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RISK OF TYPHOON AND STORM SURGES IN COASTAL AREAS OF VIETNAM

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Contents

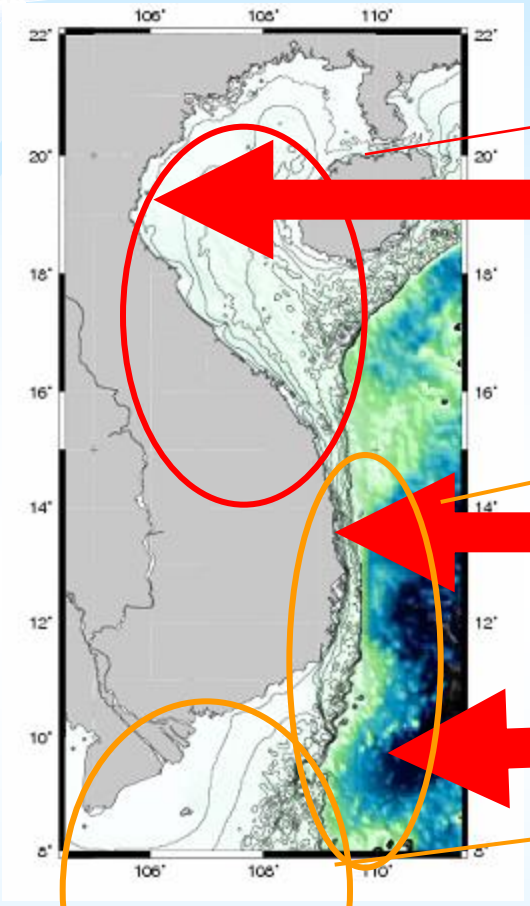
1. Methods and data

2. Typhoon and storm surge in the period 1951-2016

3. Risk of typhoon and storm surge

4. Conclusions and Future study

Possibility typhoon and storm surge in Vietnam



High Vulnerable storm surge
(abundant typhoon + shallow water)

June

Less Vulnerable storm surge
(rare typhoon + deep water)

Dec.

Less Vulnerable storm surge (shallow water +rare typhoon)

Number of Typhoon

(1) Historical of typhoon and storm surge?
(2) Risk of typhoon and storm surge?

Historical typhoon not enough for assessment typhoon and storm surge

Data and methods

Data:

- Typhoon: 1951-2016, from NCHMF and JMA
- Storm surge: Observation data and numerical simulation

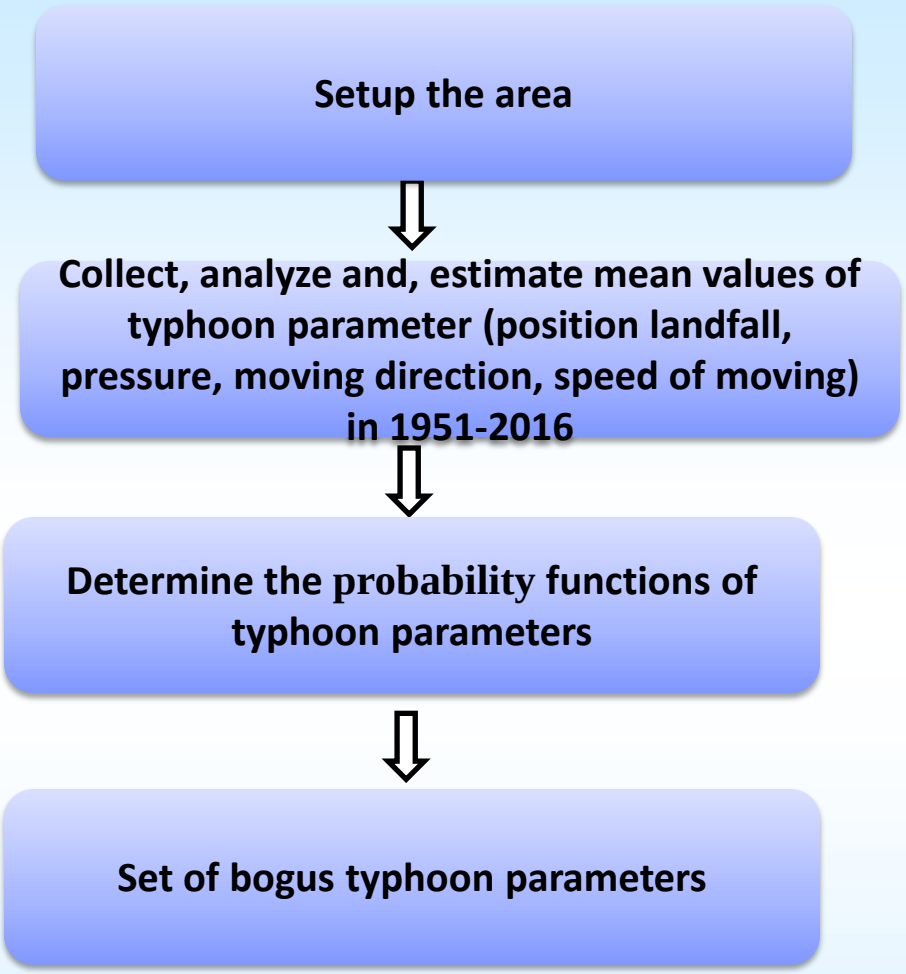
Methods:

-Monter Carlo Model: To contract set of bogus typhoons in 1000 year.
- SuWAT Model (Surge Wave and Tide): To calculate storm surge

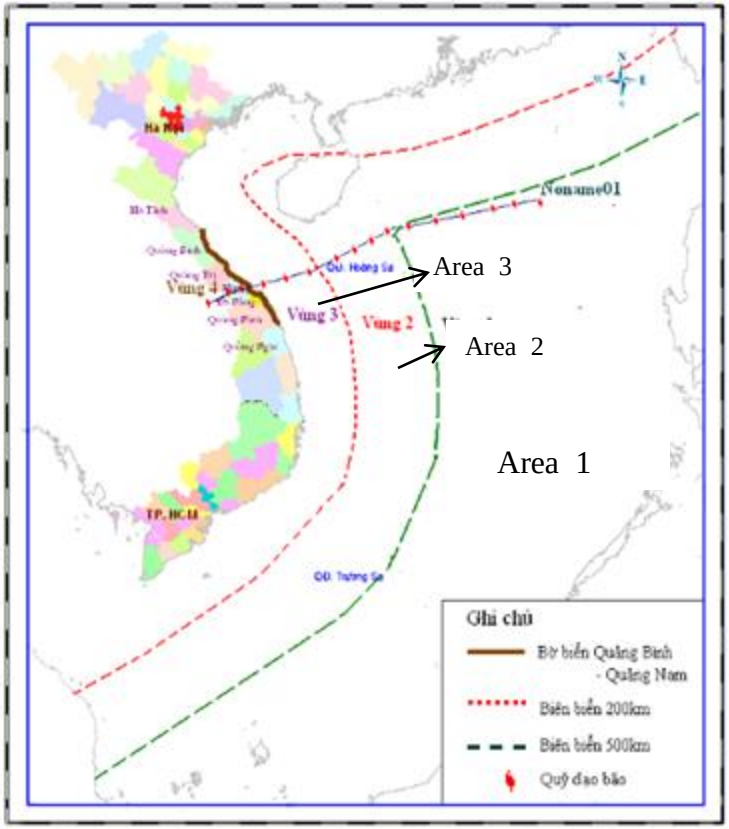
The Monte-Carlo method (to contract set of bogus typhoon)

Historical typhoon (too short)

Bogus typhoon in 1000 year (enough for asses the risk of typhoon and storm surge)



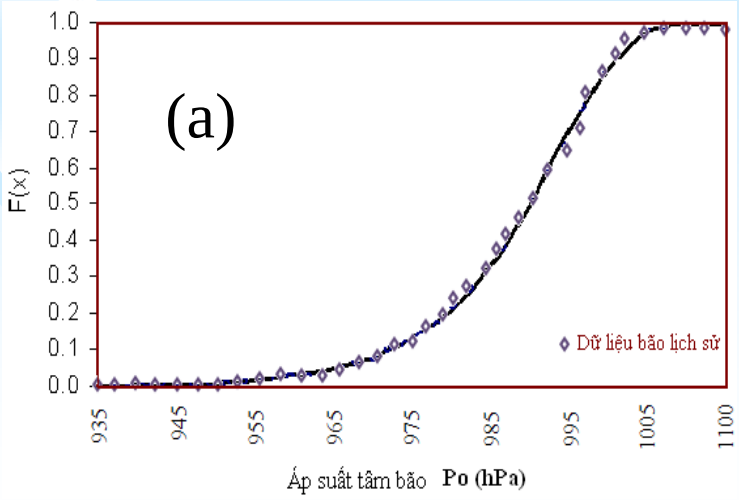
Steps to contract a set of bogus typhoon

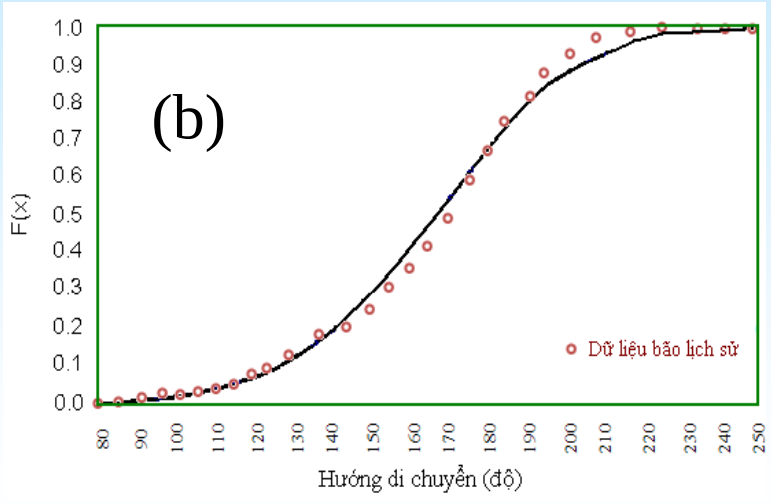


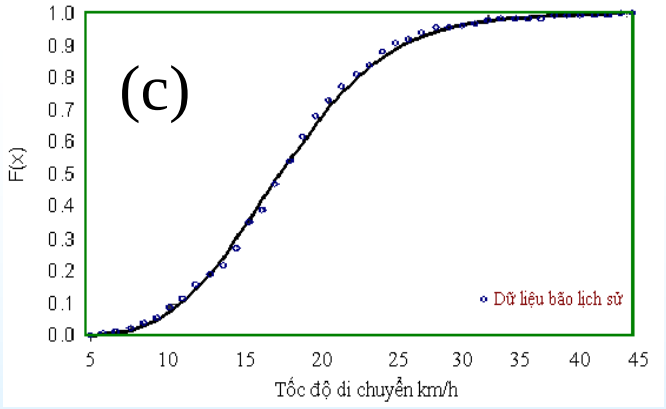
The areas for normalize historical typhoon parameters

