Computation of storm and monsoon wave parameters for sea dyke design in Vietnam

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Abstract: For the coastal zones of Vietnam, the storm and monsoon waves are considered as the maximum waves for the designed of the marine constructions as sea dyke and other constructions in the coast and in the marine areas. The most challenges are to choose the appropriate storm wave model, to formulate the wind input data set and especially to find the wave data in such utmost dangerous sea state for model validation and for analyzing the forecast results. In the report, the authors present the results of the wave model validation, assessments of the computed wave heights accuracy in the storm and monsoon weather. The wave observation by satellite, an optimist source of wave data has been also used. The obtains results are promising for the wave computations, for forecasting in general and for the research task of the project "Determining the wave heights for sea dyke design along the coastal line from Quang Ninh to Quang Nam" in particular.

1. Introduction

In the coastal zones of Vietnam, the storm and monsoon wave parameters are considered as the extreme ones for the design of sea dyke and the coastal, marine constructions. The most challenges are to choose an adequate storm and monsoon wave model, to analyze the storm wind data and especially to find the wave data in such utmost dangerous sea state for model validation and for analyzing the forecast results. In the report, the authors aim on the different wave data sources for model validation and the results of the model verification on the storm and monsoon weather in the East Sea.

2. The wave data for storm and monsoon wave model calibration and verification

Focusing on the most reliable wave data set during the storm and monsoon weather, the wave recorded in the weather buoys, in the oil platforms and the satellite wave data (Topex/Poseidon) have been used. The wave parameters recorded in the buoys and platform have very high accuracy and are long around year measurement during all kind of the weather condition including the storms and strong monsoons. An other source of the state-of-the-art wave data which was provided by the NASA's programs are the wave observations by the satellites equipped by the wave sensors – altimeters. The wave observation by the satellite can be provided in all the weather and sea states and almost for wide areas of the sea along the satellite orbit. The satellite Topex/Poseidon has been exploited by NASA from 1992. Each data set is repeated with the period of 10 days [8]. The wave data of this satellite have been used very widely in many marine researches in the world [9], [10]. The different wave data sources have been used in the calibration and verification of the wave model in the storm weather are tabulated in the table 1. The most important for a mathematical model in general and wave model in particular is the model calibration. The wave recorded in the oil platform "White Tiger" have been used for this aim during the passage of the storm named MUIFA in 2004. The table 2 shows the wave data used for wave model calibration during monsoons.

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Table 1. Storm wave data for the model calibration and verification

Storms	Date	Stations (position and depth)	Station owner	Using for
Frankie	7/1996	Buoy VN01A (18.60N 106.25E, 27m)	Marine Hydrometeorological Center	Model verification
Linda	11/1997	Buoy Hua-Hin (11.60N 100.30E, 30m)	GISTDA – Thailand	Model verification
Wukong	9/2000	Buoy 4001 (17.16N 107.38E, 30m)	HMC	Model verification
Muifa	11/2004	Oil platform MSP-1 (10.42N 108.39E, 45m)	VietsovPetro	Model calibration
Ling Ling	11/2001	TOPEX/Poseidon	NASA	Model verification
Imbudo	07/2003	TOPEX/Poseidon	NASA	Model verification

Table 2. Monsoon wave data for the model verification

Date	Stations	Station's owner
01-03/2002	Oil platform MSP-1	VietsovPetro
07-09/2002	Oil platform MSP-1	VietsovPetro
01/2002	TOPEX/Poseidon	NASA
07/2002	TOPEX/Poseidon	NASA
01/2003	TOPEX/Poseidon	NASA
07/2003	TOPEX/Poseidon	NASA
01/2003	Wave recorder DNW-5M	Institute of Mechanics
07/2003	Wave recorder DNW-5M	University of Natural Sciences, Hanoi

3. Calibration and verification of the wave model during storms and monsoons

The results of wave model calibration can be finding in our previous publication [3], focusing on the next step of the model validation, in this report the verification results will be shown. According to the results of calibration, the best fitted value of the physical formulation coefficient of Komen (CDS2) is 0.00001 (equal to the half default value, which is defined as 0.0000236). Based on the calibration result the new value of the coefficient CDS2 has been used for the following wave computation in the storm and monsoon weathers.

