Study of currents and sediment transport in local zones of U-Minh using Telemac (flow simulations), Tomawac (wave conditions) and Sisyphe (sediment simulations)

1. Introduction

In order to study the erosion process in the coast of U-Minh, Go Cong (in Mekong Delta), various numerical models are used simultaneously including Telemac2D (hydrodynamic), Tomawac (wave) and Sisyphe (sediment transport). Based on the calibrated parameters of local model (Report No.1), the following content presents the results of hydrodynamic, waves and sediment for the U-Minh coastal area, especially from the Bay-Hap to Ong Doc River, using more detailed computing mesh.

2. Study area and boundary conditions

The local area of interest is the western coastal area of the Mekong Delta, which is confined to the south, abutting the Gulf of Thailand. The average width is 40 km from the coast and 126 km from Ca Mau Cape to the north. This study area is characterized by 87 thousand unstructured triangle elements of which the largest mesh is up to 2000m (offshore elements) and the smallest is 8m (or 3m in case of built-in wavefronts) for the coastal zone.

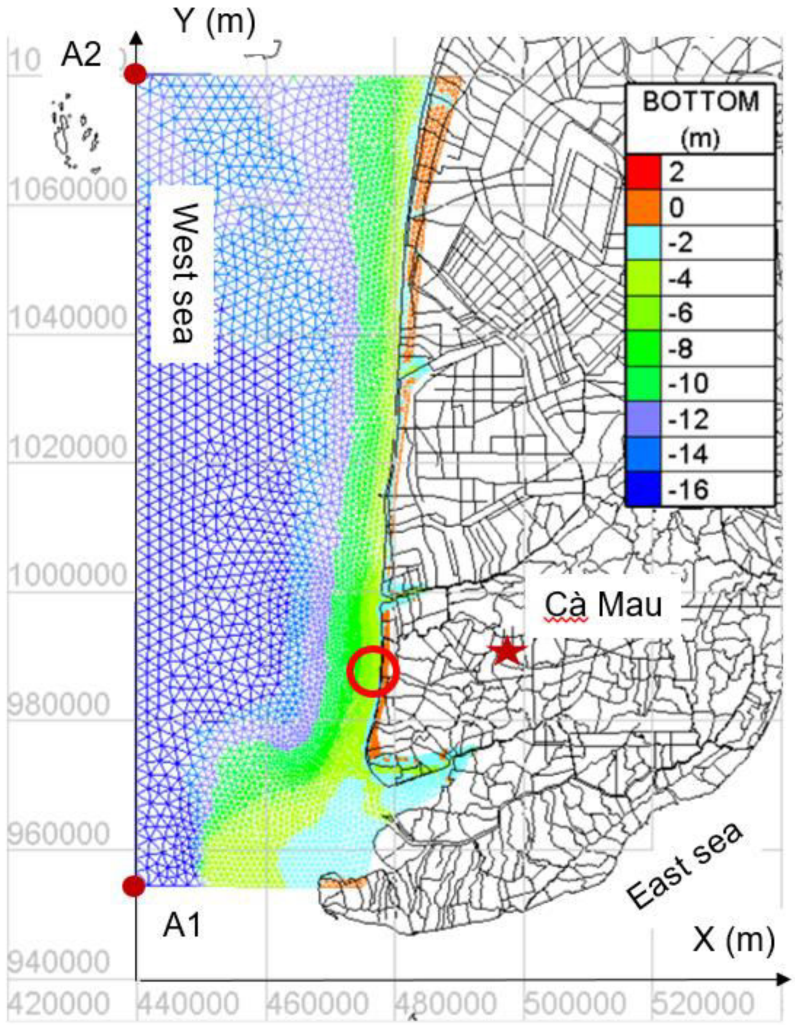

Figure 2.1a: The local study area

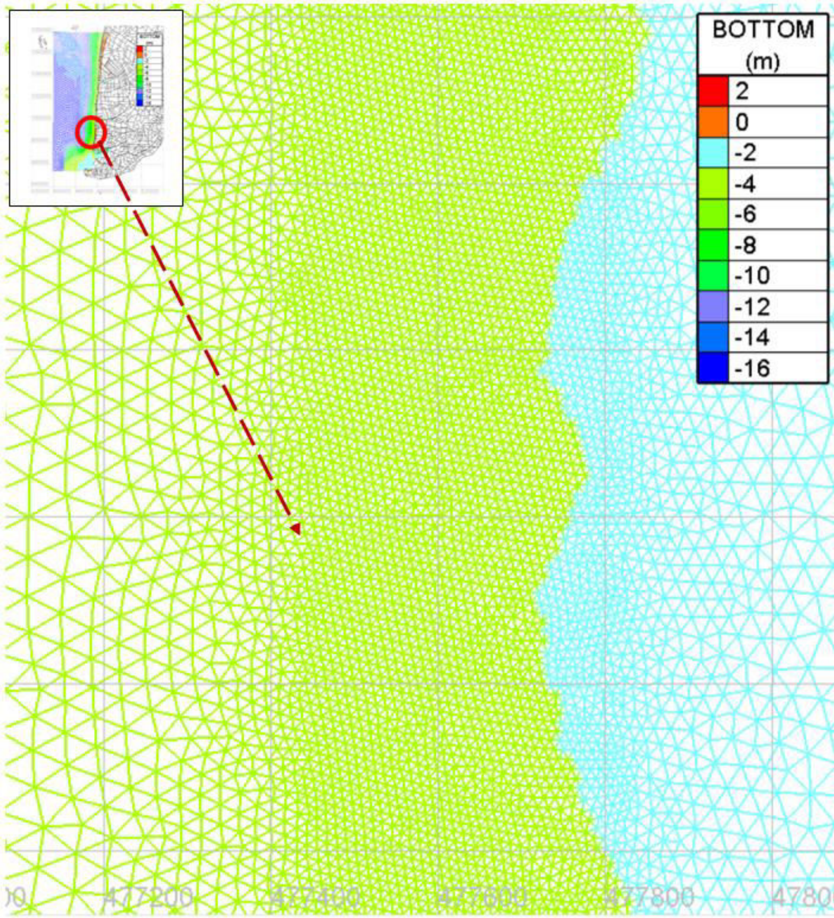

Figure 2.1b: Detailed mesh in coastal area (d_{min}=3m ÷ 8m)