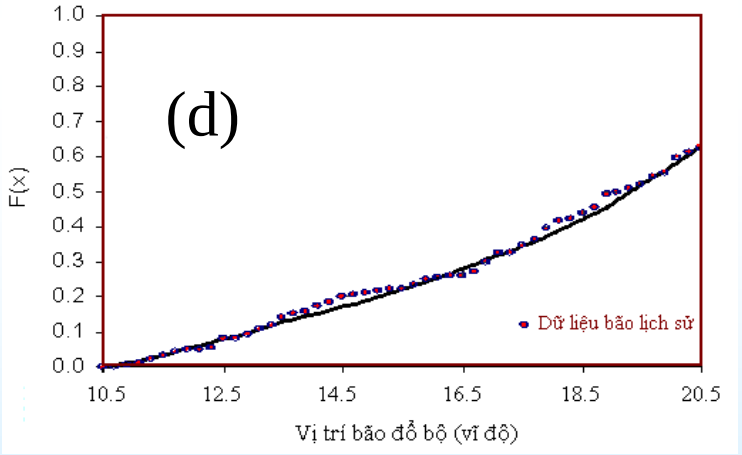
Example of normalize historical typhoon parameters

Area							Area 3			Area 2			Area 1	
H	dd	M	Y	φ	λ	θ [°]	V_f [km/h]	P_o [hPa]	θ [°]	V_f [km/h]	P_o [hPa]	θ [°]	V_f [km/h]	P_o [hPa]
10.71	24	6	2011	106.6	20.3	192.9	16.9	989.8	162.9	14.1	995.6	139.2	21.70	1004.5
8.76	30	7	2011	105.9	19.3	199.6	30.5	992.0	170.2	22.6	985.0	157.2	19.90	993.8
3.71	30	9	2011	107.1	20.8	154.2	14.2	988.7	157.5	24.1	970.0	165.1	22.60	980.6
13.56	17	8	2012	107.5	21.1	159.3	30.8	987.0	163.1	29.3	972.5	170.1	18.40	993.6
9.47	6	10	2012	109.3	13.1	181.8	24.2	1003.6	194.7	28.3	998.0	198.9	15.40	994.2
17.50	28	10	2012	106.5	20.3	162.4	14.2	975.7	156.1	23.0	971.6	157.2	23.70	998.0
11.95	23	6	2013	106.6	20.3	159.9	9.9	994.8	174.9	22.6	992.0	171.9	16.60	999.4
0.58	2	7	2013	109.9	21.5	127.5	25.6	990.7	142.6	25.3	985.0	156.9	25.85	1000.9
1.48	3	8	2013	107.5	21.1	160.2	33.6	986.2	129.8	24.8	987.5	158.2	13.70	1000.3
9.47	30	9	2013	106.5	17.6	172.5	34.8	976.0	175.4	18.6	966.2	167.2	12.70	994.1
6.35	14	10	2013	108.6	15.6	179.2	19.4	991.2	158.6	14.6	965.0	174.3	18.30	981.8
7.18	11	11	2013	107.3	20.9	154.2	21.5	976.6	127.0	30.6	957.5	168.8	34.90	952.8
22.00	18	7	2014	108.5	21.5	156.9	23.2	971.0	151.8	23.7	940.0	965.5	151.80	23.7
13.37	16	9	2014	107.6	21.2	179.8	30.2	985.4	161.4	33.7	962.5	163.7	26.30	981.9
16.56	29	10	2014	109.3	13.3	178.0	13.6	994.0	164.3	17.9	991.0	165.4	26.90	999.8









Probability function of air pressure (a), direction moving (b), moving speed (c) and position landfall (d)

A coupled of surge wave and tide (SuWAT) model

Two Dimensional Long wave Model + SWAN model

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

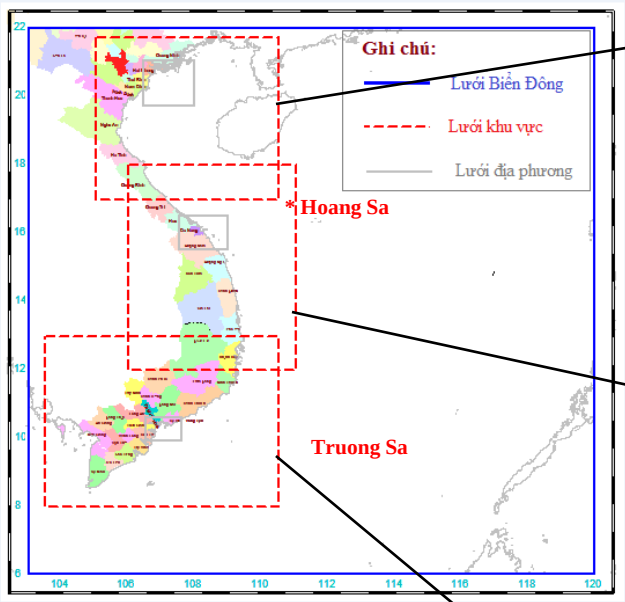
$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}\left(\frac{M^2}{d}\right)+\frac{\partial}{\partial y}\left(\frac{MN}{d}\right)+gd\frac{\partial \eta}{\partial x}$$
$$=fN-\frac{1}{\rho_w}d\frac{\partial P}{\partial x}+\frac{1}{\rho_w}\left(\tau_s^x-\tau_b^x+F_x\right)+A_h\left(\frac{\partial^2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

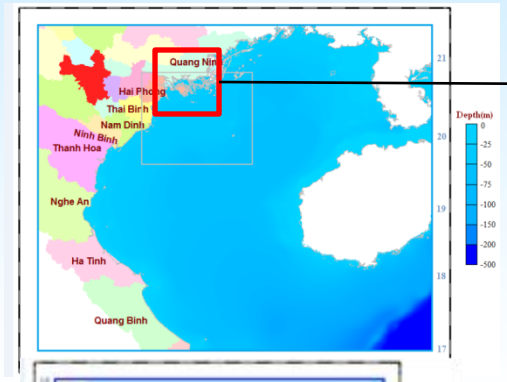
$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}\left(\frac{NM}{d}\right)+\frac{\partial}{\partial y}\left(\frac{N^2}{d}\right)+gd\frac{\partial \eta}{\partial y}$$
$$=-fM-\frac{1}{\rho_w}d\frac{\partial P}{\partial y}+\frac{1}{\rho_w}\left(\tau_s^y-\tau_b^y+F_y\right)+A_h\left(\frac{\partial^2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

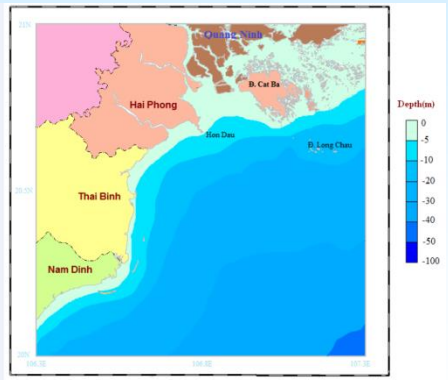
τ_s The wind stress (including **wave** dependent drag)

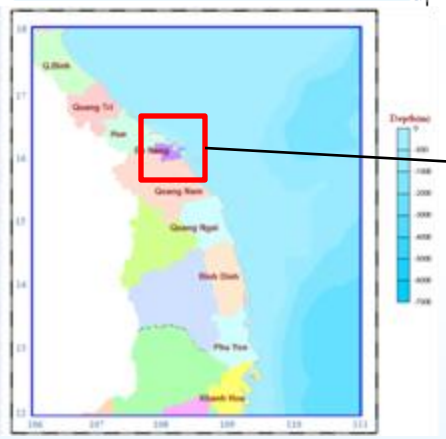
F: The wave force- which correspond to the gradients of wave-induced radiation stress

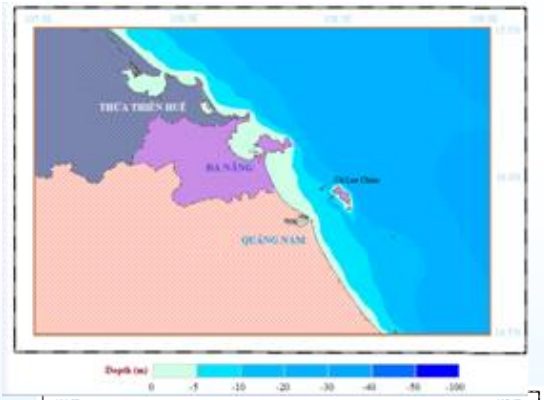
Computational domains for storm surge simulation

