THE EFFECT OF TROPICAL CYCLONES' TRANSLATION SPEEDS AND LANDFALL ANGLES ON MAXIMUM SURGE HEIGHTS ALONG IDEALIZED COASTS

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INTRODUCTION

Global warming has known to alter the cyclonic translation speed (TS) in the past, for instance, a slowdown trend of TS in the Northwest Pacific region. Thus, the importance of TS along with landfall angle (LA) has been examined over the coast of Louisiana (Rego, 2009). Not only these cyclone's characteristics but also the geometries that the cyclone is traveling over are found to be crucial to the development of storm surge. Meanwhile, previous studies mainly focus on one or two individual characteristics in specific sites, which made their conclusions limitedly understood. Therefore, this study aims to generalize the synthetic effects of TS, LA, and coastal geometries on a maximum surge height (MSH) along the coast through the numerical simulations of a series of idealized scenarios.

METHODOLOGY

A two-dimensional model in Delft3D-FM was used in this study to simulate the MSHs. The model domain consists of multi-resolution grids ranging from 16 km to 1 km, considering the cyclone's landfall spot at the center of the coastline (see Fig. 1). All these simulations were implemented without tides and waves since this study aims to investigate the synthetic effects on main surge levels. The hypothetical cyclones were generated under various TSs and LAs conditions. The TSs were altered from TS_0 to $3TS_0$ while LAs ranged varied from 0° to 180°. Additionally, the coastal layout and bathymetry were also controlled. For bathymetry, a constant bed, beds with different continental shelf widths, and a multi-sloped bed were considered. For coastal layout, an open coast and bays characterized by the morphological ratio L/E were considered (Healy, 1991). Totally, 763 idealized scenarios were simulated to obtain the MSHs along the coast. The realistic scenarios based on historical typhoon Maemi in 2003 were additionally simulated with various TSs and LAs conditions to apply developed ideas from idealized scenarios.

RESULTS AND CONCLUSIONS

The effects of the TS, LA, and coastal geometries on MSH were analyzed by simulating idealized and realistic scenarios. The trends of MSHs along the open coast extracted from each scenario were found to be almost identical despite minor discrepancies (see Fig. 2-a). The results revealed that MSHs along the open coast were amplified by fast-moving TSs. For constant bed, the scenario with TS_0 and 30° LA exhibited a distinct characteristic that generated the Kelvin wave propagating in a down-coast direction (see Fig. 2-b), while certain types of sharp LAs with a slow-moving cyclone might generate other types of oceanic waves. For the beds with different dimensions of continental shelves, trends of the MSHs were distinguishable between slow and faster-moving TSs. Nevertheless, the continental shelf with narrow width led to a peak at a sharp LA under all TSs, implying that the shelf geometry can limitedly affect the MSH. As for the multi-sloped bed, slope geometry strongly influenced the surge process in that it modulated the MSH due to the Greenspan resonance. For bays, the trends of MSHs were essentially coincident with those of open coast, while an enhancement of MSHs were observed when L/E was close to 1. Additionally, the realistic scenarios based on a historical typhoon were simulated to validate the outcome from idealized scenarios, indicating that super typhoons like Maemi, with a 75° LA, tend to slow down and generate an extreme surge in Masan Bay in a future sight. Our findings suggest that magnitude of $TS/\sqrt{gh}$, acute LA, and the continental shelf play a critical role in generating resonant waves that further change main surges. Moreover, the study demonstrates how the morphological ratio of the bay affects MSH.

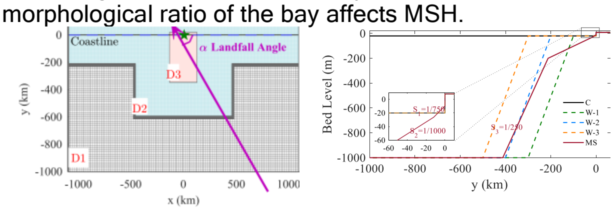
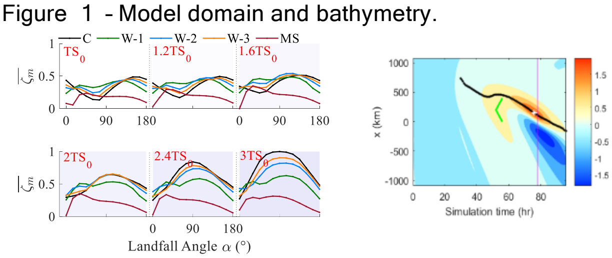


Figure 1 – Model domain and bathymetry.



(a) (b)

Figure 2 – (a) Trends of normalized MSHs sketched from varied scenarios over the open coast. Each independent shading zone is divided by TSs, while the x-axis represents LAs. (b) Space-time plot of the along-coast water level on a constant bed in one scenario simulation (TS_0 and 30° LA).

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