shoreline and development of salient were more pronounced near the detached breakwaters under future expected external forces (Fig. 6 and Fig. 7).

Future tasks are the upgrading of historical simulation by conducting sensitivity analysis of parameters and considering the storm surges. Further, it is also important to conduct PGW experiments for the different climate change scenarios due to assume uncertainty.

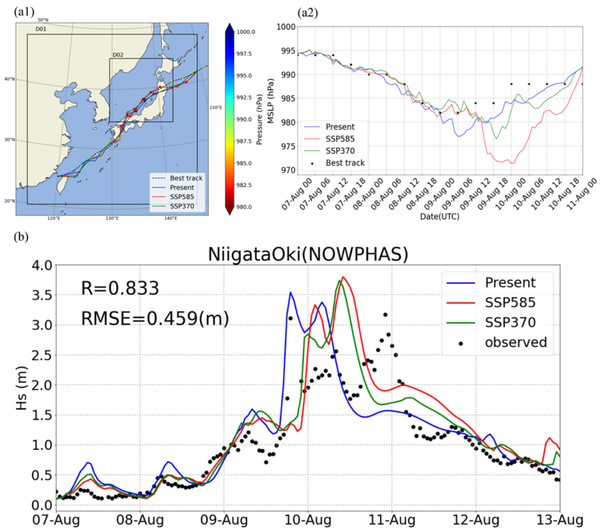

Figure 4 - Simulated typhoon tracks & MSLP(a) and Hs (b)

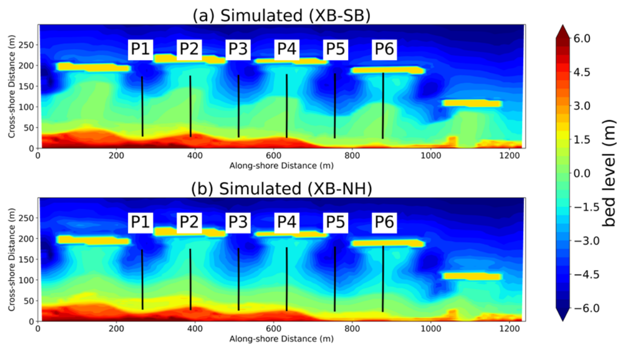

Figure 5 - Simulated results of XB-SB (a) and XB-NH (b)