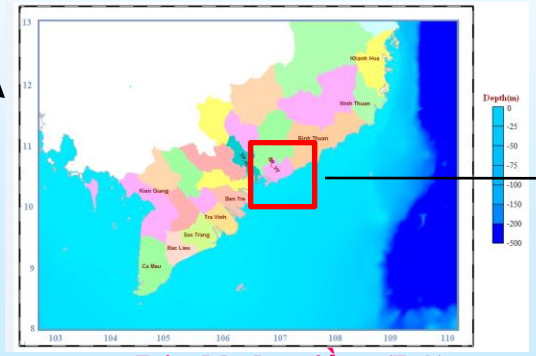


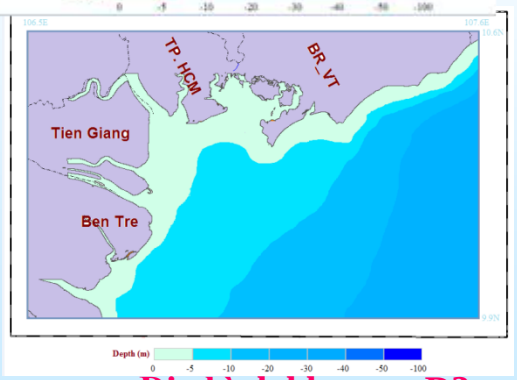










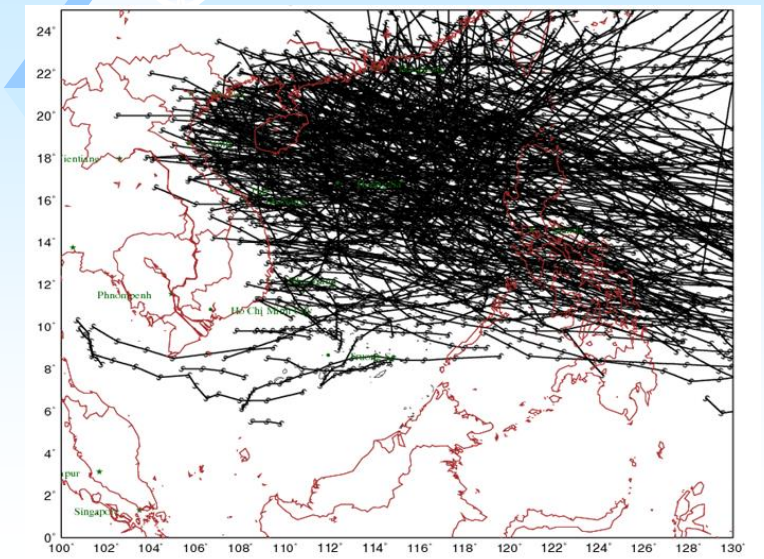


Nesting in 3 domain

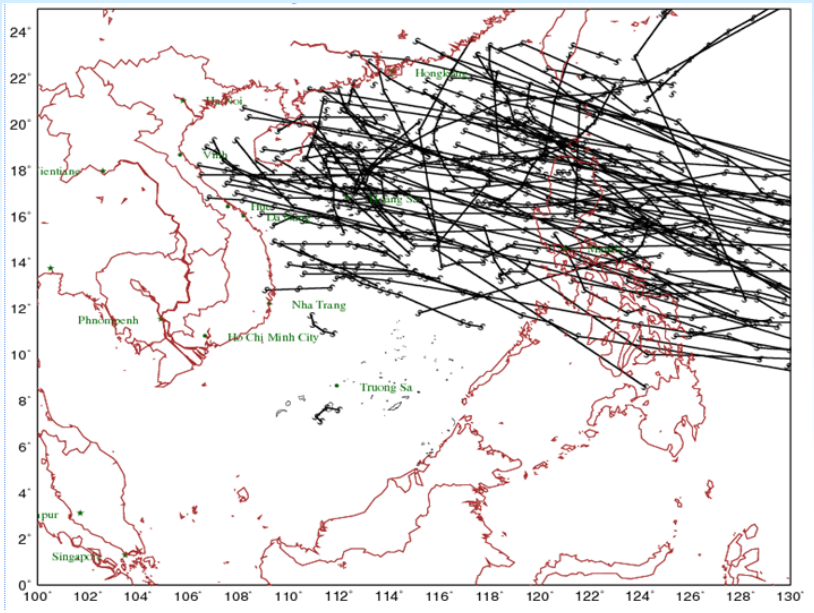
Địa hình miền (D2)

Địa hình khu vực D3

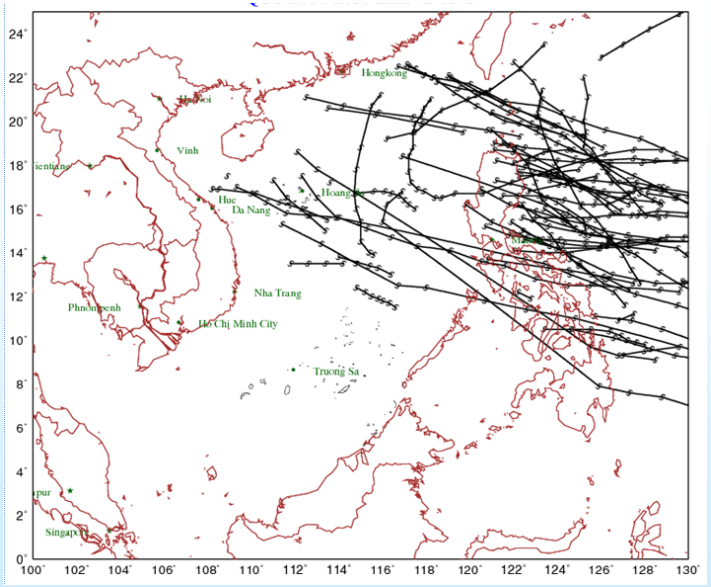
RESULTS - TYPHOONS IN 1951-2016:



(a)



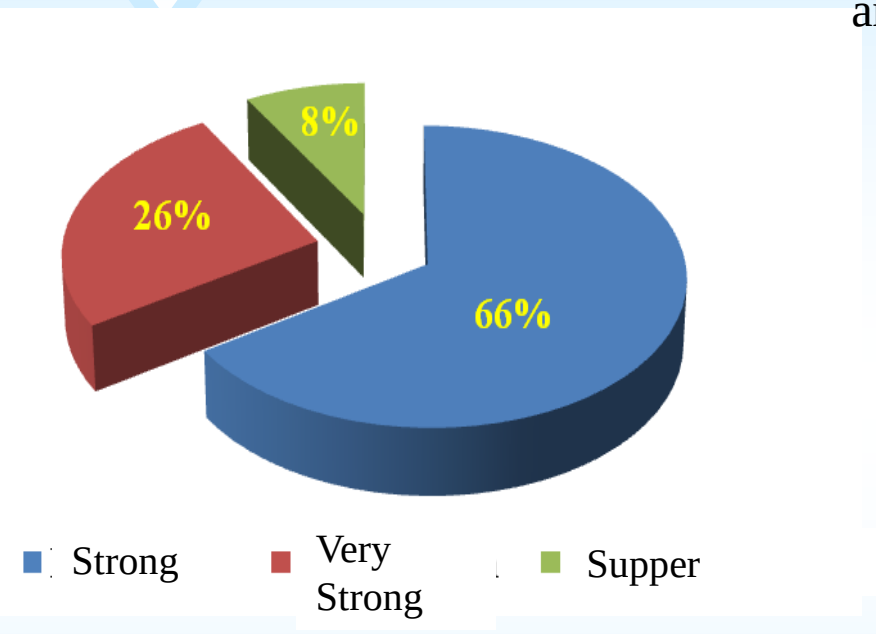
(b)



(c)

The track of typhoons in the East Sea of Vietnam: (a) Level 8 - 11, (b) Level 12-13 and (c) Level 13 and higher

RESULTS - TYPHOONS ININTENSITY (Beaufort Scale) IN THE PERIOD 1951-2016

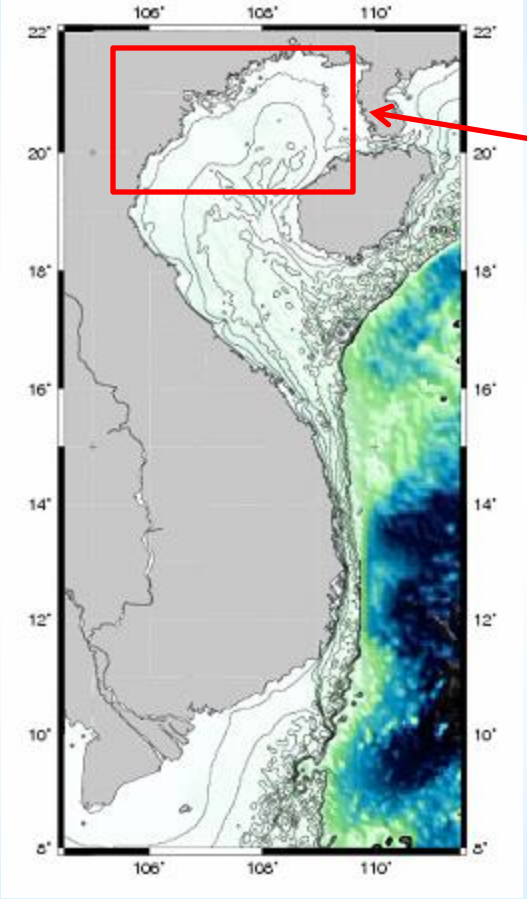


The number of typhoons affecting areas of the East Sea and coastal area of Vietnam in the period of 1951-2016.