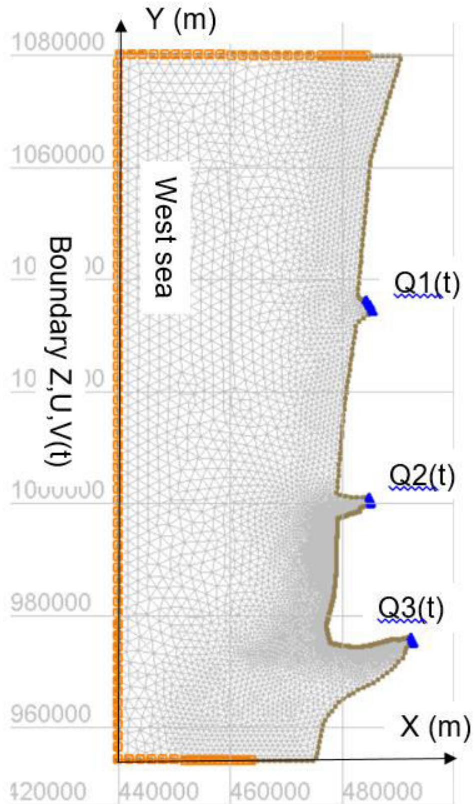

Figure 2.2: Boundary conditions

Tidal: The open boundary at offshore is determined from astronomical tide extracted from TPXO database during the study period.

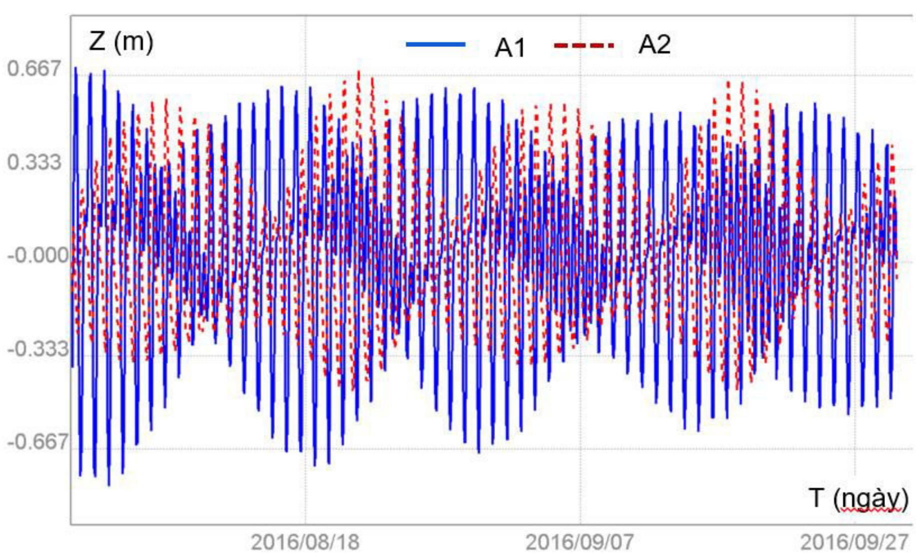

Figure 2.3: Tidal boundary at typical positions A1 and A2 during Aug. & Sep 2016

Wave: At the open boundary, wave data is determined from a global database of wind and wave effects on the surface domain determined from NOAA for the boundary conditions of the Tomawac model

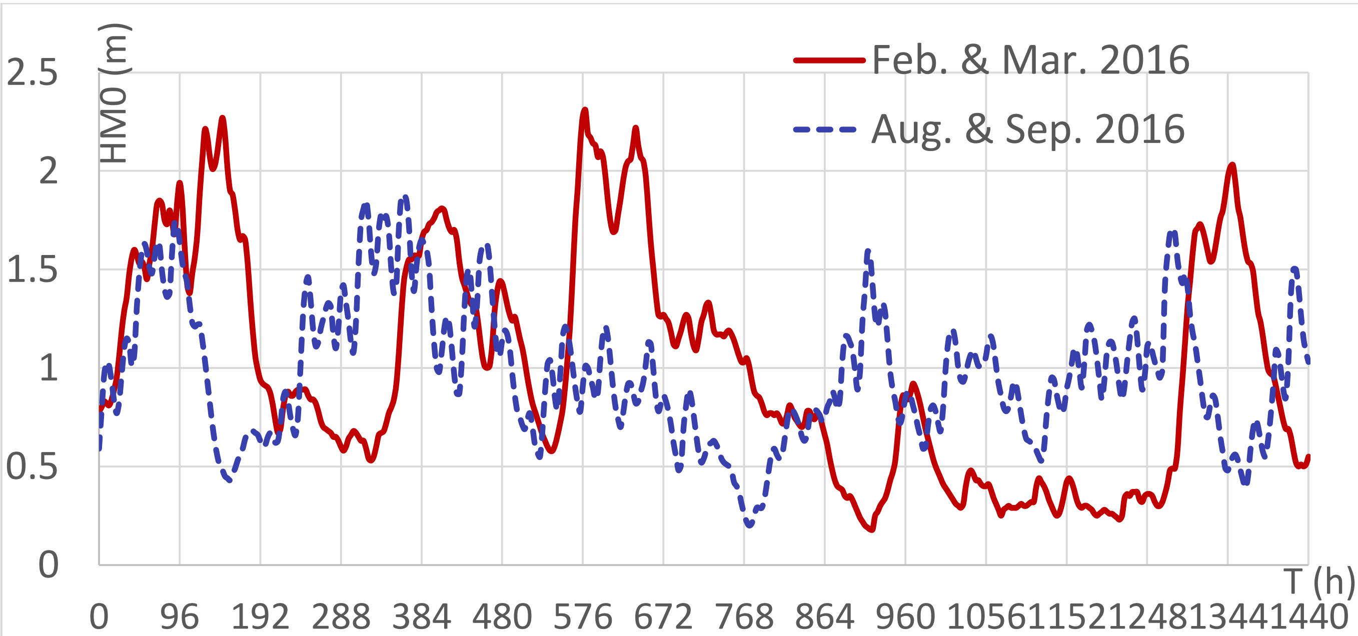

Figure 2.4a: Wave height HM0 from NOAA at coordinates (334682.9 ; 884599.1)

