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THE MECHANISMS OF AFTER-RUNNER STORM SURGE ALONG THE NORTH COAST OF VIETNAM

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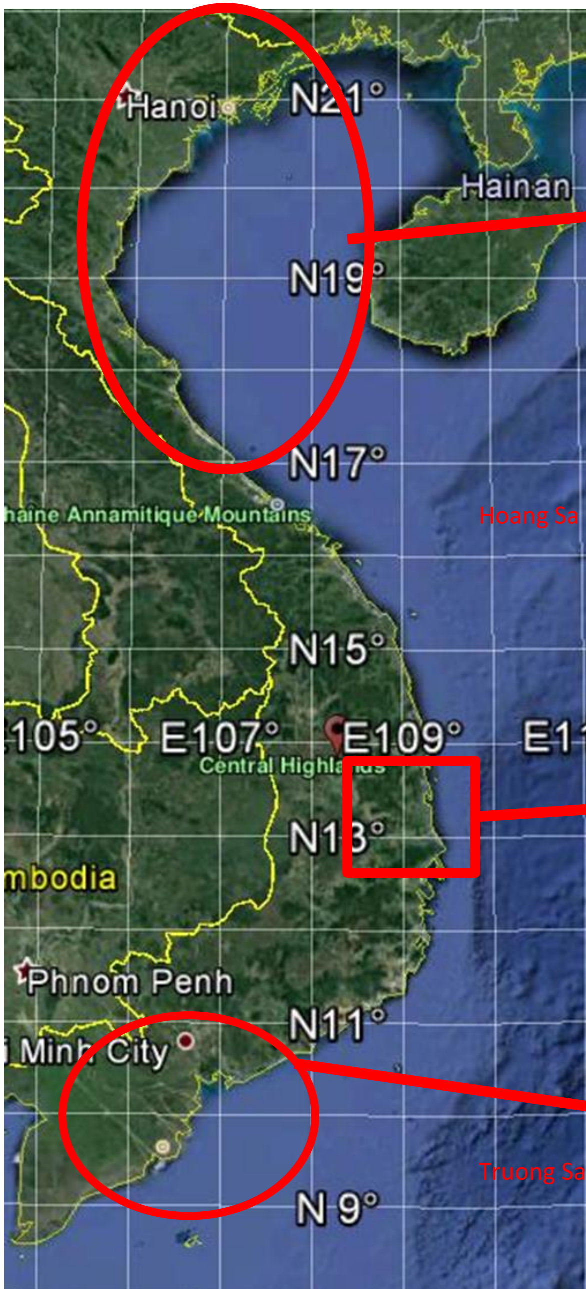
Vietnam National Center for Hydro-meteorological Forecasting

Hanoi, 26 Februal 2018

Coastal **risk** related to high water level in Vietnam

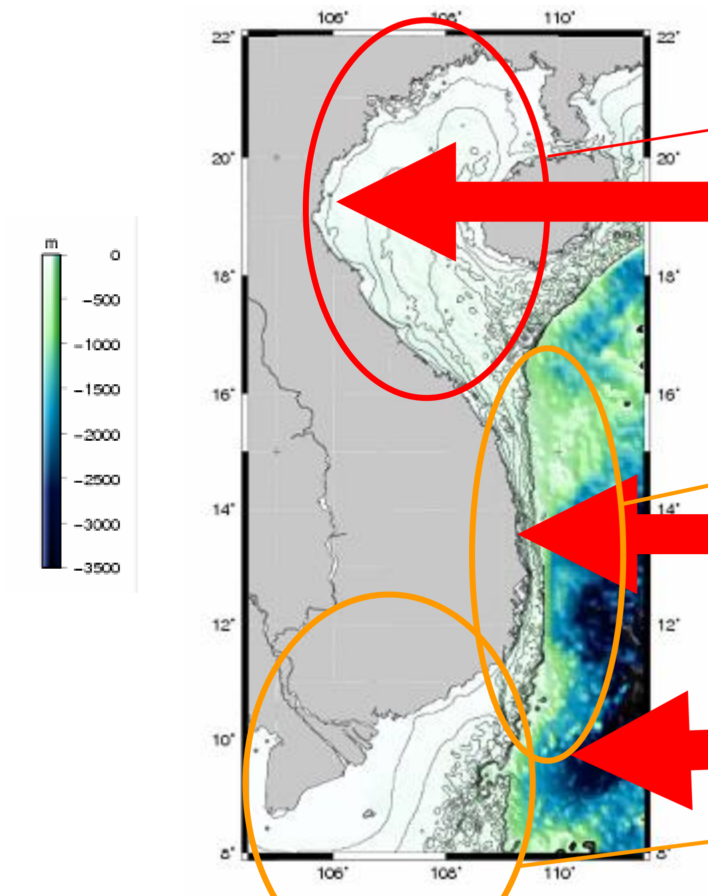


Storm surge

Abnormal water level
(Meteorological tsunami)

Spring tide (Hight tide + surge induced by moonson)

Typhoon and Storm Surge in Vietnam



June

Dec.

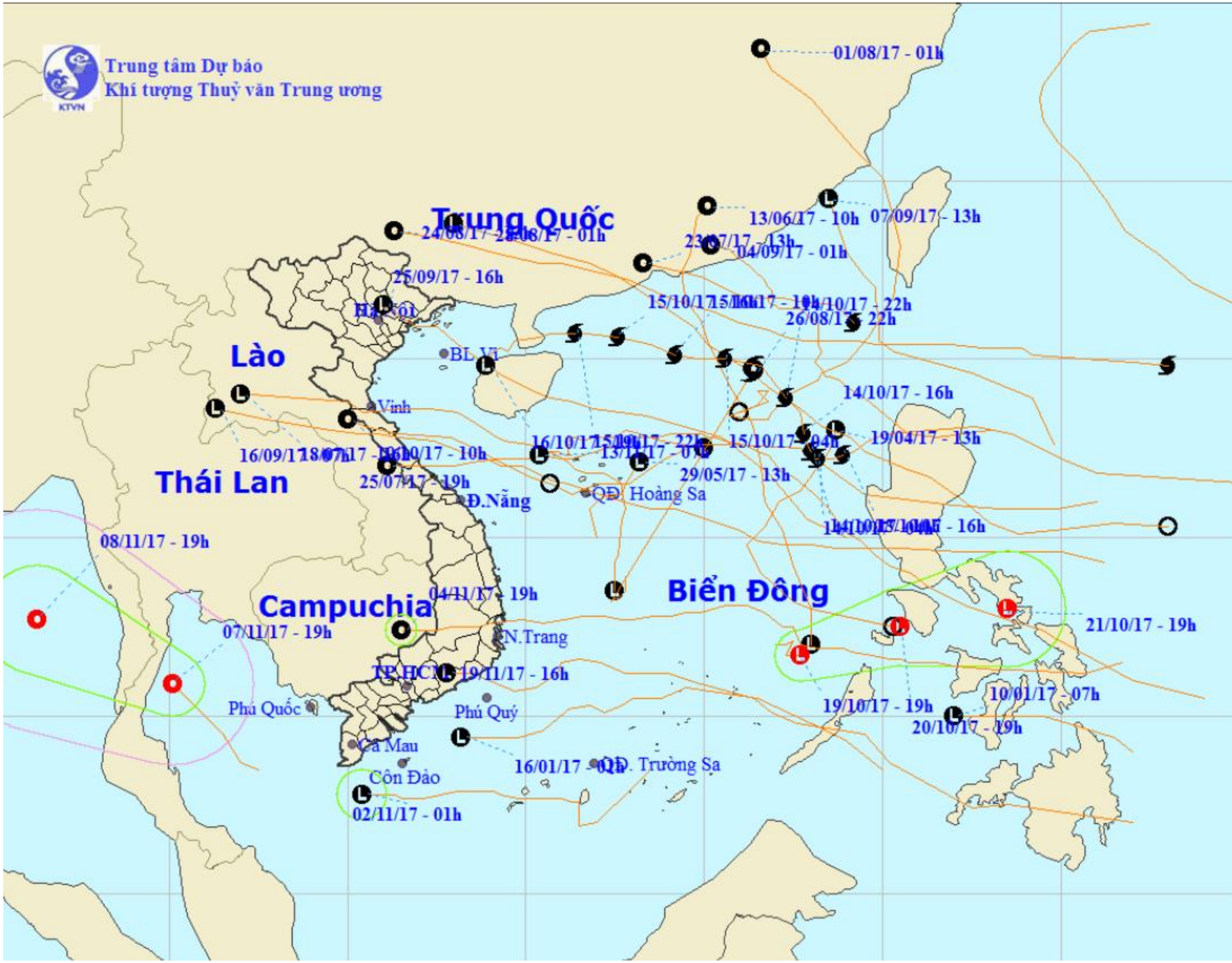
High Vulnerable storm surge
(abundant typhoon + shallow water)

Less Vulnerable storm surge
(rare typhoon + deep water)

Less Vulnerable storm surge
(shallow water +rare typhoon)

Number of Typhoon

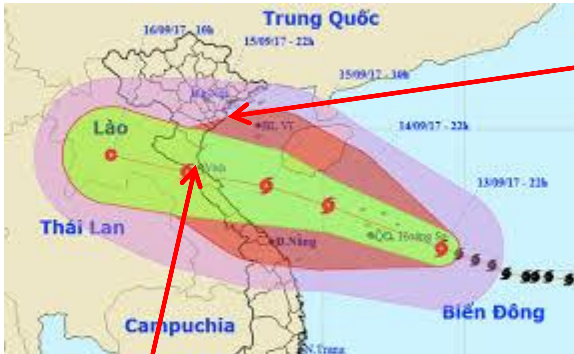
Tracks of typhoon in 2017

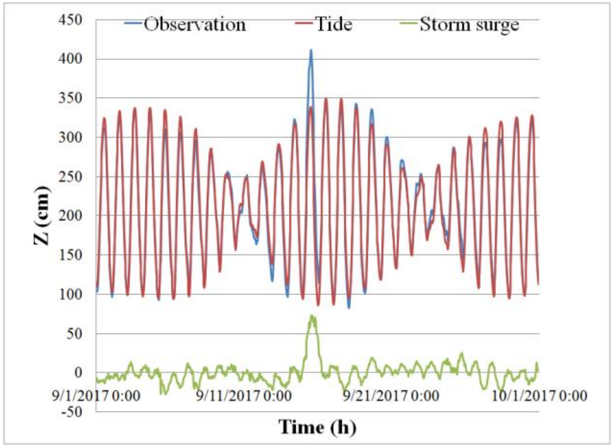


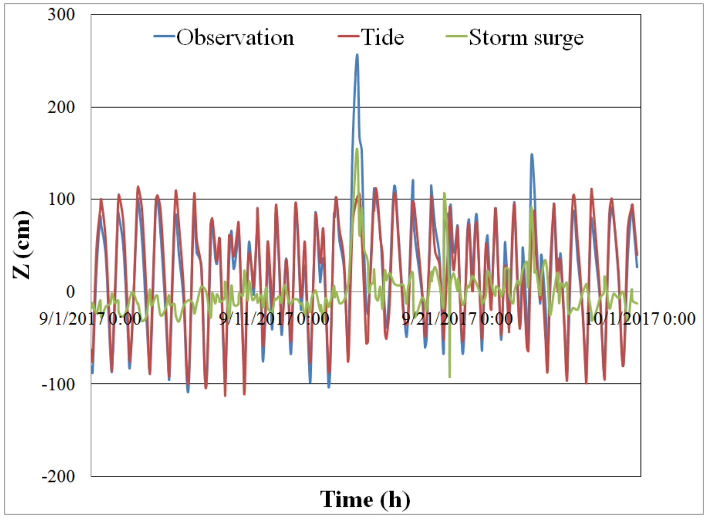
Typhoon number 2 (July/2017)

6 peoble was die and missing, more than 100 ship was broken by high wave

Typhoon number 10 (9/2017)

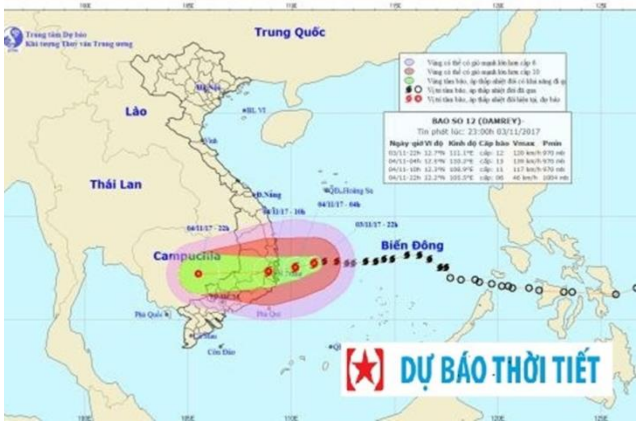






Coastal inundation due to typhoon No 10 (Sep./2017)

