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Case study on impact of storm waves on inundation characteristics

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Abstract

Modeling interactive features of storm waves and surges may be one of important but challenging tasks toward more accurate estimations of coastal hazards under severe storms. This paper discusses how storm waves and interactions of waves and surges affect amplification of local inundation characteristics through overviews of several case studies of recent coastal disasters. The paper first describes witnessed inundation characteristics caused by Super Typhoon Haiyan along the coast of San Pedro Bay and also the east coast of Eastern Samar in the Philippines. Along the west coast of San Pedro Bay, neither predicted storm surge nor storm wave can reasonably represent the following observed features: inundation around the mouth of San Pedro Bay started about an hour prior to the time when the inundation was witnessed at the inner part of the bay and the water level quickly descended after the peak around the bay mouth while it was kept high for an hour in the inner part of the bay. Along the east coast of Eastern Samar, deformation of wind wave components strongly depends on bathymetry of fringing coral reefs and refraction, diffraction and wave-wave interactions appear to have significant influence on observed locally varying damage levels and inundation characteristics. Similar locally concentrated inundation was also observed along the west coast of Batan island, the Philippines when the super typhoon Meranti passed north of the island. Significant influence of infra-gravity waves on the locally concentrated inundation characteristics was also observed in the disaster along Seisho coast on the Pacific coast of Japan when the typhoon, Fitow, hit the coast in 2007. Based on these findings, finally, this paper discusses how the numerical model should be extended for better estimations of coastal hazard with brief example of model application to South Pacific islands.

Keywords: storm waves; storm surge; circulating current; infragravity waves; fringing reef ; Haiyan; Pacific islands

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1. Introduction

Modeling interactive features of storm waves and surges may be one of important but challenging tasks for more accurate predictions of coastal hazard induced by severe storms. This paper discusses to what extent such interactive features influence on inundation characteristics through case studies of the following recent coastal disasters: the disaster along the coast of Leyte and Samar, in the Philippines, due to super typhoon Haiyan; the disaster along the coast of Batanes, Philippines, due to super typhoon Meranti; the disaster along Seisho coast, Japan, induced by typhoon Fitow. Post disaster survey and the following numerical analysis of these cases showed certain influence of wave-wave and wave-surge interaction phenomena on local amplification of coastal inundations. Finally, the paper discusses how these findings should be reflected in numerical models for predictions of coastal hazard.

2. Case Study

This section outlines findings of post-disaster survey and following numerical studies presented by authors. Special focus was put on the influence of interactions of waves and surges on observed inundation characteristics.

2.1. Interactions of storm surge and waves around San Pedro Bay

Typhoon Haiyan, called as Yolanda in the Philippines, became the strongest typhoon at the time of landfall with wind speed of 125kt and the central pressure of 895hPa. This super typhoon induced severe storm surges and inundations over the entire city of Tacloban located at the inner part of San Pedro Bay. Tajima et al.[1] reported post-survey results of this catastrophic disaster along the coast of Leyte and Samar. Fig. 1 shows a map of Leyte and Samar with alongshore distributions of measured runup heights and the water levels in the inundated area. The figure also shows the computed peak storm surge level and amplitude of storm waves. As seen in the figure, predicted storm surge levels along the coast of San Pedro Bay agree reasonably well with the observed water level while the ones along the east coast of Eastern Samar, discussed in the next section, largely underestimate the observed runup heights.

While the storm surge appears a dominant factor for determination of the inundation characteristics around San Pedro Bay, the numerical storm surge model, based on non-linear shallow water equations with additional forcing terms of wind shear stress, atmospheric pressure gradient and coriolis force, failed to represent some of witnessed inundation characteristics. In Fig.2, for example, white letters indicate the time at which inundation was first witnessed at each location while black letters and contour lines indicate the time at which computed surge water level reached its peak. As seen in Fig.2, the witnessed time of the first inundation is 8:00 at the inner part of the bay and 7:00 around the bay mouth while the peak time of computed surge is around 8:20 both at the inner part and

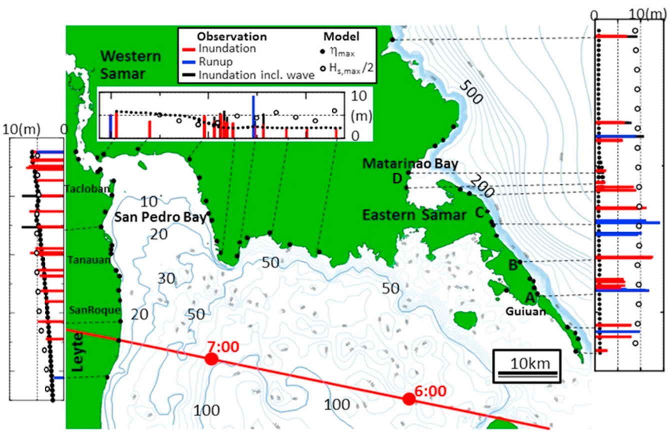

Fig.1. Track of Haiyan and observed peak water level of inundation and runup along the coast of Leyte and Samar (Tajima et al., 2016a).

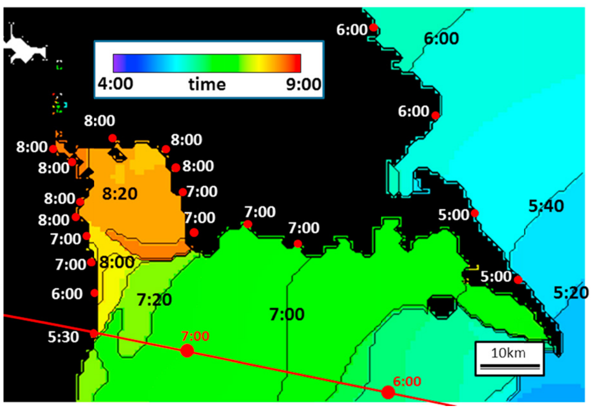

Fig. 2. Alongshore distributions of the time at which inundation was witnessed(white letters) and the time at which computed surge level reached its peak(black letters and contour lines).