Storm Surge Prediction in Vietnam

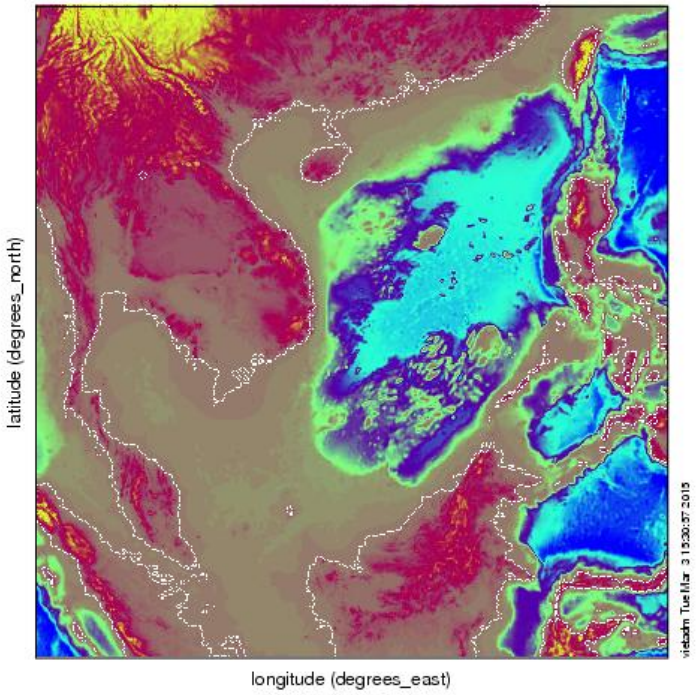
By: Nguyen Ba Thuy[1], Lars R. Hole[2], Nils Melsom Kristensen[2], Johannes Röhrs[2] and Pham Khanh Ngoc[1]

[1]VietnamNational Center for Hydro-meteorological Forecasting (NCHMF)
[2]Norwegian Meteorological Institute (MetNo)

Contents

Geographic and climate effect

- **Large and Complicate Tide**
- **Typhoon (June-November)**
- **North- East Monsoon (November-March)**
- **South - East Monsoon (June-October)**

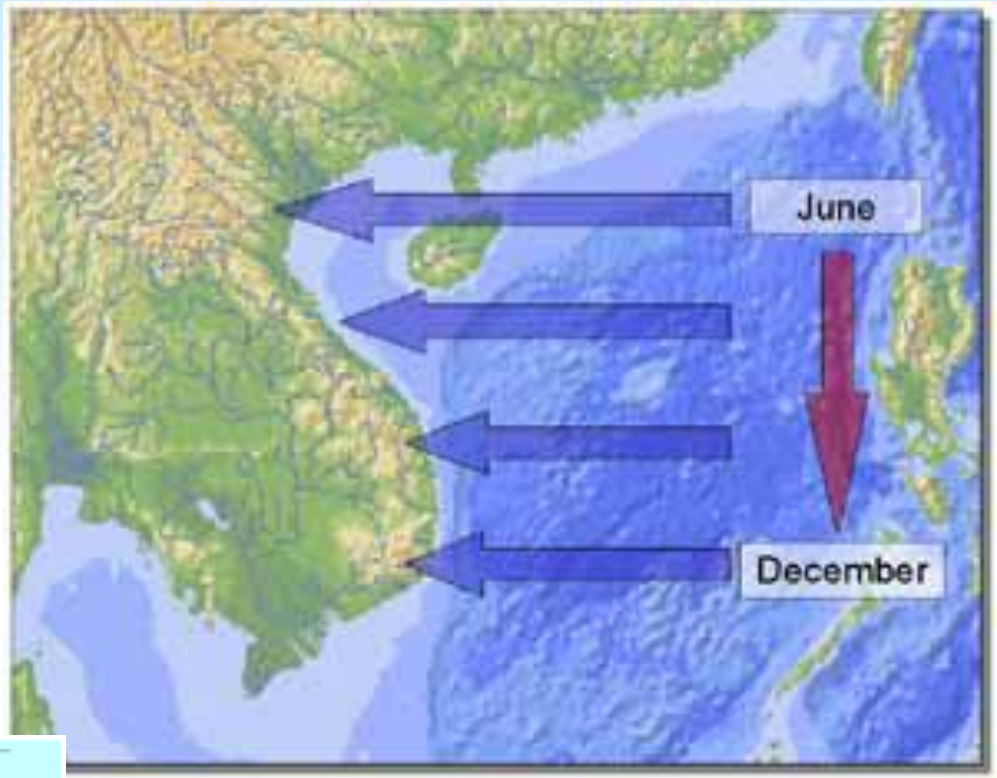


Range of GDAL Band Number 1: -5515 to 3872 (null)
Range of longitude: 97.0333 to 124.8 degrees_east
Range of latitude: -2.46667 to 26.1167 degrees_north
Frame 178 in File etopo1_bedrock_vietnam.nc

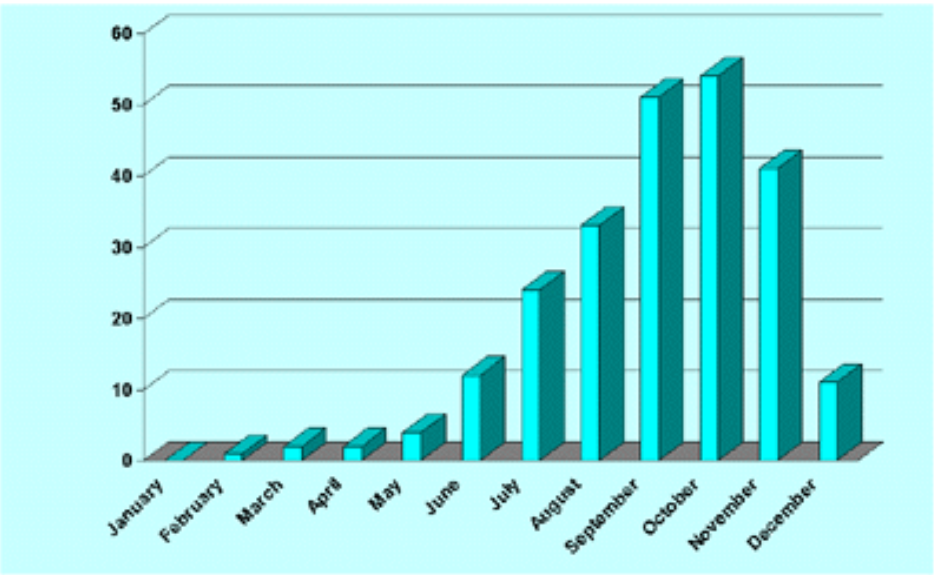
Typhoon and storm surge in Vietnam

Typhoon in Vietnam

- There are about 10-12 typhoons and 5-6 affect to land.

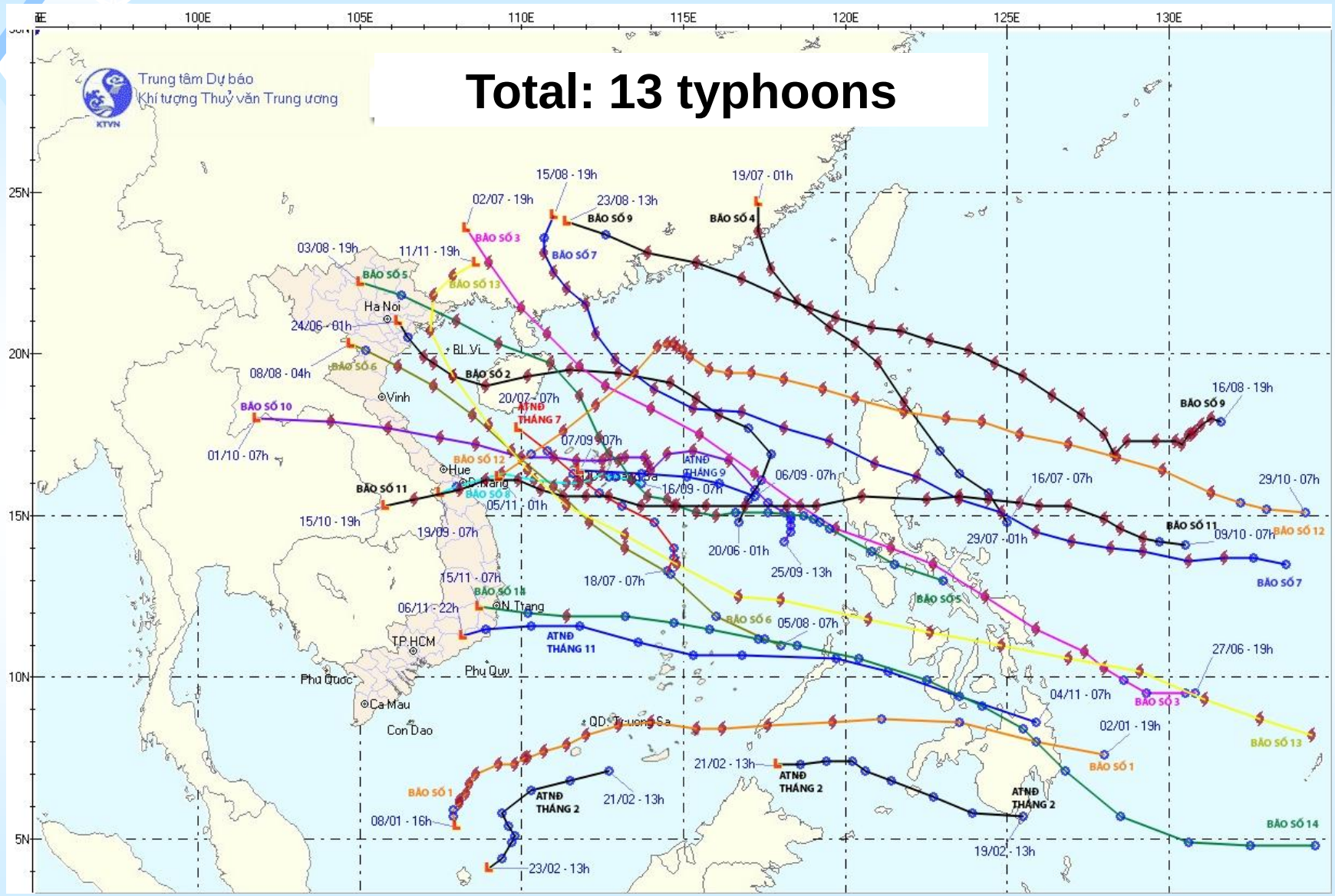


Storm distribution in South China Sea

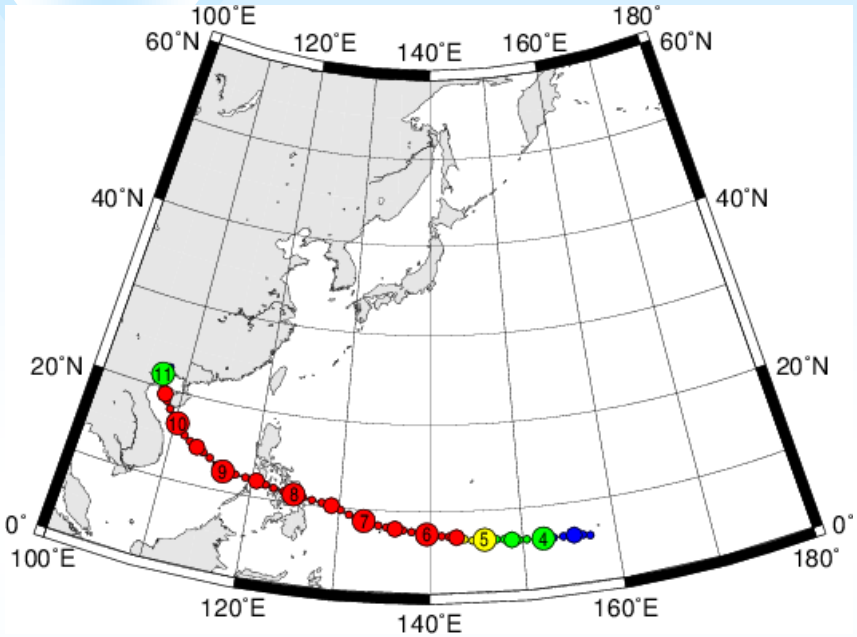


Storm numbers monthly attacking Vietnam coast in 53 years

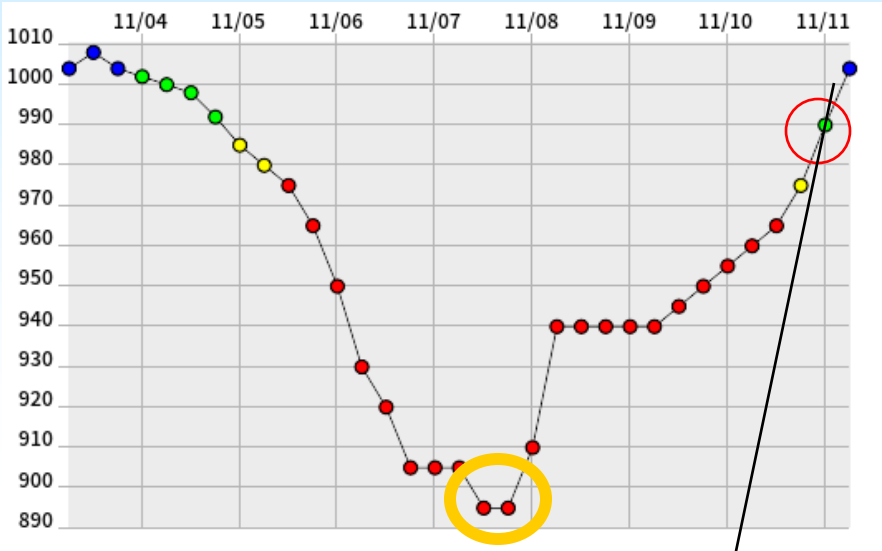
Track of typhoon in 2013



Strong Haiyan typhoon



Track



Pressure variation

Land fall the coast at Vietnam at low tide

- No inundation

Damage due to typhoon

Both Typhoon N° 10 and11 (2013): 25 people die, loss 1800 billions VND (90 million USD)