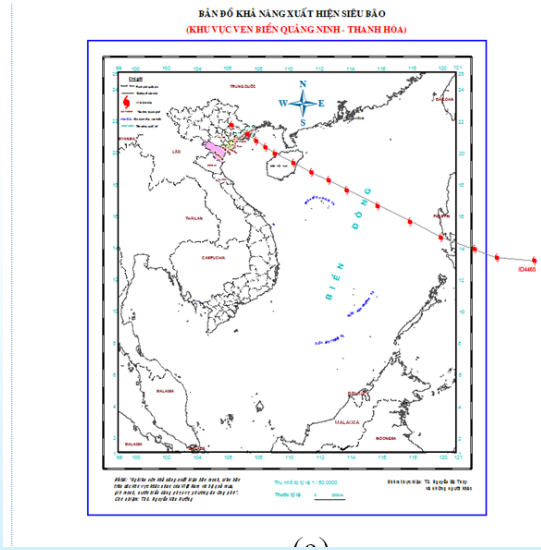
Area	Level 8 - 11	Level 12 - 13	≥ Level 13
Quang Ninh - Ha Tinh	317	23	2
Quang Binh- Phu Yen	307	55	11
Khanh Hoa- Binh Thuan	94	12	1
Ba Ria Vung Tau - Ca Mau	46	2	0
North East Sea	1816	339	90
Central East Sea	747	97	41
South East Sea	144	6	0
Total	3471	534	145

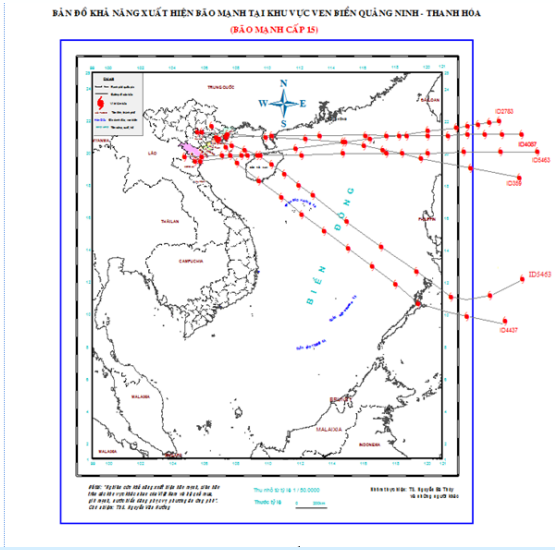
RESULTS – BOGUS TYPHOONS IN 1000 YEARS

Number of typhoon landfall the coastal area of Quang Ninh-Thanh Hoa



Province	Level 10-11	Level 12	Level 13	Level 14	Level 15	Level ≥ 16	**Total**
Quảng Ninh	86	113	5	3	4	1	**212**
Hải Phòng	38	26	2	1	0	0	**67**
Thái Bình	36	30	3	1	0	0	**70**
Nam Định	34	24	1	1	0	0	**60**
Ninh Bình	3	2	1	1	0	0	**7**
Thanh Hóa	55	48	3	1	2	0	**109**
Total	**252**	**243**	**15**	**8**	**6**	**1**	



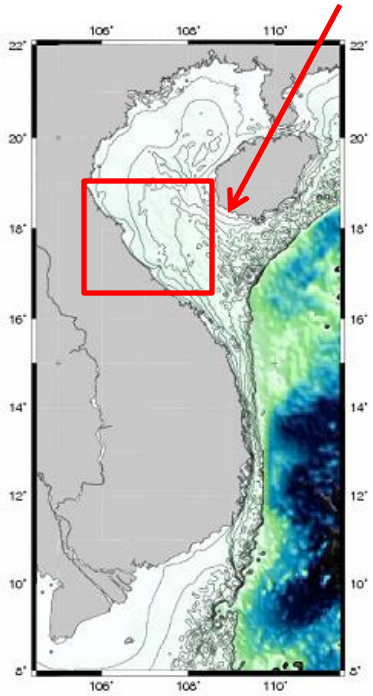


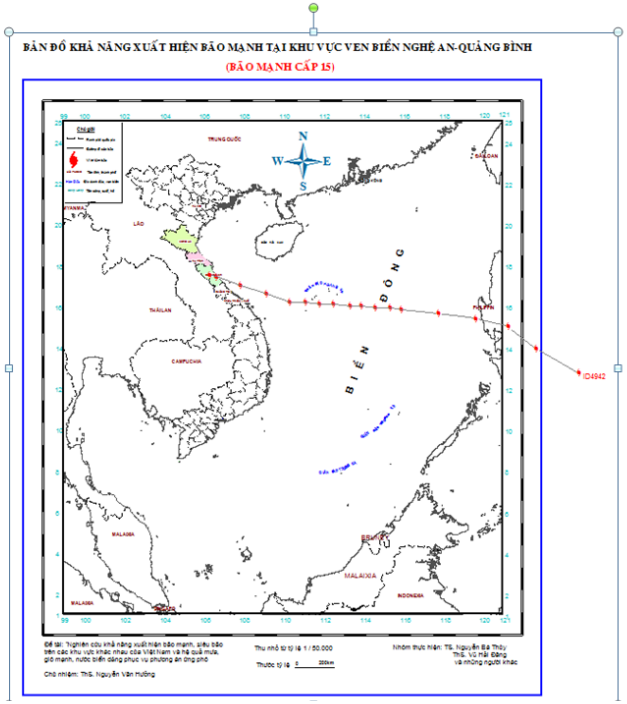
The track of bogus typhoon landfall at: level 16 (a) and 15 (b) of Quang Ninh province

RESULTS – BOGUS TYPHOONS IN 1000 YEARS

Number of typhoon landfall the coastal area of Nghe An-Quang Binh

Province	Level 1--11	Level 12	Level 13	Level 14	Level 15	Level ≥16	**Total**
Nghệ An	39	22	1	2	0	0	**64**
Hà Tĩnh	48	52	4	1	0	0	**105**
Quảng Bình	45	31	2	1	1	0	**80**
Total	**132**	**105**	**7**	**4**	**1**	**0**	



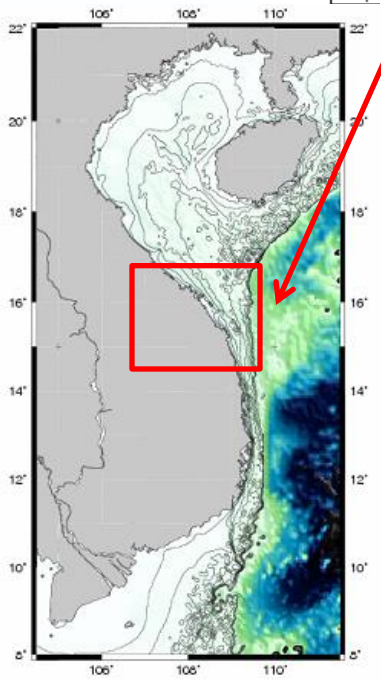


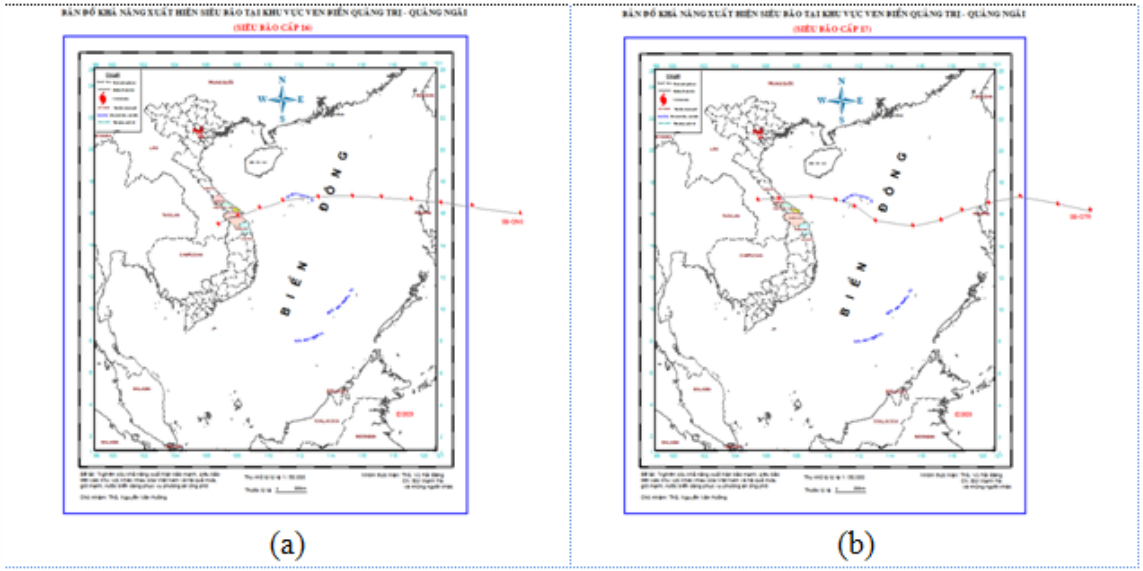
The track of bogus typhoon landfall at level 15 of Quang Binh province

RESULTS – BOGUS TYPHOONS IN 1000 YEARS

Number of typhoon landfall the coastal area of Quang Tri-Quang Nghai

Province	Level 10-11	Level 12	Level 13	Level 14	Level 15	Level ≥ 16	Level	Total
Quảng Trị	20	30	1	0	0	0	1	**52**
Huế	16	20	1	0	1	0	0	**38**
Đà Nẵng	16	9	0	1	0	0	0	**26**
Quảng Nam	30	23	2	0	0	1	0	**56**
Quảng Ngãi	35	19	1	1	0	0	0	**56**
Total	**117**	**101**	**5**	**2**	**1**	**1**	**1**	





(a) (b)

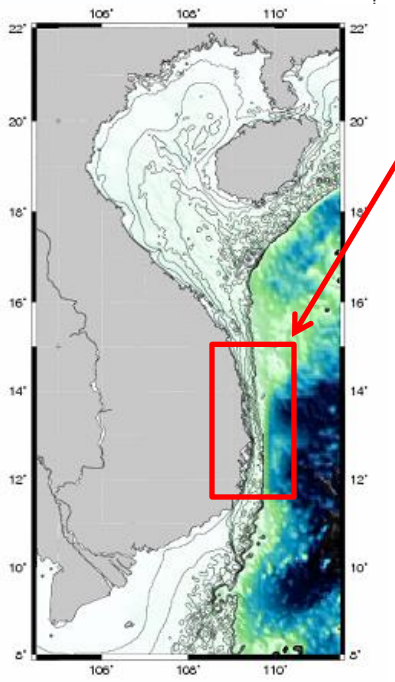
The track of bogus typhoon landfall at level 16 to Quang Nam (a) and level 17 to Quang Tri province (b)

