Sensitivity of Future Tropical Cyclone Changes to Storm Surge and Inundation: Case Study in Ise Bay, Japan

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Background and Purpose

According to recent issued IPCC 5th Assessment Report (AR5) and SREX, numbers of studies have been conducted on the impact assessment of natural disasters due to climate change. The AR5 reported that tropical cyclones will become more intense due to warmer sea surface condition in the future. On the other hand, it takes more than several decades to design and construct coastal defenses, generally. Therefore, it is important to estimate changes of storm surge risk under the future climate condition in advance. There are several coastal mega cities in Japan, which have large area below the mean sea level. Storm surge is one of the important factors to design coastal defence facilities, and an estimation of storm surge and potential risk of inundation are required to project the impact on social and economic activity under climate change in the future.

In this study, numerical storm surge simulations with inundation over the land were conducted targeting the Ise Bay including Nagoya of Japan, which suffered the severest storm surge disaster in 1959. Future changes of typhoon characteristics are analyzed to estimate possible change of intensities, generation numbers, and tracks in the Pacific Ocean, and influence of climate change on storm surge in the Ise Bay are simulated as a case study.

Methodology

First, future changes of typhoon activity at the end of 21st century are analyzed based on the latest CMIP5 of IPCC AR5 results. Second, a series of numerical simulations of storm surge including inundation is carried out against historical and future conditions based on CMIP5 analysis. Surge-WAve-Tide coupled model (SuWAT) developed by Kim *et al.* (2008) is employed as the storm surge model. To simulate inundation, SuWAT was modified to take into account overflow into the land and bottom roughness considering the land use. The storm surge elevation and inundation characteristics were compared with the historical highest record by the typhoon Vera in 1959 (so called Ise-wan typhoon). A series of simulations are carried out under the intensified central pressure and the changed typhoon track considering the analyzed typhoon characteristic change as pseudo global warming experiments.

Results

Of interest are future change of typhoon intensities, genesis numbers, track shifts, and other climatic changes. The results of CMIP5 analysis shows that the number of typhoons will increase in the future as shown in Figure 1. In addition, the future cyclogenesis centroids will move toward the center of the ocean basin in the range of 1ï 3 degrees depends on the latitude. The future change of typhoon track shift gives significant impact on the disaster assessment.

Six nesting domains from the resolutions of 7,290 m to 30 m were used for the storm surge simulations as shown in Figure 2. Figure 3 shows the track of typhoon Vera, simulated maximum storm surge and inundation in Ise Bay area, and time series of storm surge comparing with the observation (black line). The validation of storm surge hindcast shows good agreement with the historical record. The maximum magnitude of storm surge at Nagoya port was 4.5 m which is reasonable against to the observation. A series of extreme (intensified) typhoons to Ise Bay was simulated by pseudo warming experiments in the projected future climate condition. Figure 4 shows the result of storm surge under future condition. The maximum magnitude of storm surge by the intensified typhoon is 0.5 to 1.0 m larger than the one by the historical typhoon. The future change of inundation area due to storm surge will increase from 238 km^2 to 283 km^2 significantly.

This study has investigated future change of storm surge and inundation, quantitatively. Sensitivity of macro typhoon characteristics to local storm surge characteristics has been analyzed and the uncertainly of climate projection on storm surge level was discussed in detail.

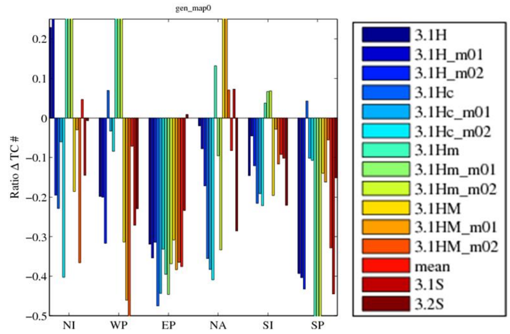

Figure 1 SST ensemble experiments of MRI-AGCM-3.1H (Mori, 2012)

