Development of a System to Forecast Inundation Damage from Storm Surge and High Waves in Advance
--- Aiming to Provide Easy-to-Understand Information That Leads to Evacuation Action

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KATO Fuminori (Ph. D. in Engineering), Head; IBI Yoichiro, Senior Researcher

Coast Division, River Department

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1. Introduction

In recent years, large storm surge and high waves have occurred and caused inundation damage in many areas. For example, Typhoon No. 21 in 2018 caused the tide level in Osaka Bay to exceed the previous highest level by about 40 cm. On the Saisho Coast, in 2017 and 2019, inundation damage caused by high waves resulting from typhoons occurred. The damage due to storm surge and high waves was serious, including the closure of roads for long hours. In order to protect the coastal hinterland from such damage and to mitigate human damage, it is necessary to forecast and disseminate the danger of inundation by storm surge and high waves at the appropriate timing, in addition to implementing structural measures such as building coastal dikes. Evacuation orders by municipalities are often issued in conjunction with storm surge warnings, but storm surge warnings alone cannot determine whether waves are overtopping coastal dikes. Therefore, it is necessary to disseminate easy-to-understand forecast information to those involved in flood prevention activities, including local governments and residents who will actually have to evacuate so that they can more concretely visualize the danger of inundation.

The Coast Division has been operating the "Wave Runup Height Forecast System," which forecasts the risk of inundation in real time, on a trial basis, since FY2007, with the aim of supporting flood prevention activities during storm surge and high waves. In this research, we extended the "Wave Runup Height Forecast System" to the "Storm Surge / High Waves Disaster Mitigation Support System" and verified the accuracy of the wave runup height forecast. This paper presents the outline of these activities.

2. Outline of the Storm Surge / High Waves Disaster Mitigation Support System

The "Storm Surge / High Waves Dissater Mitigation Support System" consists of the "Wave Runup Height Forecast Function" (**Fig. 1**) that forecasts wave runup height at 500 points nationwide based on the wave and tide level forecasts by the Japan Meteorological Agency, and the "Inundation Risk Forecast Function" that displays the risk of inundation along the coastline throughout Japan in different colors. This forecast can be viewed through a browser by the personnel in charge of coastal areas in the Regional Development Bureaus and prefectural offices.

The Wave Runup Height Forecast Function uses the runup calculation formula selected according to the seabed slope at the forecast point, and takes into account the topography and the shape of facilities, as well as the effect of wave-dissipating facilities in some points, to forecast the wave runup height every hour up to 39 hours in advance, and provides a visual indication of when and for how long overtopping waves will occur (**Fig. 2**). When a typhoon approaches, a total of five courses, which include the center of the typhoon forecast circle and four points around it, are forecast.

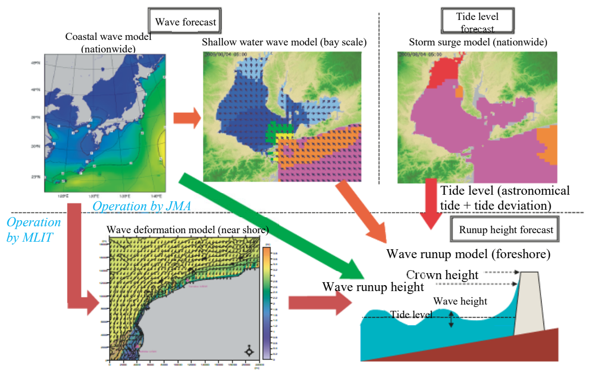

Fig. 1: Overall structure of the wave runup height forecast function

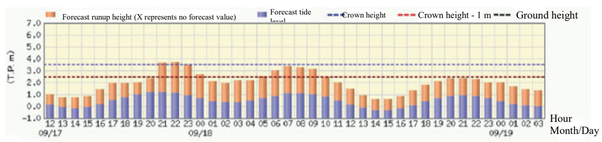

Fig. 2: Example of displaying wave runup height forecast

The newly added inundation risk forecast function targets points along coasts where the crown height is relatively low and evaluates the inundation risk of those coastal areas in three levels with a warning indicator corresponding to the wave runup height (in principle, the sum of the forecasted tide level and the forecasted wave height x 1/2) and through a comparison of forecasted tide level with crown height, and displays the results in color on the coastal line on the map (**Fig. 3**). Compared to the wave runup height forecast function, the forecast accuracy is lower, but the nationwide situation can be easily grasped.