Typhoon number 12 (Nov./2017)

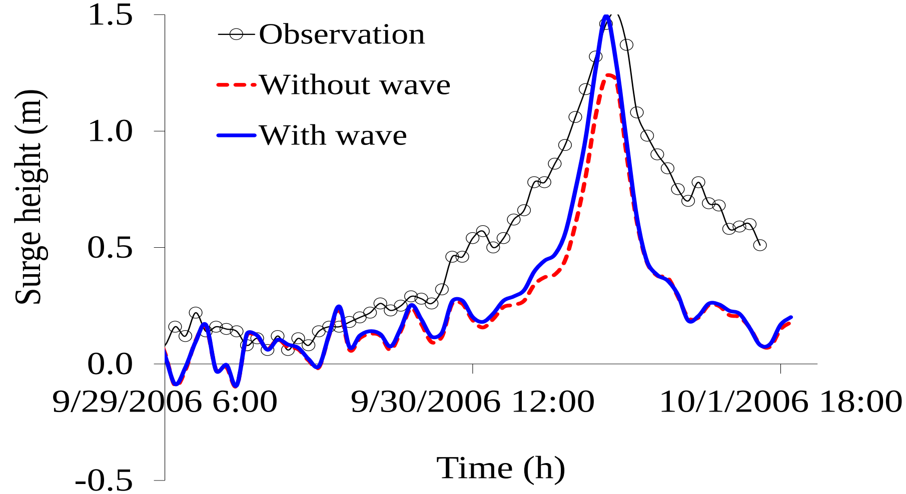


6 cargo ships was sink, 11 peoble die and 2 mising. More than 2000 ship broken by high wave

Storm surge research and prediction

Numerical Model:

- JMA model
-2D ROMS
- SuWAT
(*Best track or WRF*)



Time serial of storm surge

Journal of Coastal Research	00	0	000–000	Coconut Creek, Florida	Month 0000

Assessment of Storm Surge along the Coast of Central Vietnam

Nguyen Ba Thuy[†]*, Sooyoul Kim[‡], Do Dinh Chien[§], Vu Hai Dang[††], Hoang Duc Cuong[†], Cecilie Wettre[‡‡], and Lars Robert Hole[‡‡]

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ABSTRACT

Thuy, N.B.; Kim, S.; Chien, D.D.; Dang, V.H.; Cuong, H.D.; Wettre, C., and Hole, L.R., 0000. Assessment of storm surge along the coast of central Vietnam. *Journal of Coastal Research*, 00(0), 000–000. Coconut Creek (Florida), ISSN 0749-0208.

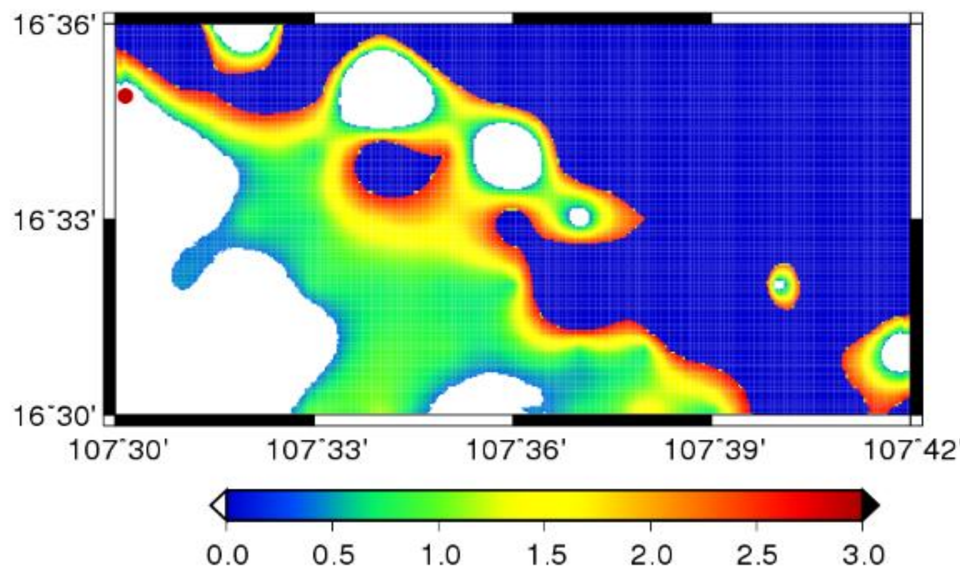
In the present paper, the interaction of surge, wave, and tide along the coast of central Vietnam is assessed using a coupled model of surge, wave, and tide. A series of storm surge simulations for Typhoons Xangsane (2006), Ketsana (2009), and Nary (2013) are carried out, considering the effects of tides and waves that combines wave-dependent drag and wave-induced radiation stress to find a predominant factor in storm surge generation. The results indicate that the surge–wave interaction is crucial to the storm surge simulation in this area. In particular, the wave-dependent drag improves an accuracy of the storm surge level up to 30%. In addition, the radiation stress contributes up to 15%. However, the tide–surge interaction is negligible because there is less than 2% difference in results with and without the tide. A series of coupled surge and wave simulations for 49 historical typhoons in the period of 1951 to 2014 show that mean peak surge levels along the coast are 2.5 m. The highest peak surge level reached 4.1 m at Cuaviet in the Quangtri Province during Typhoon Harriet (1971).

ADDITIONAL INDEX WORDS: *Typhoon; coupled model of surge, wave, and tide; interaction of surge.*

INTRODUCTION

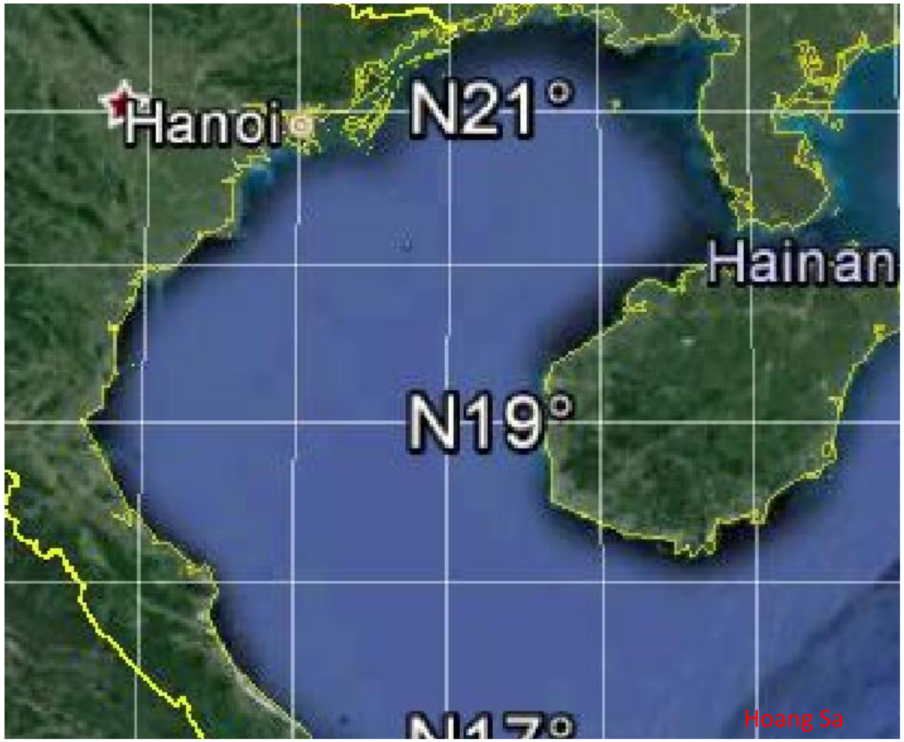
The Intergovernmental Panel on Climate Change's 5th Assessment Report (Field *et al.*, 2014) found that global climate change accelerates the activity of tropical cyclones (TCs).

wave, and tide. Several studies have introduced wind stress as a function of waves (Janssen, 1989, 1991). Since then, a number of studies that examined wave-induced stress directly obtained in coupled models of surge and wave showed the significant



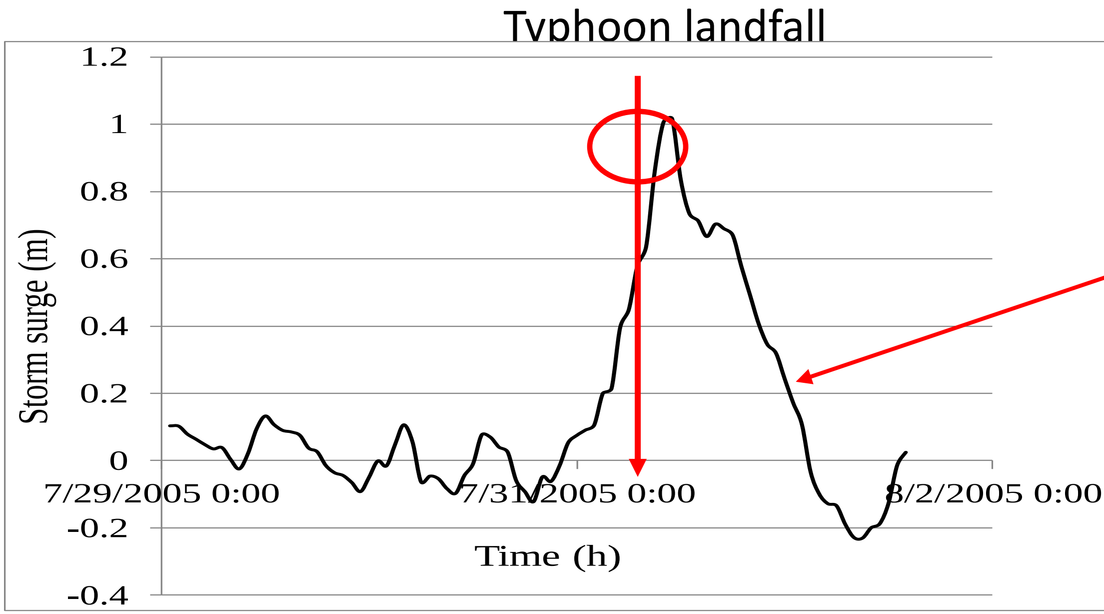
Coastal inundation due to tide + storm surge + wave setup

The after runner storm surge on the North coast of Vietnam

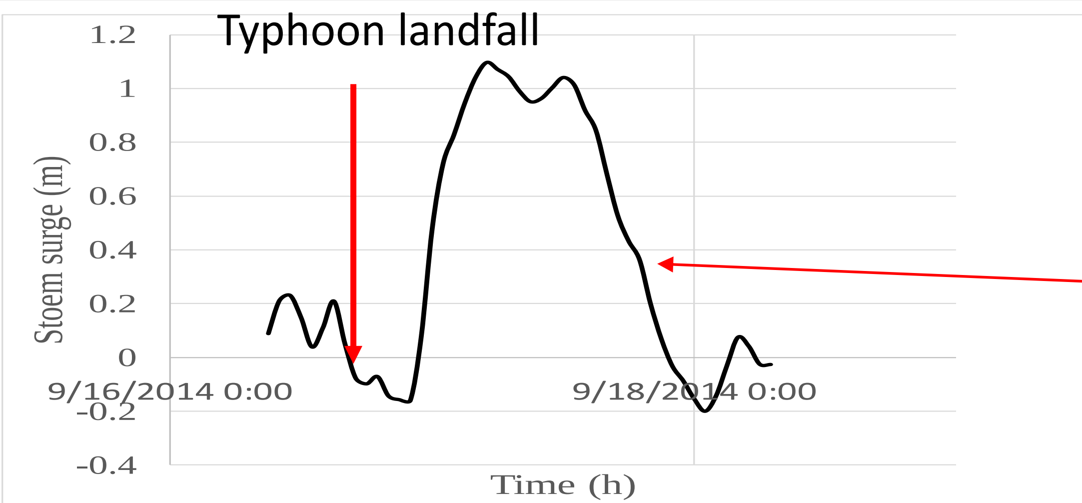


Area: The north coast of Vietnam
Typhoon frequency: 1.5 typhoons/year
Maximum storm surge: 3.4m
The after runner storm surge: 6 cases/50 years