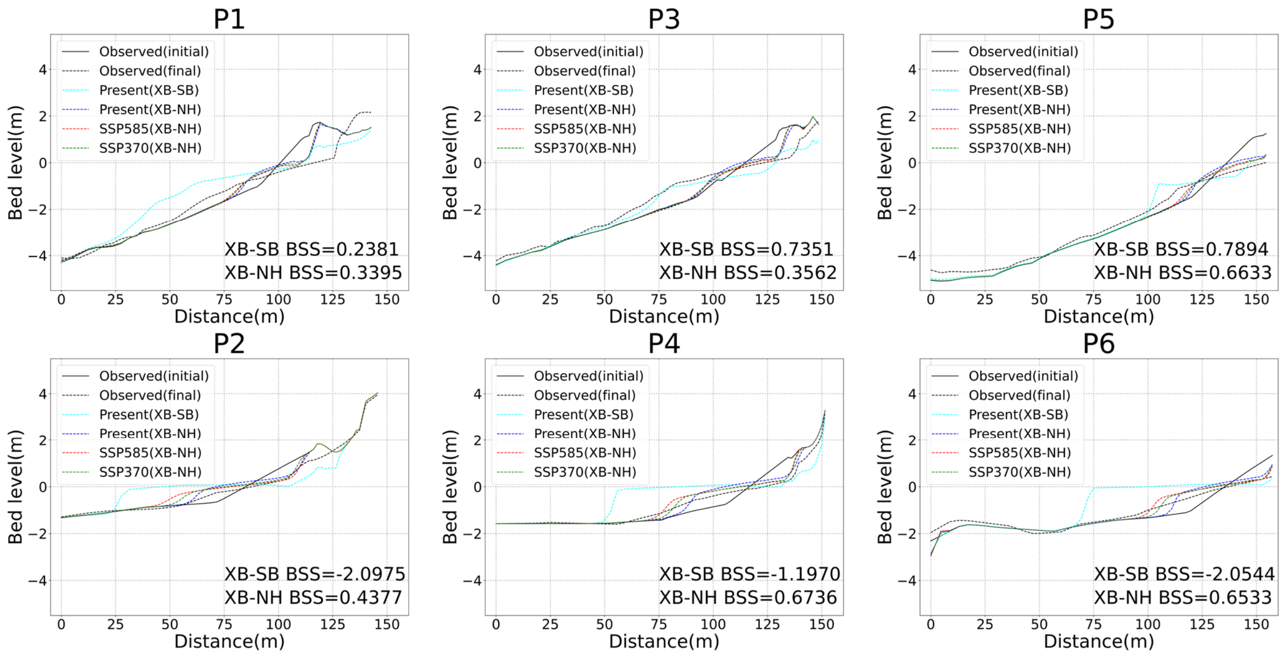

Figure 6 - Observed and simulated bed level in each cross-section line

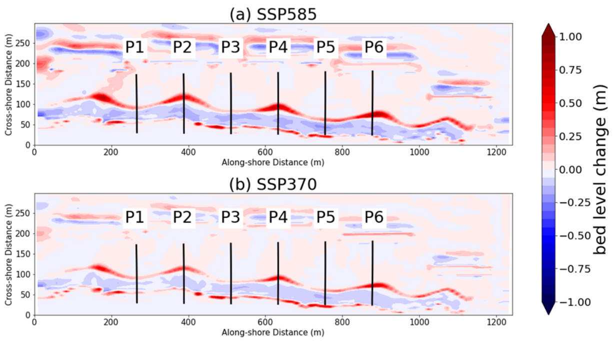

Figure 7 - Difference of bed level between present and future

CONCLUSIONS

It is expected that the morphological change caused by future typhoons become more severe even on the beaches behind detached breakwaters. Therefore, it can be said that coastal protection will be future needed to deal with severe morphological changes under climate change expected in the future.

REFERENCES

Roelvink D et al. (2009): Modeling storm impacts on beaches, dunes and barrier islands, Coastal Engineering, vol. 56, pp. 1133-1152.

Ohizumi K et al. (2022): Field surveys and numerical simulations of beach scarp in Niigata coast, Japan, 2022 International Geoscience and Remote Sensing Symposium, IGARSS 2022, pp.6935-6938.

Ito S et al. (2022): Field survey and numerical simulation of beach deformation near detached breakwater at Aoyama beach in Niigata coast during the approach of typhoon Lupit (2021), Journal of Japan Society of Civil Engineers, Ser, B3 (Ocean Engineering), (accepted).

Ito Y et al. (2021): Field survey near detached breakwaters and numerical simulation of morphological changes using XBeach model, Journal of Japan Society of Civil Engineers, Ser, B3 (Ocean Engineering), vol.77(2), pp. I_919-I_924.

Skamarock WC et al. (2008): A description of the advanced research WRF version 3, NCAR Technical Note.

Booji N et al. (1999): A third-generation wave model for coastal regions: 1. Model description and validation, Journal of Geophysical Research: Oceans, vol.104(C2), pp. 7649-7666.

Sandwell DT et al. (2014): New global marine gravity model from CrySat-2 and Jason-1 reveals buried tectonic structures, Science, vol.346(6205), pp.65-67.

Nakamura R et al. (2016): Future typhoon storm surges under different global warming scenario: case study of typhoon Haiyan (2013), Natural Hazards, vol.82(3), pp.1645-1681.

Nakamura R and Mäll M. (2021): Pseudo Global Warming Sensitivity Experiments of Subtropical Cyclone Anita (2010) Under RCP 8.5 Scenario, Journal of Geophysical Research: Atmospheres, vol.124(24), e2021JD035261.

Sutherland J et al. (2004): Evaluating the performance of morphological models, Coastal Engineering, vol. 51(8-9), pp.917-939.