A GPU-ACCELERATED NUMERICAL MODEL FOR COASTAL FLOODING

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ABSTRACT
Coastal flooding has been one of the most destructive natural disasters with enormous social and economic impacts. Previous studies in the field of traditional compound coastal flooding have investigated the combined impacts of fluctuations in water levels induced by long waves (e.g., tides, storm surges) and riverine discharge (e.g., Nederhoff et al., 2021). However, interactions between long waves, relatively short-waves, direct precipitation, and rainfall-induced overland flows are commonly neglected (Santiago-Collazo et al., 2019). This study aims to develop a GPU-based numerical model to simulate coastal flooding induced by various processes such as waves, storm surges, tides, and rainfall-induced overland flows. In order to enhance the model accuracy and computational efficiency, we coupled two distinct shallow water models, nondispersive and dispersive shallow water models. Delft3D Flexible Mesh (FM), which solves nonlinear shallow water equations, was adopted for the nondispersive shallow water model owing to its robustness and accuracy. It has been widely used for simulating various long wave phenomena (e.g., Lee et al., 2019). Besides, we adopted a GPU-accelerated Boussinesq-type model, Celeris Advent (Tavakkol and Lynett, 2017), which solves the extended Boussinesq equations to simulate long-waves as well as relatively short-waves. It has the advantage of fast computational speed by harnessing the power of GPU. The model domains are organized with a nesting method, employing a high-resolution grid exclusively within the target area for efficient numerical modeling. In the outer domain, Delft3D FM was applied to simulate long-wave phenomena, and the results were entered as a boundary condition for the nested domain of the dispersive shallow water model. An absorbing-generating boundary condition (Van Dongeren and Svendsen, 1997) was implemented for a seamless data exchange between these two models at the domain boundary to guarantee physical consistency. We further added the rainfall and infiltration terms in the continuity equation of Celeris Advent to account for the rainfall-generated overland flows. Several numerical tests have been performed to validate the performance of the proposed model. Simulated results showed good agreement between the numerical and analytical solutions. Given the inherent computational efficiency owing to the coupling system and fast computational speed of GPU, the proposed model is expected to enhance the strategy for mitigating coastal flooding by providing precise of rapid modeling of these events.

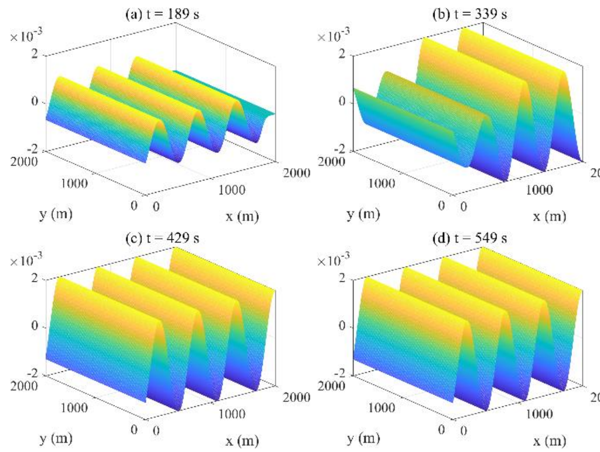

Figure 1 – Free surfaces of unidirectional sinusoidal waves at different times

ACKNOWLEDGEMENT
This work was supported by Korea Environment Industry & Technology Institute(KEITI) through R&D Program for Innovative Flood Protection Technologies against Climate Crisis, funded by Korea Ministry of Environment(MOE)(RS-2023-00218873)

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