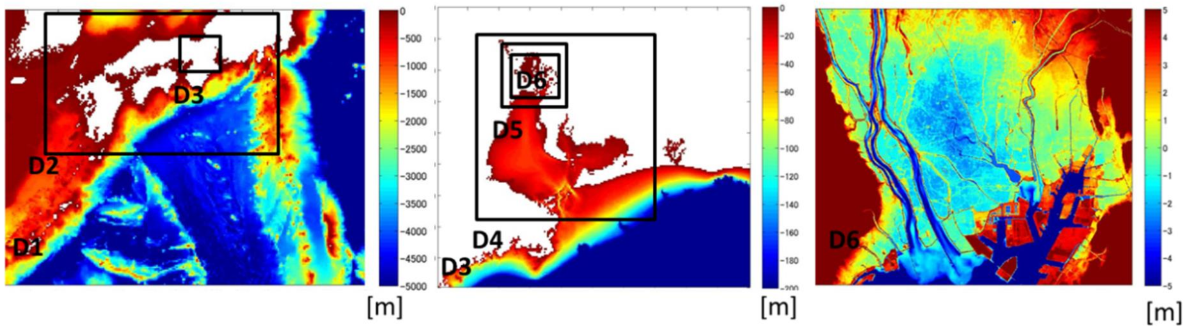

Figure 2 Simulation domains with mean water depth

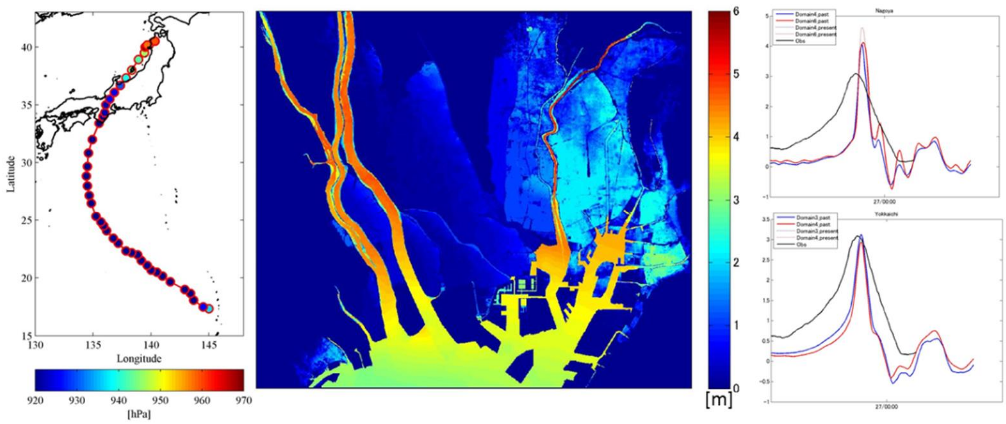

Figure 3 Track of Typhoon Vera and simulated maximum storm surge, and time series of storm surge (In case of past seawall)

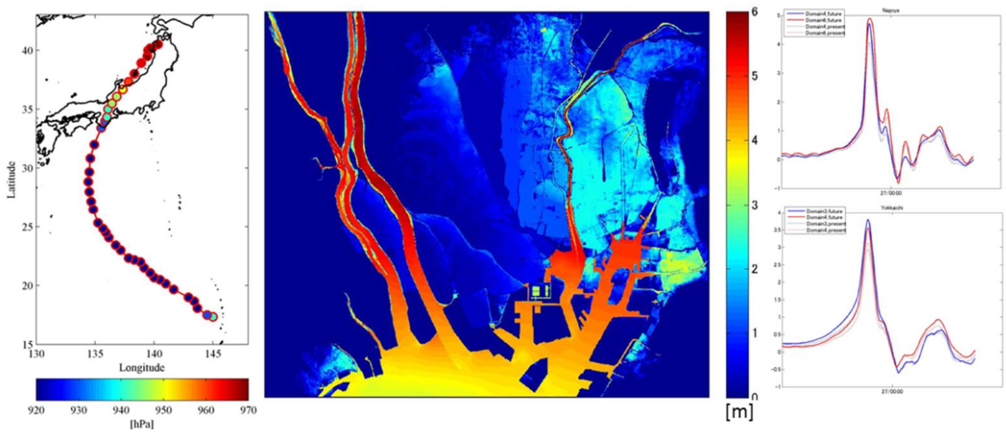

Figure 4 Track of Typhoon Ise Bay and simulation results of maximum and time series storm surge (In case of climate change)