3.1. Verification of the wave model during storm weather

Computation of storm waves in storm Frankie (07/1996)

Frankie was in the north of East Sea from 20th to 22nd July 1996, and then the storm increased its strength and hit the Red river delta on 23rd July with the maximum sustained wind speed of 42m/s. The storm caused heavy rain and devastated the coastal zone of the north of Vietnam resulted to 40 depth and more than 200 injuries in human lives. During this time the buoy station of Marine Hydrometeorological Center was exploited in the south of the gulf of Tonkin (18.490^{o}N, 105,840^{o}E) rather far from the storm center so the maximum recorded wave height was not very high. Figure 1 depicts the Frankie path and the position of the buoy station on the left and the recorded and computed wave height during the passage of Frankie on the right.

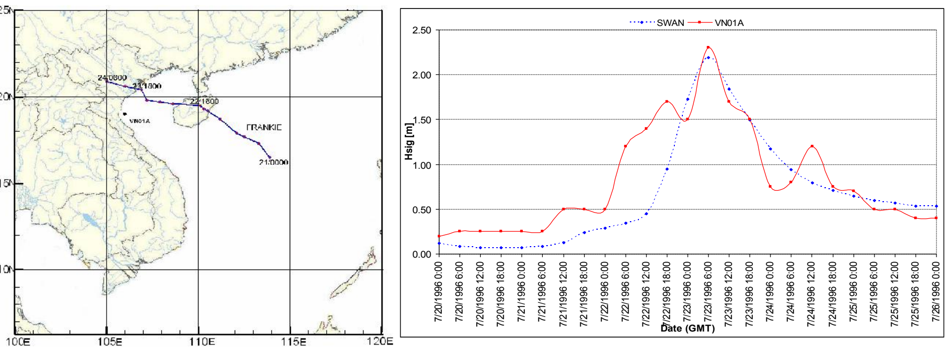

Figure 1. Frankie's path with the position of the buoy VN01A, a comparison of recoded and computed storm wave heights.

Computation of storm waves in storm Linda (11/1997)

Storm Linda formed in the south area of the East Sea, the storm passed the cape of Ca Mau and entered in the Gulf of Thailand on 2nd November and hit to the province of Parchanap Khiri Khan of Thailand. During the 4 day action the storm resulted to the depth of thousand of fish man in Vietnam, Thailand and Cambodia. Further more the storm caused of the surge with the height of 60 cm along the coast of Thailand.

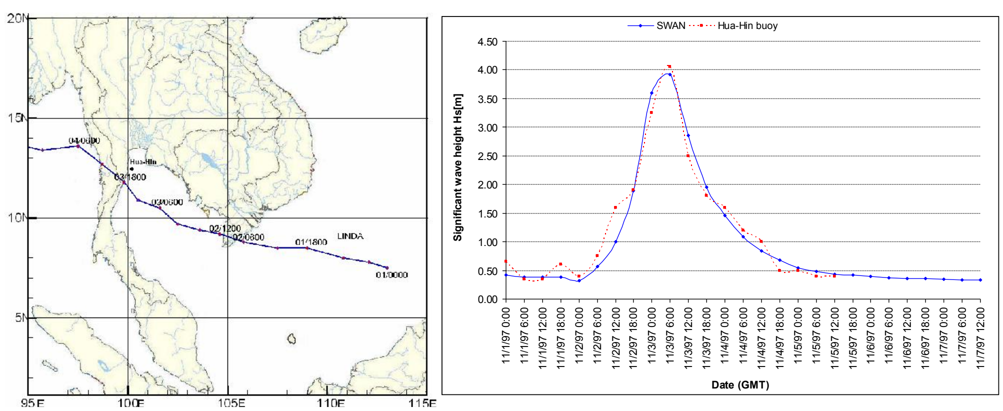

Figure 2. Linda's path with the position of the buoy Hua-Hin, a comparison of recoded and computed storm waves.