Damage due to typhoon

Television tower was collapsed by high wind force

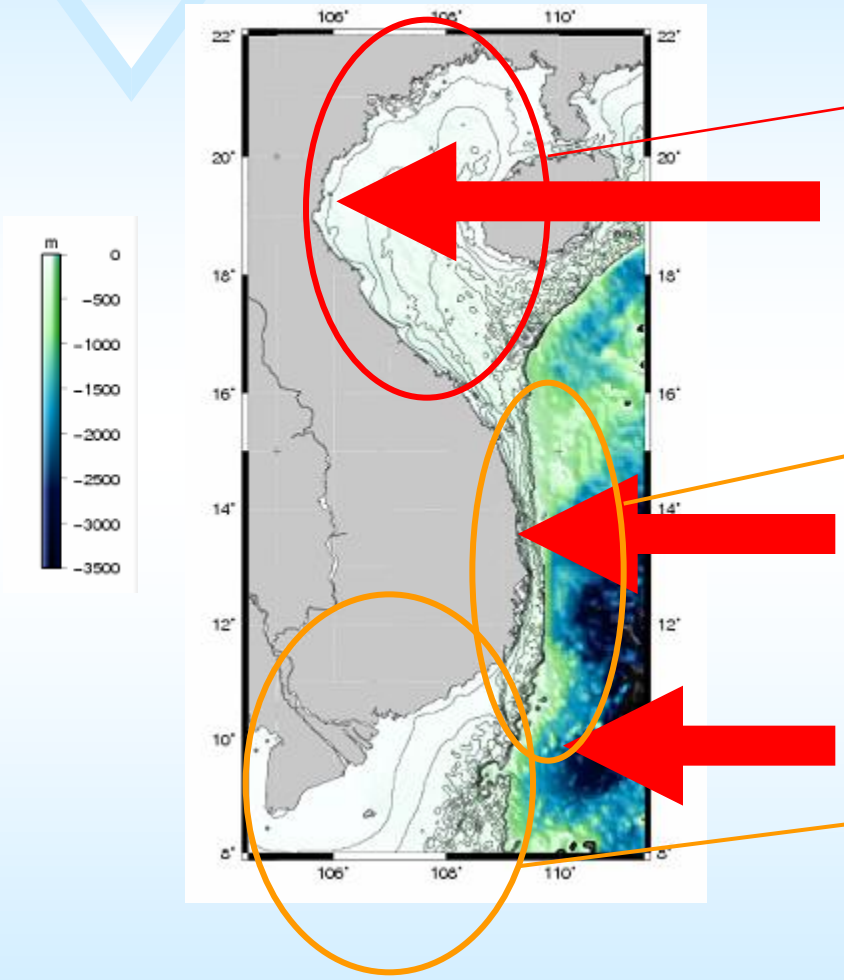
7 death and 43 injury during Sonting (2012) typhoon affect, with maximum wind speed up to 47m/s, central pressure of 945 hPa. Loss 75000 billion VND (375 million USD)

Honla breakwater was broken by high wave (up to 5m)

Damage due to typhoon

Inundation due to high tide and heavy rain at Doson in Typhoon Nº4

Typhoon and storm surge in Vietnam



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

Storm surge in Vietnam coastal

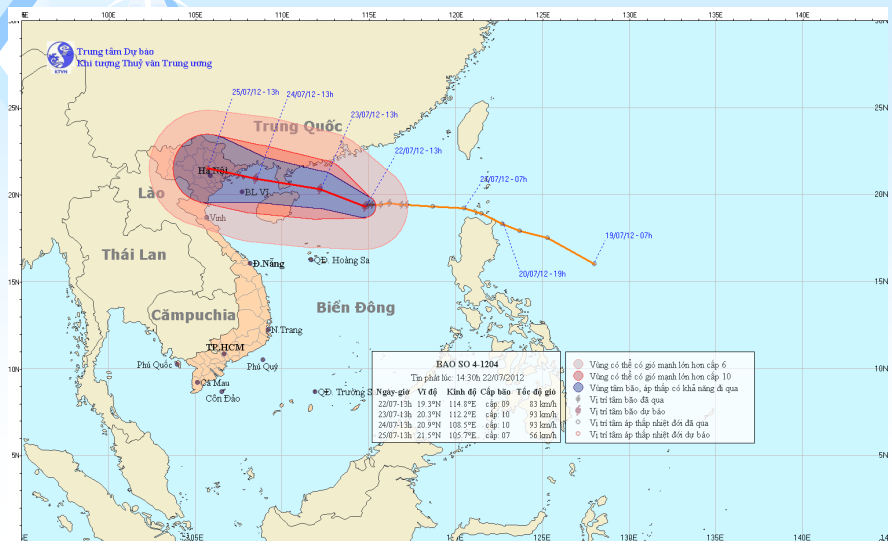
Table 1. Storms and surges along Vietnam coast

Latitude (N)	Number of storms	P%	Annual average number	Observed maximum surge (m)	Expected maximum surge (m)
21-22 North Cửa Ông	29	12.04	0.74	2.2	2.6
20-21 Cửa Ông - Cửa Đáy	39	16.19	1.00	2.2	3.0
19-20 Cửa Đáy - Cửa Vạn	34	14.11	0.87	3.0	4.0
18-19 Cửa Vạn - Đèo Ngang	29	12.04	0.74	3.4	4.0
17-18 Đèo Ngang - Cửa Tùng	16	6.64	0.41	2.2	
16-17 Cửa Tùng - Đà Nẵng	9	3.73	0.23	2.6	
15-16 Đà Nẵng - Quảng Ngãi	23	9.54	0.59	1.4	1.6
14-15 Quảng Ngãi - Bình Định	23	9.54	0.59	1.0	1.2
13-14 Bình Định - Phú Yên	11	4.56	0.28	0.8	1.0
12-13 Phú Yên - Khánh Hoà	9	3.73	0.23	0.8	1.0
11-12 Ninh Thuận -Bình Thuận	10	4.15	0.26	1.0	1.2
10-11 Bình Thuận - Bến Tre	4	1.66	0.10	1.8	2.0
9-10 Bến Tre - Bạc Liêu	3	1.24	0.08	2.0	2.4
8-9 Bạc Liêu - Cà Mau	2	0.83	0.06	2.0	2.4
Total	241	100	6.18		

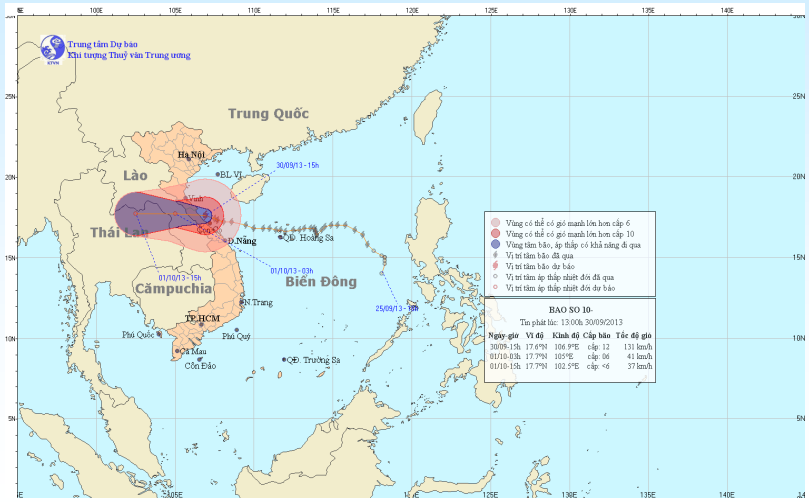
Storms and surges along Vietnam coast

Figure 5-4. Magnitude of maximum storm surge along the coast

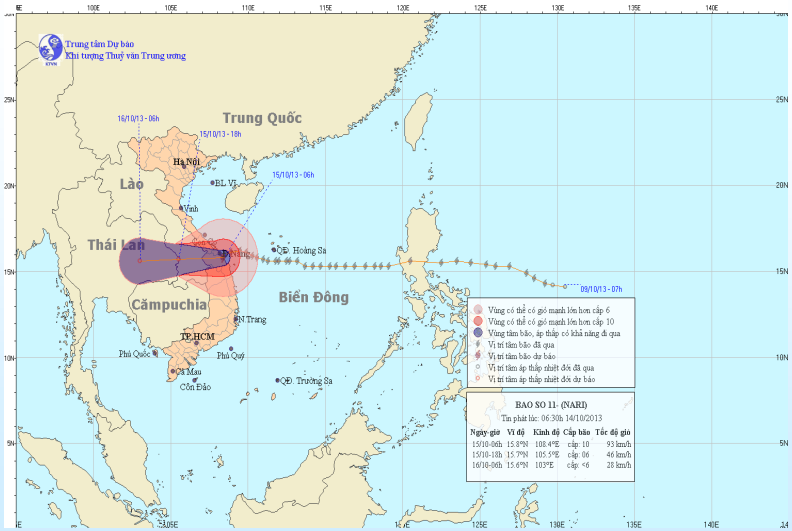
storm surge in 2013



Typhoon No 2 (land fall at high tide, surge height: 0.7m-inundation



Typhoon No 10-Wutip (strong-Surge height: 1.3m at low tide)



Typhoon No 11-Nari (strong-Surge height: 1.5m at low tide)

In 2013: 13 typhoons.

Three generated hight surge on coast

Storm surge prediction in Vietnam

SuWAT (Surge Wave and Tide) Model-Operational Model

Two dimensional long wave equations + Swan model

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

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

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

Effect of tide and wave are considered

Open bounday condition: NAO.99b, NAO.99Jb models- http://www.miz.nao.ac.jp/staffs/nao99/README_NAOTIDE_En.html).