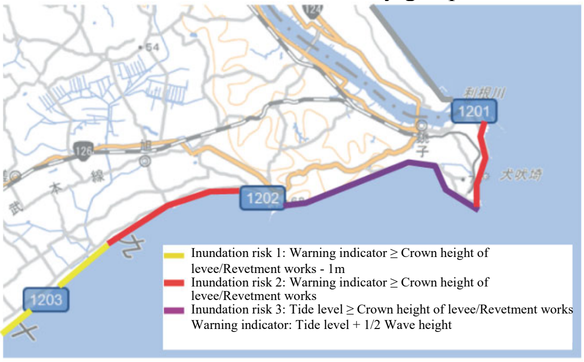

Fig. 3: Display image of inundation risk forecast

3. Verification of the accuracy of wave runup height forecast function

For the wave runup height forecast function, we conducted a quantitative verification for the typhoon No. 19 in 2019, and a qualitative verification for storm surge and high wave cases in the past five years.

In the verification of typhoon No. 19's approach, we compared the wave runup trace heights measured along the coast of Sagami Bay with the forecasted wave runup heights. As shown in **Fig. 4**, along the Odawara Coast of the Sagami Bay, the forecasted wave runup height (solid line) was higher around 18:00 on October 12, and its time maximum value was about 10 m above sea level, which was almost the same as the measured value (dashed line). Along the adjacent Ninomiya and Hiratsuka coasts, the time maximum values of the forecasted wave runup height were almost identical to the measured values.

In addition, for the storm surge and high wave cases from January 2016 to January 2021, we confirmed the number of cases where the forecast was correct, missed, or wrong by verifying whether the forecasted wave runup height exceeded the crown height when the wave overtopping occurred, and whether the wave overtopping occurred when the forecasted wave runup height exceeded the crown height. In 7 of the 28 cases where wave overtopping occurred, the forecast was correct. Missed forecasts were relatively common on the Kochi coast, where the wave forecasts of the coastal wave model were used to forecast the wave runup height. On the other hand, in the 157 cases where the forecast value exceeded the crown height, there were many cases of wrong forecast where no wave overtopping was assumed to have occurred (**Fig. 5**), which may be due to the fact that the overtopping was not fully grasped by the coastal managers. Even in the case of wrong forecast, the difference between the forecast value and the crown height was within 1 m in many cases, which indicates that the difference was relatively small, although the forecast tended to be somewhat excessive.

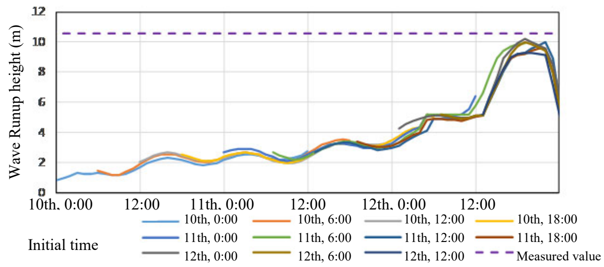

Fig. 4: Comparison of forecast and measured values (Odawara coast)

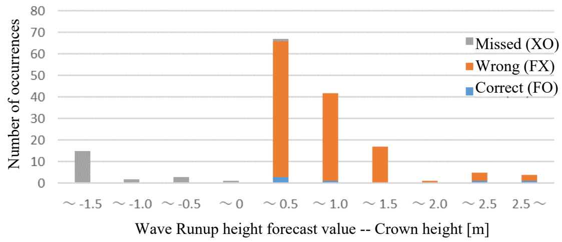

Fig. 5: Distribution of difference between crown height and forecasted wave runup height

4. Future development

In the future, we will continue accuracy verification and promote initiatives to establish an observation system for wave overtopping in order to further improve forecast accuracy. In addition, based on the opinions of the municipalities that have voluntarily started an initiative to view the forecast results on a trial basis, we would like to improve the forecast to make the forecast information intuitive and easy to understand, and provide information widely to the public to support municipalities that actually engage in flood prevention activities and encourage residents to evacuate.

☞See the following for details.

1) KATO Fuminori and FUKUHARA Naoki: Validation of Wave Runup Height Prediction During Typhoon Habibis, 2019, Based on Field Observation Data, Journal of JSCE, B2, No. 72, Vol. 2, pp. I_841-I_846, 2020
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