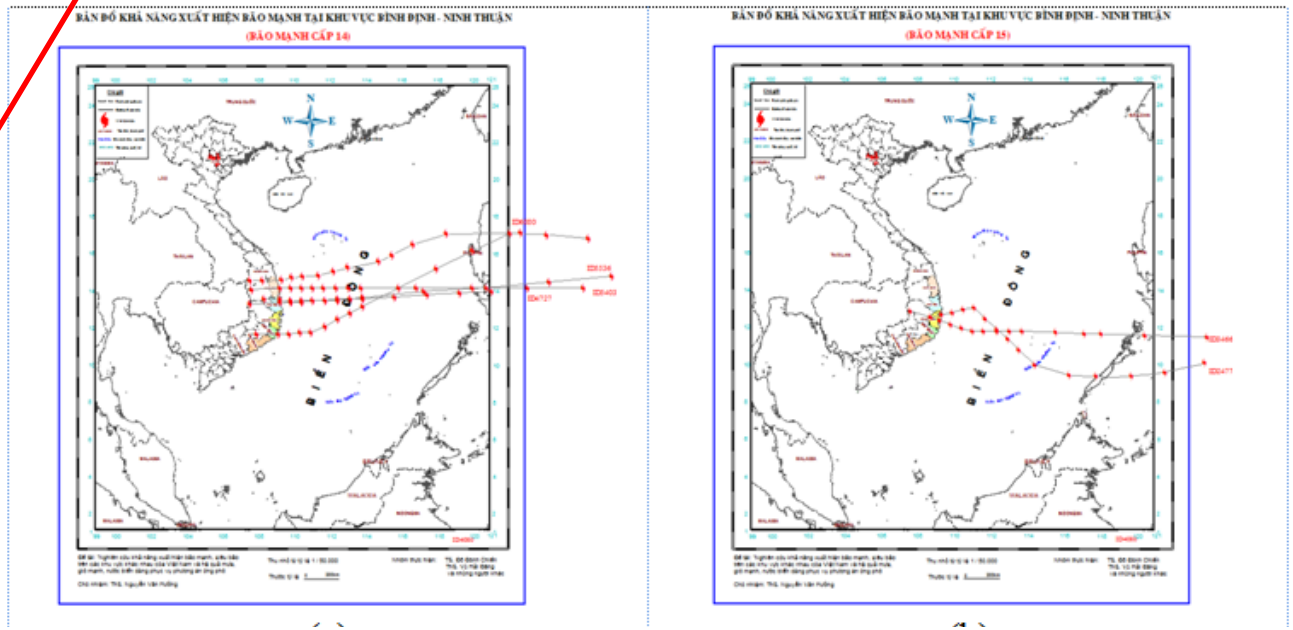
RESULTS – BOGUS TYPHOONS IN 1000 YEARS

Number of typhoon landfall the coastal area of Binh Dinh-Ninh Thuan

Vùng bờ Bình Định - Ninh Thuận |

Province	Level 10	Level 11	Level 12	Level 13	Level 14	Level 15	Total
Bình Định	20	20	25	1	2	0	68
Phú Yên	11	9	26	2	2	0	50
Khánh Hòa	16	15	36	0	0	2	69
Ninh Thuận	9	2	15	0	1	0	27
Total	56	46	102	3	5	2	



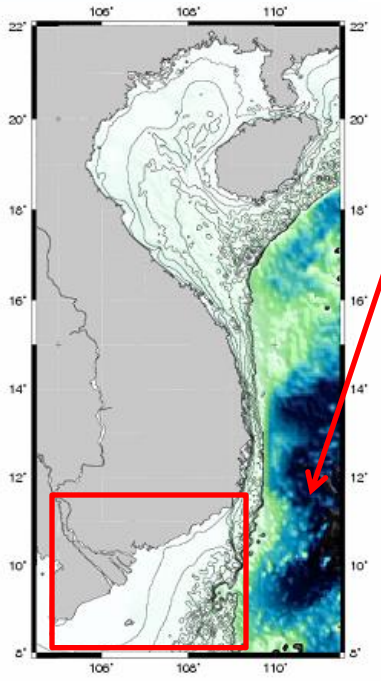


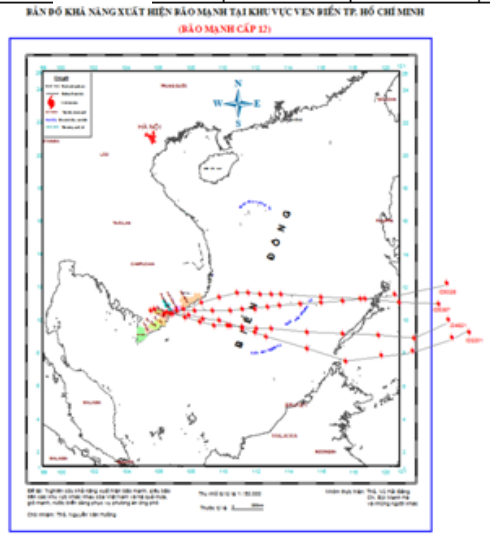
The track of bogus typhoon landfall at level 14(a) and level 15(b) to Binh Dinh-Ninh Thuan

RESULTS – BOGUS TYPHOONS IN 1000 YEARS

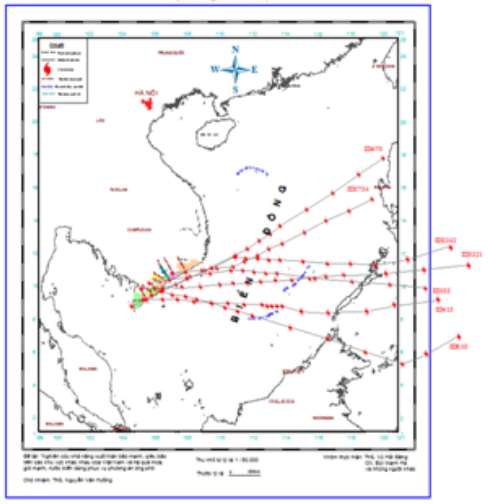
Number of typhoon landfall the coastal area of Binh Thuan-Camau

Tinh	Level 9	Level 10	Level 11	Level 12	Level 13	Total
Bình Thuận	23	1	1	0	0	25
Bà Rịa Vũng Tầu	2	1	1	1	0	5
TP. Hồ Chí Minh	3	1	1	4	0	9
Tiền Giang	4	4	2	5	1	16
Bến Tre	17	6	3	7	0	33
Trà Vinh	15	4	5	8	2	34
Sóc Trăng	9	3	2	3	1	18
Bạc Liêu	5	3	6	5	1	20
Cà Mau	23	6	9	11	1	50
Total	**101**	**29**	**30**	**44**	**6**	





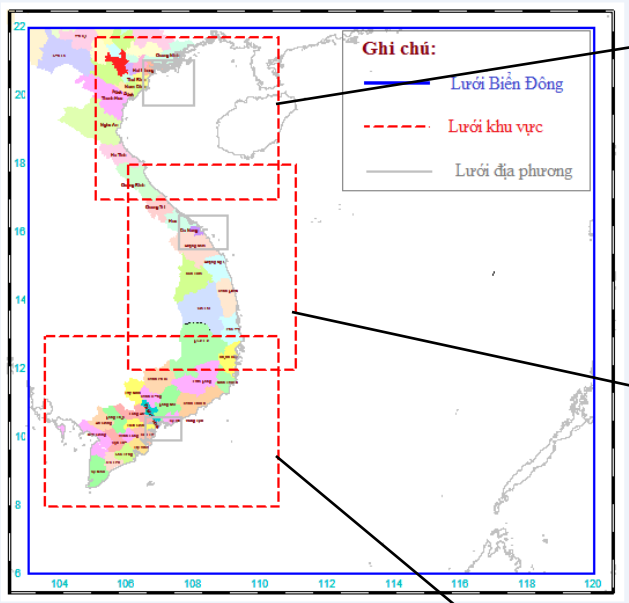
(a)

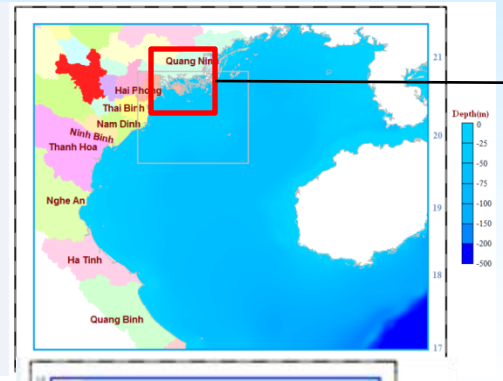


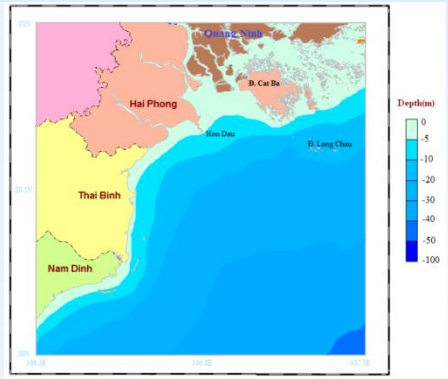
(b)

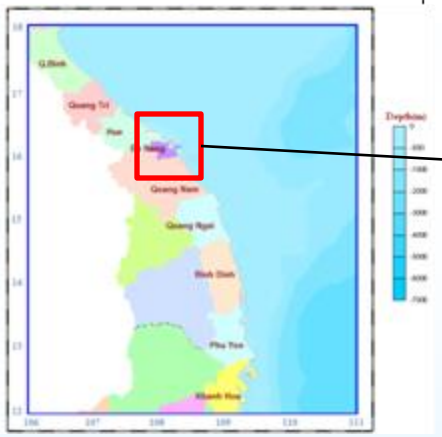
The track of bogus typhoons landfall at level 12(a) and 13(b) to Binh Thuan-Camau

