A numerical study of the storm surge in the Pearl River Estuary and coastal waters

Zhuo Zhang\textsuperscript{1,2}, Peng Chen\textsuperscript{1,2}, Zhiyao Song\textsuperscript{1,2}, Fengfu Liu\textsuperscript{1,2}, Fei Guo\textsuperscript{1,2}, Dong Zhang\textsuperscript{1,2}

1 Key Laboratory of Virtual Geographic Environment (Nanjing Normal University), Ministry of Education, Nanjing, China
2 Jiangsu Center for Collaborative Innovation in Geographical Information Resource Development and Application, Nanjing, China

ABSTRACT

The FVCOM-based shallow water circulation model, was used to study the influence on surge by uncertainties in typhoon prediction. Typhoon Mangkhut was used as a typical storm surge scenario to validate the model. A series of synthetic storm surge scenarios was developed based on the original Typhoon Mangkhut to investigate the characteristics of the behavior of surge around the Pearl River Estuary. The main conclusions herein can enhance the learning about storm surge and possible inundation in the area.

KEY WORDS: Storm surge; typhoon; numerical model, Pearl River; tide-surge interaction.

INTRODUCTION

Storm surge is a major hazardous factor which causes the flooding damage, life loss and transport block in coastal and estuarine regions. Most surges in summer and autumn in China are caused by typhoon, developed from the tropical cyclone born in Western Pacific. From statistic data, these typhoons averagely cause 25 billion yuan every year in China (Liu, et al, 2018). The Pearl River Delta, located on the south coast of China and is one of the most developed economic zone in the world, especially suffered vast economic loss in the past decade for its high occurrence of typhoon. With the global warming and the increment of sea level, the typhoon occurrence and the induced surge become increasingly frequent. During the period from 2008 to 2019, more than 50 typhoons approach and cause surge in Pearl River Estuary and nearshore waters, including super typhoons like Hagupit (2008), Rammasun (2014), Mujigae (2015) and Mangkhut (2018). Of these, Typhoon Mangkhut recently caused the most devastating damage and influenced nearly 3 million local residents. Consequently, there is a growing concern about accurate storm surge prediction and the subsequent hazard mitigation response, which must be based on a clear understanding of the factors that contribute to storm surge in the specific area.

Many efforts have been carried out for numerical modeling and analysis of surges induced by typhoons and cyclones. Tide and surge usually occur simultaneously with the result that their superposition and interaction determine the high water level, which is referred as the basis for coastal engineering design and flood hazard assessment. A few early studies either separated the surge and tide, or neglected the effect of tide on surge. Through theoretical investigation, Proudman (1955) claimed that for a progressive wave, the height of a surge with its maximum occurring near to time of tidal high water was less than that of a surge with its maximum occurring near to the time of tidal low water. Prandle and Wolf (1978) analyzed the observation results in the Thames estuary with a numerical model and concluded that surges tend to reach a maximum on rising tide irrespective of the phase relationship between tide and surge in the open seas. Zhang et al. (2010) studied the oscillation of storm surge by the tide-surge interaction in shallow water of the Tanwan Strait and emphasized both roles of nonlinear bottom friction and the special geometry of the strait. Park and Suh (2012) found that the storm surge was in an inverse proportion to water depth and tide. These results provided useful insight into the processes with surge and tide propagating together.

Besides tide, typhoon-induced storm surge is determined primarily by the meteorological forcing such as tropical cyclone’s intensity, size, track, forward speed and so on. Numerous scholars conducted researches about how uncertainties for the meteorological data affected the surge prediction in numerical model. Peng et al. (2004) used an integrated storm and inundation modeling system to simulate and compare the storm surge and inundation under various tracks, minimum central pressures, radius of maximum wind and forward speed. Zhong et al. (2010) conducted similar sensitivity experiments for the storm surge in a semi-enclosed bay using a real case of Hurricane Isabel (2003). Irish et al. (2008) claimed that the storm size as well as the wind speed, played an important role in surge generation through analysis of the historical record and numerical simulation. In China, Guo et al. (2009) conducted a series of numerical experimental cases to study the effect of land reclamation and cyclonic parameters on the highest water levels in Hangzhou Bay. Yin et al. (2017) investigated the effect of potential sea level rise and typhoon intensity on storm