# SUBGRID NUMERICAL MODELING OF TSUNAMI AND STORM SURGE INUNDATION IN A COASTAL URBAN SETTING

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## INTRODUCTION

Modern coastal cities are facing increased danger coming from the ocean as they continue to expand by land reclamation, due to high population density with limited amount of land. The 2018 Typhoon Jebi in Japan induced a storm surge of more than 3m in the Osaka area, which caused substantial damage to the Kansai International Airport, and more than 15,000 perished in the 2011 Tohoku Earthquake Tsunami. It is urgent to develop a reliable numerical model for the inundation within a coastal urban area, to further aid the pre-disaster preparation and prevention of further casualties.

This experiment used a physical model of a coastal city to simulate various wave conditions which may lead to city inundation. The results of the physical experiment were compared with those from a subgrid numerical model based on the shallow water equation using the topography of the physical experiment obtained from LIDAR scanning (Kennedy et al., 2019). The experiment aims to provide a better understanding on the variation of tsunami or storm surge inundation level at different locations of the city due to the ground elevation, building arrangement, and shielding effects. The result from this experiment will serve to increase the accuracy of coastal numerical models and revise the current hazard maps and evacuation plans.

## EXPERIMENTAL SETUP

The experiment was conducted in the Hybrid Tsunami Open Flume in Ujigawa Open Laboratory (HyTOFU) at Kyoto University. The physical model used in the experiment was a 1/250 model of the city center of Kainan, Wakayama, with a width of 4.0m and a length of 8.0m (Yasuda et al., 2015). The wave generator in HyTOFU was capable of producing various wave conditions to accommodate different flooding situation. In this experiment, the applied conditions were solitary waves with wave height of 5cm and 6cm, constant water flows with flow rate of 0.015, 0.020, 0.035, and 0.080 $m^3/s$, and Nankai trough tsunami conditions with normal estimated wave height and wave height $\sqrt{2}$ times greater than the estimate. In total 8 wave gauges were set up at different locations across the city such as port, industrial and residential zones. After the experiment, LIDAR scanning was conducted on the physical model to obtain the topography of the model.

## RESULTS

The results from wave gauges provided the time variation of water level in the inundation event. The maximum inundation, as well as the time to reach maximum inundation of each wave gauge location was collected. The wave gauge results display that the maximum inundation and the required time to reach that may depend on various factors, including the distance from the location to coastline, density as well as height of buildings surrounding the location, etc. The digital surface model (DSM) data from the LIDAR scanning further provided ground elevation of each wave gauge location, which was useful for wave gauge data calibration, and the relationship between the maximum inundation and the building pattern. Numerical modeling using a subgrid model based on the shallow water equation was also conducted. The initial results indicate that the subgrid model shows a good match between the experiment results, although in several locations there is deviation possibly due to the complexity of the city topography. The study will continue to improve the result of numerical model and compare with other well-known inundation models.

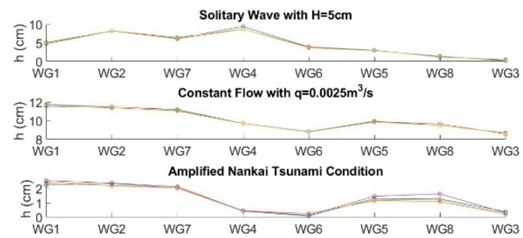


Figure 1 – Overview of maximum inundation level of each run from each wave gauge varying wave conditions. Wave gauges are in order of wave arrival.

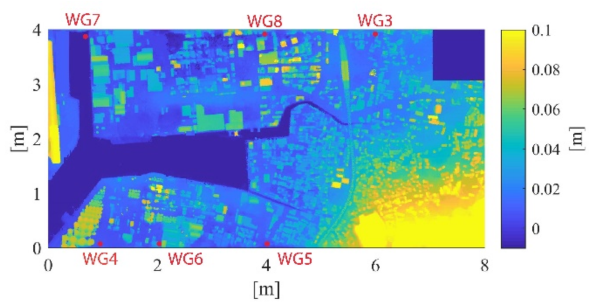


Figure 2 – Topography of physical model used in the experiment generated by LIDAR scanning with wave gauge locations within the model.

## REFERENCES

Kennedy et al. (2019), Subgrid theory for storm surge modeling, Ocean Modeling, ELSEVIER, vol. 144, 101491.

Yasuda et al. (2015), Tsunami inundation experiment using coastal city model, J. Jpn. Soc. Civil Eng, vol. 72, pp. 385-390.