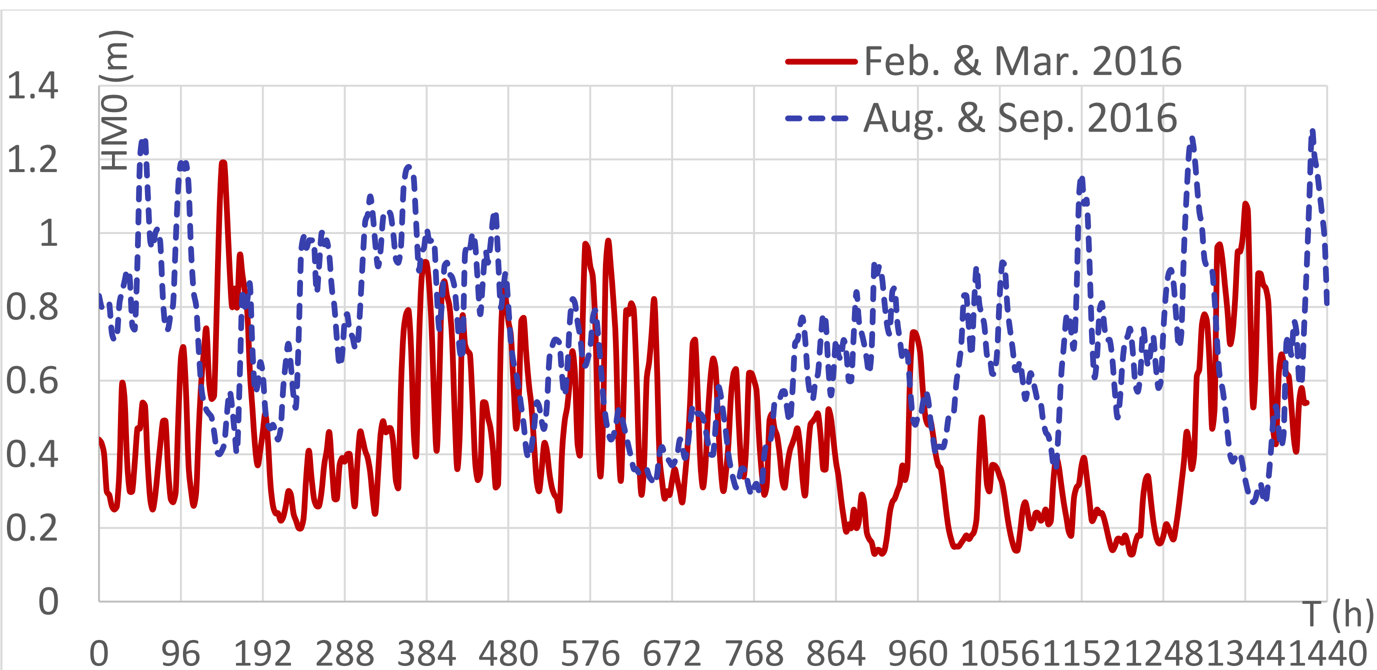

Figure 2.4b: Wave height HM0 from NOAA at coordinates (335343.7 ; 1050487.3)

The data from the two graphs show that the trend in wave intensity in the East Sea is usually greater than that in the West Sea.

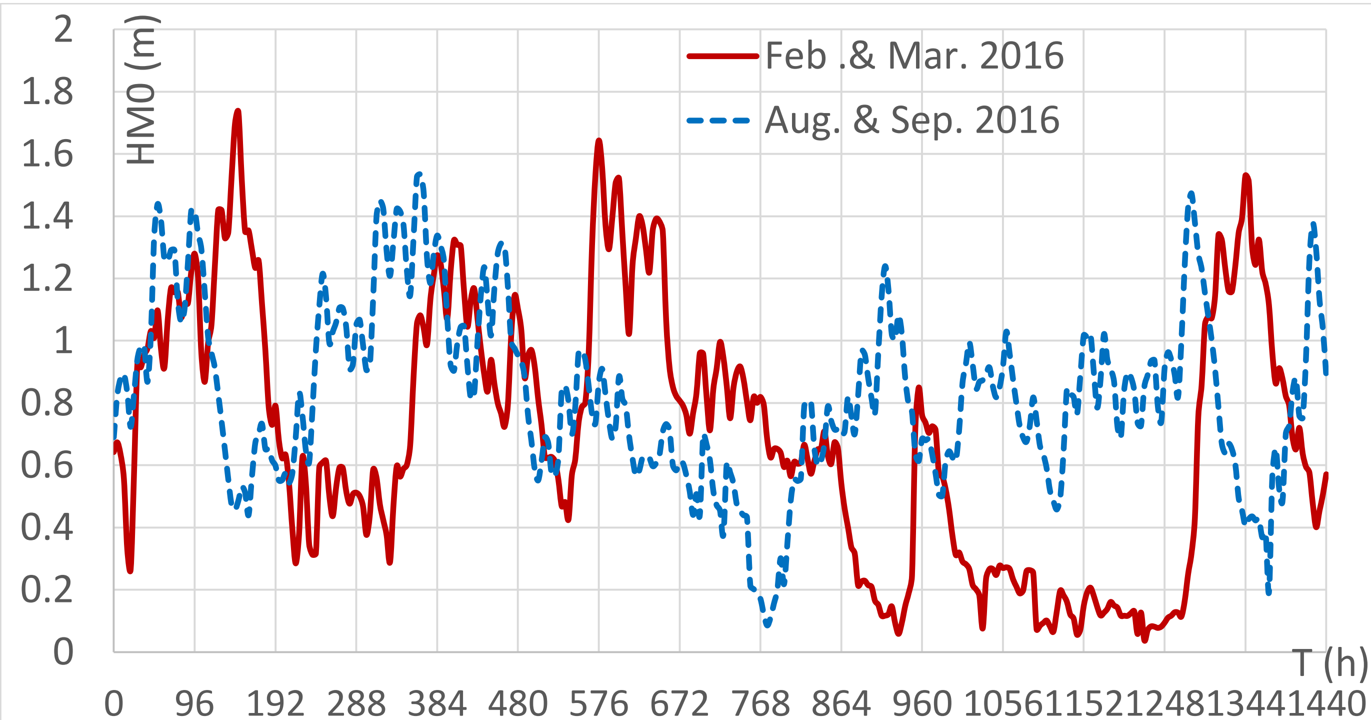

Figure 2.4c: Wave height HM0 from NOAA at position A1 of coordinates (439869.6 ; 954419.1)