The after runner storm surge



Normal storm surge

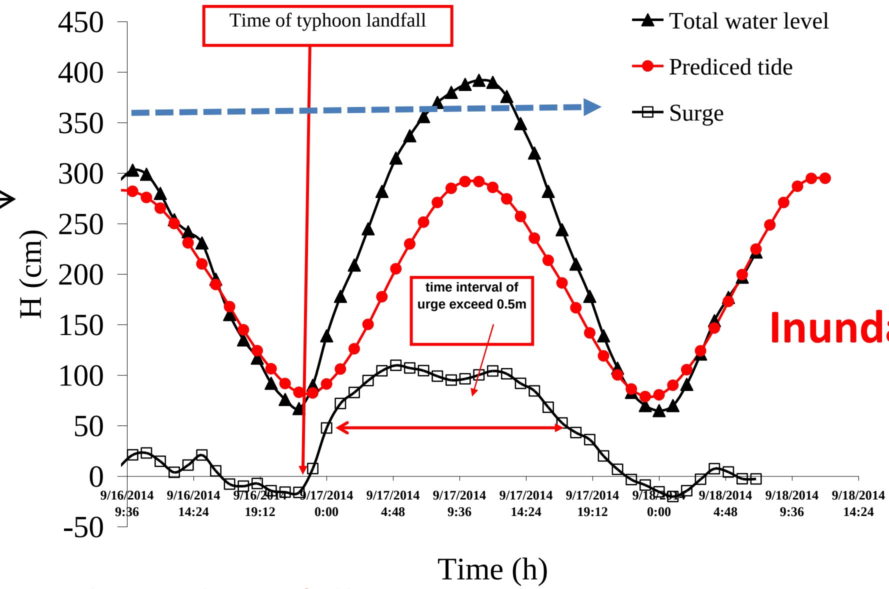


After runner storm surge

Storm surge at Hondau station during typhoon Wukong (2005) and Kalmaegy (2016)

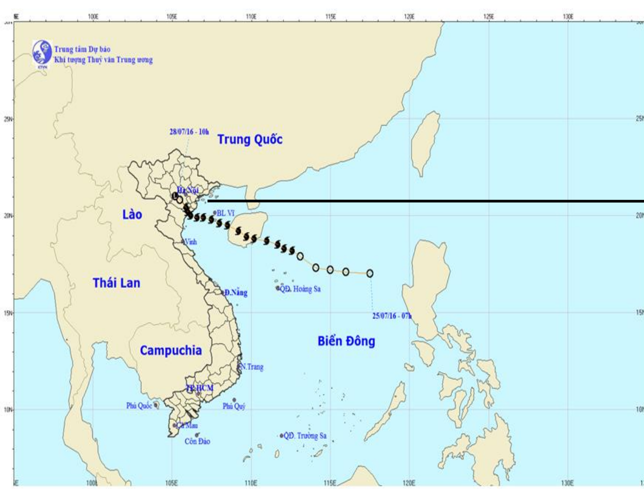
The after runner of storm surge cases

Kalmaegi (9/2014)

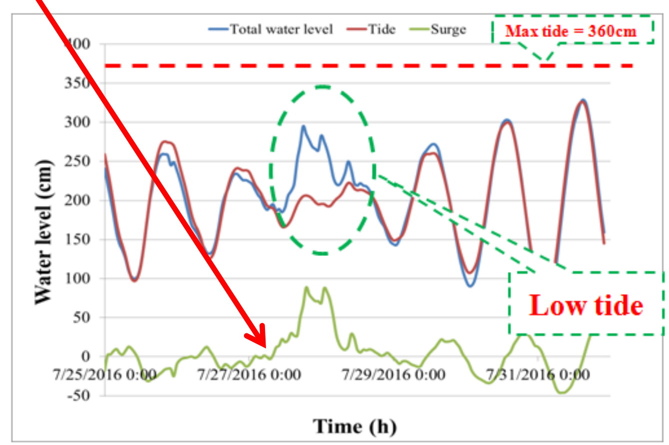


Inundated

Typhoon land fall



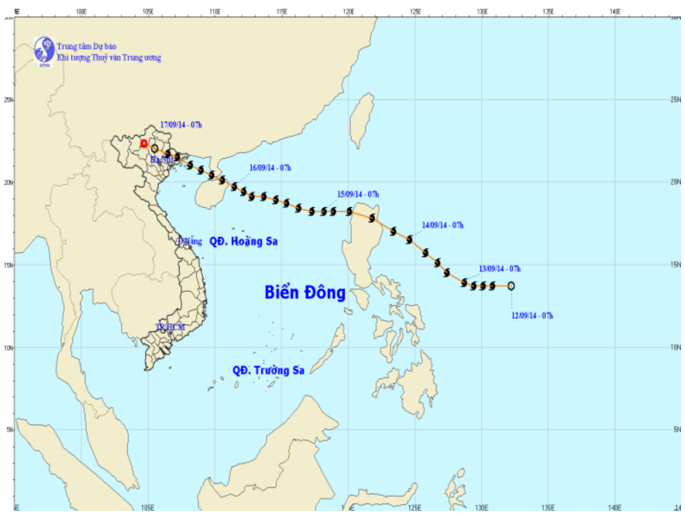
Mirinae (7/2016)



No inundation

Observation water level, predicted tide and storm surge at Hondau station

Typhoon Kalmaegi (9/2014) – After runner storm surge case



Track of typhoon Kalmaegy

- Damage by wind is not much.

- But Storm surge + high tide + high wave generated inundation at Haiphong coast after the typhoon landfall 5 hours.

Một chủ của hàng kinh doanh lâu năm tại khu 1 Đồ Sơn cho hay, người dân sống ở đây quen với bão gió rồi. "Bão vào chúng tôi không sợ bằng khi bão đi qua. Khi đó gió Nam thốc lên kết hợp với đỉnh triều cường thì nguy hiểm lắm. Trận bão cách đây 4 năm, hàng m3 đá dưới biển và đá kè bị nước biển vò vụn ném thẳng vào cửa hàng, gây vỡ hàng loạt cửa kính, hư hỏng nhiều thiết bị, thiệt hại lên tới 40-50 triệu đồng", ông này nói.

Nước biển đã làm ngập toàn bộ tuyến đường tại khu 1 dài gần một km, tràn vào các nhà hàng, khách sạn và đang chảy ngược vào các khu dân cư của phường Ngọc Hải, quận Đồ Sơn.

High wave and inundation at Haiphong coast

Operational Forecasting Model in 9/2014 (conventional method)

Two dimensional long wave model + Empirical Typhoon Model

$$\begin{cases} \dfrac{\partial Du}{\partial t} + \dfrac{\partial Du^2}{\partial x} + \dfrac{\partial Duv}{\partial y} = -\dfrac{1}{\rho_w g} D \dfrac{\partial(\varsigma - \varsigma_0)}{\partial x} - \dfrac{1}{\rho_w}(\tau_{ax} - \tau_{bx}) + fDv \\ \dfrac{\partial Dv}{\partial t} + \dfrac{\partial Duv}{\partial x} + \dfrac{\partial Dv^2}{\partial y} = -\dfrac{1}{\rho_w g} D \dfrac{\partial(\varsigma - \varsigma_0)}{\partial y} - \dfrac{1}{\rho_w}(\tau_{ay} - \tau_{by}) - fDu \end{cases}$$

$$\frac{\partial \varsigma}{\partial t} + \frac{\partial Du}{\partial x} + \frac{\partial Dv}{\partial y} = 0$$

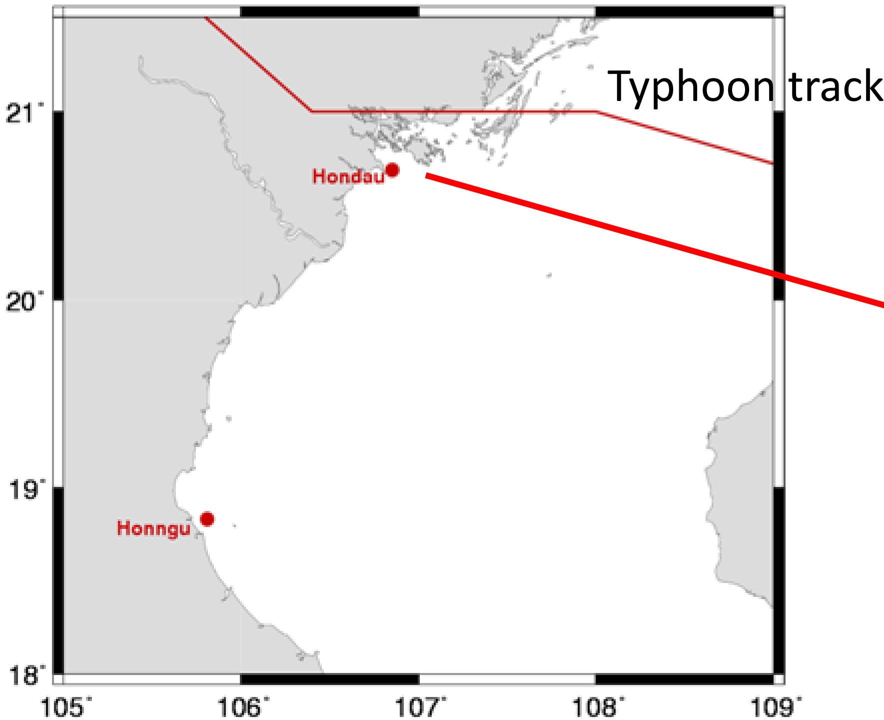
- Empirical Typhoon Model:

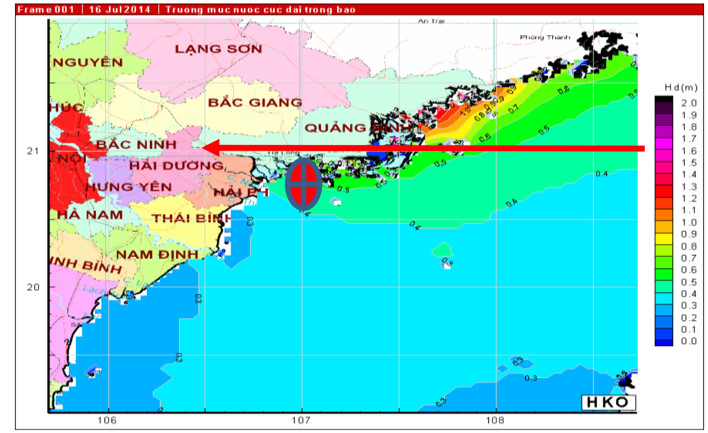
$$P(r) = P_\infty - \frac{P_\infty - P_c}{\sqrt{1 + (r/r_0)^2}}$$

$$-\frac{v^2}{r} - fv = -\frac{1}{\rho}\frac{\partial P}{\partial r}$$

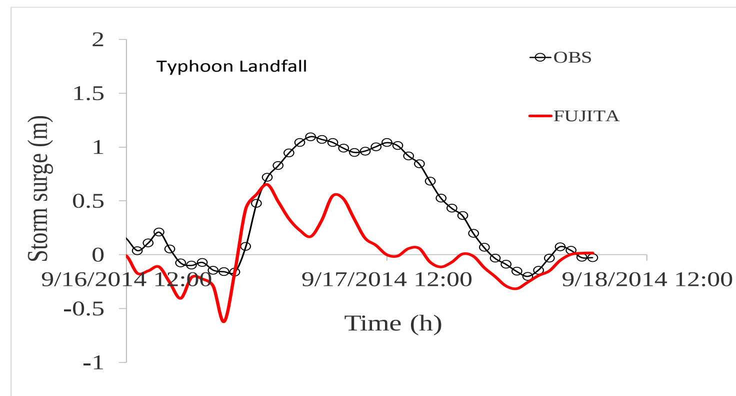
(Fujita model)

Result of Operational forecasting (2D long wave model + Fujita model)