Storm surge prediction in Vietnam

- Wind and Pressure Model:

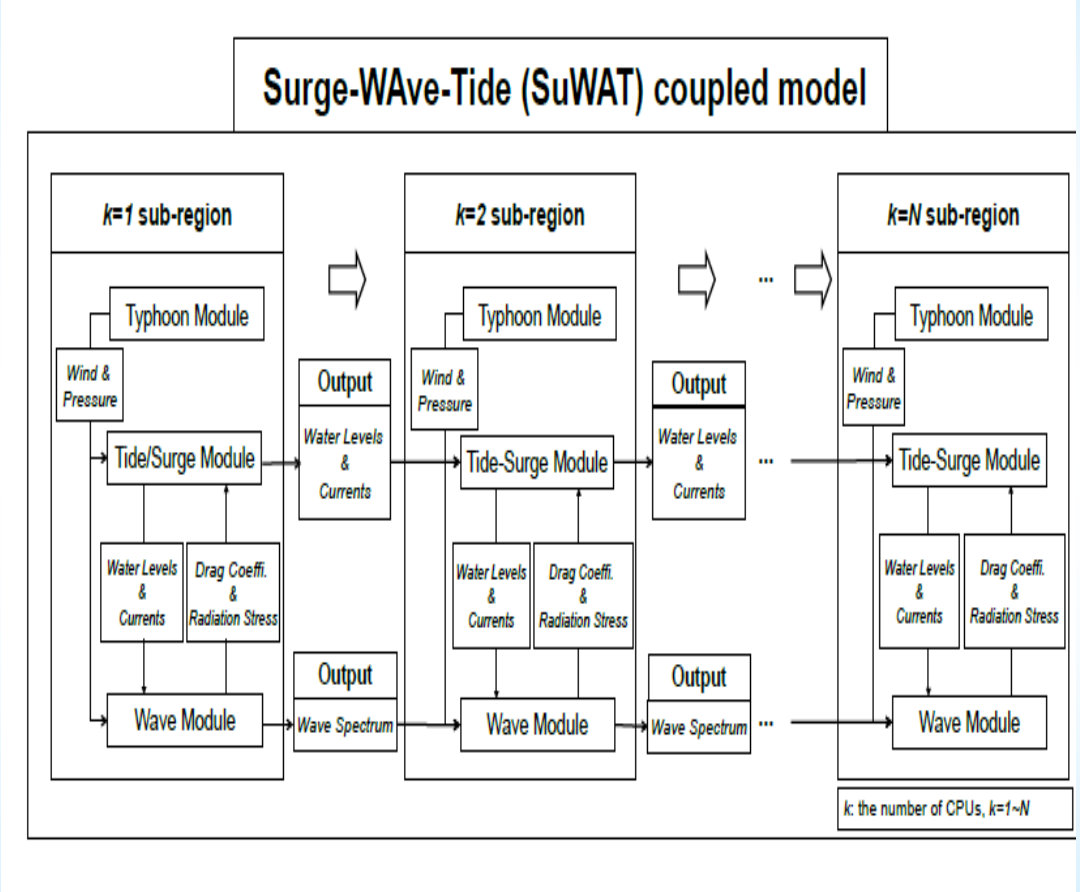
+ Typhoon Model: Empirical model

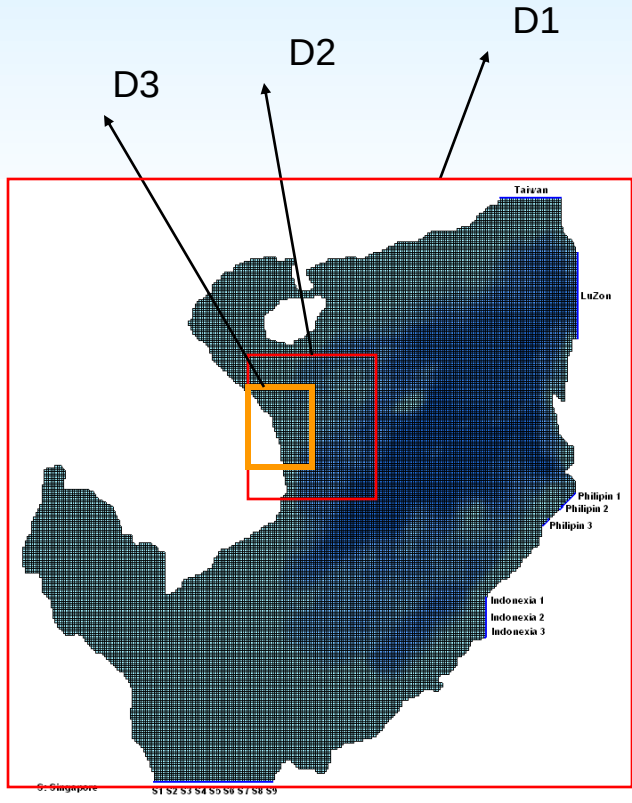
$$P(r) = P_\infty - \frac{P_\infty - P_c}{\sqrt{1 + (r/r_0)^2}}$$ (Fujita)

$$V = \begin{pmatrix} v_x \\ v_y \end{pmatrix} = c_1 \begin{pmatrix} -V_g(\sin\alpha \cdot \cos\theta + \cos\alpha \cdot \sin\theta) \\ V_g(\cos\alpha \cdot \cos\theta - \sin\alpha \cdot \sin\theta) \end{pmatrix} + c_2 \begin{pmatrix} v_{tx} \\ v_{ty} \end{pmatrix} e^{-\frac{\pi r}{500}}$$

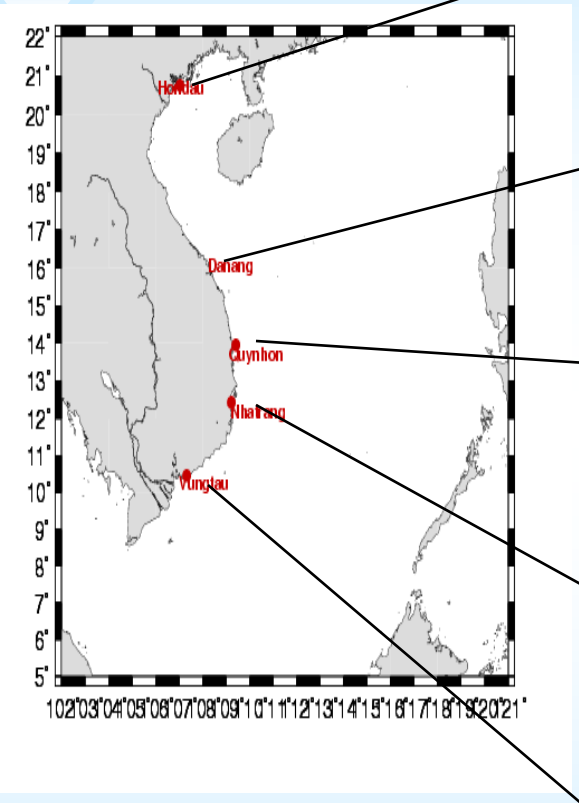
+ NWP: WRF

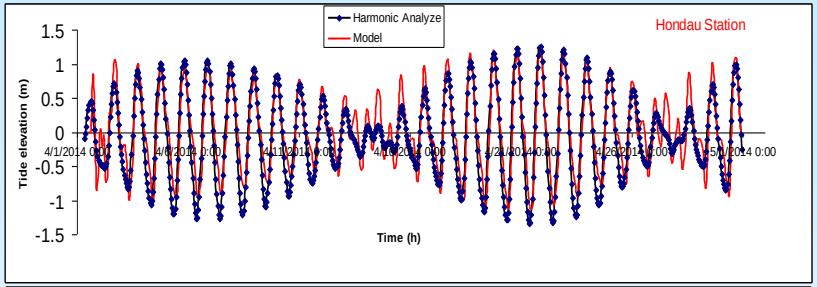
Structure of SuWAT Model in Vietnam

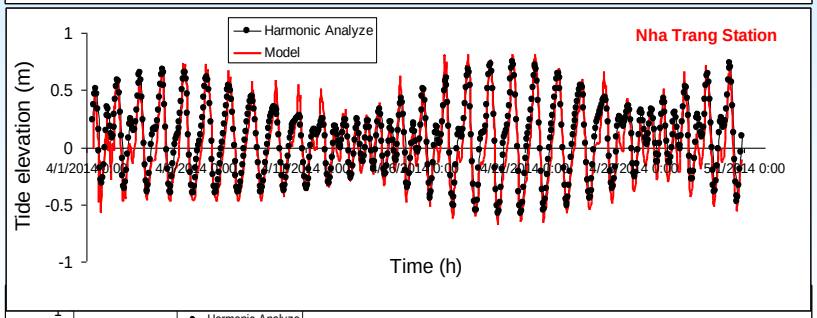


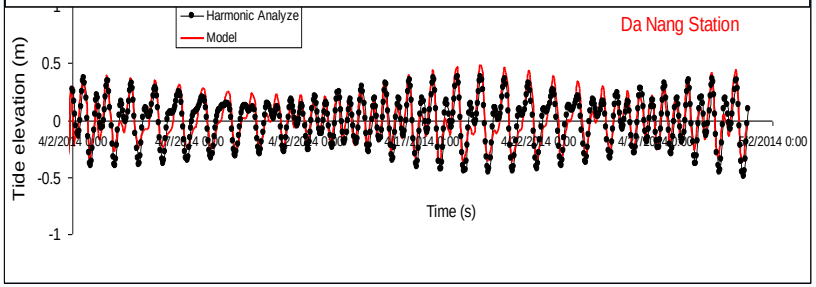


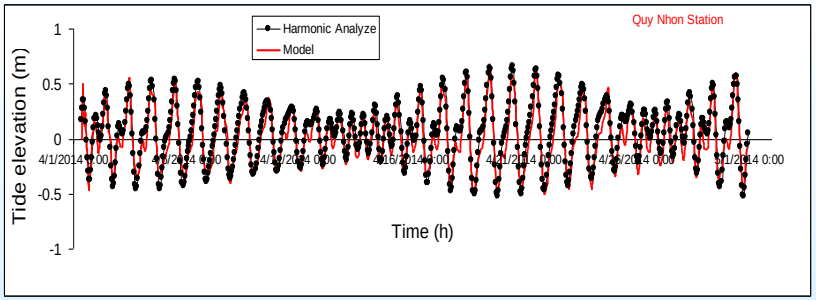
Verifying the SuWAT Model on Tide on April 2014

