LOW LATITUDE TYPHOON INDUCED STORM TIDE IN SINGAPORE: A MONTE CARLO APPROACH FOR STORM TIDE MODELLING

Serene Hui Xin Tay, Tropical Marine Science Institute, National University of Singapore, Singapore, serenetay@nus.edu.sg
Dieu Huong Trinh, Tropical Marine Science Institute, National University of Singapore, Singapore, huongtrinh@nus.edu.sg
Seng Keat Ooi, Tropical Marine Science Institute, National University of Singapore, Singapore, sk.ooi@nus.edu.sg

BACKGROUND

Within 5 degrees of the Equator, it has been known as the cyclone-free zone due to insufficient Earth's background rotation to support vortex spin-up (Anthes, 1982). However, Steenkamp et al. (2018) pointed out that there are about 213 tropical cyclones formed between 5ºN and 5ºS during the period 1900-2017 based on the International Best Track Archive for Climate Stewardship (IBTrACS) (Knapp et al., 2010).

In December 2001, typhoon Vamei was formed at 1.4ºN and 106.5ºE (Figure 1) and made landfall 60 km northeast of Singapore. An analysis by Chang et al. (2003) suggested that the return frequency for such a typhoon is approximately 1 in 400 years which suggests that the possibility of a tropical storm occurring in the Singapore Straits cannot be ignored. Considering the population density and high value assets on this small island, the consequences of surge, inundation and flooding due to a tropical storm could be devastating to Singapore.

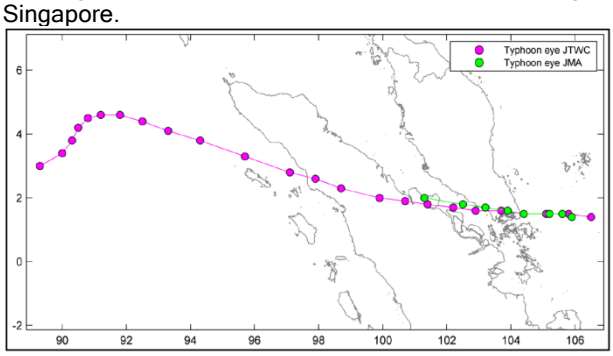

Figure 1-Track of Typhoon Vamei recorded by Joint Typhoon Warning Centre (JTWC) and Japan Meteorological Agency (JMA) (adopted from Tay, 2010)

Previously, Tay (2010) had quantified the extreme water levels caused by tide, sea level anomalies and typhoon-induced surge based on one assumed 'worst' typhoon scenario after performing sensitivity tests on typhoon parameters such as track, forward speed and radius of maximum wind. As this assumed 'worst' typhoon scenario was made without consideration of the physics of the typhoon evolution, the likelihood of this typhoon scenario may be almost impossible.

In this paper, we attempt to develop a statistical model to characterize all historical low latitude typhoons recorded and generate a population of synthetic typhoons near Singapore. Thereafter we simulate extreme storm tide (combined typhoon-induced surge and tide) events in Singapore using these Monte Carlo simulated synthetic typhoons and a hydrodynamic tidal model to determine the maximum storm tide around Singapore.

HYDRODYNAMIC MODEL

The hydrodynamic model applied in this paper is the so-called Singapore Regional Model (Coarse) built in the Delft3D modelling environment. The tidal model has been well calibrated and validated in Malacca Strait with tidal gauges located in west coast of Malaysia Peninsular (Kurniawan et al. 2011).

SYNTHETIC TYPHOONS

Based on the records in IBTrACS, historical typhoons formed in the low latitude zone (between 5ºN and 5ºS) are characterized in a statistical model that represents typhoon intensity and movement; the parameters include central pressure, forward speed, radius of maximum wind and maximum sustained wind. The statistical model is then used to develop a population of synthetic typhoons that provide wind (Figure 2) and pressure fields as boundary conditions for the hydrodynamic model to simulate storm tide. This Monte Carlo approach is applied to Singapore.

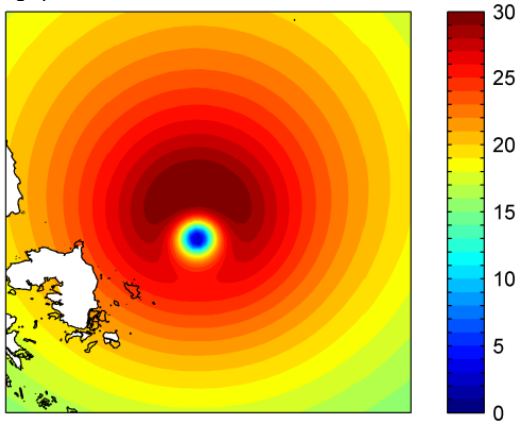

Figure 2-A synthetic typhoon wind field (in m/s)

REFERENCES

Anthes (Ed.). (2016). Tropical cyclones: their evolution, structure and effects (Vol. 19). Springer.
Kurniawan, Ooi, Hummel, Gerritsen (2011). Sensitivity analysis of the tidal representation in Singapore Regional Waters in a data assimilation environment. Ocean Dynamics, 61(8), 1121-1136.
Steenkamp, Kilroy, Smith (2019). Tropical cyclogenesis at and near the Equator. Quarterly Journal of the Royal Meteorological Society, 145(722), 1846-1864.
Tay (2010). Typhoon-induced extreme water levels near Singapore: A numerical model investigation. MSc Thesis. Delft University of Technology. Delft.