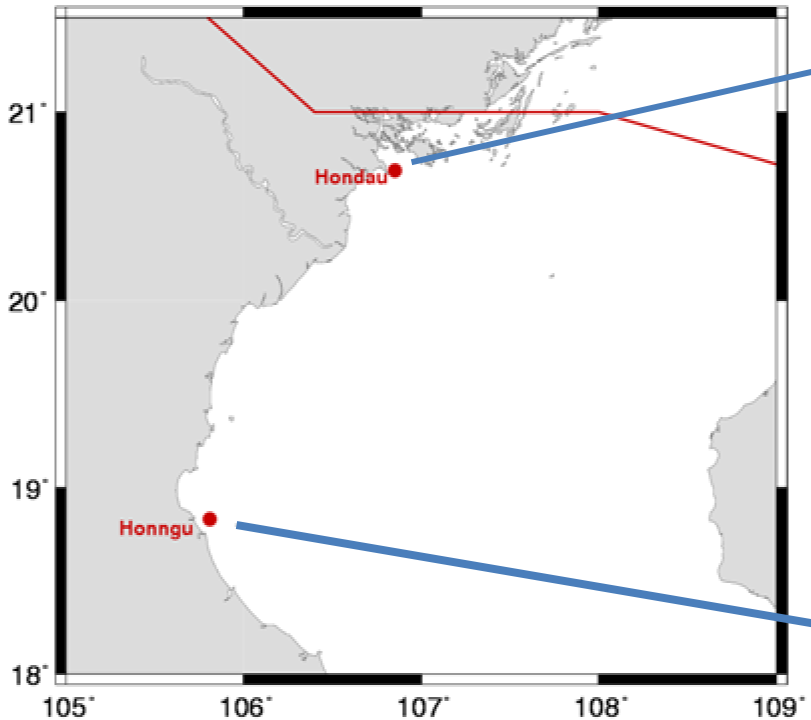
Maximum storm surge

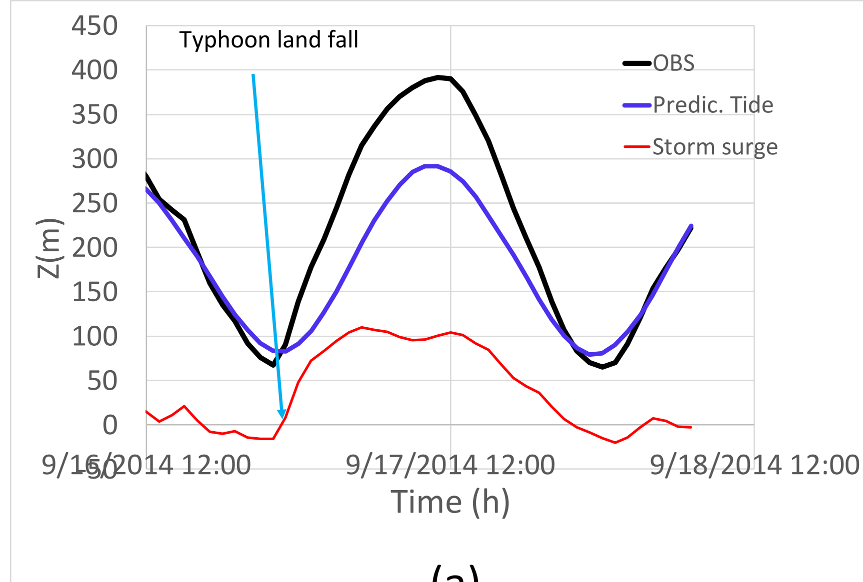


Model and observation storm surge

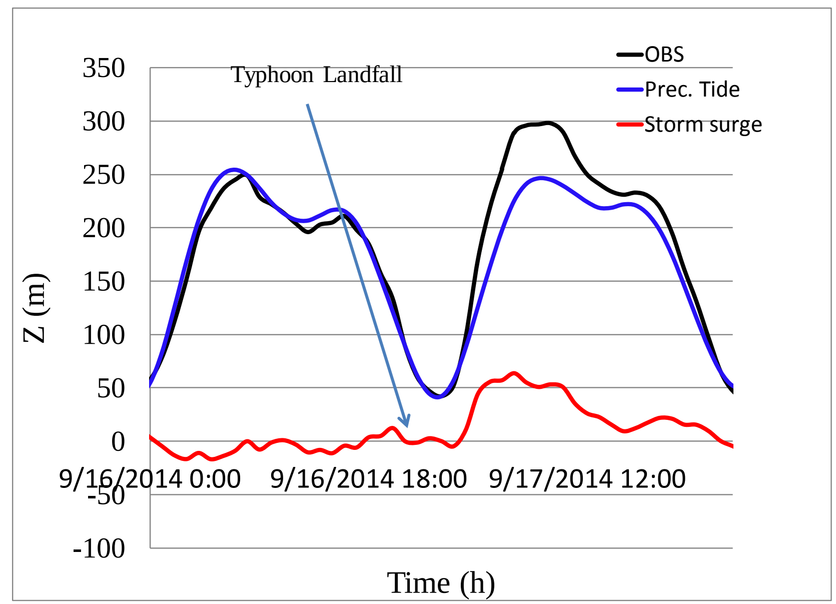
Simulated result showed storm surge not high at Hondau station, and at low tide –> No warning. But infact inundation occurred. **We miss warning**

Storm surge observation data





(a)



(b)

Time profile of total water, tide and storm surge at Hondau (a) and Honngu station (b)

2. Numerical Model (coupled of surge wave and tide)

Two Dimensional Long wave Model + SWAN

$$\frac{\partial \eta}{\partial t} + \frac{\partial M}{\partial x} + \frac{\partial N}{\partial y} = 0$$

$$\frac{\partial M}{\partial t} + \frac{\partial}{\partial x}\left(\frac{M^2}{d}\right) + \frac{\partial}{\partial y}\left(\frac{MN}{d}\right) + gd\frac{\partial \eta}{\partial x} = fN - \frac{1}{\rho_w} d \frac{\partial P}{\partial x} + \frac{1}{\rho_w}\left(\boxed{\tau_s^x} - \tau_b^x + \boxed{F_x}\right) + A_h\left(\frac{\partial^2 M}{\partial x^2} + \frac{\partial^2 M}{\partial y^2}\right)$$

$$\frac{\partial N}{\partial t} + \frac{\partial}{\partial x}\left(\frac{NM}{d}\right) + \frac{\partial}{\partial y}\left(\frac{N^2}{d}\right) + gd\frac{\partial \eta}{\partial y} = -fM - \frac{1}{\rho_w} d \frac{\partial P}{\partial y} + \frac{1}{\rho_w}\left(\boxed{\tau_s^y} - \tau_b^y + \boxed{F_y}\right) + A_h\left(\frac{\partial^2 N}{\partial x^2} + \frac{\partial^2 N}{\partial y^2}\right)$$

τ_s The wind stress (including wave dependent drag)

F: The wave force- which correspond to the gradients of wave-induced radiation stress

Stress on the surface

$$\tau_s = \rho_a C_D \overrightarrow{W}_{10} \left| \overrightarrow{W}_{10} \right|$$

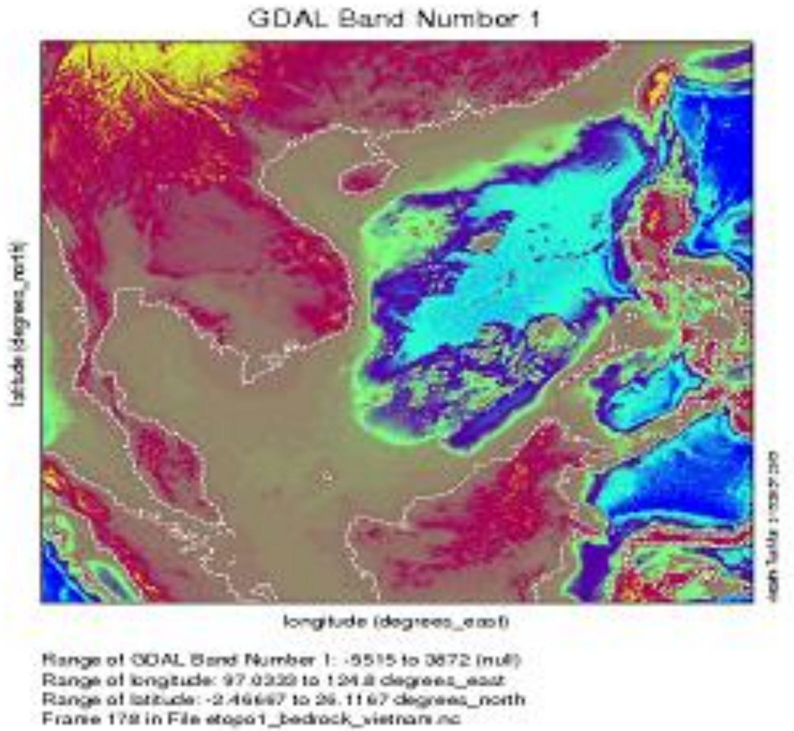
- The case **uncoupled** with wave: The conventional C_D (Honda and Mitsuyasu, 1980). Sure induced by wind stress and air pressure only:

$$C_D = \begin{cases} (1.290 - 0.024W) \times 10^{-3} (W \leq 8\, m/s) \\ (0.58 + 0.063W) \times 10^{-3} (W > 8\, m/s) \end{cases}$$

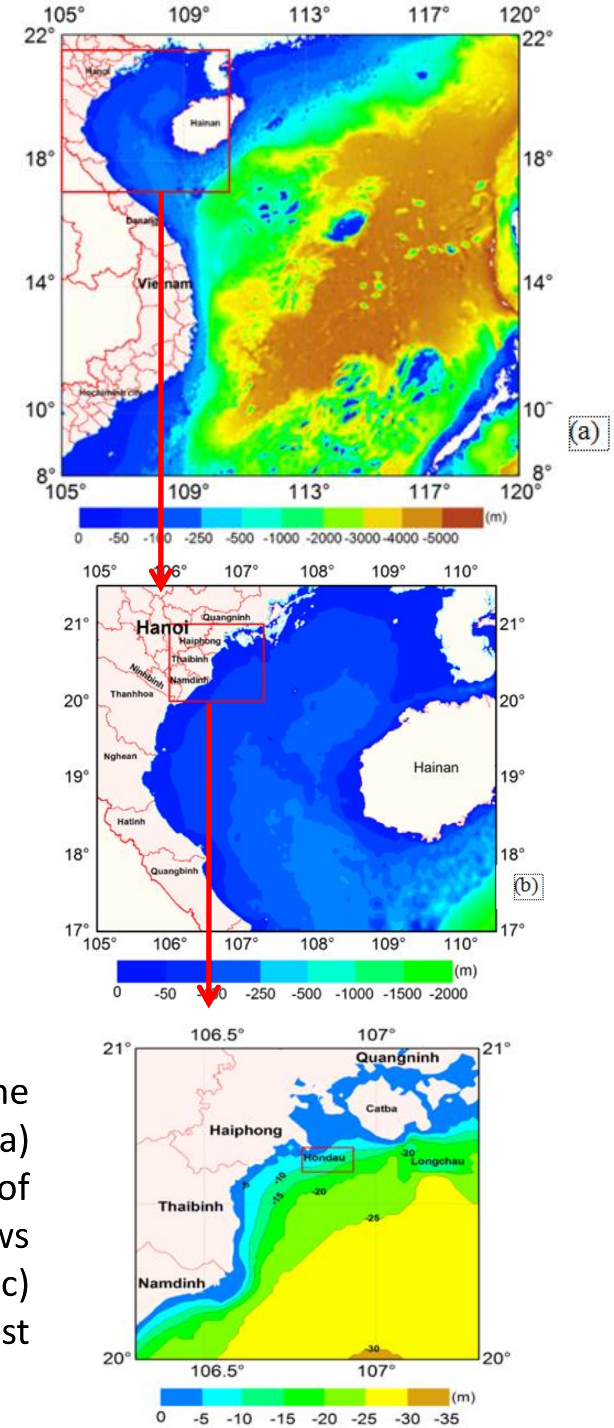
- The case **coupled** with wave: The wave dependent drag C_D (Janssen, 1991). The stress on the surface consider wave:

$$C_D = u^2 / U(z)^2 = \left[\kappa / ln \left(\frac{z + z_e - z_0}{z_e} \right) \right]^2$$