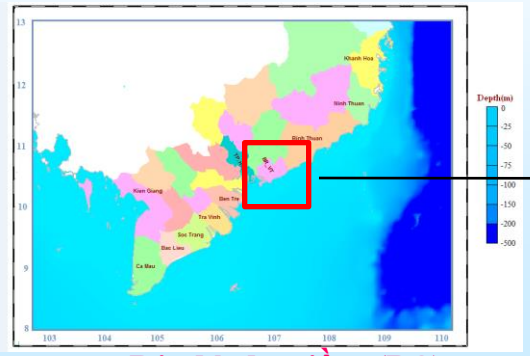
Computational domains for storm surge

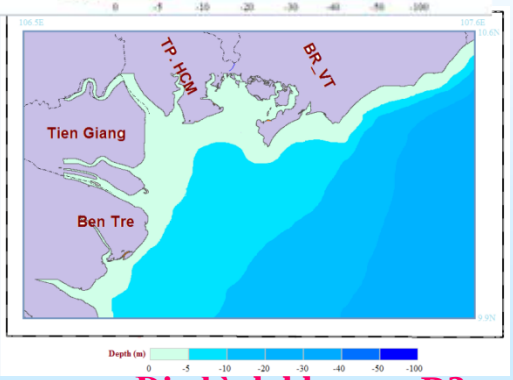












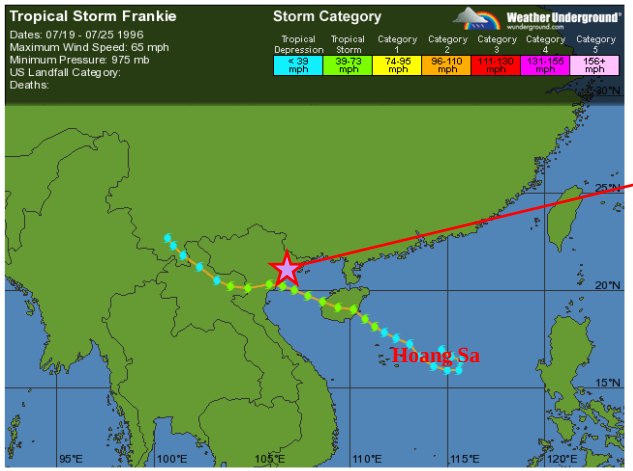
Nesting in 3 domains

Địa hình miền (D2)

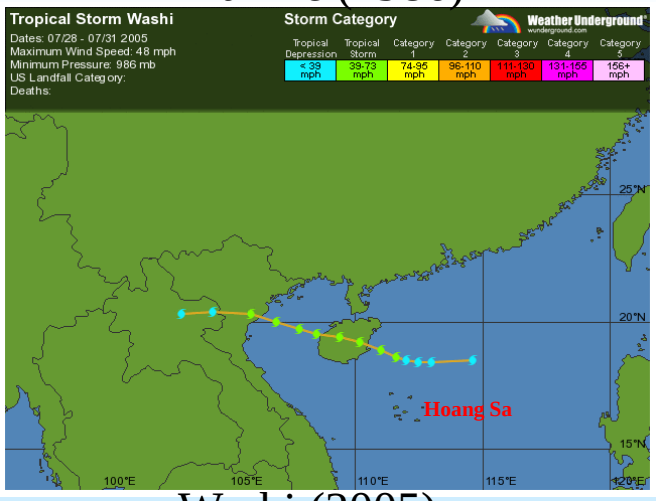
Địa hình khu vực D3

RESULTS – Validation the SuWAT model on storm surge

The North coast:

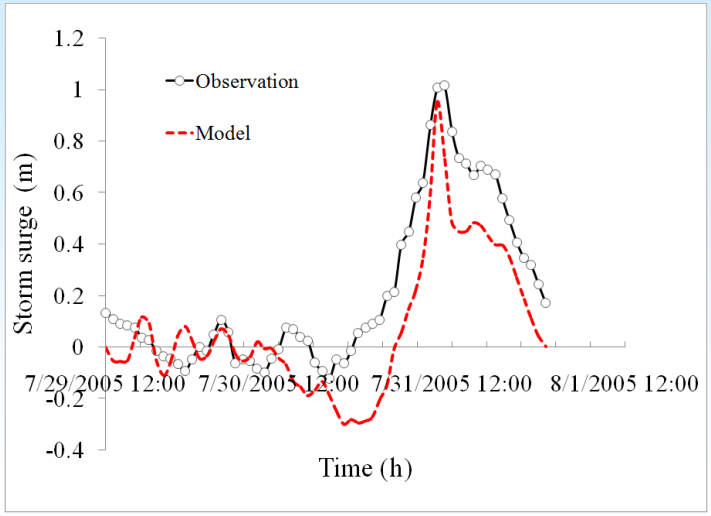


Frankie (1986)

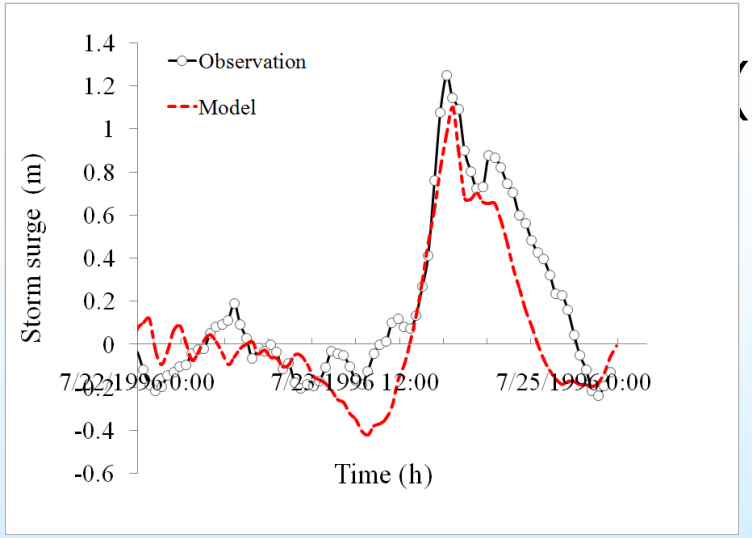


Washi (2005)

Hondau station



(a)

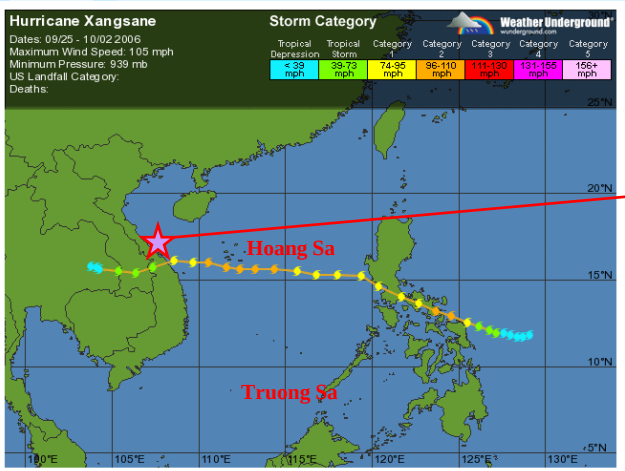


(b)

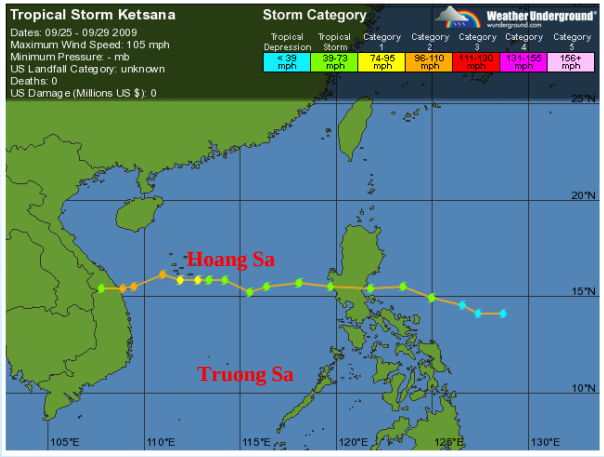
Measured and computed storm surge at Hondau station Induced by typhoon Frankie 7/1996 (a) and typhoon Washi 7/2005 (b)

RESULTS – Validation the SuWAT model on storm surge simulation

The Middle coast :

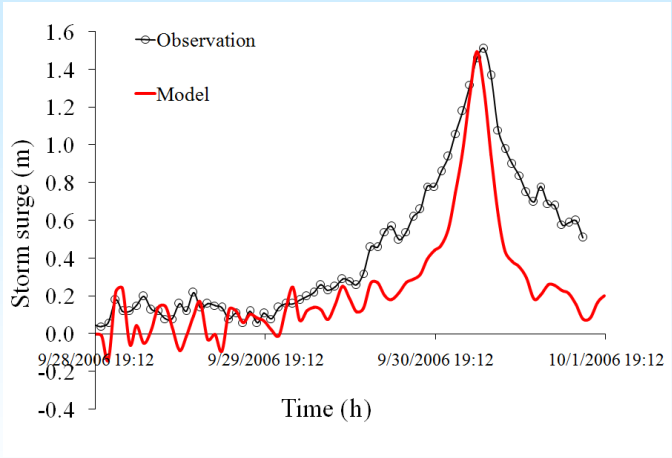


Xangsane (2006)

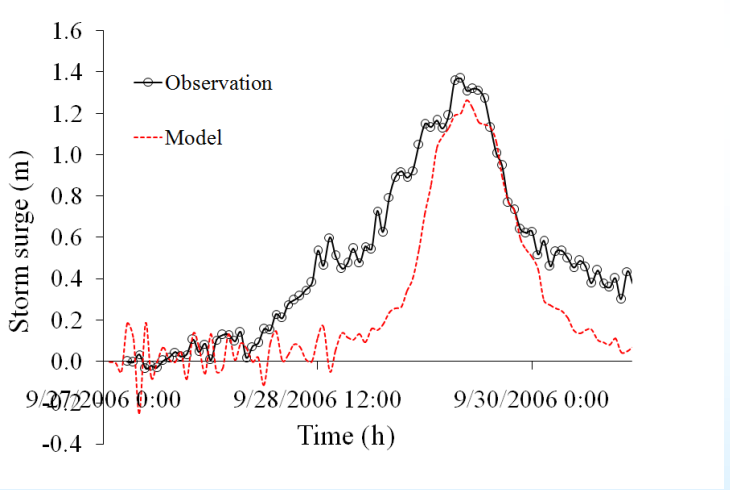


Ketsana (2009)