In Figure 2, the storm track and the position of the Hua-hin buoy (12.3^{o}N,100.2^{o}E) of GISTDA Thailand is depicted. The computation and recoded wave heights are also shown in the right.

Computation of storm waves in storm Wukong (09/2000)

Storm Wukong was first declared in the north of the East Sea on 4th September 2000. After passing the Hainan Island the storm decreased the strength and hit Nghe An province of Vietnam. During the time, the buoy 4001 was operated in the coastal zone of the Quang Tri province quite near the maximum wind zone of the storm and recorded wave heights are rather high. Similar to the about two storms the path, buoy's position and the comparison of recorded and computed wave heights are shown in Figure 3.

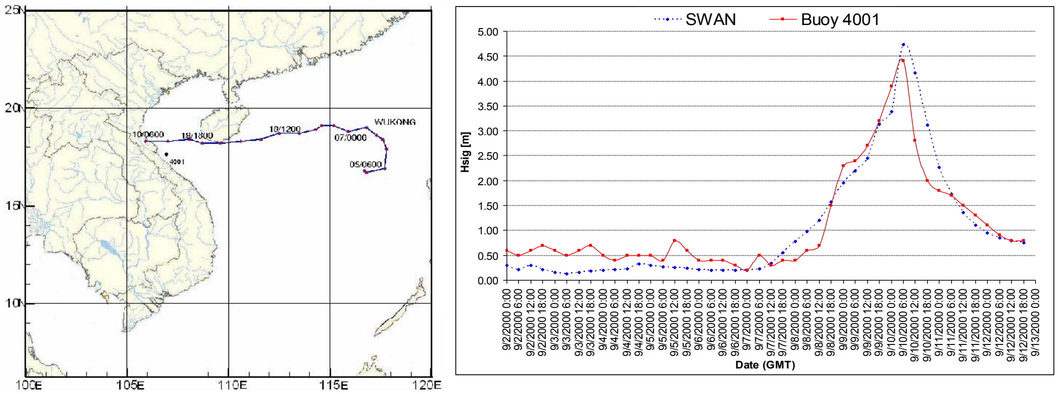

Figure 3. Wukong's path with the position of the buoy 4001, a comparison of recoded and computed storm waves.

Computation of storm waves in storm Ling Ling (11/2001)

Storm Ling Ling formed in the Pacific Ocean, east of Philippines on 6th November 2001. The storm passed Philippines two days later and increasing it strength to became a typhoon with the maximum sustained wind speed of 70m/s. The storm landed in the south path of the central coastal zone of Vietnam (from the provinces of Binh Dinh to Phu Yen) and disappeared in the border of Vietnam and Cambodia.

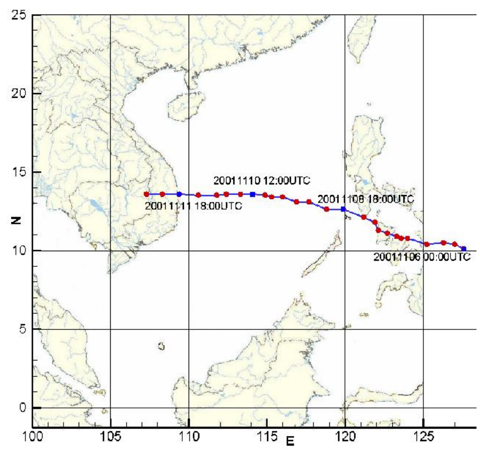

Figure 4. The storm's track of Ling Ling

The storm tract is shown in Figure 4, the storm wave heights computed by the wave model and observed by the satellite at the moment (18h 8th November 2001) during the activity of the storm in the East Sea are shown in Figure 5.