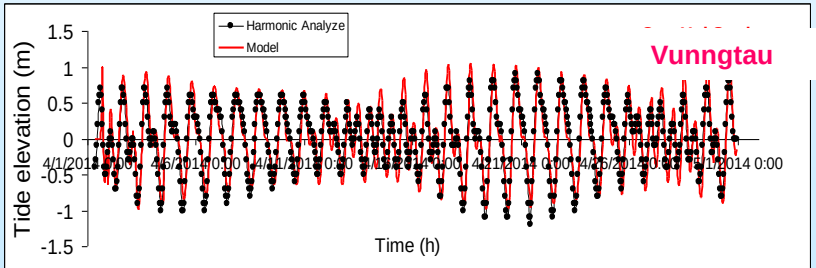




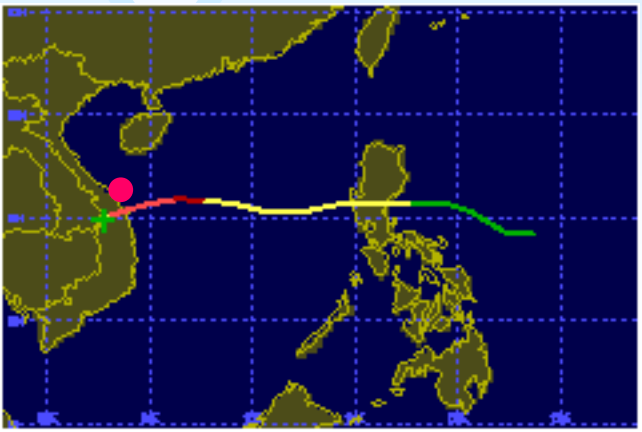




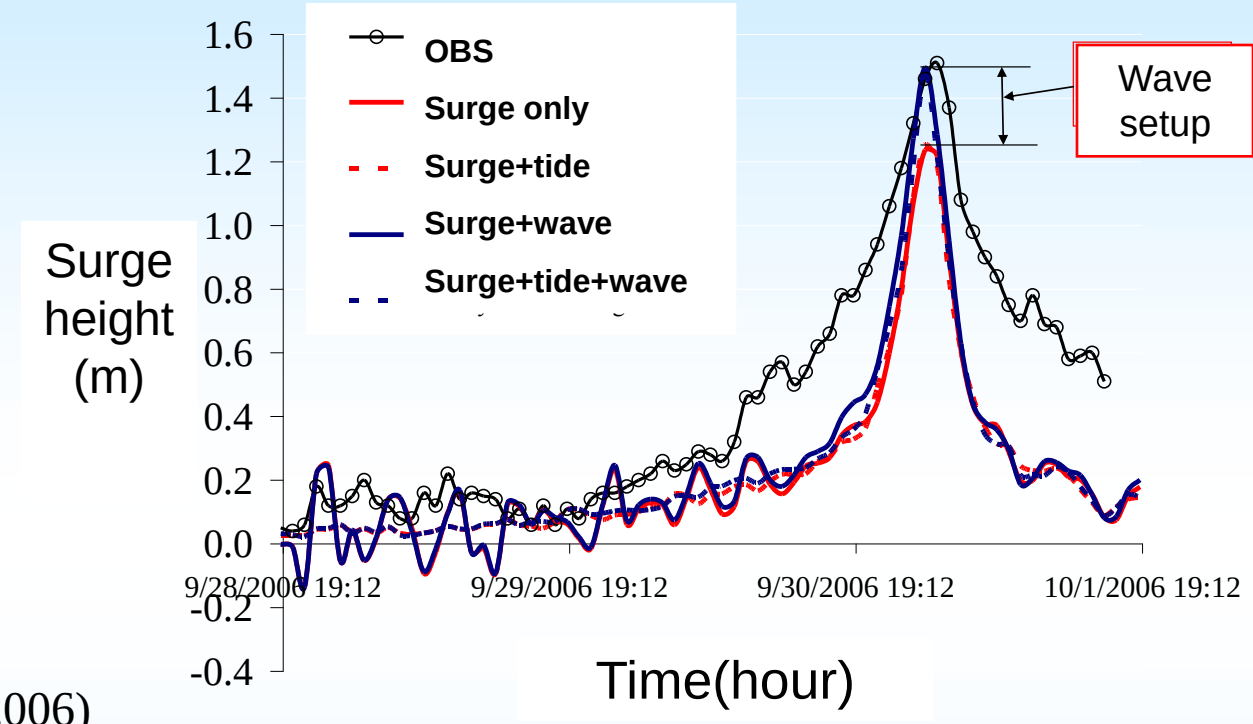




Effect of wave on Storm surge



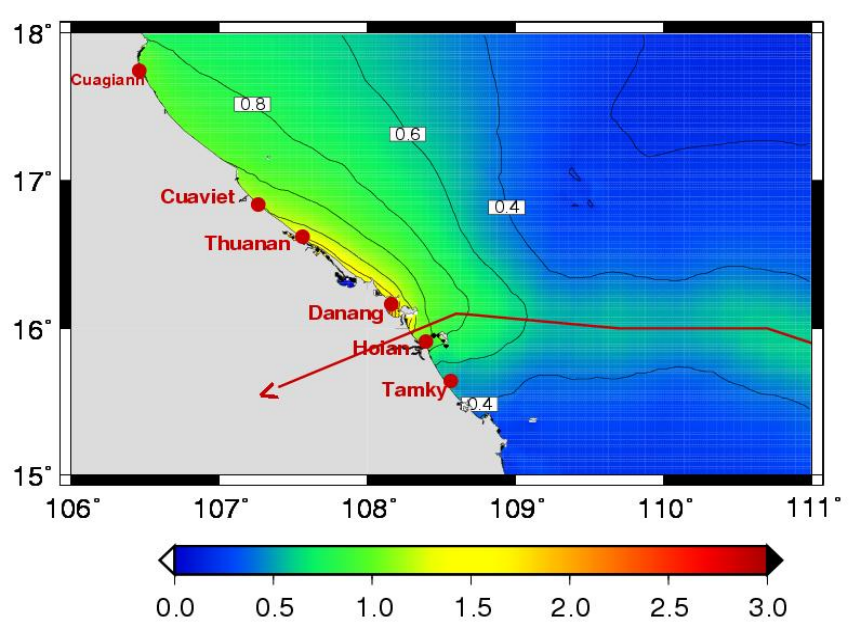
Track of Xangsena typhoon (9/2006) land fall at Danang (middle of Vietnam)



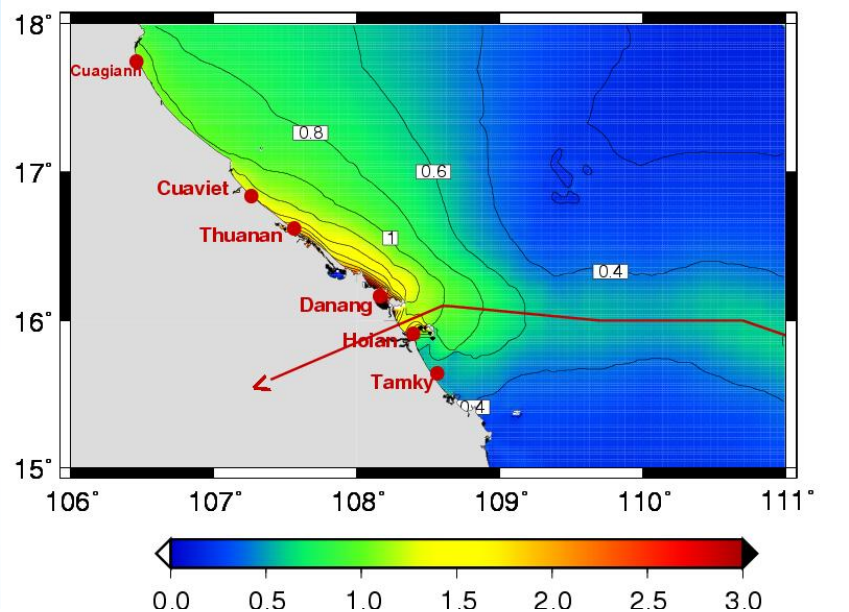
Variation of storm surge at Danang Station

Effect of tide is insignificant, but wave significant

Effect of tide and storm surge on wave height



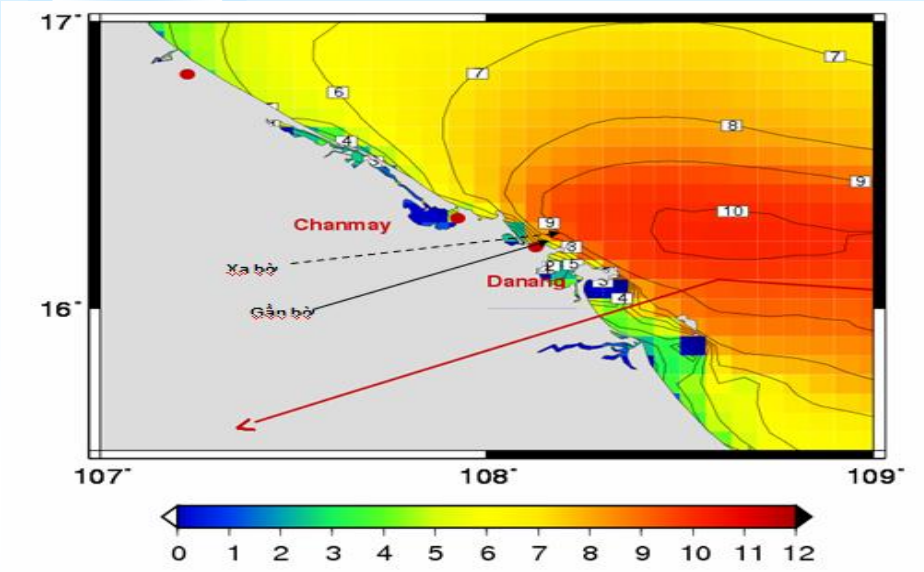
(a) Without consider wave



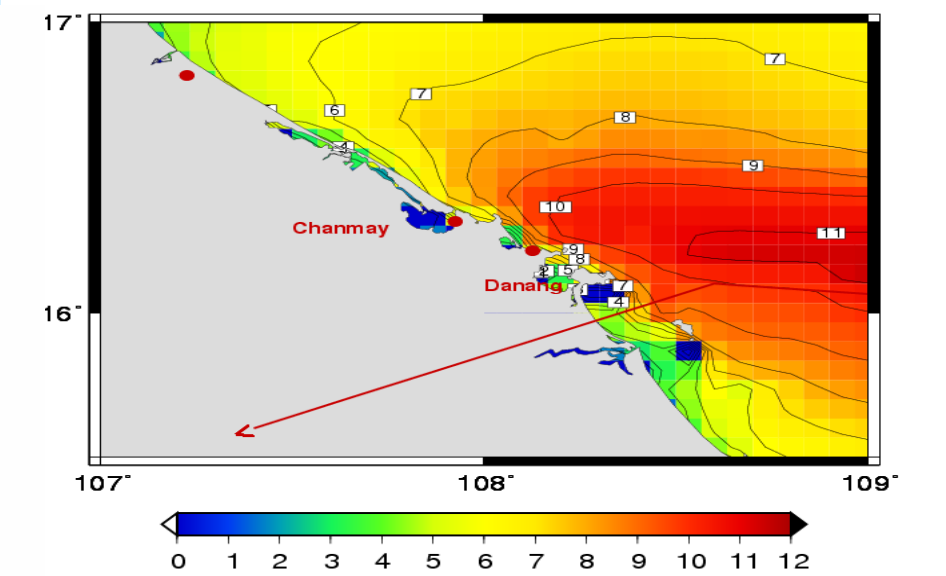
(b) With wave

Maximum storm surge

Effect of tide and storm surge on wave height



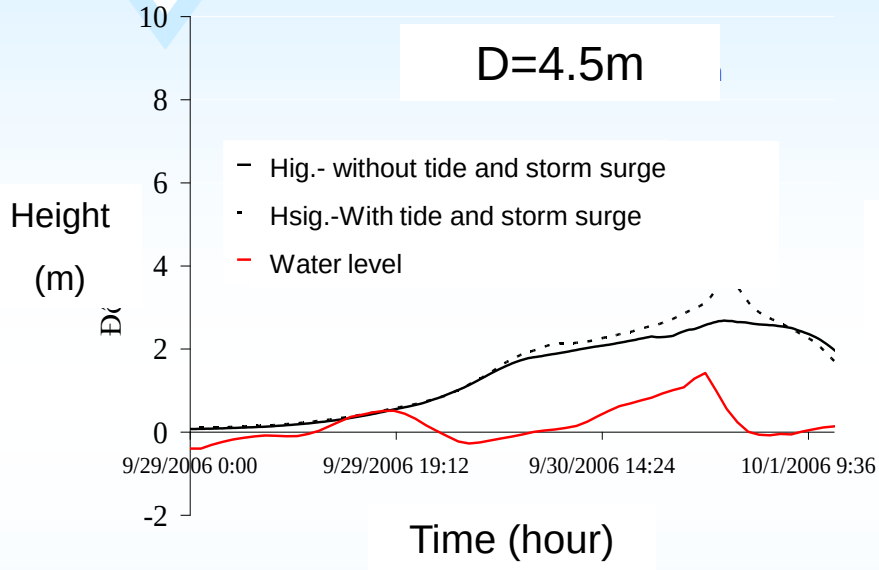
(a) Without consider wave

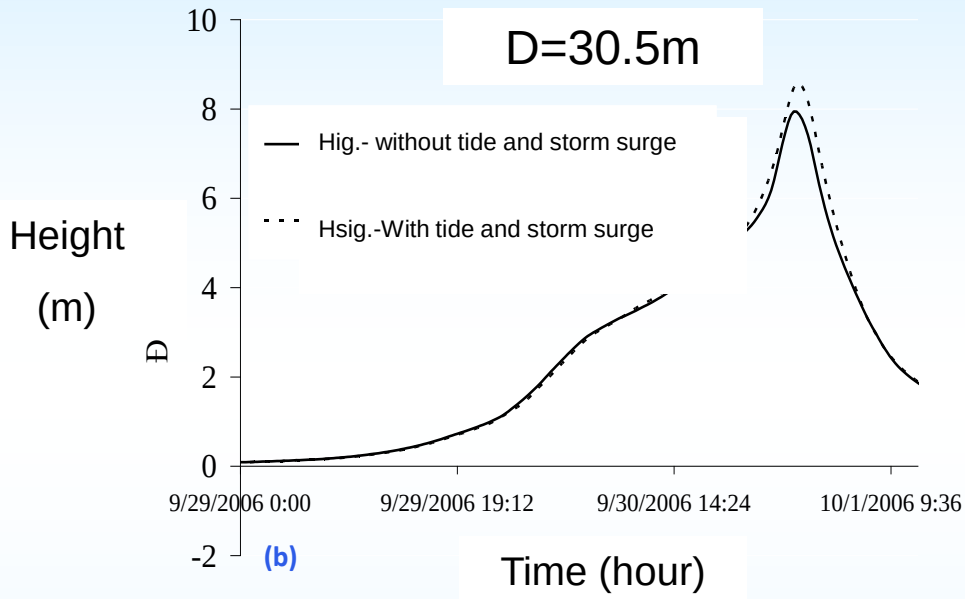


(b) With wave

Maximum significant wave height

Effect of tide and storm surge on wave height





Time variation of Hsig. at shallow and deep water point

ROMS Model - Under research

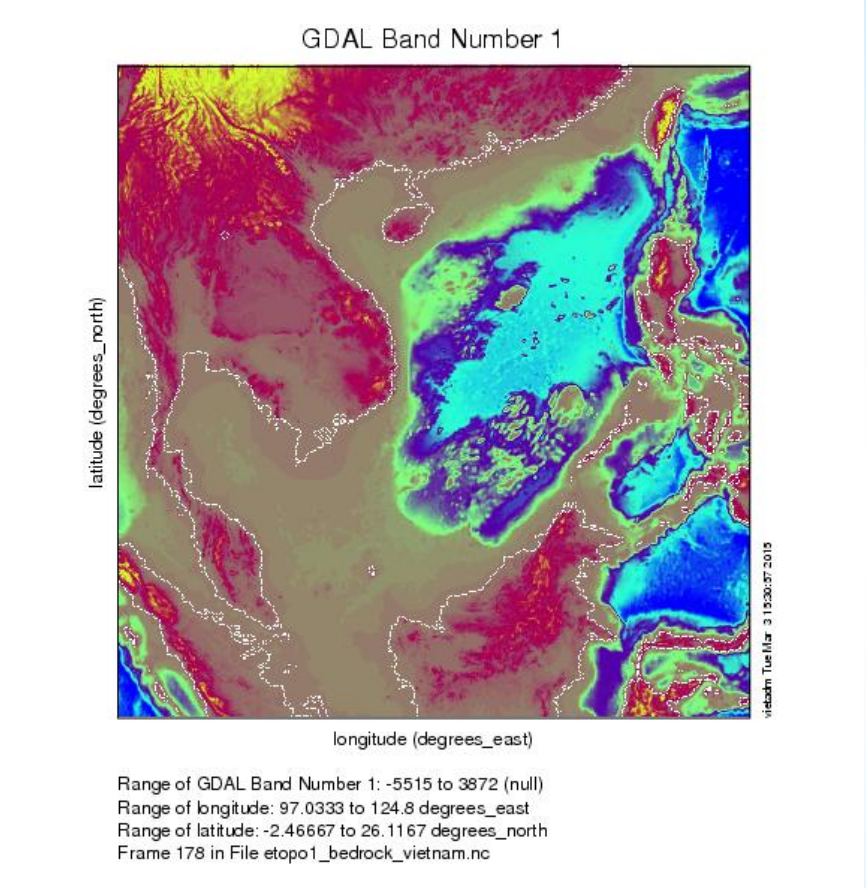
- Model setup by: Norwegian Meteorological Institute under the project “Strengthen the early warning system” at National Centre for Hydrometeorological Forecasting of Vietnam (NCHMF)