Sontra station



(a)



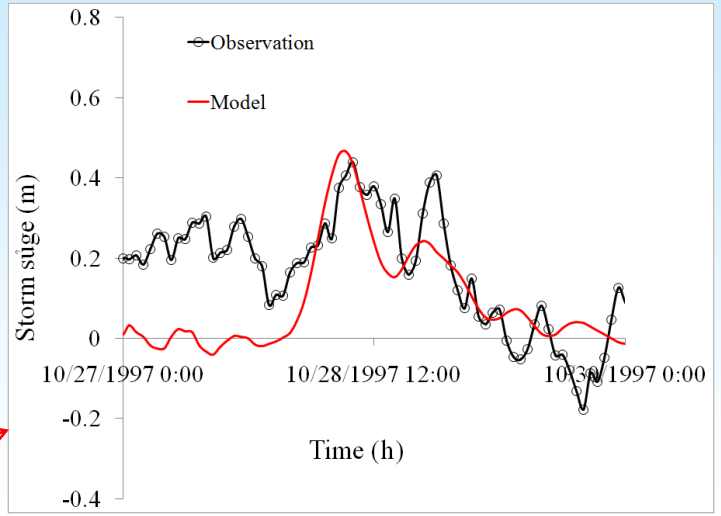
(b)

Measured and computed storm surge at Son Tra station Induced by typhoon Xangsane 9/2006 (a) and typhoon Ketsana 9/2009 (b)

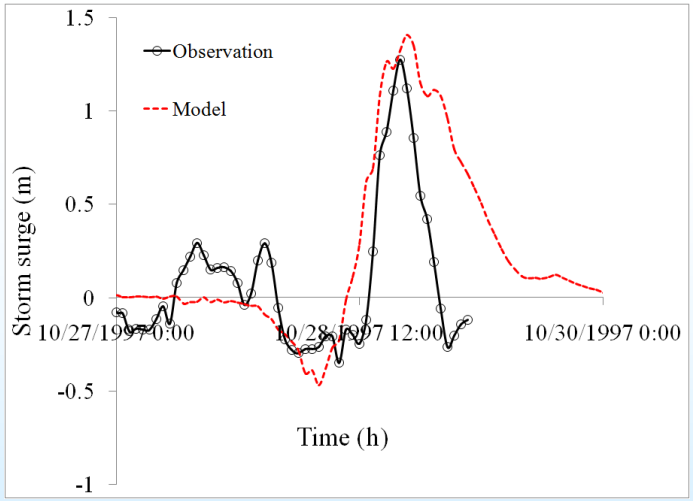
RESULTS – Validation the SuWAT model on storm surge simulation

The South coast :

Track of typhoon Linda



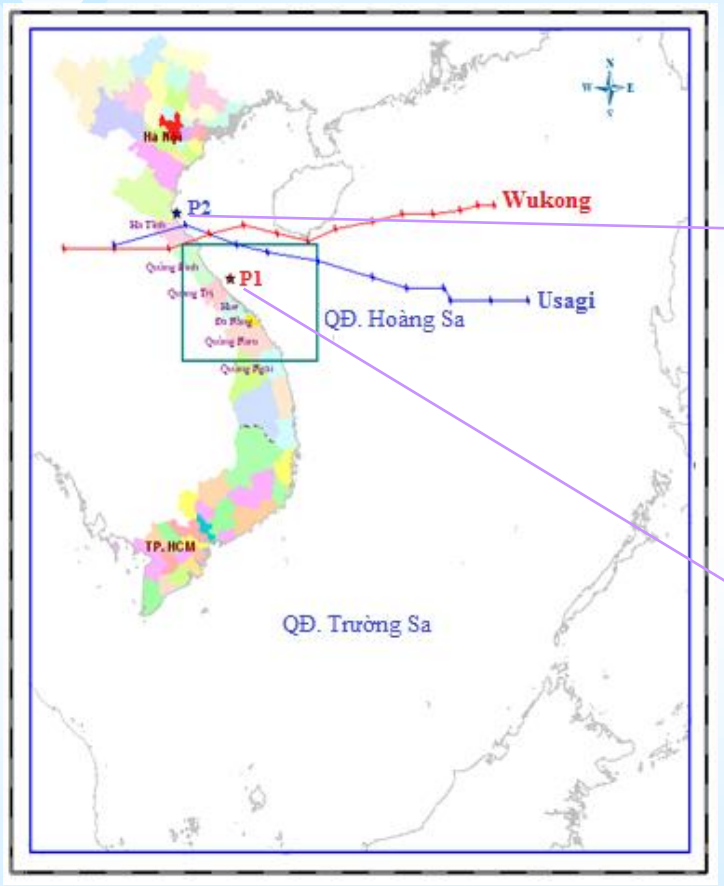
(a)

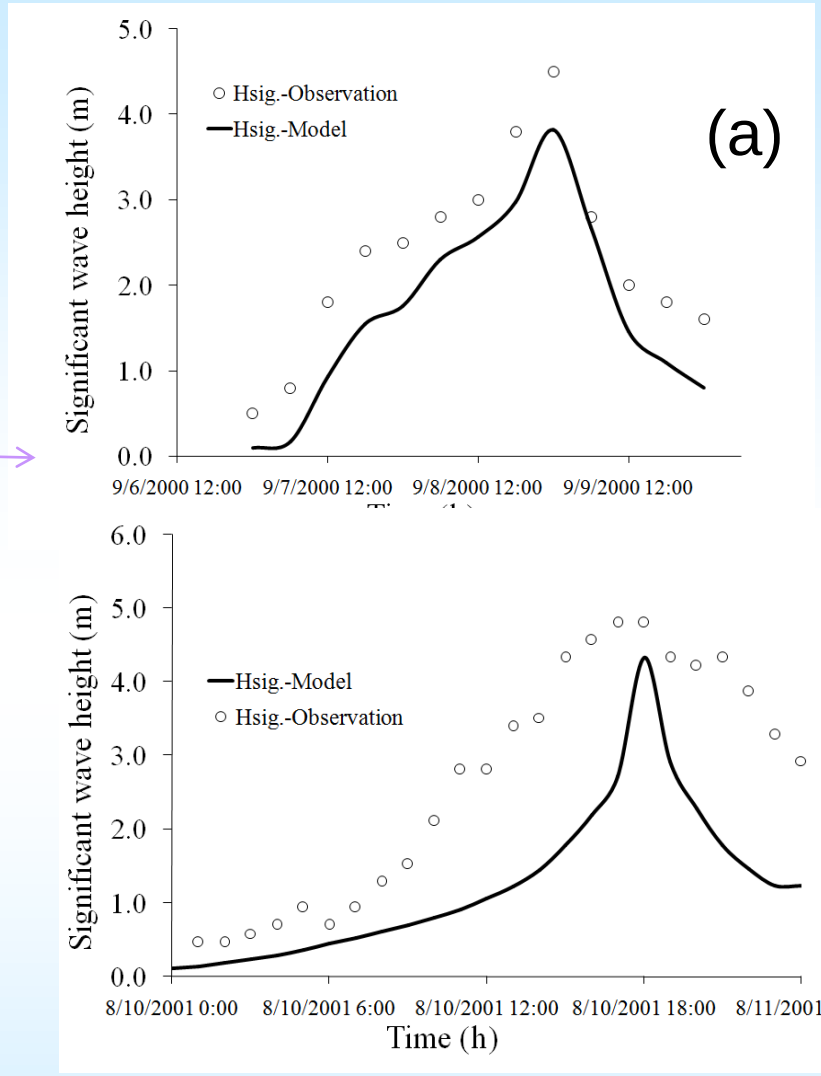


(b)

Measured and computed storm surge at Son Tra (a) and Ghenh Hao (b)
Induced by typhoon Linda 11/1997

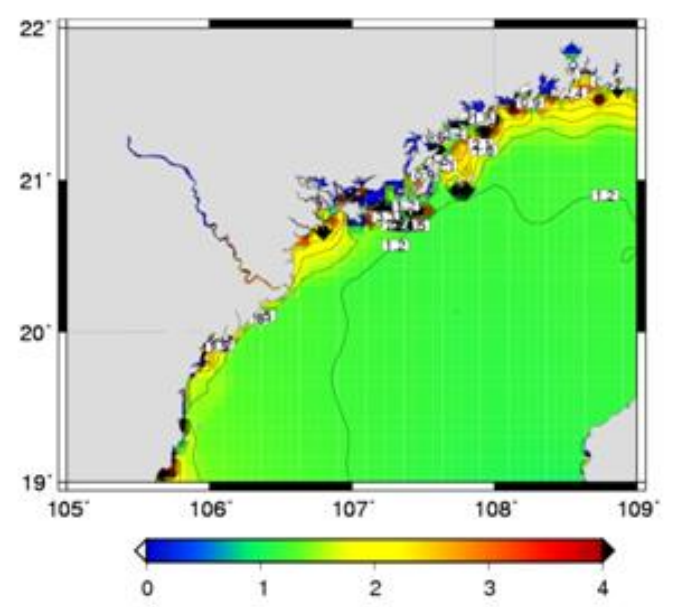
Validation the Model on storm Wave



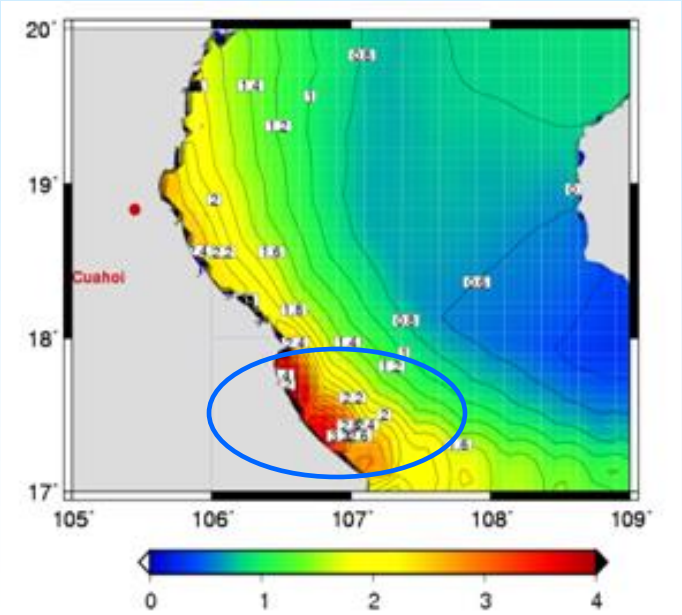


Comparison between measured and calculated significant wave during Typhoon Wukong (9/2000) (a) and Usagy (8/2001) (b)