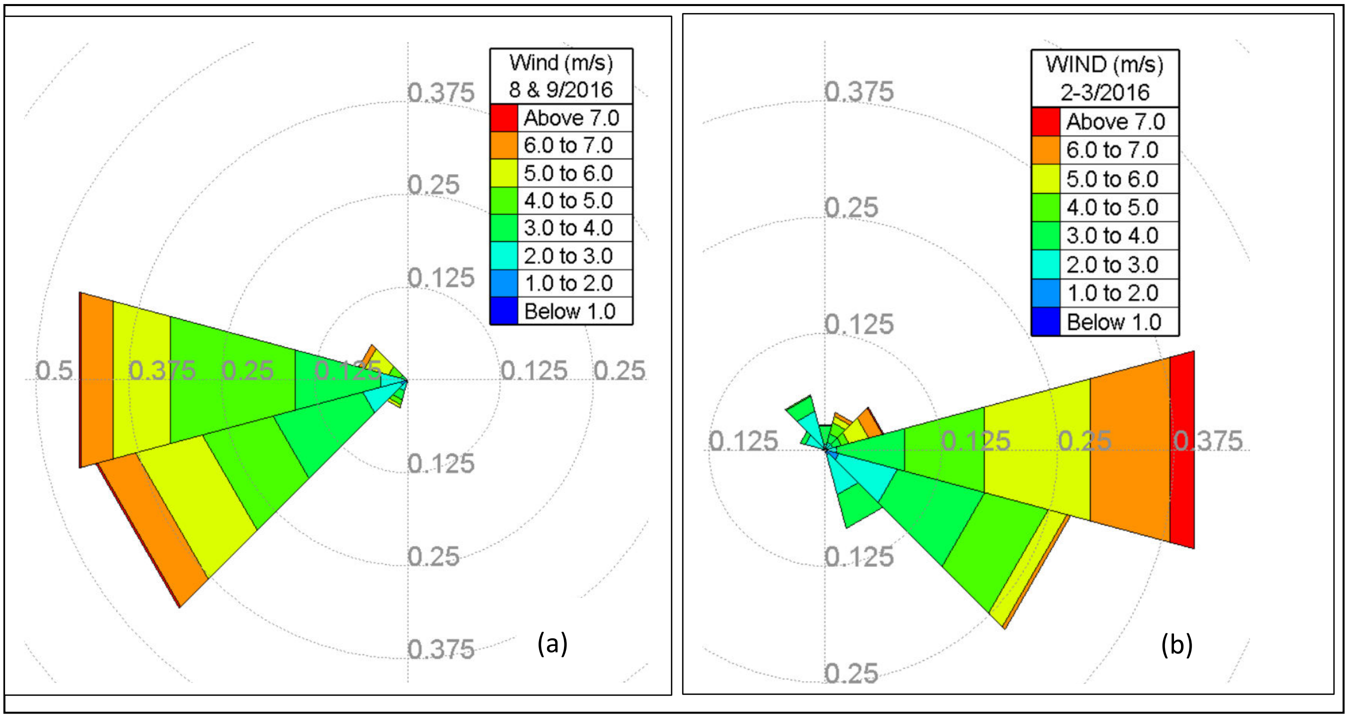

Figure 2.5: Typical wind rose in U-Minh coast in: (a) 8-9 /2016 and (b) 2-3/2016

The results from the wind rose show that there are two monsoonal periods. In the months of January & February, the winds are relatively intense compared to August and September. Wind direction in January & February is mainly from the East, while in August and September; it is mainly in the west and southwest.

Discharge: Discharges in Ong-Doc river are taken as follow:

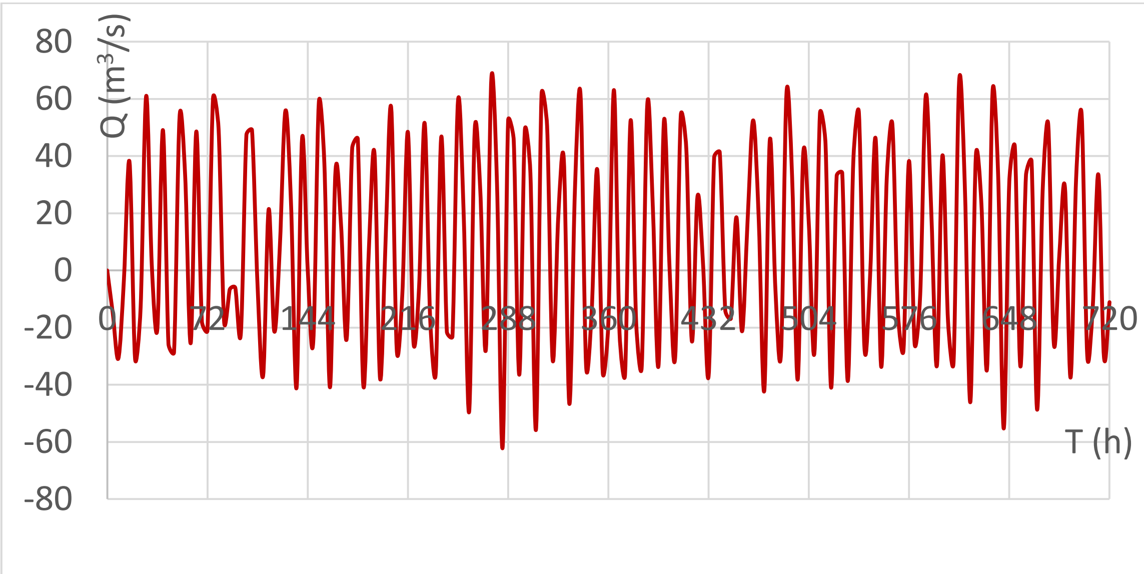

Figure 2.6: Discharge in Aug. 2016 at Ong-Doc river.

Sediment

Simulation of sediment transport in the area is considered as non-cohesive transport. The distribution of sand is assumed to be uniform throughout the study area. From the monitoring data of granular, the particle size is divided into four representative sizes: 0.06mm, 0.125mm, 1.0 mm, 1.5mm; with the initial rates of 40%, 30%, 20% and 10%.

The boundary conditions are:

- The open offshore boundary is free and in balance condition.
- In the upstream areas, the boundary conditions are specified as Direclet type using monitoring level.

The main parameters of simulation are as follows:

- The law of friction is set as Nikuradse's law.
- The bottom sediment transport model is set as Soulsby - Van Rijn's law.
- The settling velocity is determined by the Van Rijn, depending on the characteristic of the sediment layer.
- The Shields value in Van Rijn's equation depends on the dimensionless dimension of the sediment class.