<u>-Meteorological Model:</u>

+ WRF

+ Resolution: 15km.

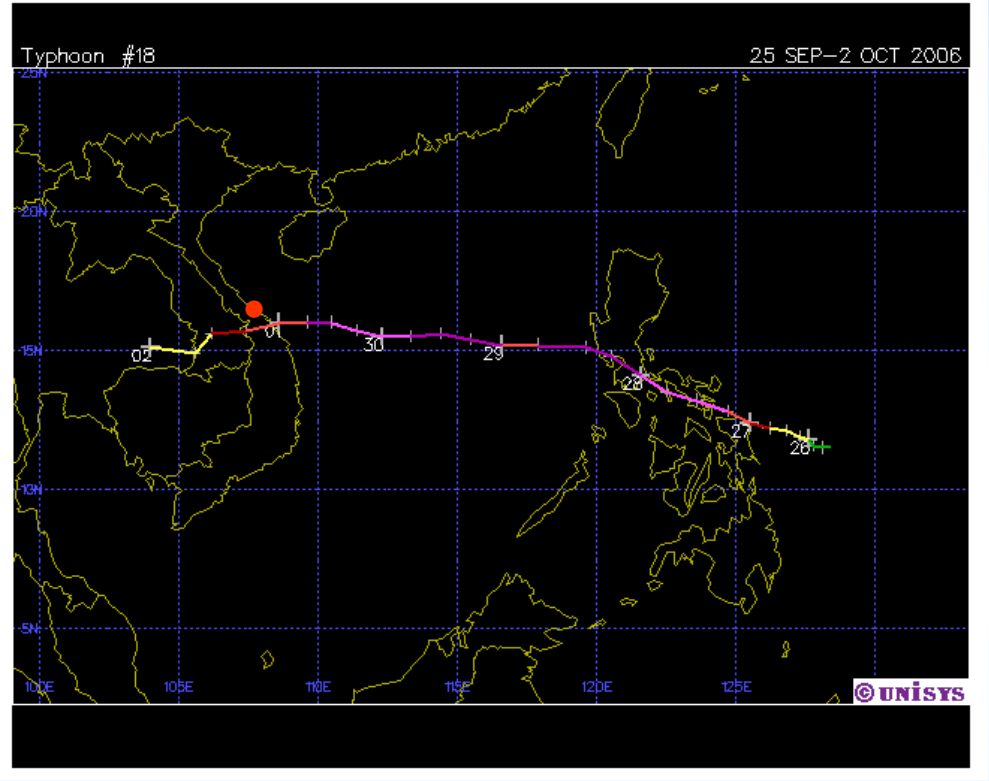
+ Boundary: GSM-JMA GFS-NCEP



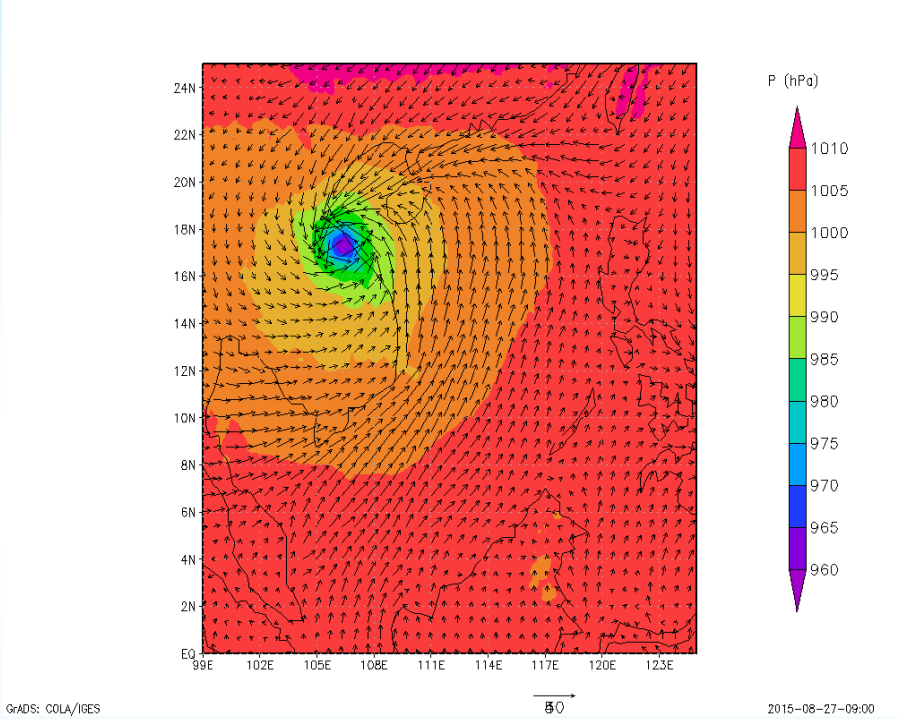
Computational domain and bathymetry

Some Preliminary Results

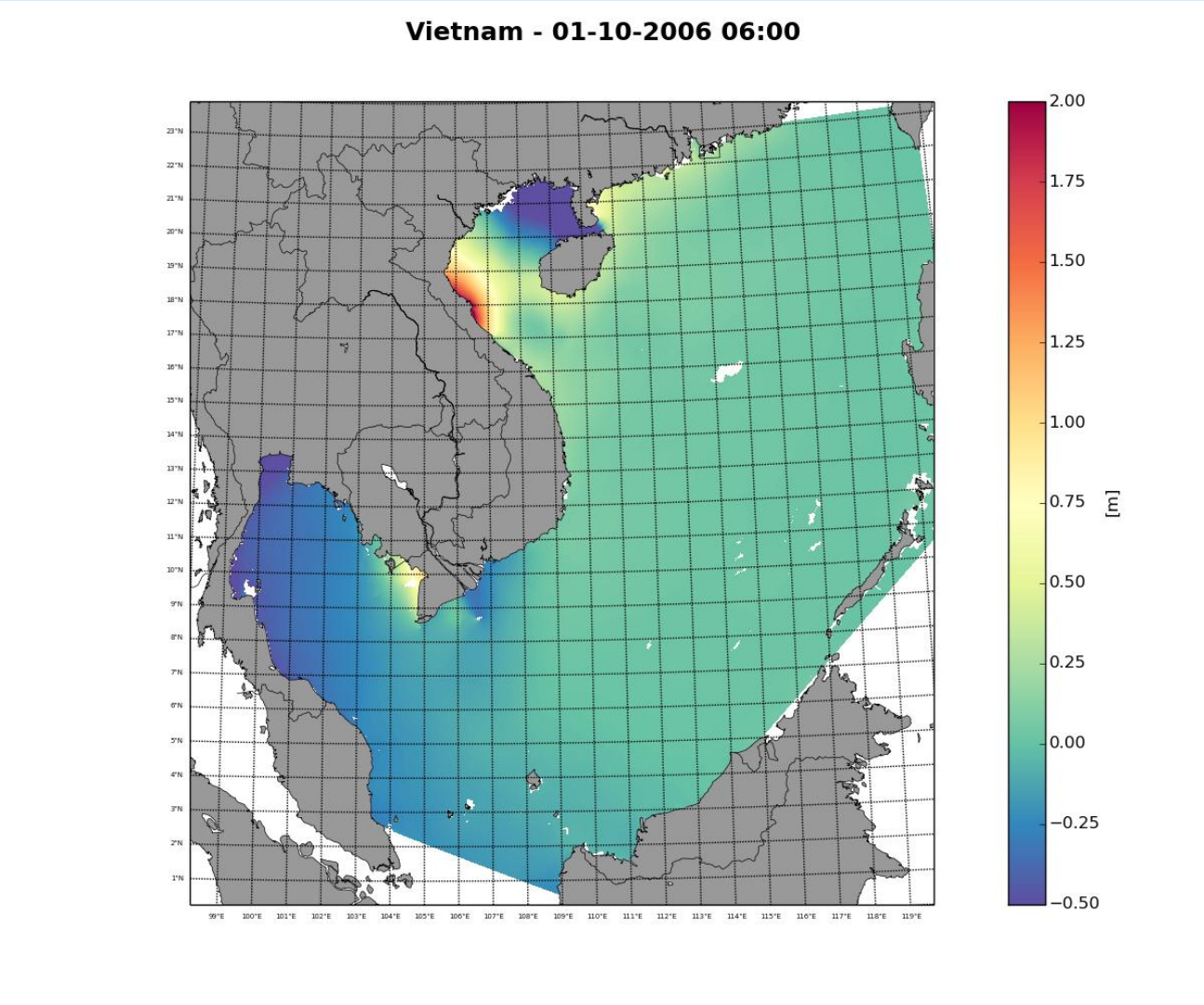
Case 1: Xangxane typhoon 2006



Track of Xangsena typhoon (9/2006) land fall at Danang (middle of Vietnam)

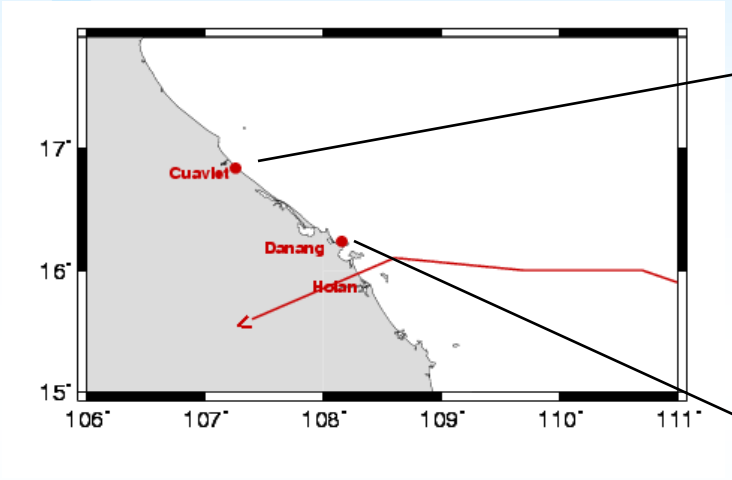


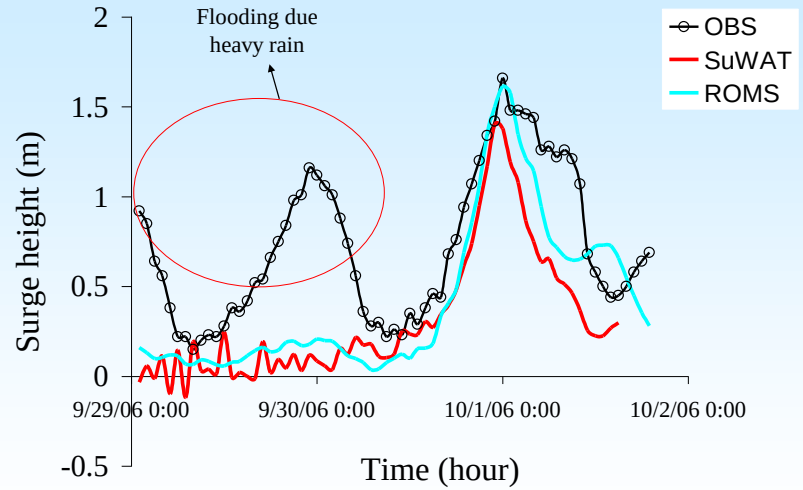
Wind and pressure at the time typhoon land fall –WRF model