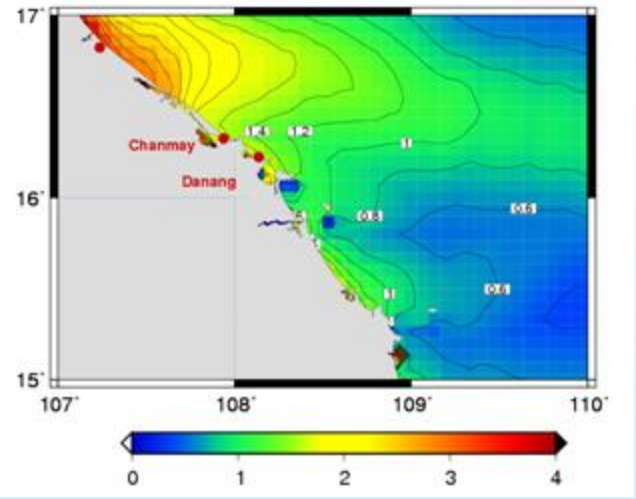
Maximum storm surge in the period of 1951-2016



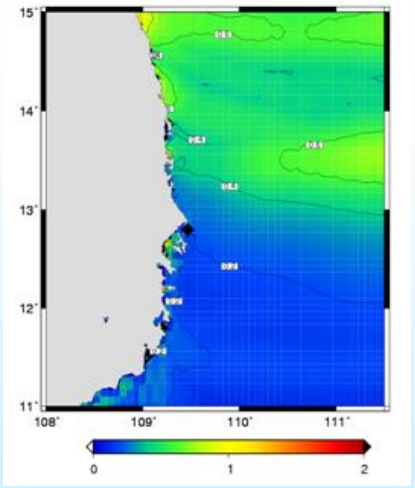
Quang Ninh – Thanh Hoa



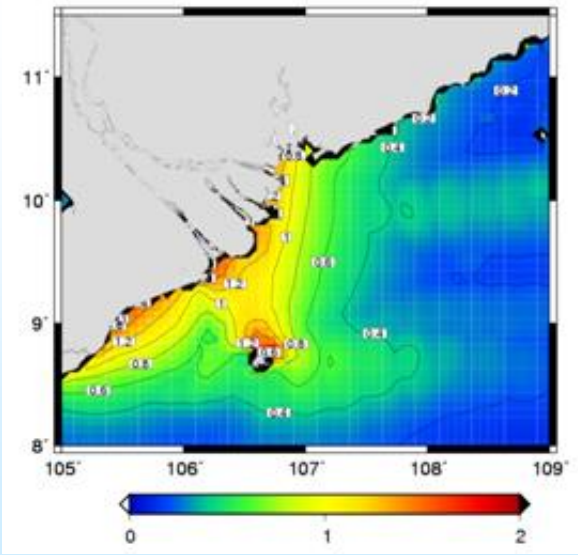
Nghe An – Quang Binh



Quang Tri - Quang Nghai

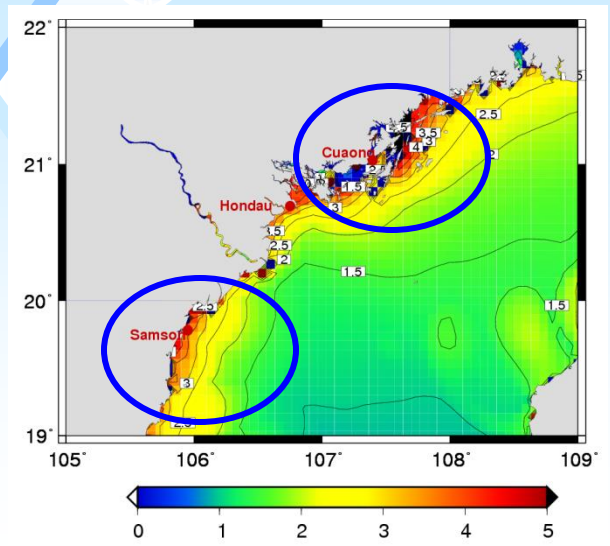


Binh Đinh – Ninh Thuan

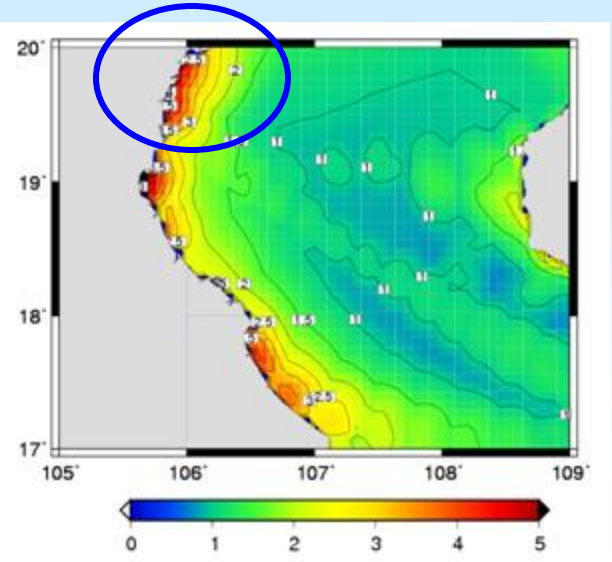


Binh Thuan – Camau

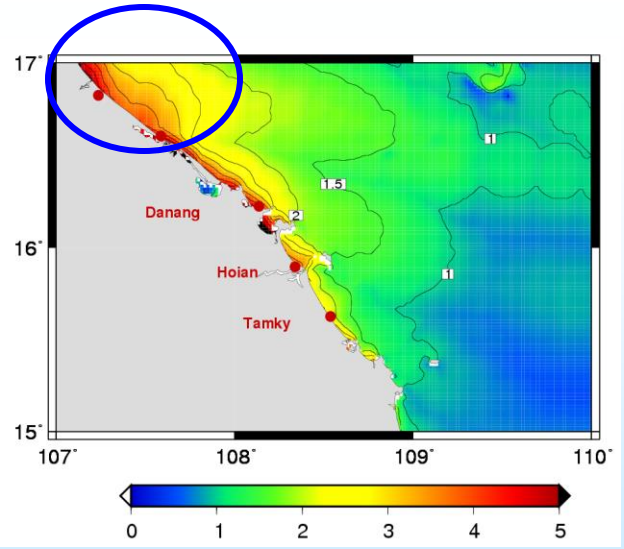
Risk of storm surge (based on 1000 years typhoons)



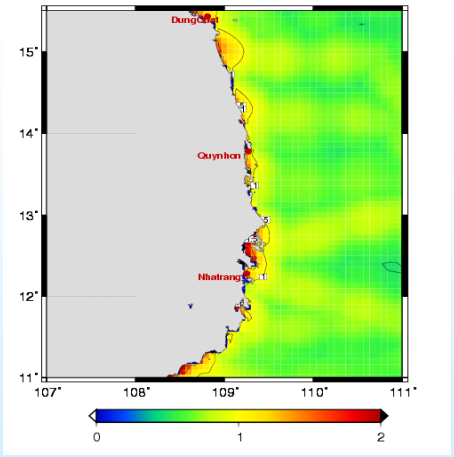
Quang Ninh – Thanh Hoa



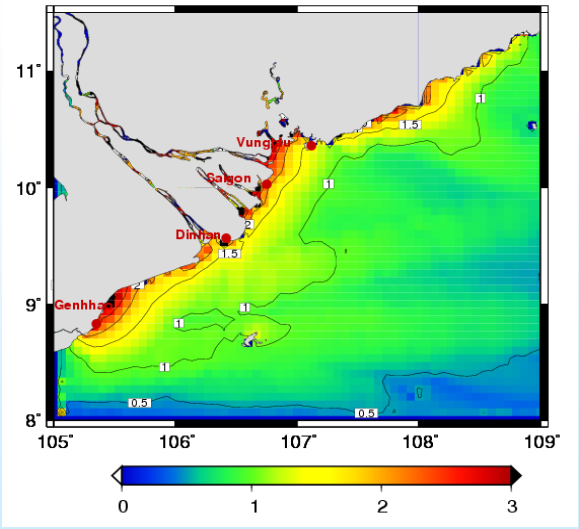
Nghe An – Quang Binh



Quang Tri - Quang Nghai



Binh Đinh – Ninh Thuan



Binh Thuan – Camau

Conclusions

- The coastal provinces from Quang Ninh to Thanh Hoa experienced storm surges up to 3.0m. The South area of Nghe An - Quang Binh and the North of Quang Tri-Quang Nghai storm surges can be reached over 4,0m. Binh Thuan-Ca Mau also recorded storm surges up to 1.5m.

- In the 1,000 years there were 6213 typhoons, of which 4678 typhoon hit the coastal region from Quang Ninh to Ca Mau. In particular, Quang Ninh-Thanh Hoa of level 16, Nghe An-Quang Tri of level 16, Quang Binh-Phu Yen of level 17, Binh Dinh-Ninh Thuan of level 15 and Binh Thuan - Ca Mau of level 13.

- The risk of storm surges in the 1000 year: Highest storm surges are Quang Ninh-Hai Phong (4.5 m), Thanh Hoa-Nghe An (4.0m), Quang Tri (5.0m). The coastal area of Southen part are also at risk of storm surges up to 2.5m.

Future study

-Coastal inundation due to tide, storm surge and wave for each coastal area should be done in future.

- For strong/supper typhoon the model for operational forecasting storm surge should be coupled with tide and wave