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Real-time sand beach and dune erosion modeling using coupling of heterogeneous hydrodynamic and morphological models

Seung-Won Suh (1) and Hyeon_Jeong Kim (2)

(1) Kunsan National University, Kunsan, Korea, Republic of (suh@kunsan.ac.kr), (2) Kunsan National University, Kunsan, Korea, Republic of (liswjd@naver.com)

Beaches are constantly changing owing to extreme meteorological and oceanic forcing. During severe storm periods, not only the natural beach but artificial sand dunes can be altered or destroyed due to large waves. To simulate real-time coastal morphological changes, researchers have used a tight or loose coupling scheme in nesting techniques over the entire domain to capture the refined region of interest in order to incorporate meteorological effects, coastal circulation, wave impact, and erosion modeling. In addition, it is important to minimize or eliminate any additional computational time and frequently occurring errors during the nesting procedure to realize an efficient and quick computation for real-time simulation.

In this study, we considered an unstructured ADCIRC+SWAN model and an XBeach model via an external Perl script batch file to provide efficient coupling for the morphological variations in beaches and retain the computational accuracy and speed regardless of the grid structures used in the early warning system (EWS) for sand beach erosion. The proposed approach was calibrated using the data from sensitivity tests conducted for the past storms and was then applied to coastal beach erosion during the latest typhoon Chaba in 2016. The proposed coupling scheme was then applied to a beach erosion vulnerability analysis for a target return period of the extreme event by generating synthetic storms.

According to the sensitivity tests, the most important forcing factor for erosion was the incoming wave characteristics induced by meteorological conditions such as extreme cyclones. In formulating the cyclone vortex, the parameters representing the asymmetric vortex shape played a more important role than those representing the symmetric type. In the computation for the typhoon Chaba in 2016, the morphological change computed by the parameter model was found to be more reliable than the simulated data provided 87 h in advance by the Regional Data Assimilation and Prediction System of the Korea Meteorological Agency (KMA). The simulated results showed that some regional erosion occurred due to waves exceeding the threshold height of 2.0 m.

In addition, the simulation was applied to predict damage to artificial sand dunes that had been built without considering the storm damage due to the typhoon Sanba attack in 2012 in the detailed design stage. It was found that the computed results could suggest the optimal location, type, height of crest, and width of the artificial sand dunes at the pre-design stage in order to prevent beach erosion damage. As the coupled model can be applied not only to real-time EWS but also to future vulnerability evaluation, it is considered as a useful morphological tool in integrated coastal zone management.