3. Model calibration

The model was calibrated with monitoring stage at the Ong-Doc River and wave measured from October 15, 2016 to October 31, 2016 at the coordinates (464620,1029689.9).

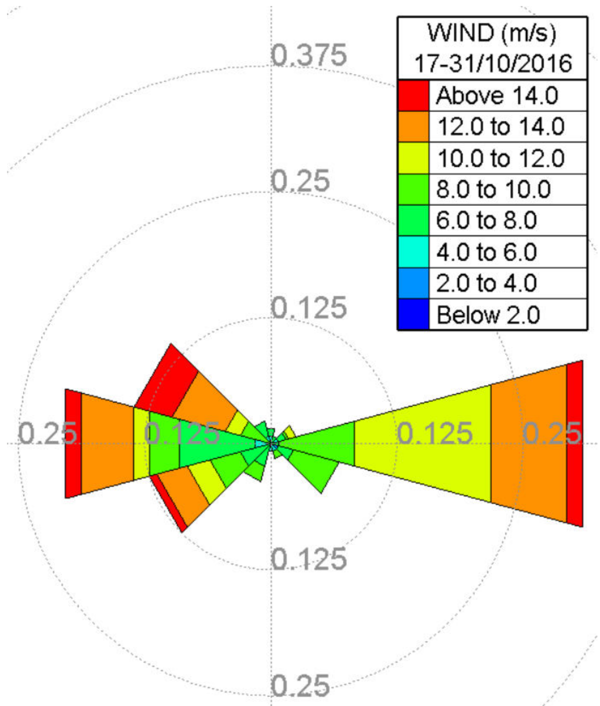

Figure 3.1: Distribution of wind in a typical position at U-Minh coast from 17/10/2016 to 31/10/2016

Analysing wind direction data show that there are two distinct trends during this period:

- In the period from 17/10/2016 to 26/10/2016, the east wind is changing from 45^0 to 135^0.
- In the period from 26/10/2016 wind direction is mainly west with wind angle of about 270^0.

This result is clearly reflected in the mean wave direction result at the following review position.

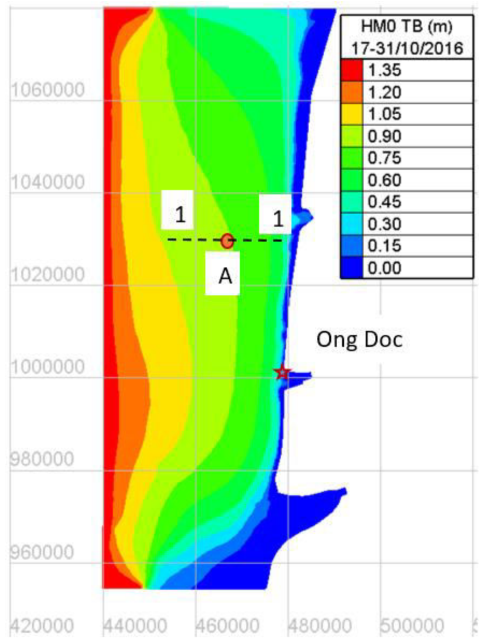

Figure 3.2: HM0 wave field average from 17/10/2016 to 31/10/2016

a. Stage calibration

The results of stage calibration at Ong Doc's gauge station are shown in the following graph:

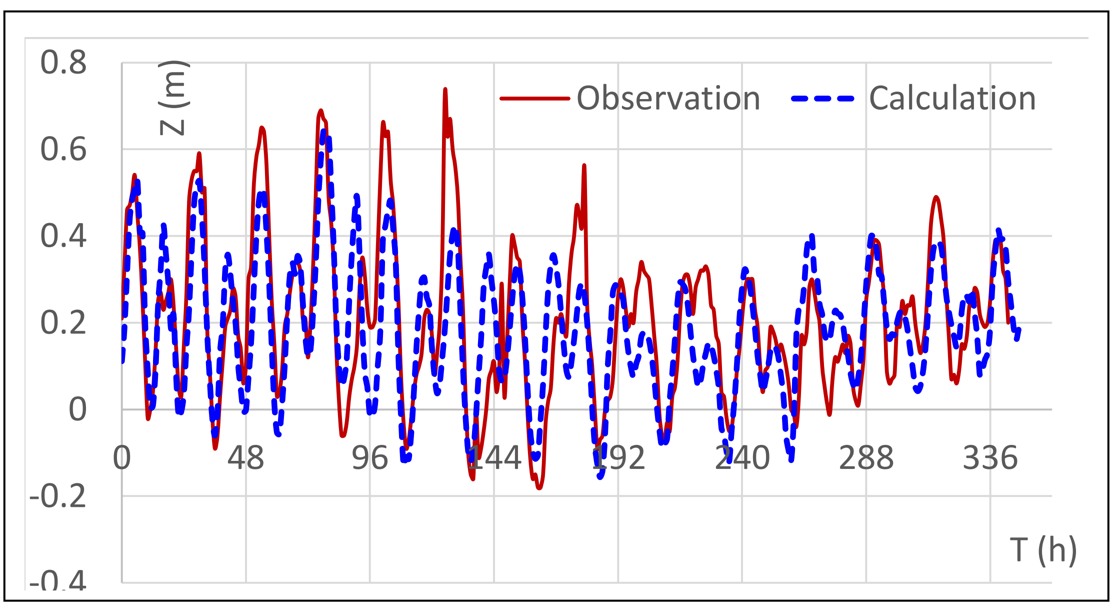

Figure 3.3: Comparison of stage from monitoring data and simulation at Ong Doc from 17/10/2016 to 31/10/2016

The NASH indicator assesses the suitability of the observed value and the calculated value was 0.56. This relatively small value is explained by two main causes: tide data collected from NOAA global data in the West Sea are quite complex, with poor accuracy and topography data has not been updated.

b. Wave calibration

The wave calibration results of the model are summarized in the following graphs:

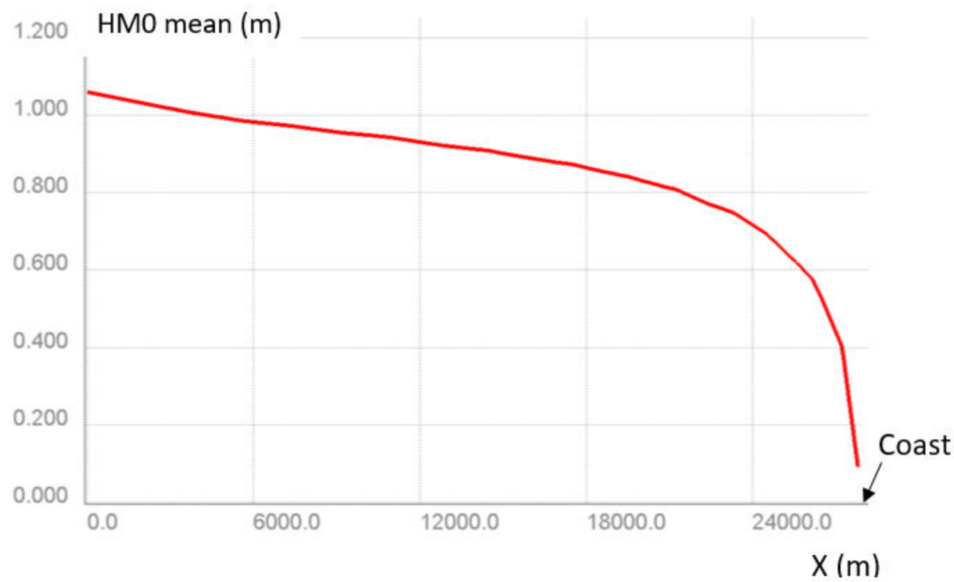

Figure 3.4: Average wave height HM0 at section 1-1

The above graph shows the reducing effects of coastal wave due to topographic bottom friction, which play an important role in this area.

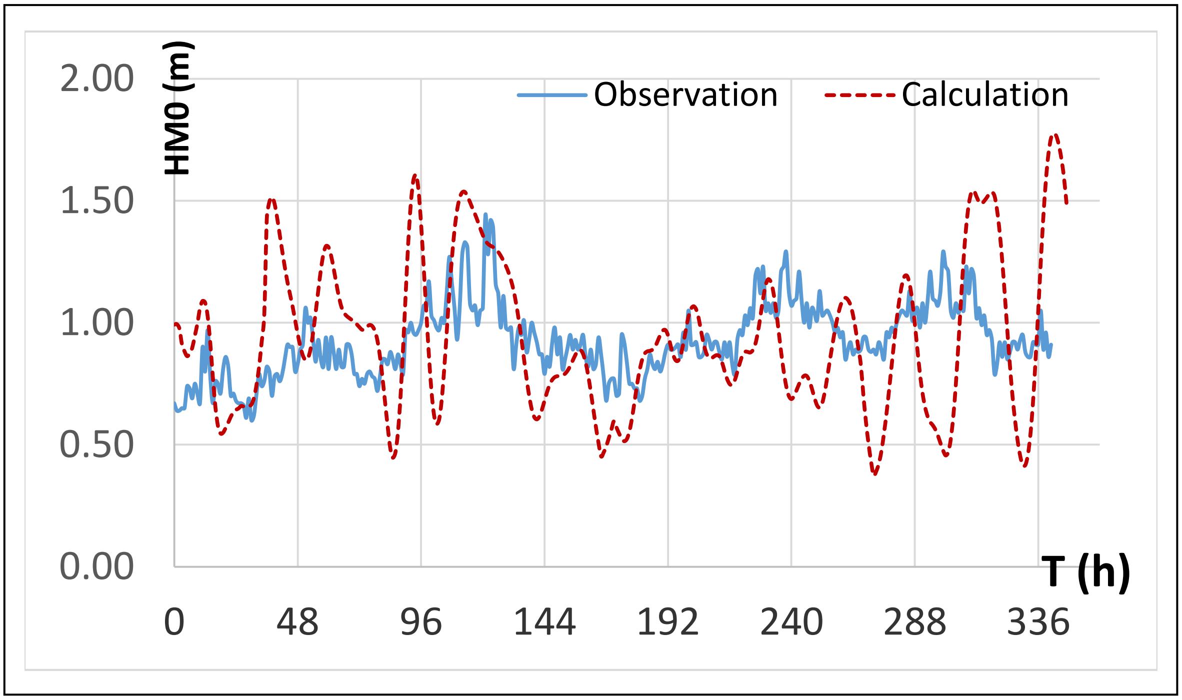

Figure 3.5: Wave HM0 at position A (464620,1029689.9) for the period 17/10/2016 to 31/10/2016

The graph shows that the mean value of the HM0 wave between observation and calculation is relatively appropriate; however the maximum and minimum values are quite different.

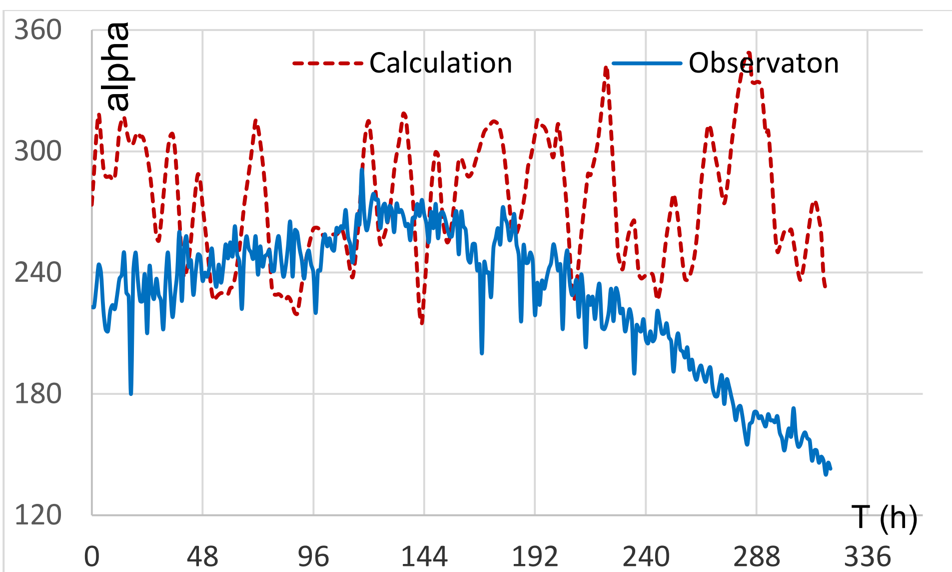

Figure 3.6: Wave direction (compared to the south) at A (464620.,1029689.9) for 17/10/2016 to 31/10/2016

The graph shows that the wave direction at position A (about 14 km from the shore) is almost perpendicular to the coast (270^0). This result is consistent with the measured wave location point A near coast and the monsoon of wind following east during this time (from October 17, 2016 to October 26, 2016). While the observation data shows that the wave direction follows the trend toward the north with a mean coastline of 50^0.