Computational domains for WRF and Storm surge model

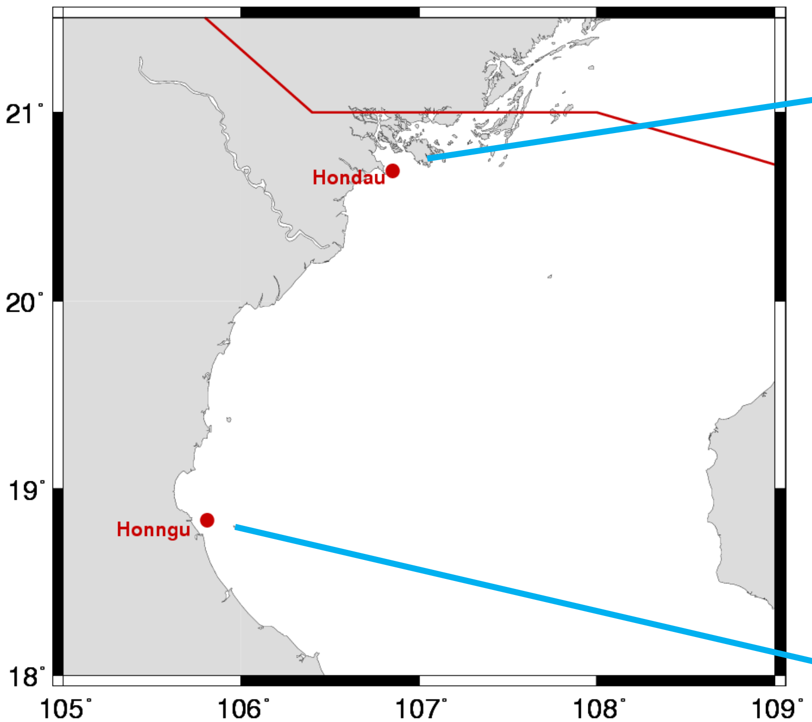


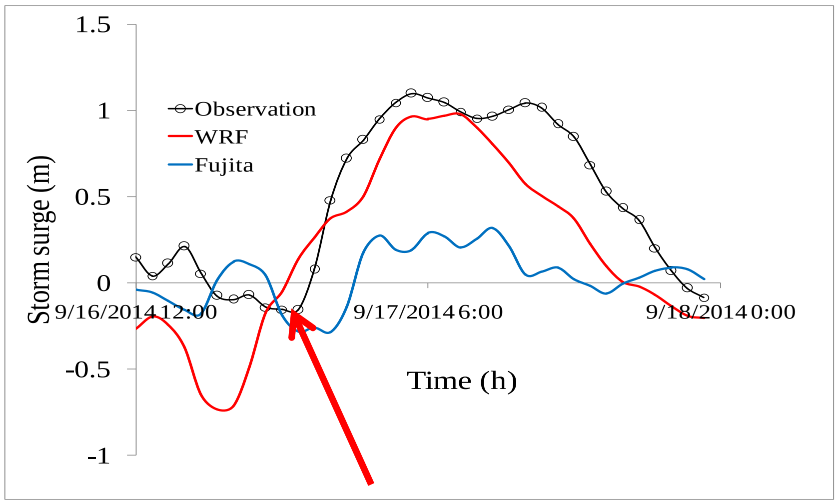
WRF model



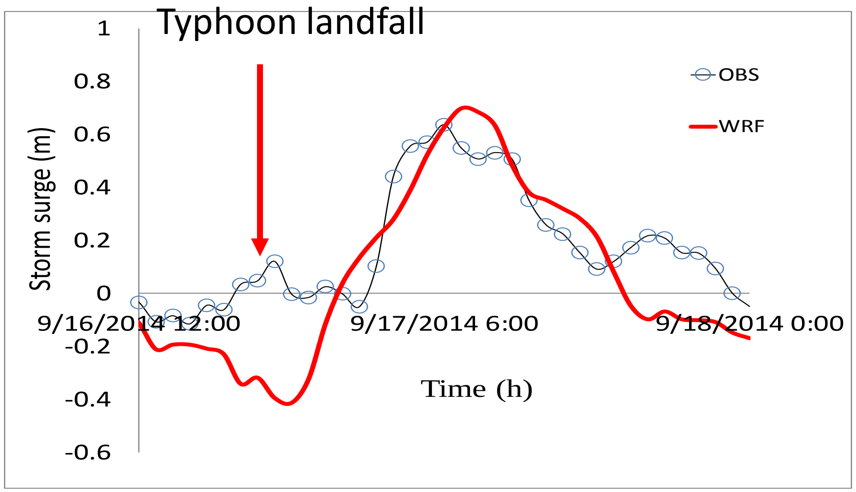
Geophysical domains of the study area with three levels. (a) shows the outermost domain of the Vietnam coast. (b) shows the intermediate domain. (c) focuses on the innermost domain with Hondau station.

Results of SuWAT + WRF model





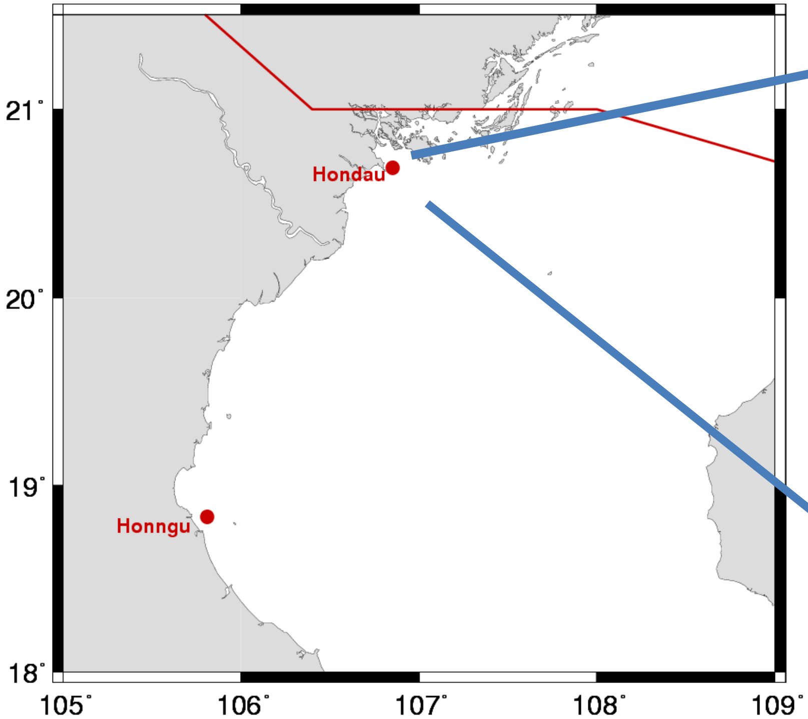
Typhoon landfall

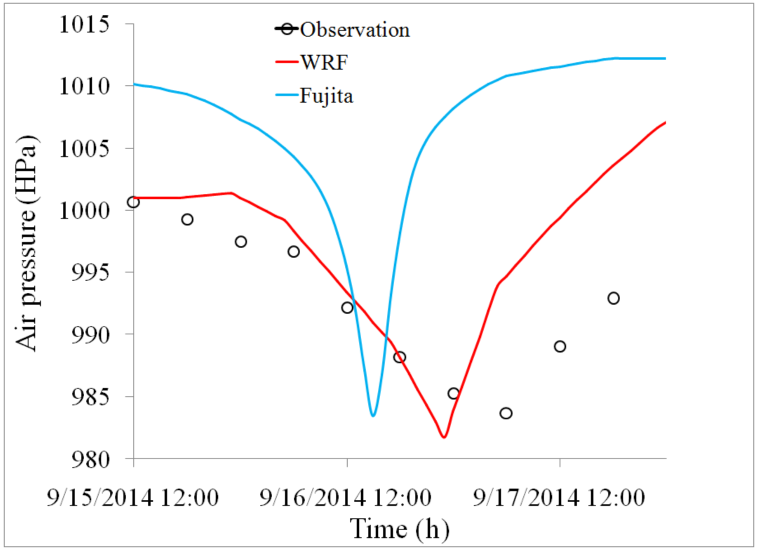


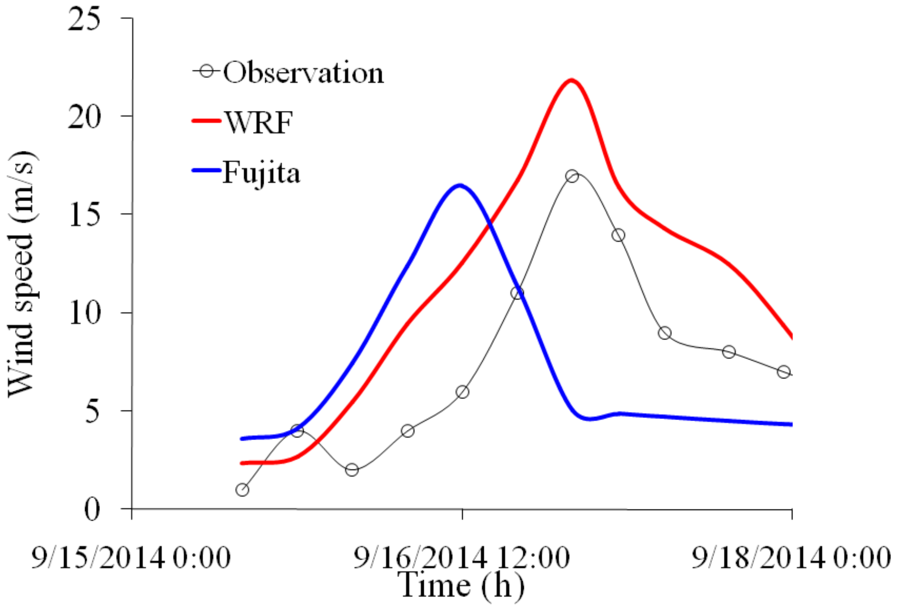
SuWAT+WRF is well simulated the storm surge at two stations

Comparison of calculated and simulated storm surge at two station using wind and pressure from WRF

Wind and pressure data



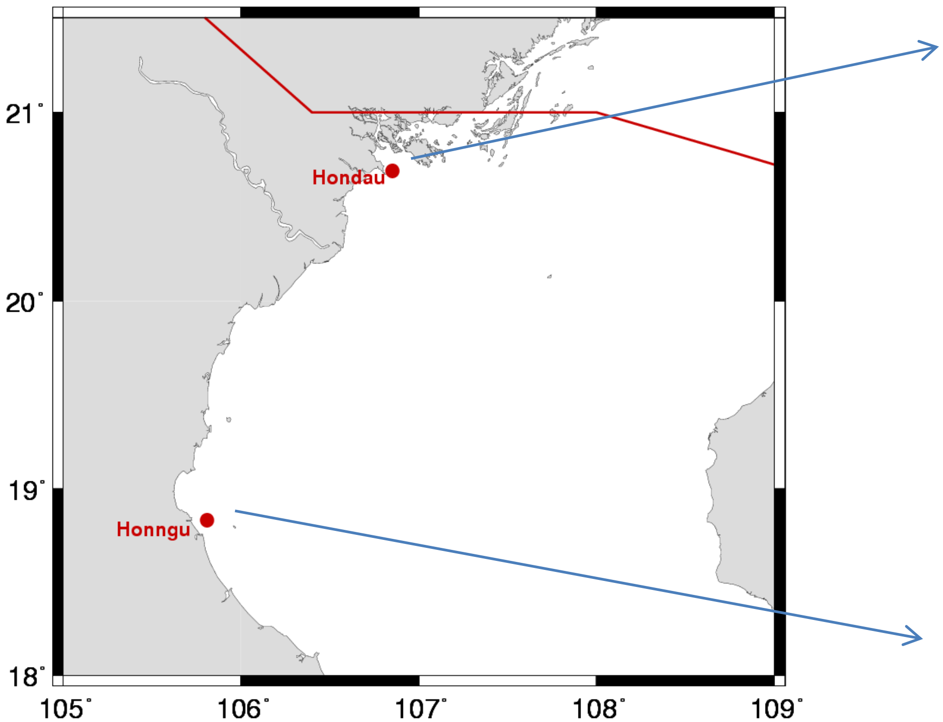


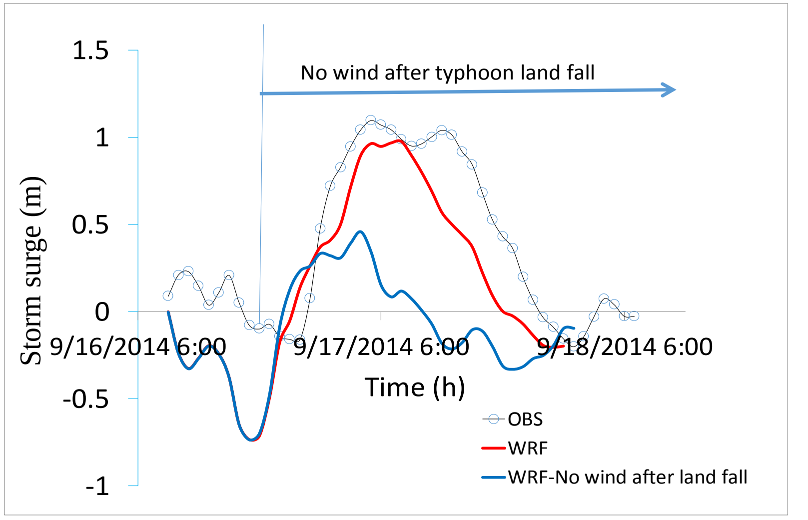


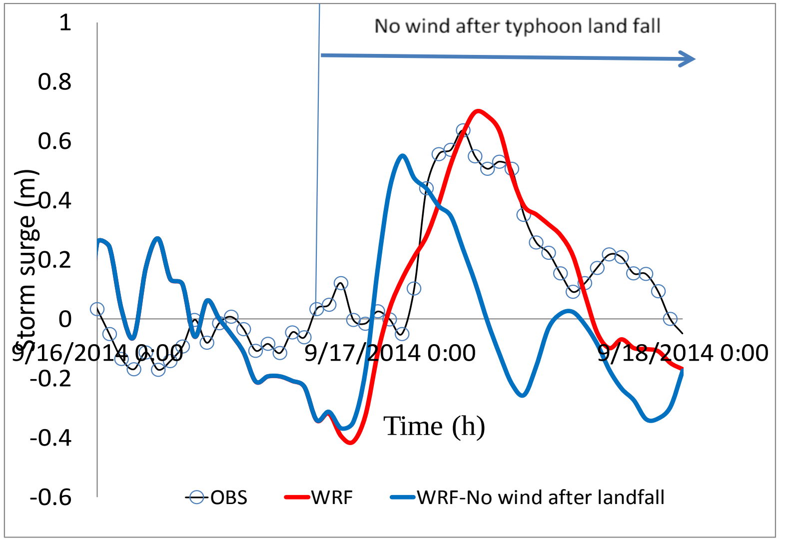
The WRF model simulated well wind and pressure than the empirical typhoon model

Measured and predicted pressure (above) and wind speed (below) and at Hondau station