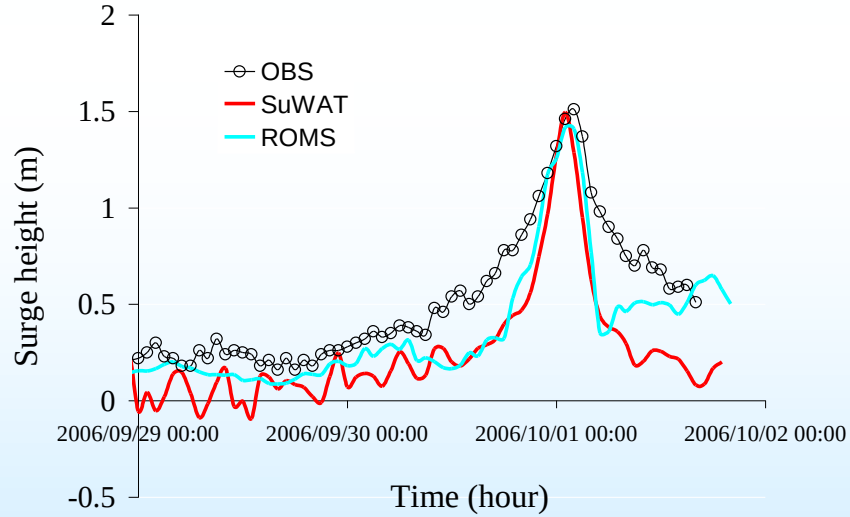


Distribution of surge height at the time typhoon Xangxane (9/2009) land fall – ROMS Mode Results

Verifying the model with OBS data for typhoon Xangxane (9/2006)





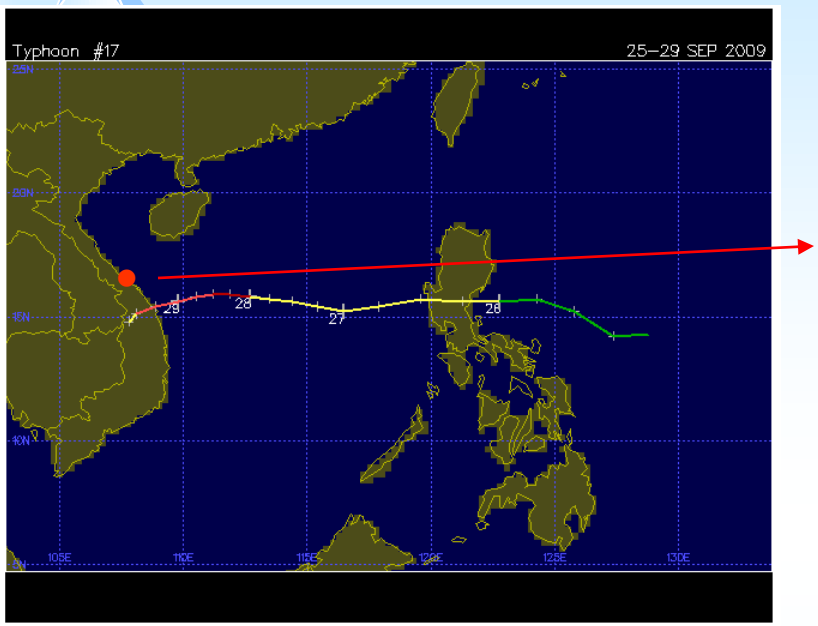


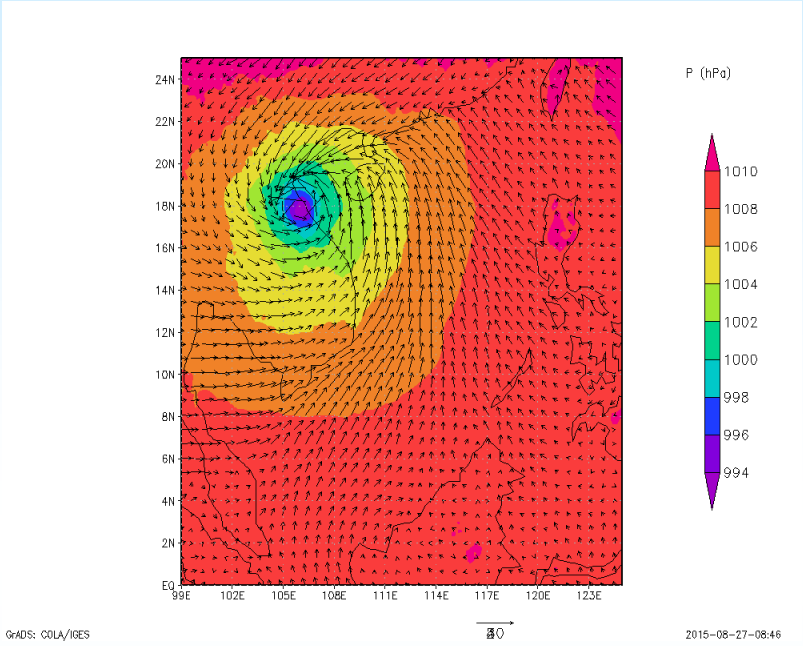
Cuviet: river station

Danang: Sea station

Time Variation of Storm Surge at Cuviet (above) and Danang (below) Stations

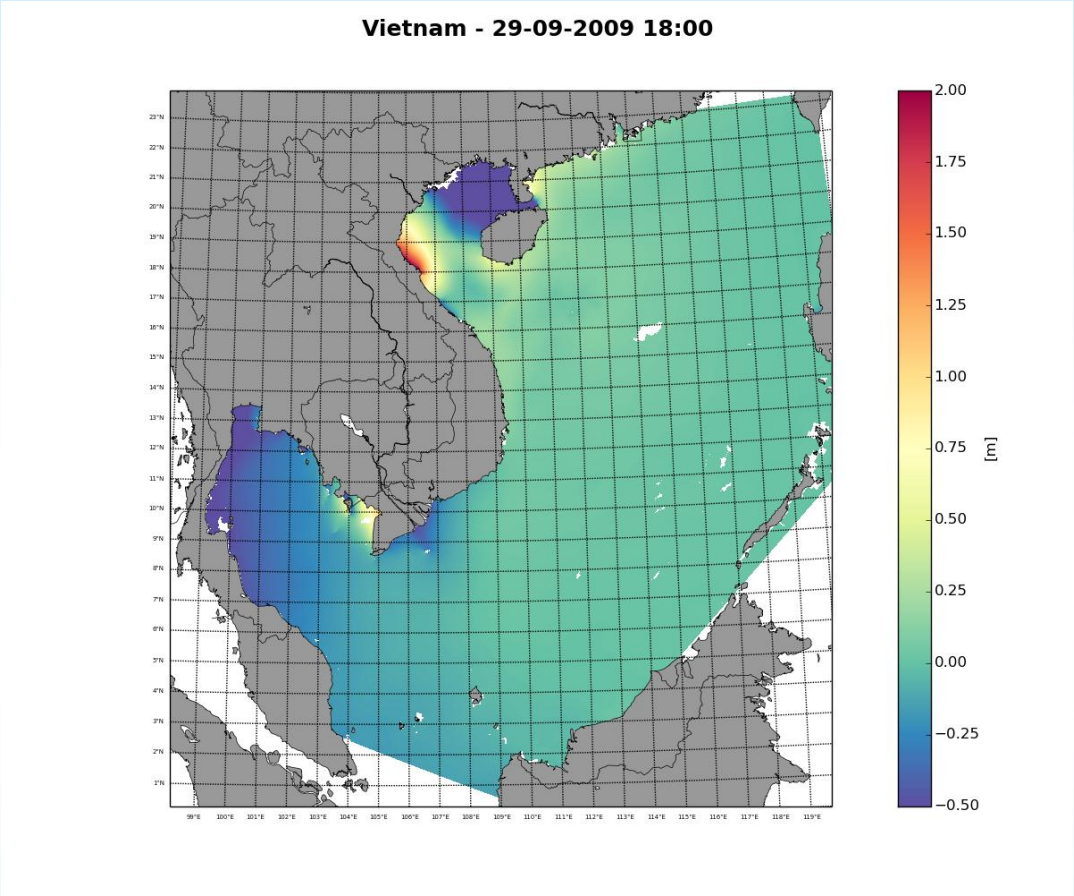
Case 2: Ketsena typhoon (9/2009)





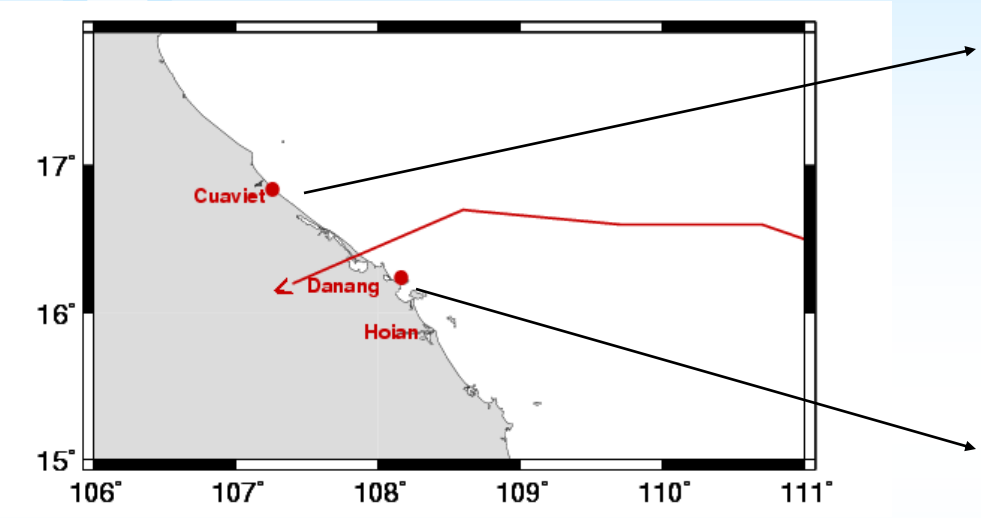
Track of Ketsena typhoon (9/2009) land fall at Danang (middle of Vietnam)

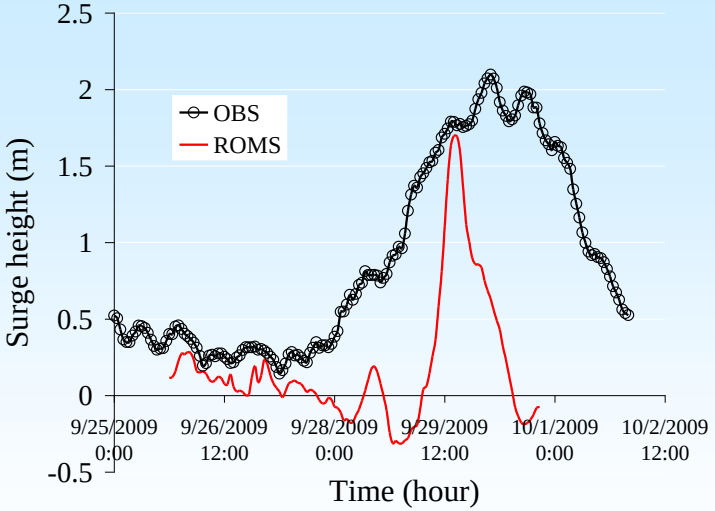
Wind and pressure at the time typhoon land fall –WRF model

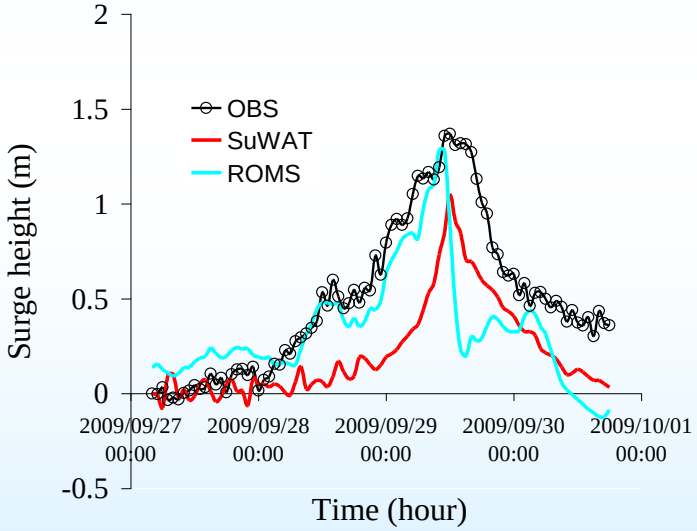


Distribution of surge height at the time typhoon Xangxane (9/2006) land fall -ROMS Mode Results