The wave direction after 240h is highly variable in the simulated results, which can be explained by the change in wind direction (mainly from East to West, see Figure 3.1).

c. Sediment calibration

The following results show the results of the average sediment computed in October 2016 and compared with the results obtained from satellite data.

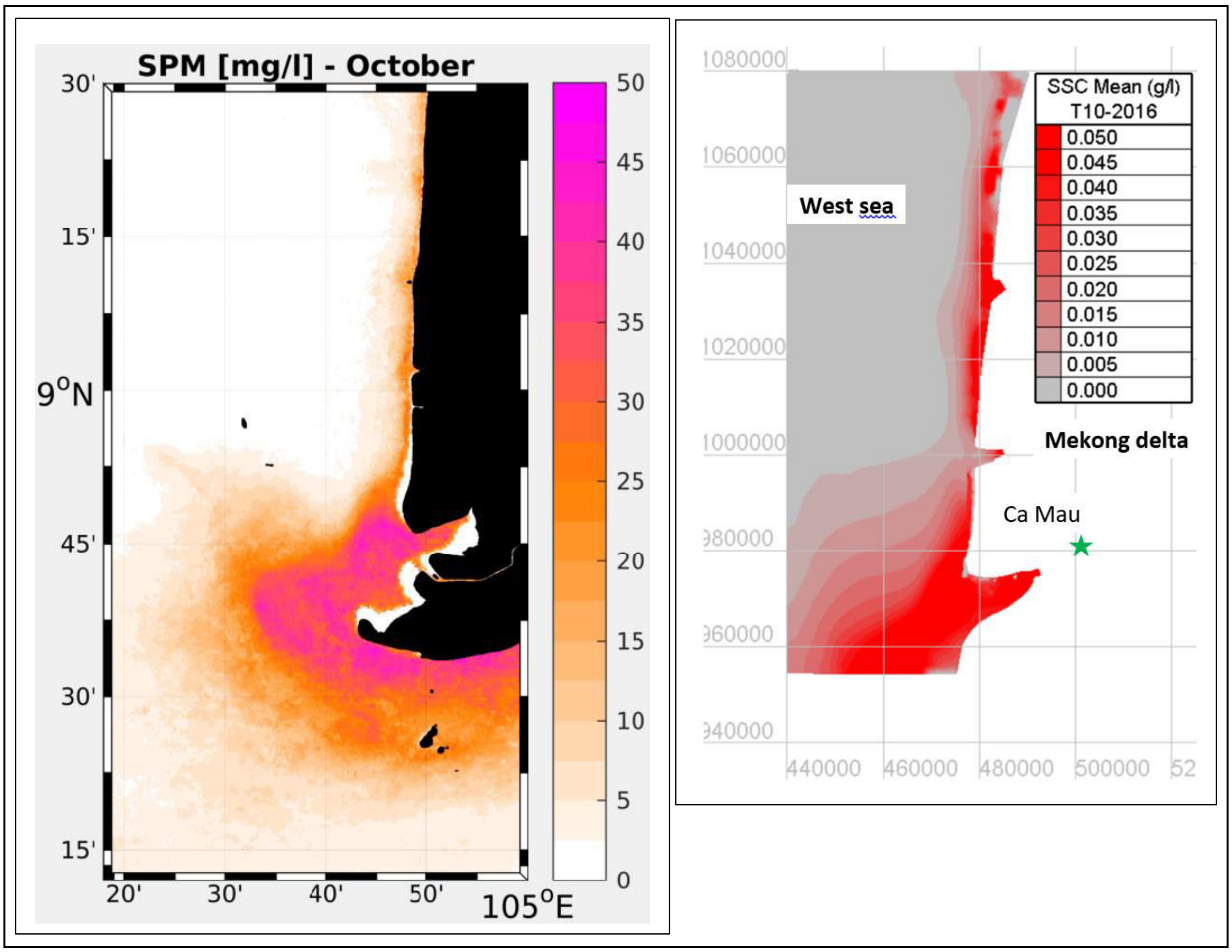

Figure 3.7: Average sediment value in October: (a) satellite data, (b) model results.

The above chart shows that the simulation results from the model are quite good compared with monitoring data from satellites.

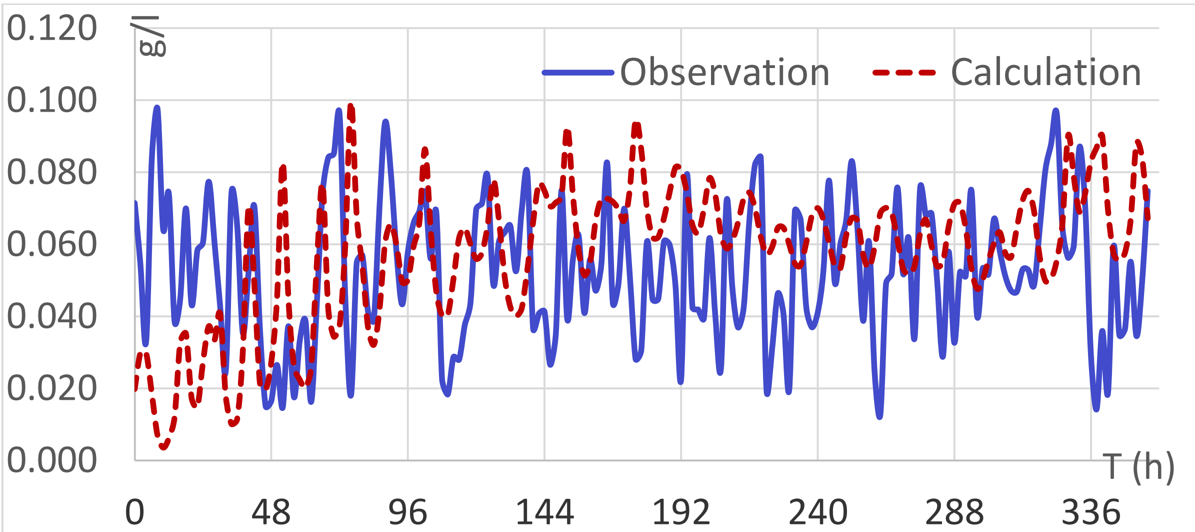

Figure 3.8: SSC observed and model results at position A (464620,1029689.9) from October 17, 2016 to November 1, 2016