Effect of front and tail wind field on storm surge



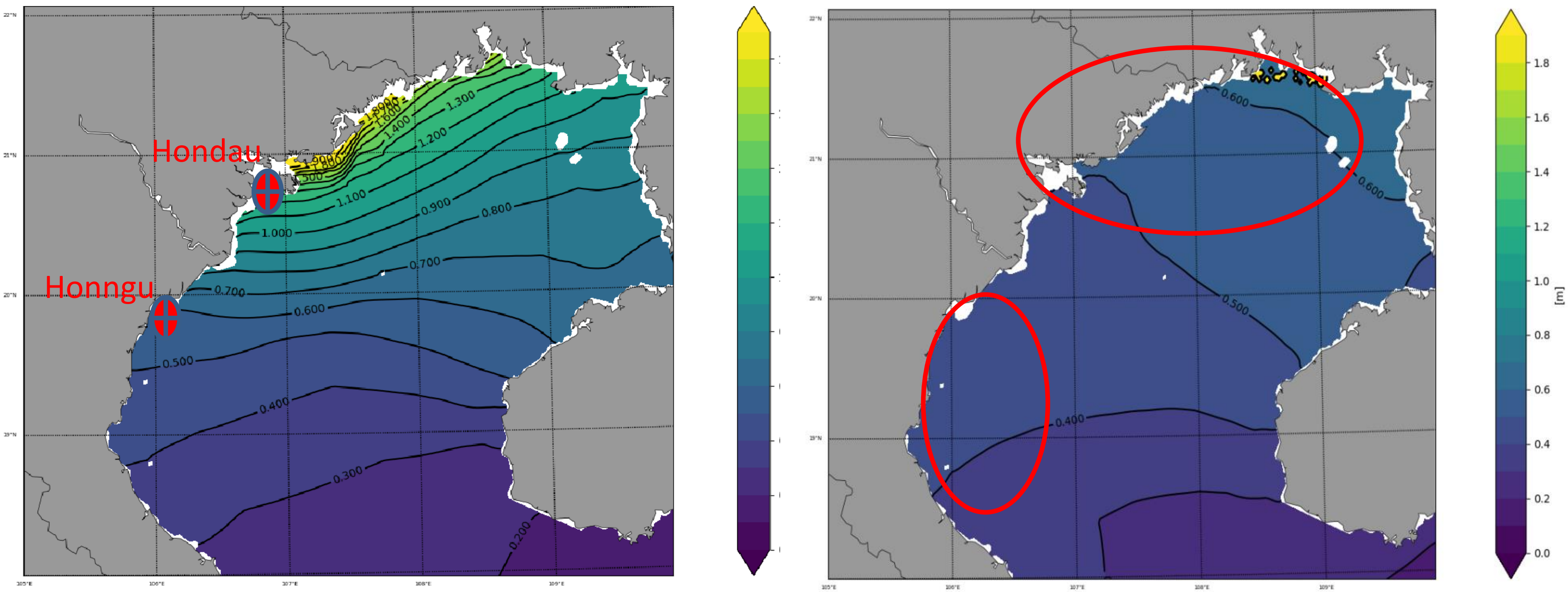




Storm surge at Hondau station is mostly induced by tail wind. But at Honngu station is due to the inertia force

Comparison of calculated and simulated storm surge at two station for two case using WRF model. One using front and tail wind field (above), the other using the front wind field only (below).

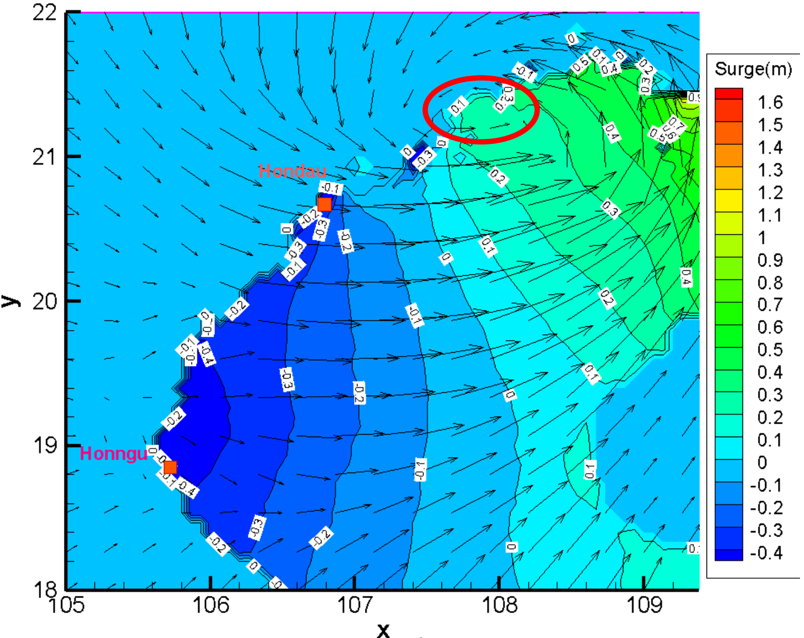
Effect of front and tail wind field on storm surge



Maximum storm surge for the case the model using front and tail wind field (left) and front wind field only (right)

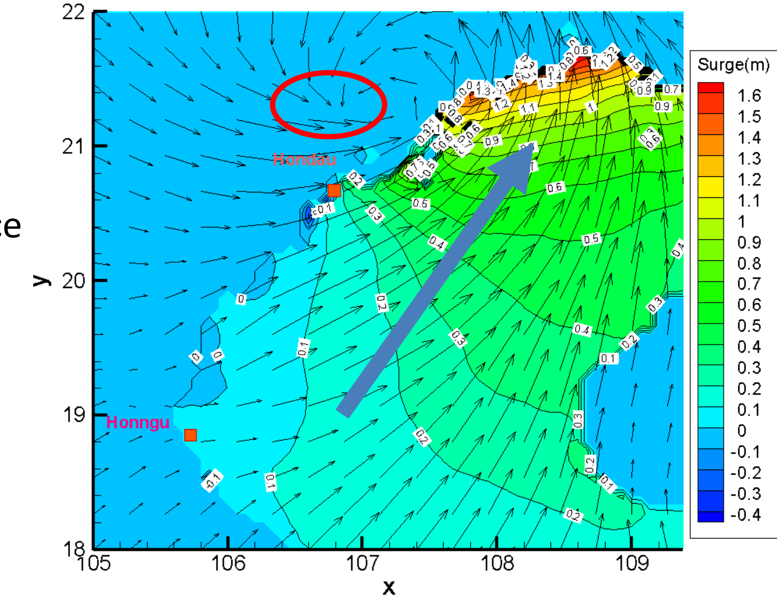
The result at the Honngu station is not so much different between two cases. It means storm surge at Honngu station is due to water moving from North to the south **?.**

How the surge generated at the Northern part (Hondau station)

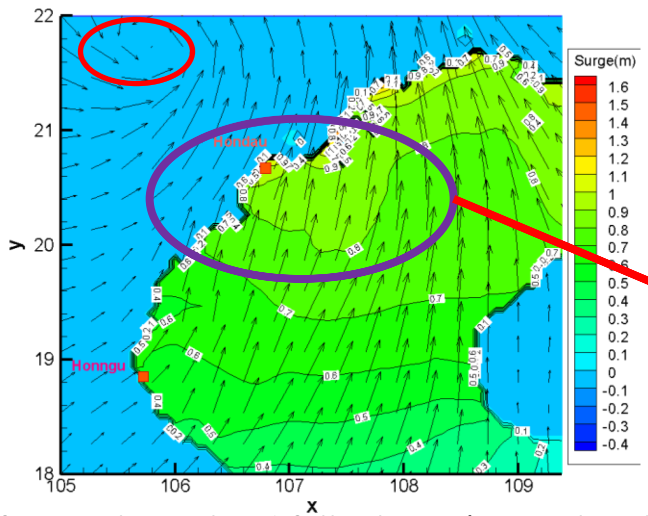


At the time typhoon land fall (water level at two station is down)

Wind and water surface elevation



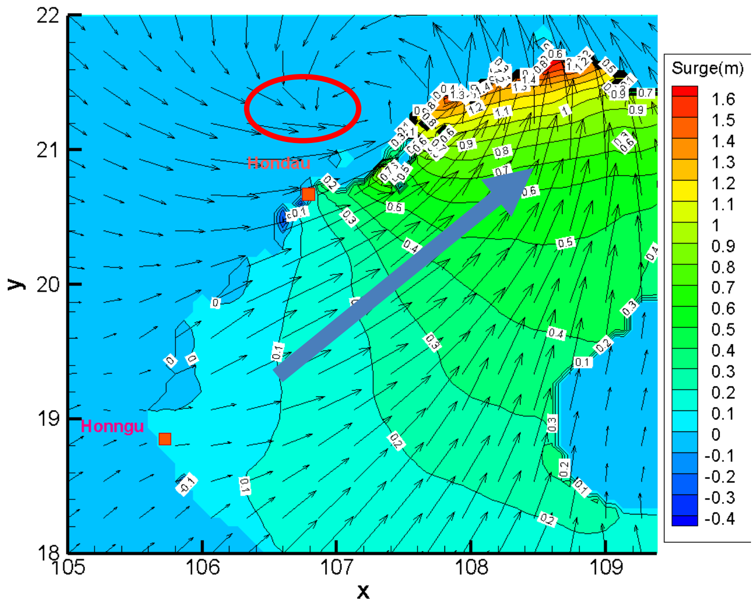
After typhoon land fall 4 hour (water level at Hondau station is going up)



After typhoon land fall 6 hour (water level at Hondau station get maximun)

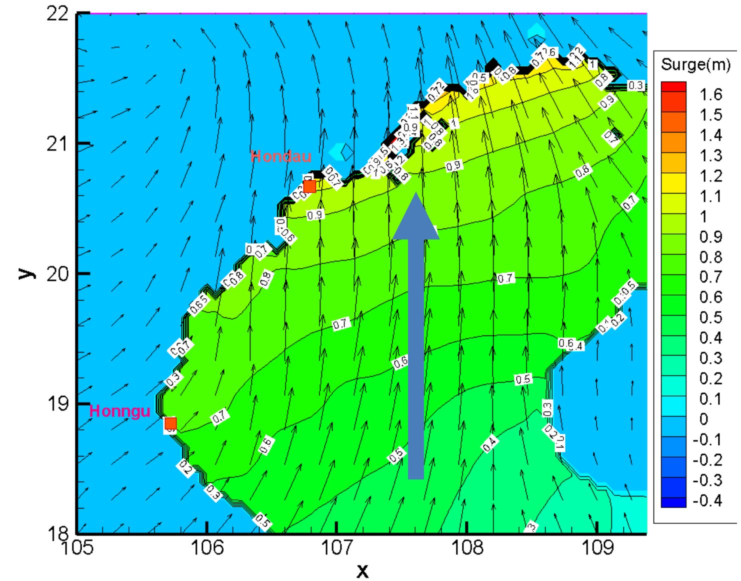
The tail wind fields of typhoons are more important than front wind fields.