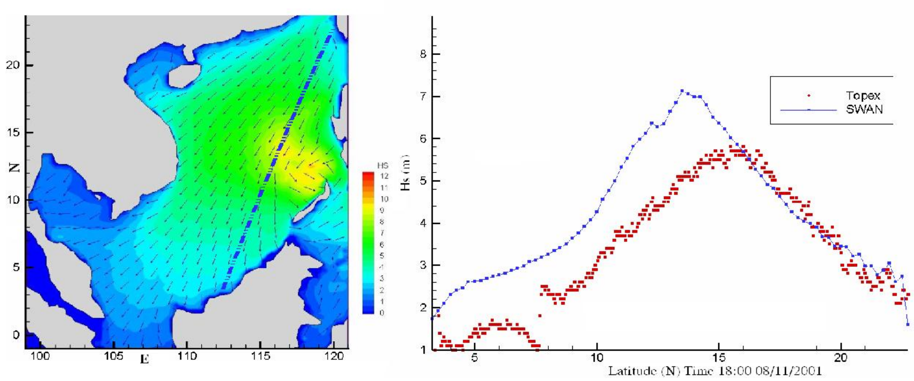

Figure 5. Satellite orbit and a comparison of satellite observed and computed wave heights caused by storm Ling Ling (18h 08th November 2001)

Computation of storm waves in storm Imbudo (07/2003)

Like storm Ling Ling, storm Imbudo formed in the Pacific Ocean, and then the storm passed Philippines and came to the north of the East Sea on 22nd July 2003. After that the storm decreased it intensity and hit to the north part of the peninsular of Loichau, China on 24th July 2003. The storm track, satellite orbit and result of wave heights comparison are demonstrated in Figures 6 and 7.

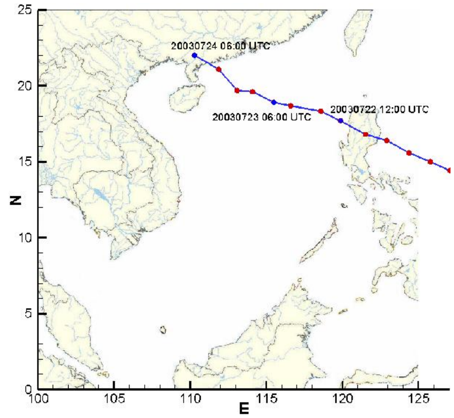

Figure 6. Storm track of Imbudo

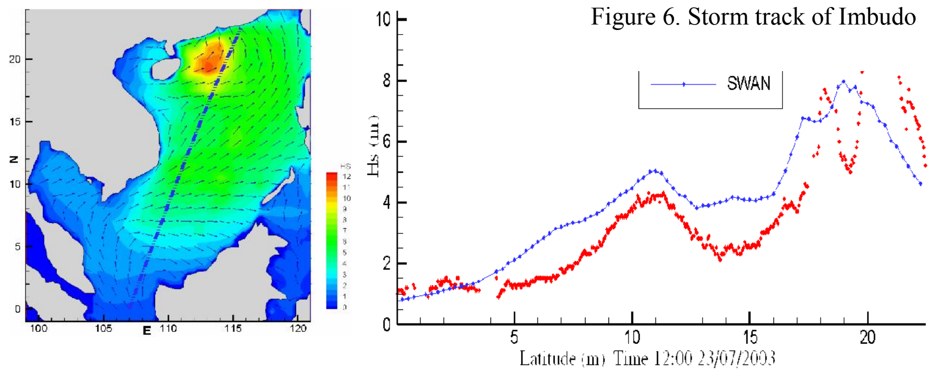

Figure 7 Satellite orbit and a comparison of satellite observed and computed wave heights caused by the storm Imbudo (12h 23rd July 2003).

According to the results of the comparisons, the wave model is rather good in simulating (both in one fix station and in the distribution along the satellite orbit) of the maximum wave heights during the storm and monsoon weathers.

In order to have the quantitative assessments, the values of bias (BIAS) and roof mean square (RMS) have been used to analyze the data set of measurement and computation wave heights of the storms (Frankie, Linda and Wukong) as follows:

$$BIAS = \frac{1}{N}\sum\left(Hcom_i - Hobs_i\right) \qquad (1)$$

$$RMS = \left\{\frac{1}{N}\sum\left(Hcom_i - Hobs_i\right)^2\right\}^{1/2} \qquad (2)$$

Where: N- Number of the wave heights (i), H*comi* – computed wave heights, H*obsi* – recorded wave heights.

