Real-Time Probabilistic Prediction of Storm Water Level at Japanese Ports

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This study proposes the framework of real-time “probabilistic” storm water level prediction and then examines the prediction for a model typhoon, which crosses or passes by target ports in Japan’s Seto Inland Sea. The prediction includes the storm surge simulation for 109 typhoon tracks and provides the probability of a disastrous storm water level for the port facility and coastal defense.

INTRODUCTION

Every year, several typhoons approach the Japanese Islands and a few make landfall. Among recent typhoons, Typhoon Bart in 1999 brought a storm surge of approximately 3.5 m into Yatsushiro Bay, Kyushu Island, near the time of a spring high tide. The storm surge triggered flooding water levels, reaching the roofs of one-story houses on low-lying land, and took 12 lives in these houses. Fig. 1 shows the variation in the storm water level with time at the affected place. It was difficult to identify the difference between the actual storm water level and the usual astronomical tide level until 5:00 a.m., as well as to imagine that the storm water level had risen by 4 m until 6:30 a.m. owing to a significant storm surge and the usual rise in astronomical tide level. From such events, we should recognize the necessity of storm water level prediction for disaster prevention work, such as tide gate operation, sand bag piling and evacuation orders, before the storm water level reaches the point of disaster. Meteorological organizations not only in Japan but also in the other countries in the world issue the most probable typhoon track with the range of the standard prediction error. The persons in charge of disaster prevention work carry out the work if they feel there is a certain high risk of flooding; however, they do not know the probability that a higher-than allowable-water level will manifest.

A numerical meteorological model, however, has a certain range of uncertainty in typhoon track prediction. Meteorological organizations, thus, provide the most probable typhoon location at several lead times, such as 12, 24, and 48 h, as well as indicate the standard estimation error. The Japan Meteorological Agency (JMA) uses the prediction error circle, which the typhoon center enters with a probability of 70%, and assumes 5 typhoon tracks, which trace the center, leftward, rightward, forward and backward points, respectively, of the prediction error circle at each lead time. Then, the agency conducts a storm surge simulation for these typhoon tracks, estimates the storm water level as the sum of the storm surge and the astronomical tide level, and has the responsibility of issuing a storm surge warning to the public if the storm

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water is estimated to reach a disastrous level. Other local governments, institutes, and universities in Japan are also studying or operating their storm surge prediction for local flood prevention works and safe port activities (Yamaguchi et al., 1995; Nukada et al., 2003; Nakahira et al., 2003; Kawai et al., 2005; Tsuji et al., 2007). Some of their simulations assume one or several typhoon tracks based on the JMA prediction error circle.

If a typhoon is located far enough from the target ports such that the radius of the prediction error circle covering the target ports is large, and if the storm water level prediction examines a small number of typhoon tracks, then the prediction drops the worst typhoon track among numerous theoretically possible typhoon tracks. Persons in charge of disaster prevention work will lose their confidence in the prediction when the actual storm water level exceeds the predicted level. On the other hand, the actual storm water level seldom reaches the highest predicted level among several typhoon tracks. Some people may interpret the usual overprediction as a “failure” of the prediction, which may make them careless. Thus, probabilistic storm water level prediction—i.e. simulating the storm surge for a certain large number of typhoon tracks and providing the probability density distribution of the storm water level at target ports—is one of the methods to mitigate the above-mentioned confusion.

This paper starts with the verification of 3 typical wind models for storm surge computation and chooses one of them by considering its applicability to real-time storm water level prediction. This paper then proposes the framework of real-time probabilistic storm water level prediction that assumes 109 typhoon tracks and examines the prediction for a model typhoon. The prediction can grasp the range of the possible storm water level and estimate the