How the surge generate at the Southern part (Honngu station)

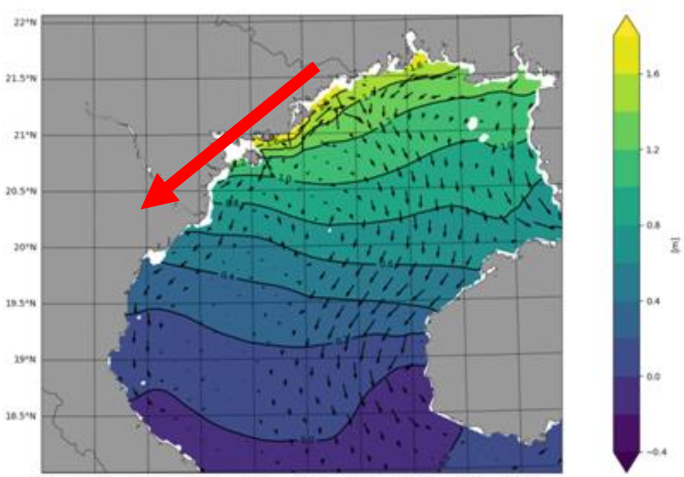


After typhoon land fall 4 hour (water level at Hondau station is going up)

Wind and water surface elevation



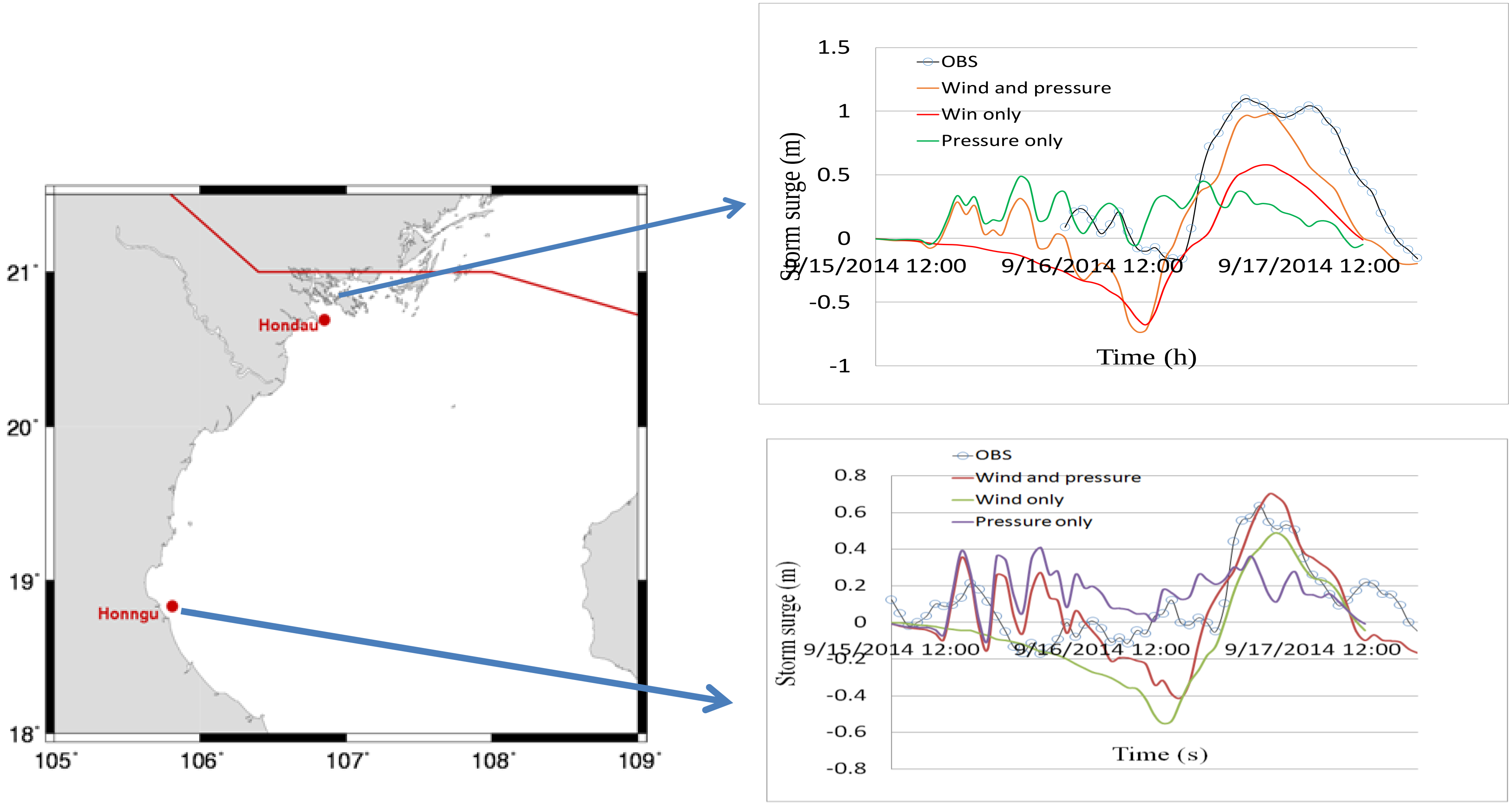
After typhoon land fall 8 hour



Water surface elevation and current

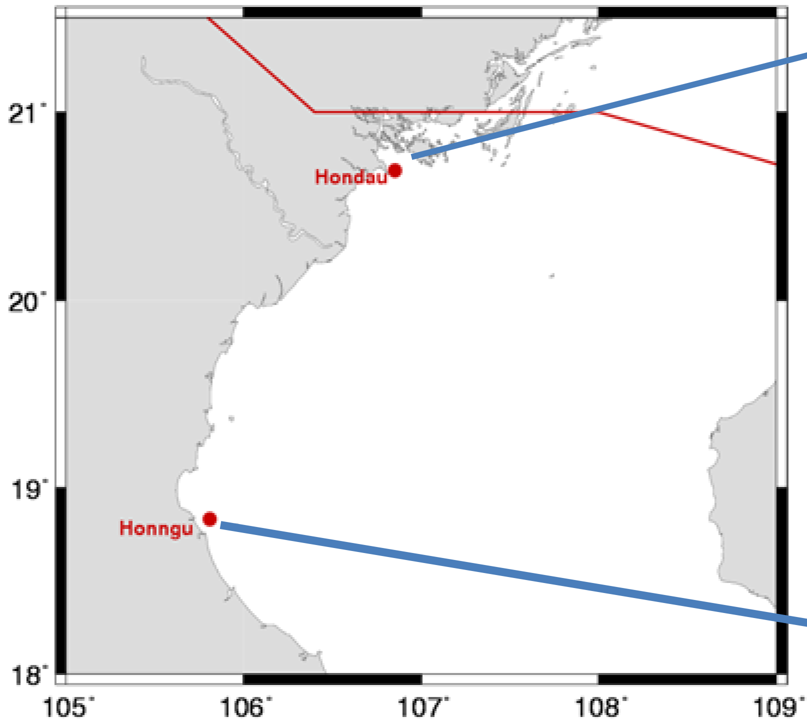
Storm surge on the southern part (Honngu station) due to the tail wind and water moving from the north.

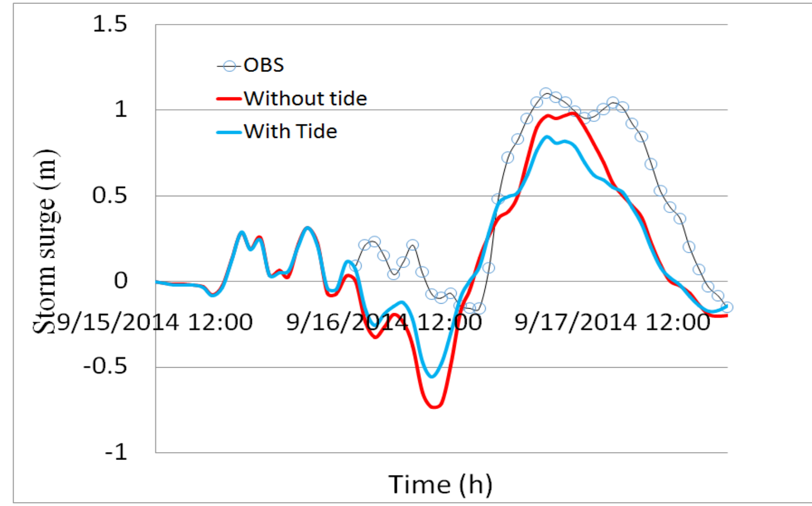
Effect of wind and pressure on storm surge

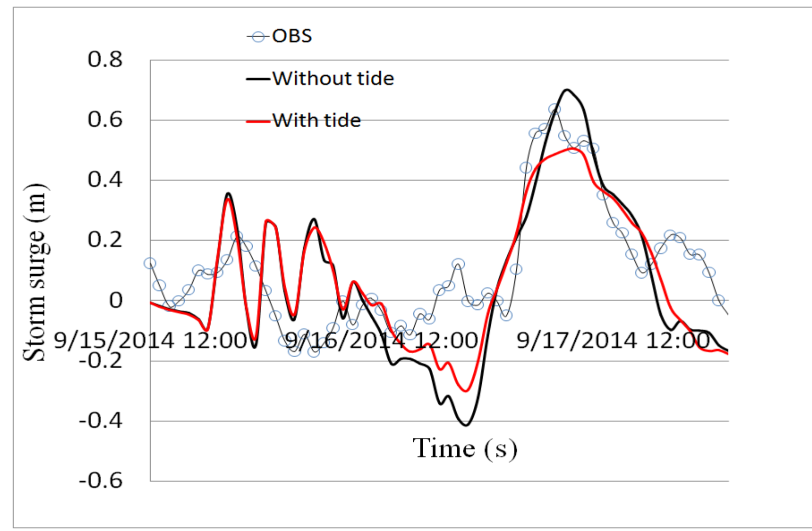


Comparison of calculated and simulated storm surge at two station for 3 cases of wind + pressure, wind only and pressure only (data from WRF model). **The contribution of wind is mainly.**

Effect of tide storm surge

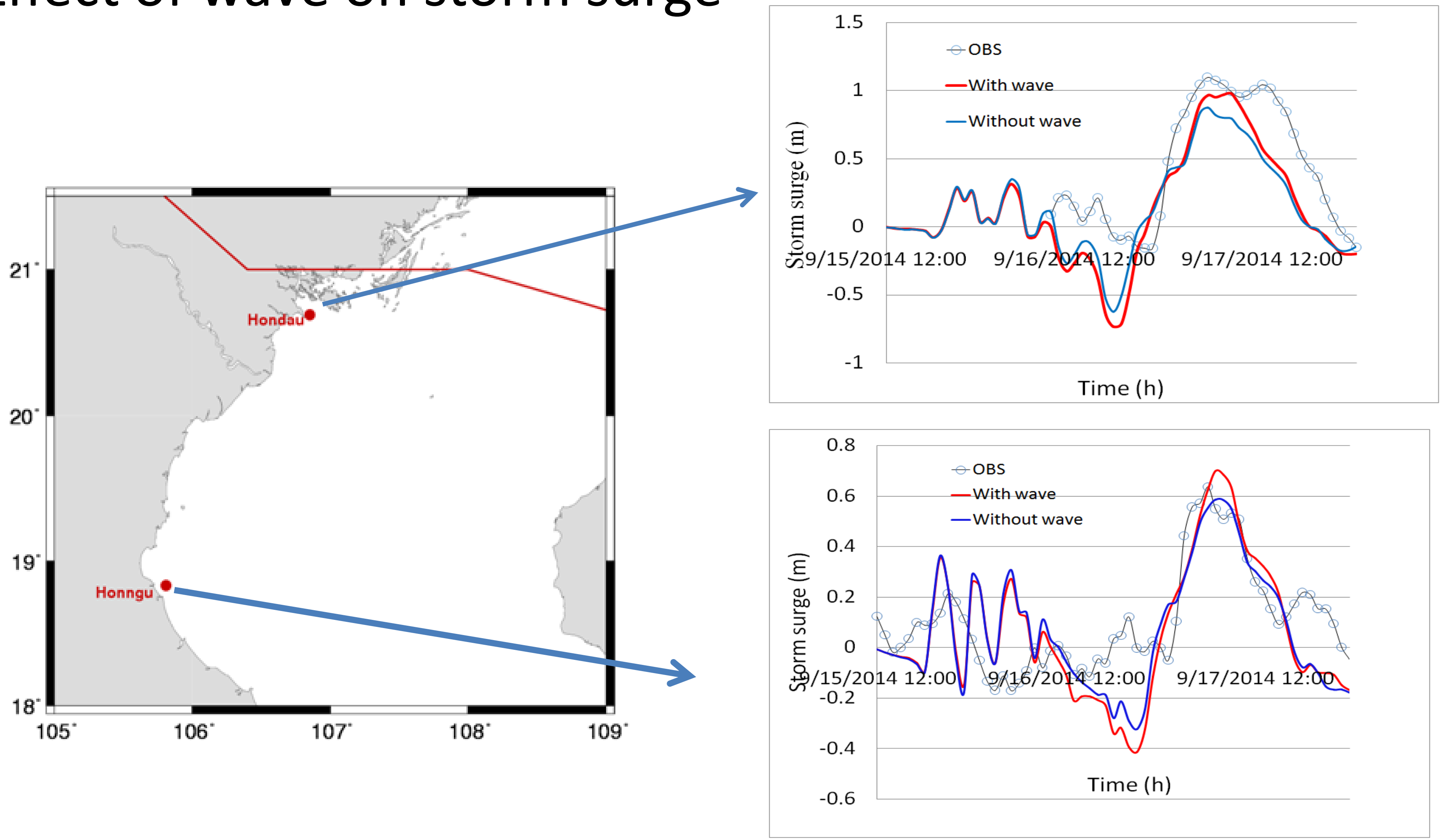






Comparison of simulated and observation storm surge. The simulated results for two case, with and without consider tide.

Effect of wave on storm surge



Comparison of simulated and observation storm surge. The simulated results for two case, with and without consider wave.

Conclusions:

-During the typhoon Kalmaegy, the surge reach up to one metter after the typhoon landfalled and the duration of up to half a day.

-The SuWAT model gave the results closed to the observation data in both the height and the duration when using wind and pressure from the WRF model. Meanwhile, the traditional method of using the empirical typhoon model gave undersimated.

- The strong tail wind is the main cause of the after-runner surge in this case.