The obtained values of BIAS and RMS in the above mentioned three storms are tabulated in the table 3

Table 3. The BIAS and RMS [m] for three storms

Storms	**Accuracy**	
	BIAS	**RMS**
Frankie	-0.144	0.353
Linda	-0.030	0.216
Wukong	-0.078	0.393
Mean	-0.080	0.320

The BIAS is negative for all the three storms which mean that the computed values always less than the recorded. The root mean square values have the mean value of 0.32m is accepted for the storm wave heights computations.

3.2. Verification of the wave model during monsoon weather

For the monsoon climate in the East Sea, two most representative months are chosen as January (for northeast monsoon) and July (for southwest monsoon). The computed wave heights for two the duration of the time are tabulated together with the recorded wave heights in the oil platform MSP-1 and observed wave heights by the satellite for comparisons.

Verification of the wave model during northeast monsoon

Figures 8, 9 and 10 demonstrate the comparison of computed and recorded wave heights at the station MSP-1 from January to March 2002 and the results of the comparison wave height distribution along the satellite orbits in different moments during the winter season.

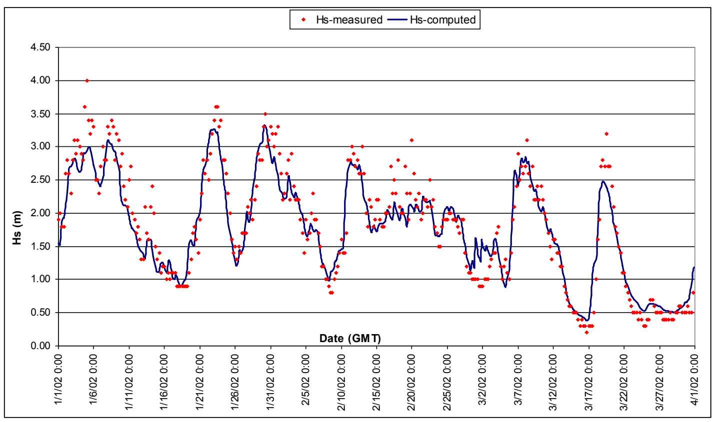

Figure 8. A comparison of computed and recorded wave at MSP-1 from January to March 2002

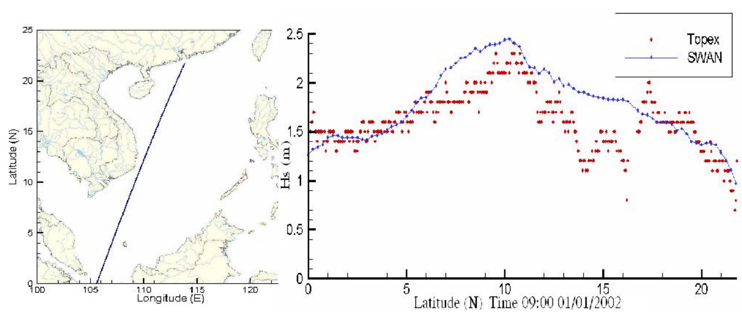

Figure 9. Satellite trajectory and wave heights (computed and observed along the satellite trajectory) at 9h 01st January 2002

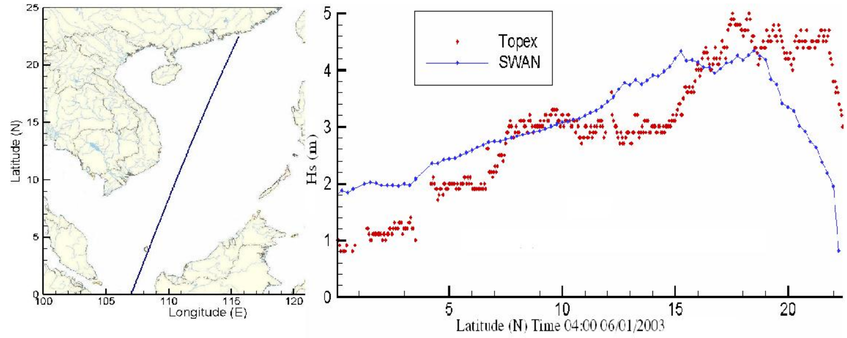

Figure 10. Satellite trajectory and wave heights (computed and observed along the satellite trajectory) at 4h 06th January 2003

The comparison of the computed and recorded wave heights at the coastal zone of the Hai Hau district, Nam Dinh province is shown in the table 4.