Verifying the model with OBS data for typhoon Ketsena (9/2009)



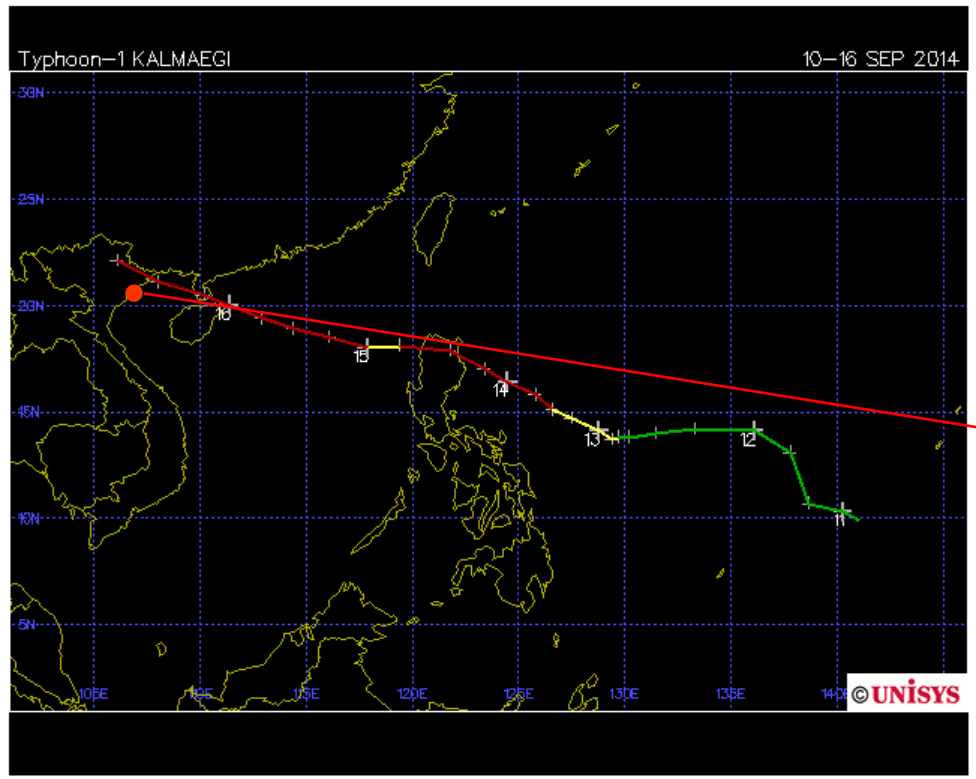




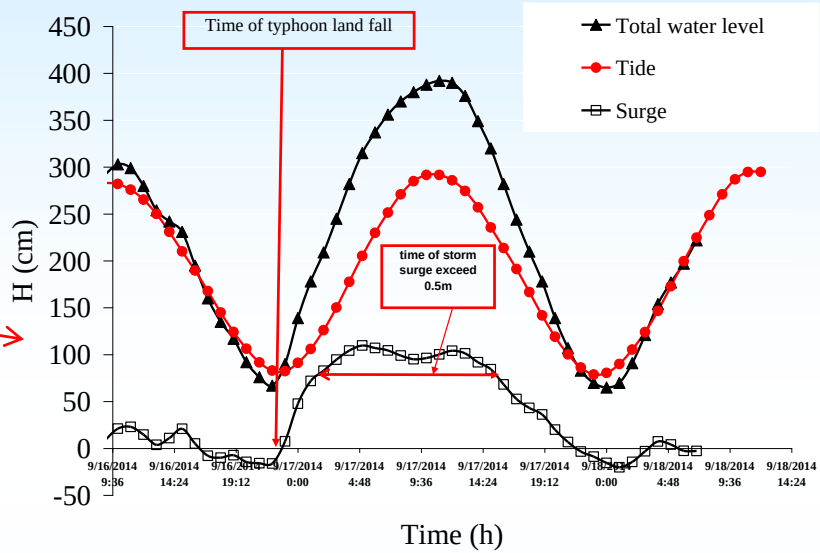
In this case: SuWAT using Empirical typhoon Model (Fujita Model)

Time Variation of Storm Surge at Cuaviet (above) and Danang (below) Stations

Case 3: Kalmaegi typhoon 2014



Track of Xangsena typhoon (9/2006) land fall at Danang (middle of Vietnam)



Time Variation of total level, tide and Surge at Hondau Station

The surge generated after typhoon landfall and reached to 12 hours (look right figure). This is due to South-West monsoon.

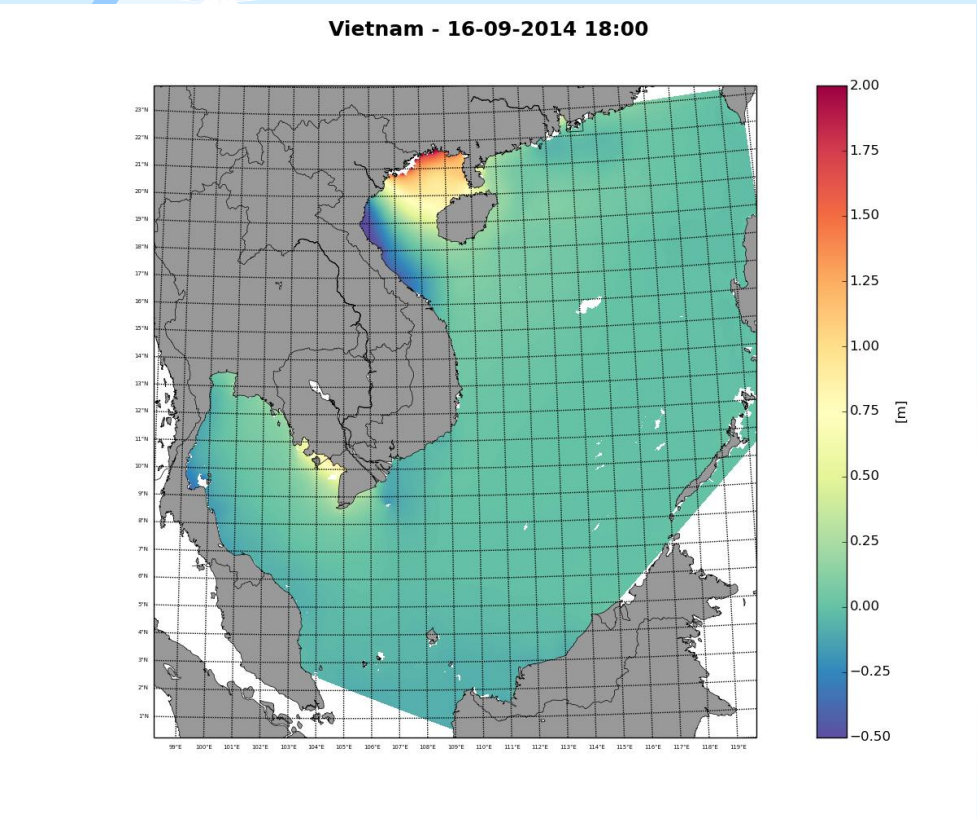
Suge and wave after typhoon Kalmaegi Land fall 12 hour

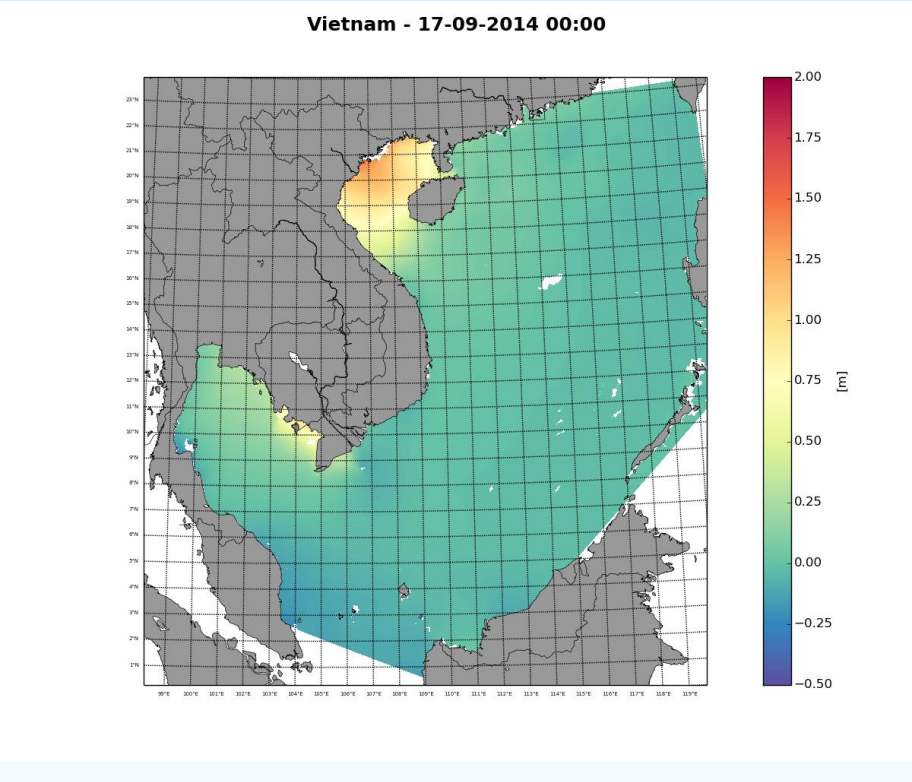
Một chủ của hàng kinh doanh lâu năm tại khu 1 Đồ Sơn cho hay, người dân sống ở đây quen với bão gió rồi. "Bão vào chúng tôi không sợ bằng khi bão đi qua. Khi đó gió Nam thốc lên kết hợp với đỉnh triều cường thì nguy hiểm lắm. Trận bão cách đây 4 năm, hàng m3 đá dưới biển và đá kè bị nước biển vò vụn 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.

Dù bão đã suy yếu thành áp thấp nhiệt đới, nhưng sáng nay tại khu du lịch Đồ Sơn, TP Hải Phòng, gió vẫn rất mạnh, sóng đánh dữ dội.

Surge + high tide + wave generated inundation at Haiphong coast

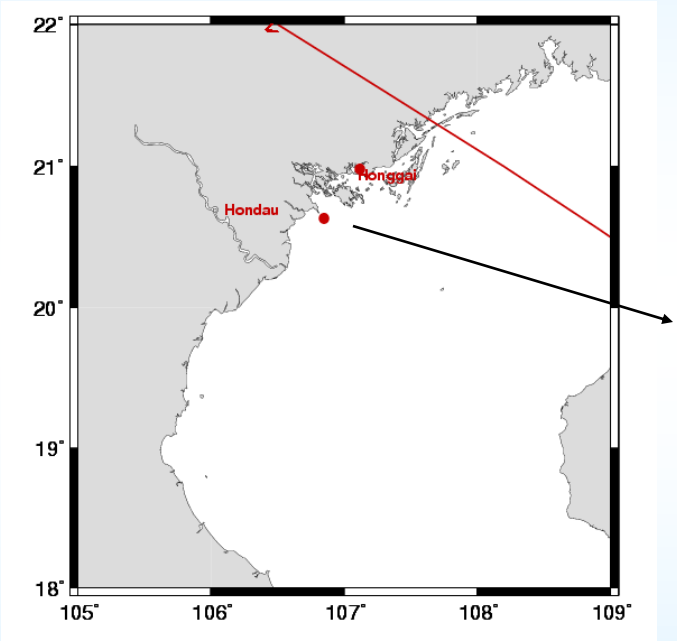
Nước biển đã làm ngập toàn bộ tuyến đường tại khu 1 dài gần một km, tràn vào các nhà hàng, khách sạn và đang chảy ngược vào các khu dân cư của phường Ngọc Hải, quận Đồ Sơn.

