Available online at www.sciencedirect.com

ScienceDirect

Procedia IUTAM 25 (2017) 70–73

Procedia IUTAM

www.elsevier.com/locate/procedia

IUTAM Symposium on Storm Surge Modelling and Forecasting

The recent development of storm surge modeling in Taiwan

Tso-Ren Wu[a,*], Yu-Lin Tsai[a], and Chuen-Teyr Terng[b]

[a]*Graduate Institute of Hydrological and Oceanic Sciences, NCU, Chunli, Taiwan, China*
[b]*Marine Meteorology Center, CWB, Taiwan, China*

Abstract

Storm surge is an important issue in Taiwan because our country is located at the typhoon prone area and surrounded by the Pacific Ocean and the Taiwan Strait. People live at coastal areas need to pay attention to the damages of storm surge, especially the inundlation during typhoon's duration. Therefore, the accurate and highly efficient operational storm surge system is required to provide not only the information of water elevations but also potential inundation areas. The large computational domain should be adopted to cover the complete typhoon life-cycle, and the atmospheric model and tidal model are expected to be coupled inside. COMCOT-SS (COrnell Multi-grid Coupled Tsunami Model – Storm Surge) fulfils above-mentioned requirements and solves nonlinear shallow water equations with multi-scale wave propagations and inundation calculation. In this study, 2015 category-5 Typhoon Soulik is chosen for model validation, and the results are in a good agreement with observed data. Coastal inundation induced by Typhoon Soulik is also simulated to study the variation of storm tides and tides. By a series of strict validations and operational experiments, COMCOT storm surge operational system has been the official forecasting model at Central Weather Bureau, Taiwan since July, 2016, and has successfully predicted the storm surges induced by 2016 category-5 Typhoon Nepartak.

Selection and peer-review under responsibility of IUTAM Symposium on Storm Surge Modelling and Forecasting.

Keywords: COMCOT storm surge model; Taiwan storm surge operational system; coupling with WRF model and TPXO model.

1. Introduction

Storm surge in Taiwan is a big issue because our country is located at the typhoon prone area and surrounded by the Pacific Open Ocean and the narrow Taiwan Strait. During typhoon's incoming duration, people live near coastal regions need to pay their attention to the damages of storm surge, especially the surge inundation. Therefore, the accurate and highly efficient operational storm surge model is required in near-shore regions, and provides not only water elevations but also the information of potential surge inundation areas. Also, the large computational

* Corresponding author. Tel.: 886-3-4227151 ext. 65687; fax: 886-3-4222894.
E-mail address: tsoren@ncu.edu.tw

2210-9838
Selection and peer-review under responsibility of IUTAM Symposium on Storm Surge Modelling and Forecasting.
10.1016/j.piutam.2017.09.011

domain should be adopted to cover the complete typhoon life-cycle in this model, and the regional-scale atmospheric model and global tidal model are expected to be coupled in the operational processes.

The COMCOT (COrnell Multi-grid Coupled Tsunami Model) model has been chosen to develop the storm surge operational system because of well-developed advantages like nested-grid scheme, solving nonlinear shallow water equations (NSWs) on both Cartesian and spherical coordinates, and calculating inundation with the wet-dry cell treatment (Wang and Liu[1]; Koh et al.[2]; Li et al.[3]; Fraster et al.[4]). In order to fulfil the operational efficiency, Open-Mp (Open Multi-Processing) is adopted in COMCOT model, which efficiency is at least 10 times more than the original version (Lin et al.[5]). Not only WRF model but also TPXO tidal model (Dushaw et al.[6]) have been coupled in this study. The category-5 2015 Typhoon Soulik is chosen to validate our model accuracy with the resolution of 200 meters at coastal regions, and tidal conditions are also considered in our simulations to study the interaction between storm surges and tides.

2. Methodology

The nonlinear shallow water equations (NSWs) could be adopted to calculate the storm surge propagations when we consider storm surge is a kind of long wave because its wavelength is 20 times much longer than the water depth (Bode and Hardy[7]). Our COMCOT storm surge model includes large-scale wave propagations, near-shore dynamic process, nonlinear terms, Coriolis Effect, and bottom shear stresses. The governing equations in COMCOT storm surge model are:

$$\frac{\partial \eta}{\partial t}+\frac{1}{R\cos\varphi}\left\{\frac{\partial P}{\partial \psi}+\frac{\partial}{\partial \varphi}\left(\cos\varphi\cdot Q\right)\right\}=0 \tag{1}$$

$$\frac{\partial P}{\partial t}+\frac{1}{R\cos\varphi}\frac{\partial}{\partial \psi}\left(\frac{P^2}{H}\right)+\frac{1}{R}\frac{\partial}{\partial \varphi}\left(\frac{PQ}{H}\right)+\frac{gH}{R\cos\varphi}\frac{\partial \eta}{\partial \psi}-fQ+F_\psi^b=-\frac{H}{\rho_w R\cos\varphi}\frac{\partial P_a}{\partial \psi}+\frac{F_\psi^s}{\rho_w} \tag{2}$$

$$\frac{\partial Q}{\partial t}+\frac{1}{R\cos\varphi}\frac{\partial}{\partial \psi}\left(\frac{PQ}{H}\right)+\frac{1}{R}\frac{\partial}{\partial \varphi}\left(\frac{Q^2}{H}\right)+\frac{gH}{R}\frac{\partial \eta}{\partial \varphi}+fP+F_\varphi^b=-\frac{H}{\rho_w R}\frac{\partial P_a}{\partial \psi}+\frac{F_\varphi^s}{\rho_w} \tag{3}$$

where η denotes free surface elevation, h denotes still water depth, P,Q indicate momentum flux, ψ,φ denote longitude and latitude, H denotes total water depth ($H=\eta+h$), g indicates gravitational acceleration, ρ_w denotes water density, F^s denotes wind shear stress, f denotes Coriolis coefficient, and F^b denotes bottom friction.

The tidal information provided by TPXO model are inputted from specified boundaries, so we could consider the nonlinear interaction between storm surges and tides at the same time. In order to consider the bottom shear stress, Manning's coefficient is specified as 0.013 in coastal regions.

3. Results and Discussions

The storm surges induced by 2015 catogory-5 Typhoon Soulik have been simulated by COMCOT storm surge operational model, and the parametric typhoon model is used as forcing terms in this study. The evolution of storm surge generated by Typhoon Soulik before- and after- landfall is plotted in Fig. 1 and Fig. 2. The large-scale storm surges is concentric before making landfall at the Taiwan Island because pressure drop primarily triggers water increasing, and then the shape of storm surges is non-symmetric at near-shore regions since wind shear stress turns to be the main force after making landfall in Fig. 3. The simulated storm surges (storm tides minus pure tides) are compared with observed surge deviations (observed water elevation minus harmonic tides), and the comparisons are in a good agreement in Fig. 4. In Taiwan coastal regions, the inundation induced by storm tides and tides are also analyzed with nonlinear shallow water equations in Fig. 5. The water elevation increases at least 0.3 m in Pintung because of Tpyhoon Soulik and causes surge inundation at low-lying areas and estuaries.