Table 4 The comparison of the computed and recorded wave heights at the coastal zone of the Hai Hau district, Nam Dinh province [11].

Date	**LT1**				**LT2**			
	Hcom.	Hmeas.	Hcom–Hmeas	$(Hcom–Hmeas)^2$	Hcom.	Hmeas.	Hcom–Hmeas	$(Hcom–Hmeas)^2$
4/1 -10h	0.35	0.40	-0.05	0.0025	0.34	0.55	-0.21	0.0441
13h	0.41	0.40	0.01	0.0001	0.35	0.39	-0.04	0.0016
16h	0.38	0.38	0.00	0.0000	0.43	0.33	0.10	0.0100
19h	0.41	0.41	0.00	0.0000	0.47	0.51	-0.04	0.0016
22h	0.37	0.46	-0.09	0.0081	0.37	0.41	-0.04	0.0016
5/1 -1h	0.69	0.67	0.02	0.0004	0.60	0.77	-0.17	0.0289
4h	0.78	0.91	-0.13	0.0169	0.69	0.91	-0.22	0.0484
7h	0.99	1.06	-0.07	0.0049	0.90	1.10	-0.20	0.0400
10h	0.96	1.03	-0.07	0.0049	0.88	1.08	-0.20	0.0400
13h	0.90	1.04	-0.14	0.0196	0.85	0.95	-0.10	0.0100
16h	0.81	0.63	0.18	0.0324	0.41	0.66	-0.25	0.0625
19h	0.63	0.77	-0.14	0.0196	0.58	0.69	-0.11	0.0121
22h	0.68	0.76	-0.08	0.0064	0.60	0.63	-0.03	0.0009
6/1 - 1h	0.70	0.78	-0.08	0.0064	0.60	0.76	-0.16	0.0256
4h	0.86	0.98	-0.12	0.0144	0.57	0.60	-0.03	0.0009
7h	0.69	0.81	-0.12	0.0144	0.39	0.68	-0.29	0.0841
10h	0.61	0.70	-0.09	0.0081	0.46	0.40	0.06	0.0036
13h	0.49	0.58	-0.09	0.0081	0.51	0.33	0.18	0.0324
16h	0.33	0.37	-0.04	0.0016	0.29	0.28	0.01	0.0001
19h	0.42	0.40	0.02	0.0004	0.32	0.34	-0.02	0.0004
22h	0.57	0.44	0.13	0.0169	0.50	0.40	0.10	0.0100
7/1 –1h	0.33	0.35	-0.02	0.0004	0.28	0.29	-0.01	0.0001
	BIAS = - 0.044 ; RMS = 0.092				BIAS = - 0.076 ; RMS=0.138			

Verification of the wave model during southwest monsoon

Similar to the northeast monsoons, Figures 11, 12 and 13 demonstrate the comparison of computed and recorded wave heights at the station MSP-1 and the results of the comparison wave height distribution along the satellite orbits in different moments during the summer season of 2002.

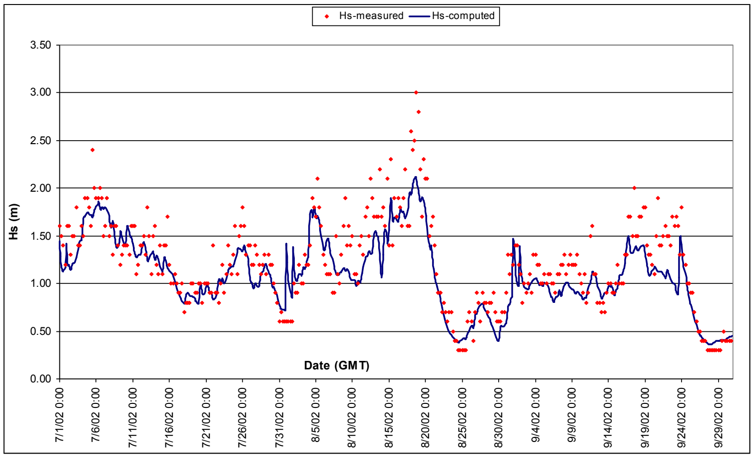

Figure 11. A comparison of computed and recorded wave at MSP-1 from July to September 2002