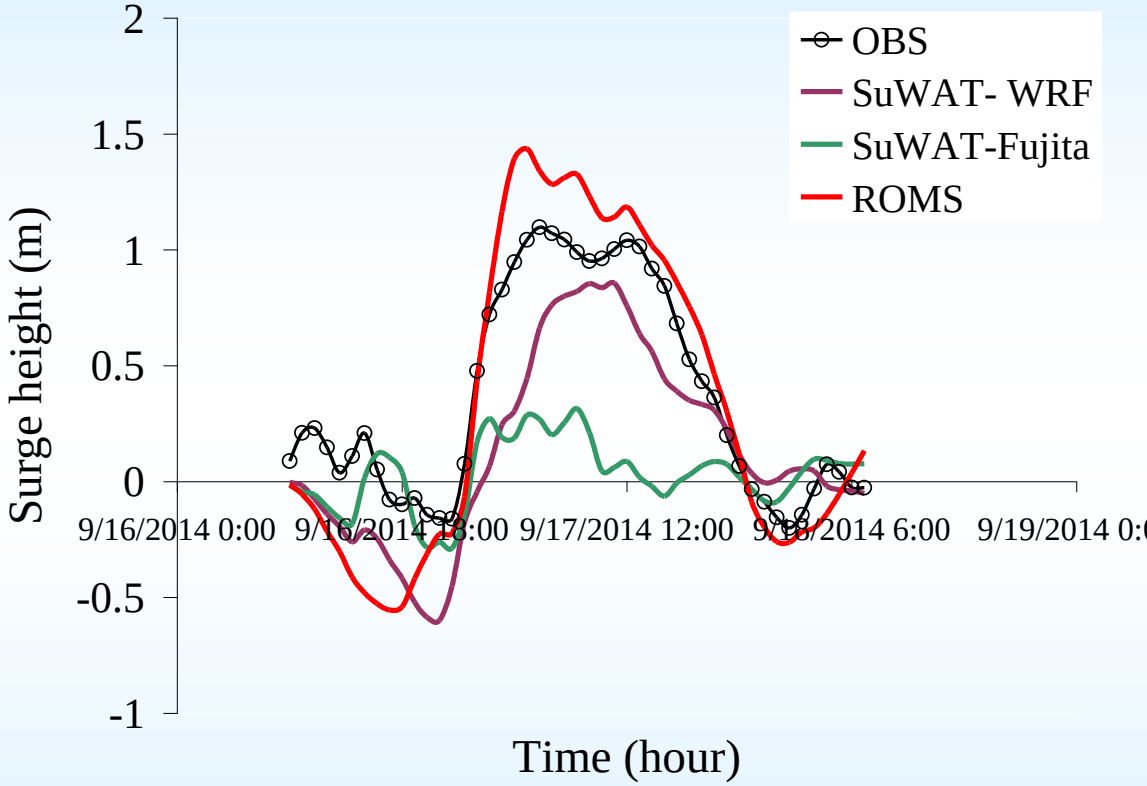




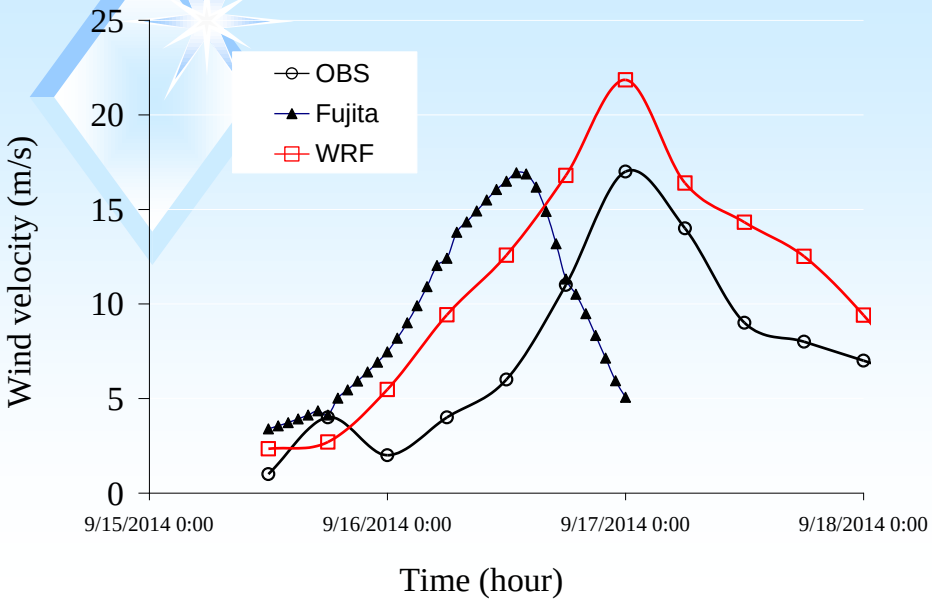
Distribution of surge height at the time Kalmaegi typhoon 9/2014 land fall 3 and 6 hour - ROMS Mode Results.

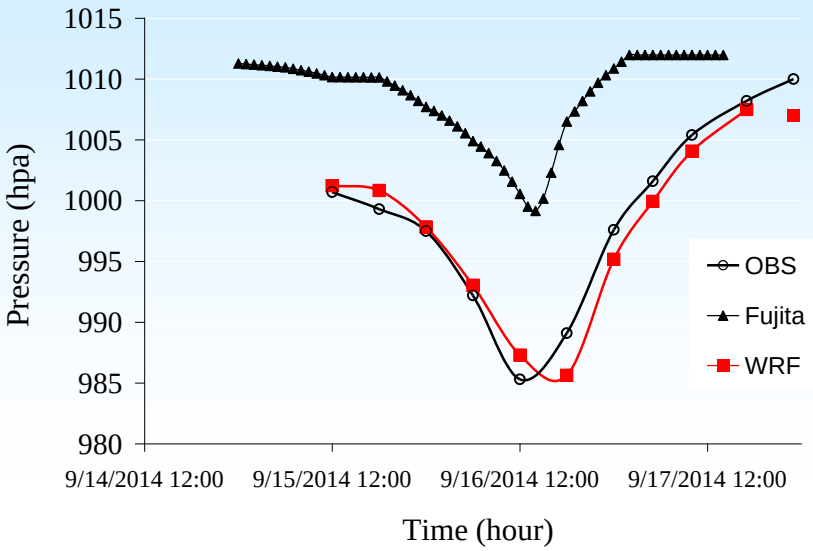
Verifying the model with OBS data for typhoon Kalmaegi (9/2014)





Time Variation of Storm surge at Hondau Station



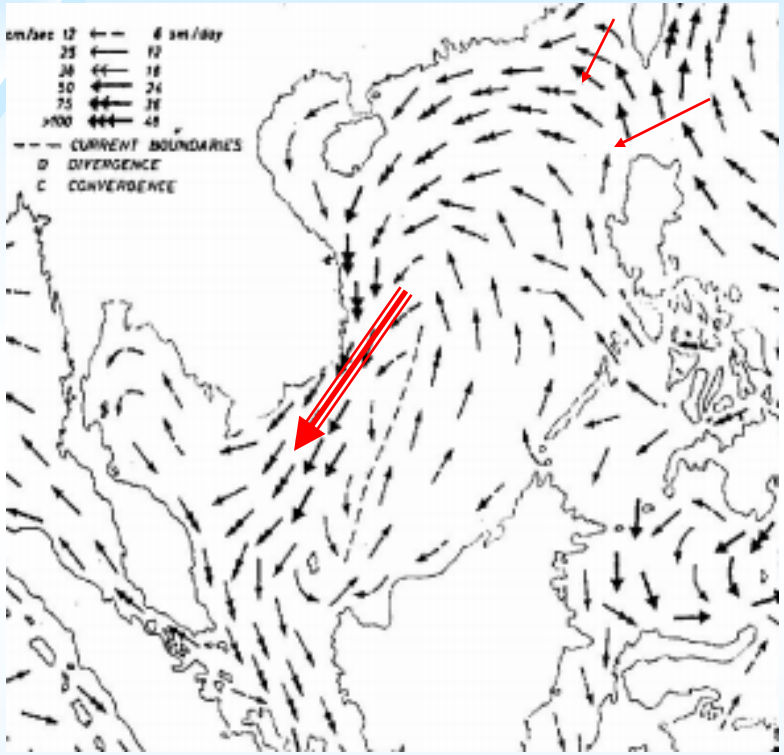


Time variation at Hondau station during typhoon Kalmaegi (9/2014)

Conclusion and future work

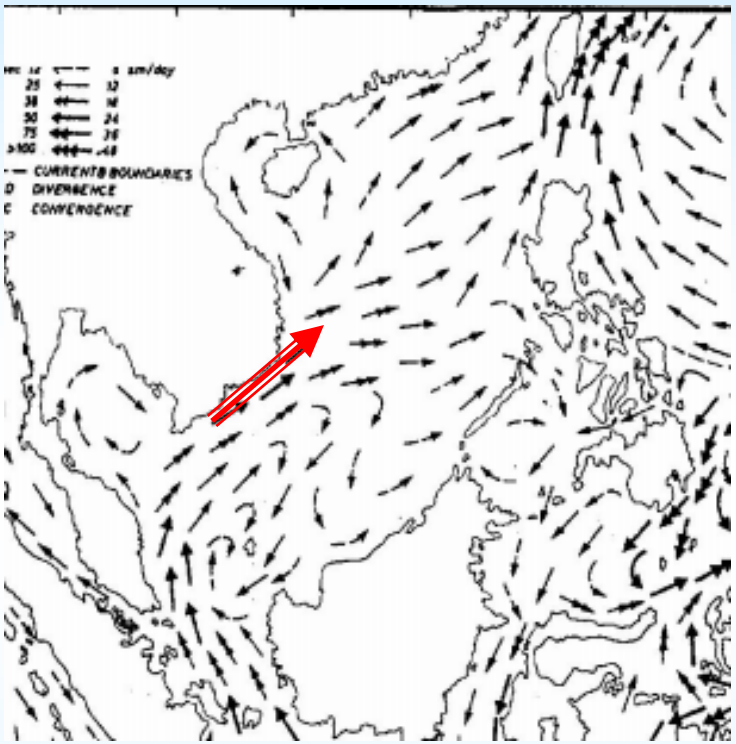
1. ROMS model can simulate good agreement surge not only in the case of typhoon, but strong wind.
2. Operation surge in monsoon (wind and airpressure variation)
3. Coastal inundation due to storm tide.
4. Asiimilation for HF radar (wave and surface current)

Surface ccean current in South China sea and the coast of Vietnam – Result from observation and analyze



In winter (Dec.-Jan.)

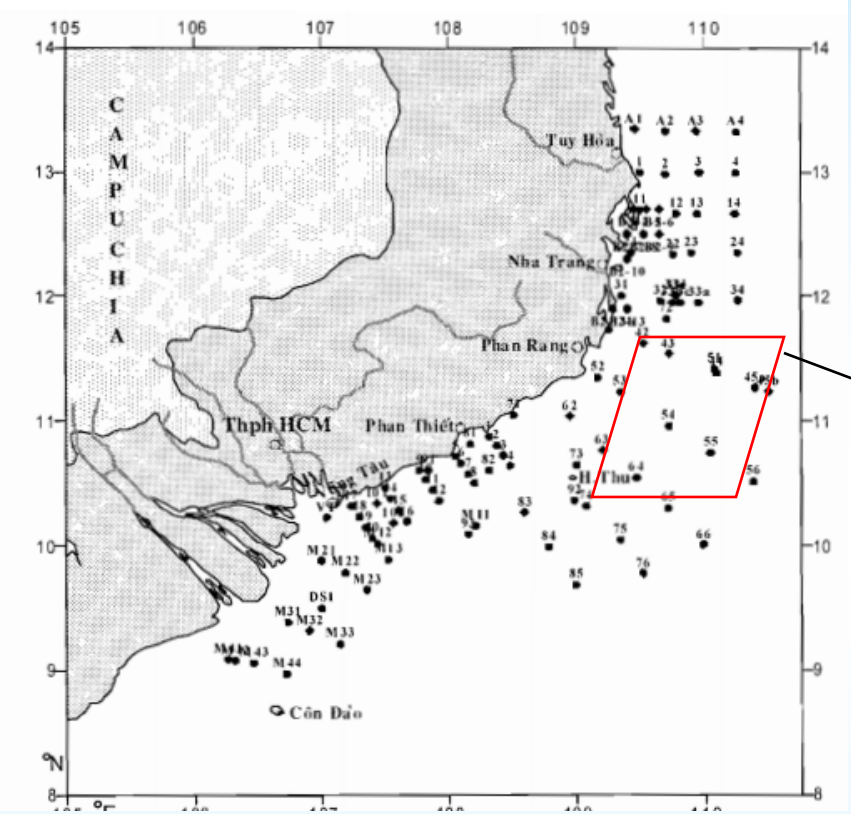
- Strong surface current in SW direction



In summer (Jun-Aug.)

- Strong surface current in NE direction

Upwelling in SW monsoon



Upwelling zone

Observation station for investigation upwelling

Thank You - Questions and Discussion?