Numerical simulation of hydrodynamics affected by vegetation in the Chongming Dongtan Wetland in Yangtze River Estuary

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ABSTRACT

Taking the Chongming Dongtan Wetland in the Yangtze River Estuary as study region, a three-dimensional hydrodynamic model was established considering the temporal and spatial distributions of vegetation features based on Delft3D in this paper to analyze the influence of vegetation on hydrodynamics. In general, hydrodynamics around coastal wetlands was changed due to the interactions of vegetation and tide. Water level was raised and flow velocity was decreased due to the presence of vegetation. Results in this paper can provide scientific information for coastal protection and restoration.

KEY WORDS: Coastal Wetland; Delft3D; vegetation; hydrodynamics; velocity; water level.

INTRODUCTION

In recent years, hydrodynamics influenced by vegetation has been paid much attention, and the interaction of flow and vegetation has been studied by several numerical simulations. A depth averaged two-dimensional hydrodynamic model was established by Wang et al. (2006) to study the influence of vegetation on velocity of unidirectional flow in the Nansi Lake, China, of which the vegetation induced resistance term was considered. A wave-current coupled CH3D-SWAN model was established by Sheng et al. (2012) to analyze the attenuation effect of vegetation on storm surge. The results showed that the attenuation effect became more obvious with the increase of vegetation height, vegetation density and vegetated area width, but this study used an idealized slope to approximate coastal area, without considering actual terrain, hydrological conditions and other conditions. Delft3D model was used by Hu et al. (2015) to reveal the influence of wetland vegetation on flow structure and turbulence characteristics under storm surge conditions in Breton Sound, a semi enclosed bay in Louisiana, USA. It was found that the maximum surge was decreased by vegetation and the reduction rate was increased with the growing vegetation height and rhizome density. The IHFOAM numerical model was applied by Maza et al. (2015) to reveal the mechanism of the interaction between tsunami wave and coastal mangrove. Using MIKE 21 model, a hydrodynamic-salinity coupling model was established by Qiao (2018) to simulate the effects of vegetation on flow field in the Liaohe Estuary. The results had shown that flow velocity decreased significantly due to the presence of vegetation and the flow direction was also changed. By coupling SWAN model with ECOMSED model, the numerical model of wind, wave, current and vegetation coupling in Liao River Estuary Wetland was established by Shi (2019). The study showed that the existence of vegetation delayed the flooding time and the wave height attenuation in vegetated area was more obvious than that in other waters.

Large quantities of sediment are deposited in the Yangtze River Estuary, resulting in the formation of major coastal wetlands (Chongming, Changxing, Hengsha, Jiuduansha, and Nanhu). In the coastal wetlands of the Yangtze River, vegetation distributes in an obvious strip or arc pattern along the low tide zone to the high tide zone as Scirpus maritimus, Spartina alterniflora and Reed (Liu et al., 2021). There are differences in the characteristics (density, height, stem, spatial distribution) of vegetation in different growth phenophases, which will cause changes in the hydrodynamic characteristics. However, according to satellite image data and field investigations (Zhang, 2018), the coastal wetlands of the Yangtze River have experienced a reduction in the area of tidal flats, biodiversity, and plant coverage in recent years under the influence of upstream runoff and sediment transport rate. In this paper, taking the Chongming Dongtan Wetland as study region, influences of seasonally vegetation features (height, stem diameter, density) on hydrodynamics were analyzed through numerical simulation based on Delft3D model. The focus of this paper is to study the interaction between flow and vegetation in different growth phenophases. Results can provide theoretical reference for the protection and restoration of environment in the coastal wetlands of the Yangtze River and other similar regions.

Delft3D MODEL

Delft3D provides a three-dimensional rigid vegetation module for simulating aquatic vegetation (Delft, 2006), coupled with Delft3D-FLOW module, which is a multi-dimensional hydrodynamic (and