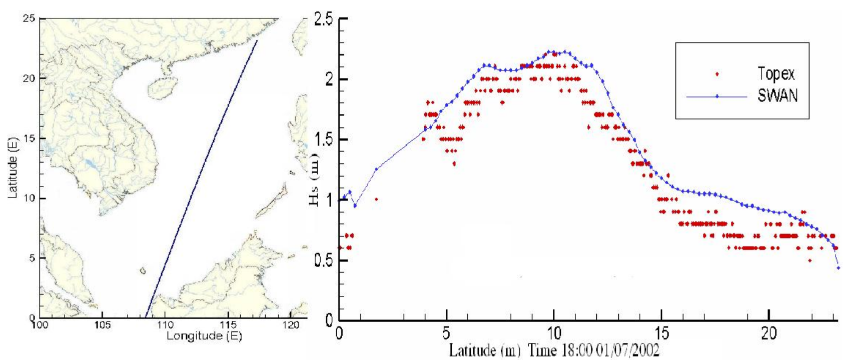

Figure 12. Satellite trajectory and wave heights (computed and observed along the satellite trajectory) at 18h 01st July 2002

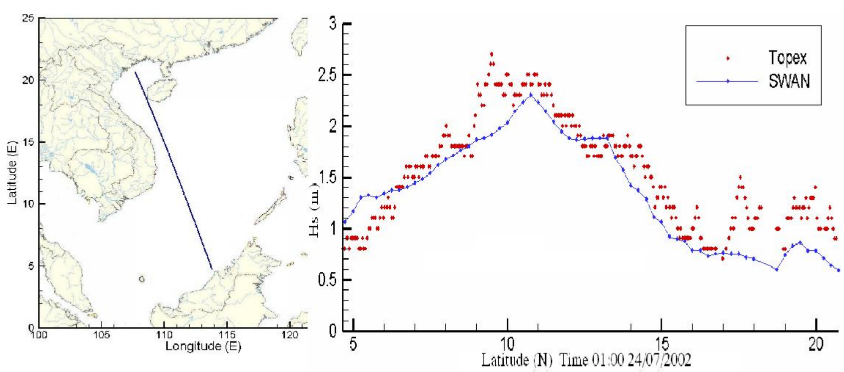

Figure 13. Satellite trajectory and wave heights (computed and observed along the satellite trajectory) at 1h 24th July 2002

4. Conclusions

With the average of 4-5 storms hitting the Vietnamese coastline every year and some decades of monsoons, our country is suffering from great damage of infrastructures and lost of human lives. Storms and monsoons induced significant waves which, especially in the coastal zones, can destroy houses, dyke, and move large amounts of sand from beaches to the offshore resulting in shoreline erosion. Therefore modeling of storm and monsoon waves is an important task of all the engineers and scientists. In order to meet the need of obtaining the adequate wave modeling at all and to fulfill the research task of the project "*Determining the wave heights for sea dyke design along the coastal line from Quang Ninh to Quang Nam*" of the program "*The program of sea dyke upgrading for development of economy and society of the coastal zones and estuaries*" in particular, the authors have developed the SWAN model for storm and monsoon waves computation. The most challenge is to collect the adequate wave data for model calibration and verification. The several of data sources have been obtained including the observed wave parameters by satellite. The SWAN model fist has been calibrated by the waves recorded at the oil platform MSP-1 during the activity of the storm MUIFA, then with the calibrated coefficient CDS2 the model have been used to simulate storm and monsoon waves for many storm and monsoon events. The computed wave heights shows reasonably well fitted with the measured values. The obtained results afford the promising of using the SWAN model in research and forecast.

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