Recent progress in storm surge forecasting

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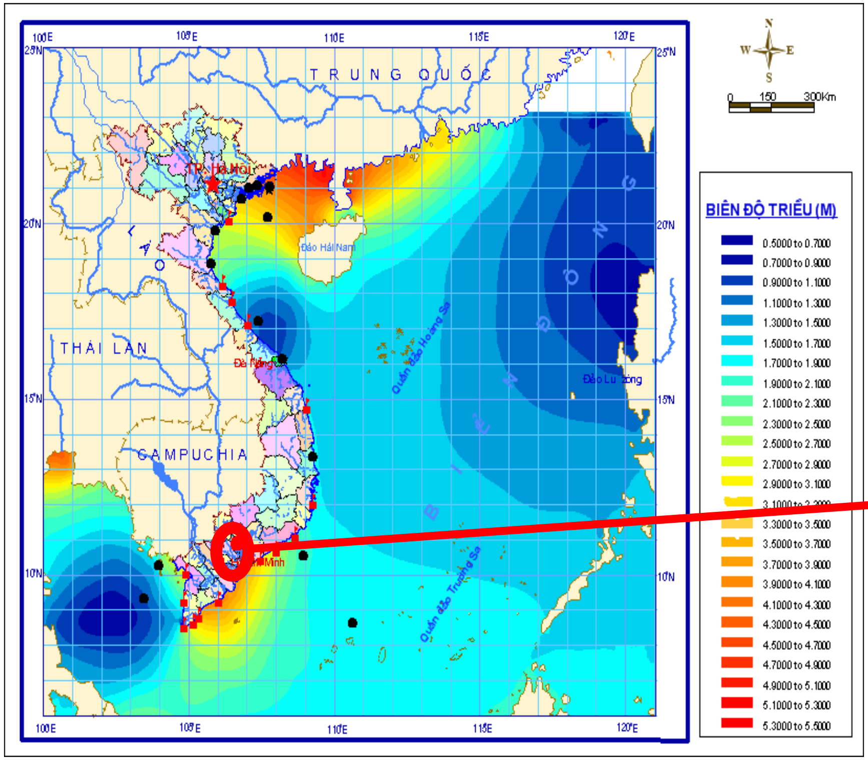
Abstract

This paper briefly summarizes recent progress in storm surge forecasts, one of topics discussed in the fourth International Workshop on Tropical Cyclone Landfall Process (IWTCLP 4) held during5-8 December, 2017. In the workshop, improvement of storm surge forecasting systemwas mainly discussed with relevance to the problem of estimating the impacts of tropical cyclone landfall. To deal with storm surges, accurate TC condition (predictions and forecasts) as input, reasonable storm surge predictions (with forecasting systems), and effective advisory / warning (useful information as product) are necessary. Therefore, we need to improve storm surge related matters systematically: input, prediction system, and effective information. This report tries to highlight recent progress in the field of storm surge on the three concerning points: improvement in storm surge forecasting models / system, TC conditions as input for storm surge predictions, and informative products for end users.

Spring tide in Hochiminh city

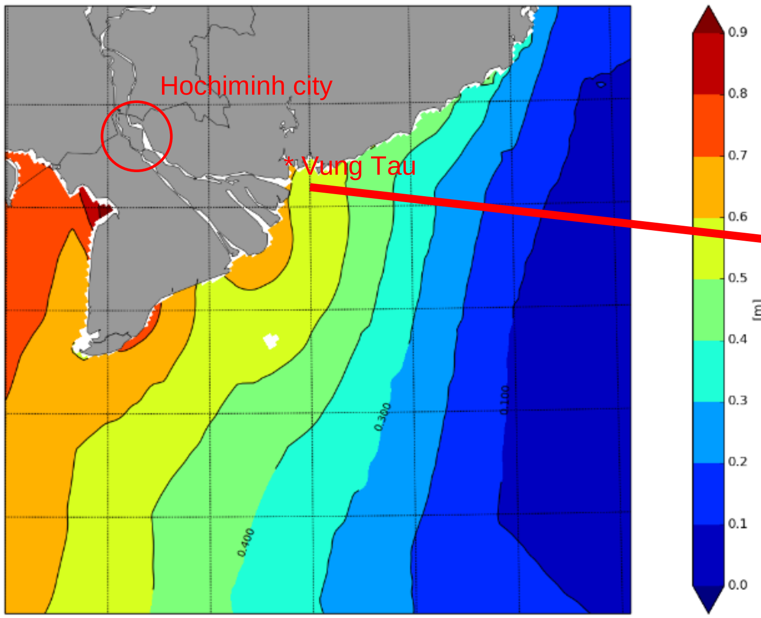
Spring tide in Hochiminh City is related to Surge induced by monsoon or not?



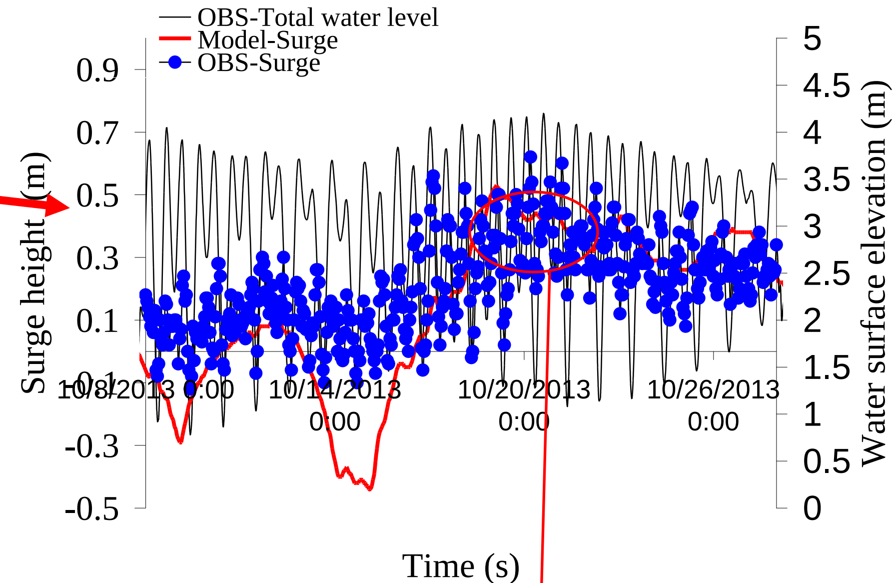
Maximum tide amplitude

Flooding in Ho Chi Minh City in 20/11/2011

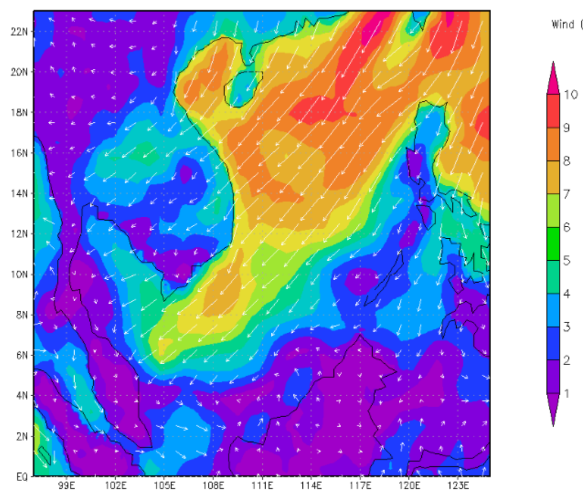
Spring tide in Hochiminh city on 20/10/2013



Maximum water surface elevation during the monsoon 10/2013



Time profile of total water surface elevation, predicted and measure surge height



Wind field at 20/10/2013

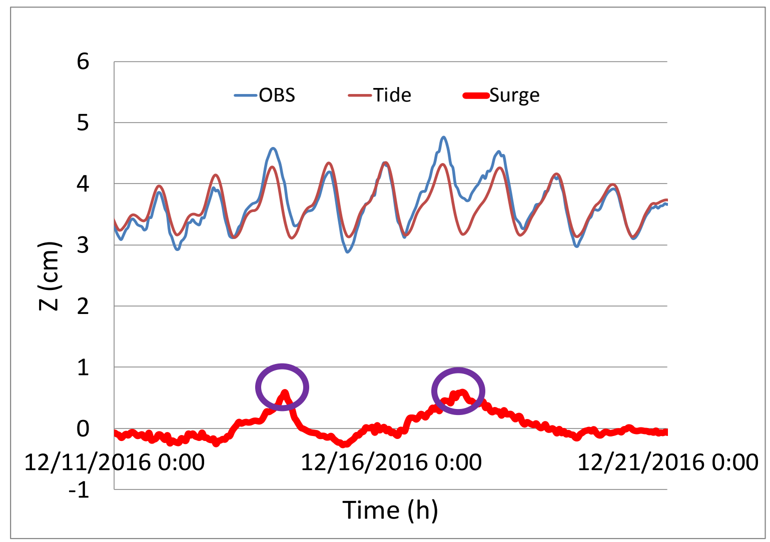
It related to flooding in Hochiminh City on 20/10/2013

Spring tide = high tide+ surge (by moonson)

High Oscillation of water level on the middle coast of Vietnam

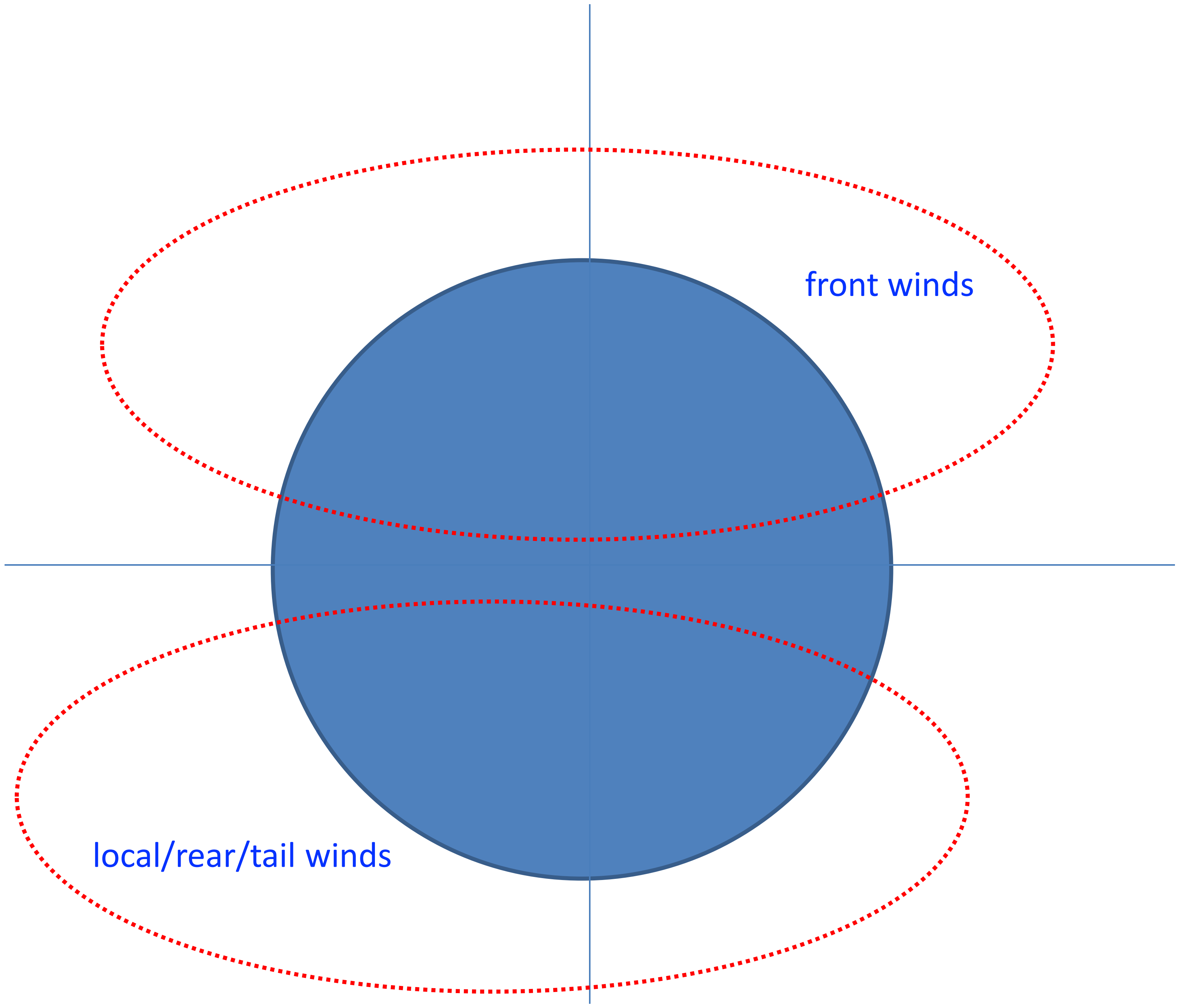
High tide at Tuyhoa in Dec. 2016

(No typhoon and calm wind. But the inundunation height up to 1m, and go in land up to 200m). Meteorological tsunami?.



Time serial of total water level, tide and surge

To simulate this phenomenal need high resolution of ocean and atmosphere model.
Next study


front winds
local/rear/tail winds