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Evaluation of Storm Surge Caused by Typhoon Yolanda (2013) and Using Weather - Storm Surge - Wave - Tide Model

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Abstract

This paper presents a comparison between numerically estimated storm surge invoked by typhoon Yolanda (2013) and field survey results. In order to estimate the typhoon more accurately, TC-Bogus scheme is used in typhoon simulation. This scheme has a potential to improve an initial atmospheric field and give a better results, in terms of routes and minimum sea surface pressure of the typhoon. In the results of calculated storm surge, a height of the estimated storm surge reached approximately 5.0 m at Tacloban. This value is a good agreement with the measured height. The timing of the storm surge was 00:00 UTC 8th November 2013. The estimated time of the storm surge invoked by Yolanda is almost the same with that of information from residents. Thus, the storm surge model composed of the WRF, FVCOM, SWAN and WX-tide has a potential to reproduce the storm surge realistically.

Keywords, Yolanda; Haiyan; Storm surge; ARW-WRF; FVCOM; Tacloban; Phillipines; Typhoon.

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1. Introduction

Storm surge invoked by typhoon Yolanda (2013) caused widespread damage to coastlines in Leyte and Samar Island. In Philippines, typhoons frequently have come 5-10 times annually, according to RSMC best track (Japan Meteorological Agency, hereafter JMA, 2014). Especially, the typhoon Uring (1991) lost approximately five thousands of people their lives due to its strong wind and invoked flooding (Rudolph and Guard, 1991). Additionally, there were other catastrophic typhoons attacking Philippines, such as Super Typhoon “ROSING” in 1995, Typhoon “FRANK” in 2008 (Etro and Bassi 1995, Cooper and Robert, 2008). However, typhoon Yolanda is a rare typhoon which caused huge storm surge and made the people lost their lives mainly due to its storm surge in Philippines. Additionally, based on the research conducted by Takagi et al. (2015), typhoon Yolanda is an abnormal typhoon, in terms of her route and intensity among past typhoons approaching near Philippines.

There have been researches on simulating typhoons by using regional atmospheric models, such as the ARW-WRF version 3 (Skamarock et al., 2008; hereafter WRF). The WRF has a potential to conduct forecast for 180 hours by using Global Forecast System (hereafter, GFS, NOAA, 2015). Also, the WRF is able to reproduce past typhoons. Then, there are a lot of researches regarding forecast and hindcast by using the WRF (E.g. Mori et al., 2014). Furthermore, the WRF can be used as the boundary layers, such as wind velocity and sea level pressure, to storm surge models (E.g. Tasnim et al., 2014; Mori et al., 2014). Thus, the WRF is considered to be as the standard model, giving the boundary layer of storm surge model. For estimating the storm surge, the unstructured, finite volume community ocean model (hereafter, FVCOM; Chen et al., 2003) has been carried out in several researches (E.g. Weisberg and Zheng 2006; 2008). The FVCOM employs the finite volume method as a discretization, conserving mass and momentum equation accurately (Chen et al, 2003). Furthermore, flexible unstructured meshes can be adjusted to complex geometries (Chen et al, 2003).

In this research, the storm surge model composed of the WRF, FVCOM 3.1.6 (Chen et al., 2011), SWAN (Booji et al., 1999) and WX-tide (WXTide32, 2007) is used to estimate the storm surge invoked by typhoon Yolanda. Also, the field survey conducted in the periods of 5th-13th December 2013 (Shibayama et al., 2014) is explained. In this investigation, they measured the heights of the storm surge from the left water mark and from the eyewitness of the residents (Shibayama et al., 2014), and heard the way of mitigation (Esteban et al., 2014; 2015). Finally, the estimated results of the storm surge are compared with the field results.

2. Storm surge model outline

Fig.1 shows an outline of consisted models. First, the WRF is used to estimate wind velocities and pressures at 10 m above sea level. Then, the results of these atmospheric fields near ocean surface are used as the initial and boundary conditions to the FVCOM, in order to estimate the pressure surge and wind induced set-up of the storm surge. The wind field is also used as the boundary conditions of the SWAN to calculate the wave set-up. The WX-tide is employed to estimate astronomical tide levels. Then, the storm surge is reproduced using the sum of the pressure surge and wind induced set-up of FVCOM, the wave set-up of SWAN and astronomical tide levels of WX-tide.

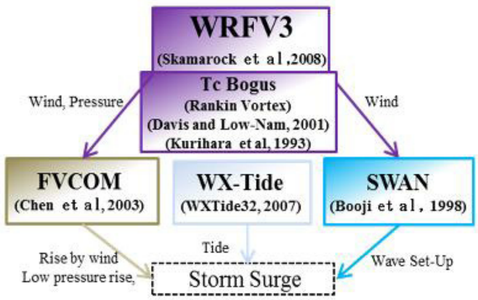

Fig.1 The outline of storm surge model.

3. Summary of the typhoon Yolanda (2013) and Field Survey

Typhoon Yolanda is recognized as typhoon 12:00 UTC 5th November 2013 and then grew to super-typhoon with its minimum pressure of 895 hPa and its maximum wind speed of 64 ms^{-1}. Because typhoon Yolanda was conserving its energy continually until the time of landing on Leyte Island, the widespread destruction was occurred in Philippines. In the field survey, Tacloban, which is most affected by the storm surge, was mainly surveyed by Philippines Storm Surge Joint Survey Group (Shibayama et al., 2014). Then, the coastline of Leyte and Samar Island