4. Model validation

The model was validated with wave, sediment and velocity measured from February 25, 2017 to Mars 12, 2017 at the coordinates (464620,1029689.9).

a. Hydrodynamic validation

The following graph presents the flow velocity at the considered position:

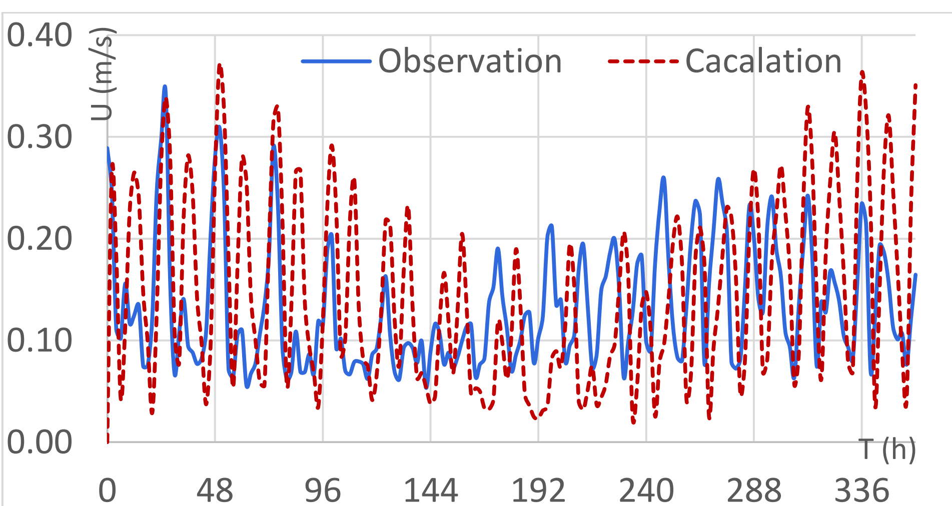

Figure 4.1: Value of velocity from monitoring data and from simulation from February 25, 2017 to March 12, 2017

The mean velocity of observation is 0.13 m / s and the simulated value is 0.14 m / s. The relative error is 7.7%.

b. Wave validation

The following chart presents the results of the HM0 (m) wave at the study location:

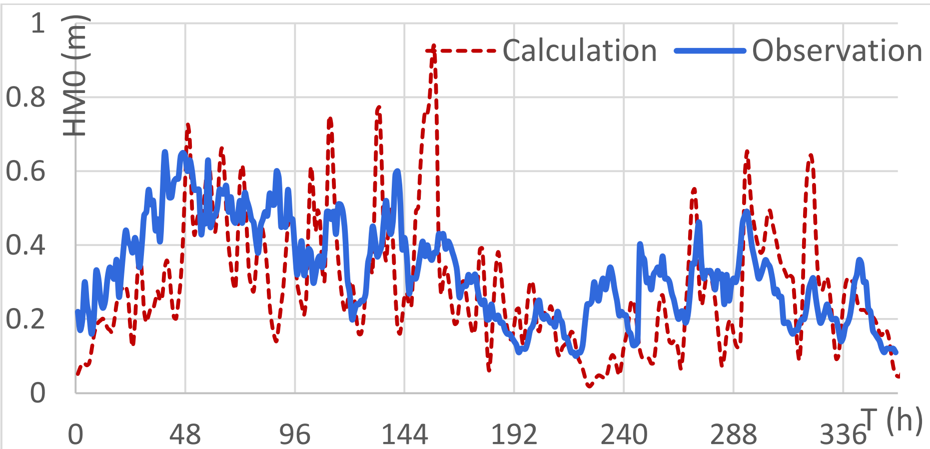

Figure 4.2: Wave value HM0 (m) observed and modelled from February 25, 2017 to March 12, 2017

The observed average HM0 wave value is 0.33 m and the simulation value is 0.29 m. The relative error is 12.1%.

c. Sediment validation

The following chart shows the results of suspended sediment at the site of consideration:

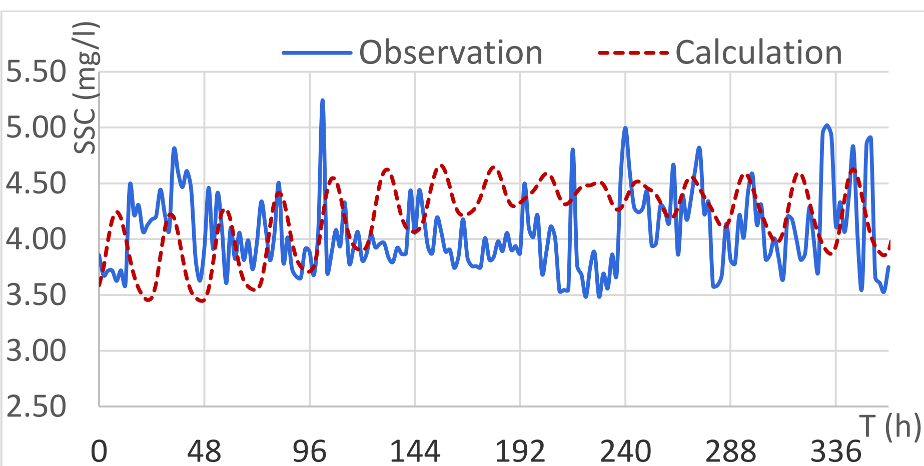

Figure 4.3: Sediment concentration SSC (mg / l) observed and modelled from February 25, 2017 to March 12, 2017

The average concentration of suspended sediment was 4.05 mg / l and the simulated value was 4.19 mg / l. The relative error is 3.45%.

5. Simulation of local zones of U-Minh

Simulations are made for two representative seasons: the southwest monsoon season and the northeast monsoon season. Each simulation season lasts for 2 months:

- West-South monsoon season: 8-9 / 2016
- East - North monsoon season: 2-3 / 2016

a. Hydrodynamic

The results show that the flow tends to go from Ca-Mau cap to the north. Simulation results for the local area indicate a trend of mainstream going from the East Sea to the West Sea.

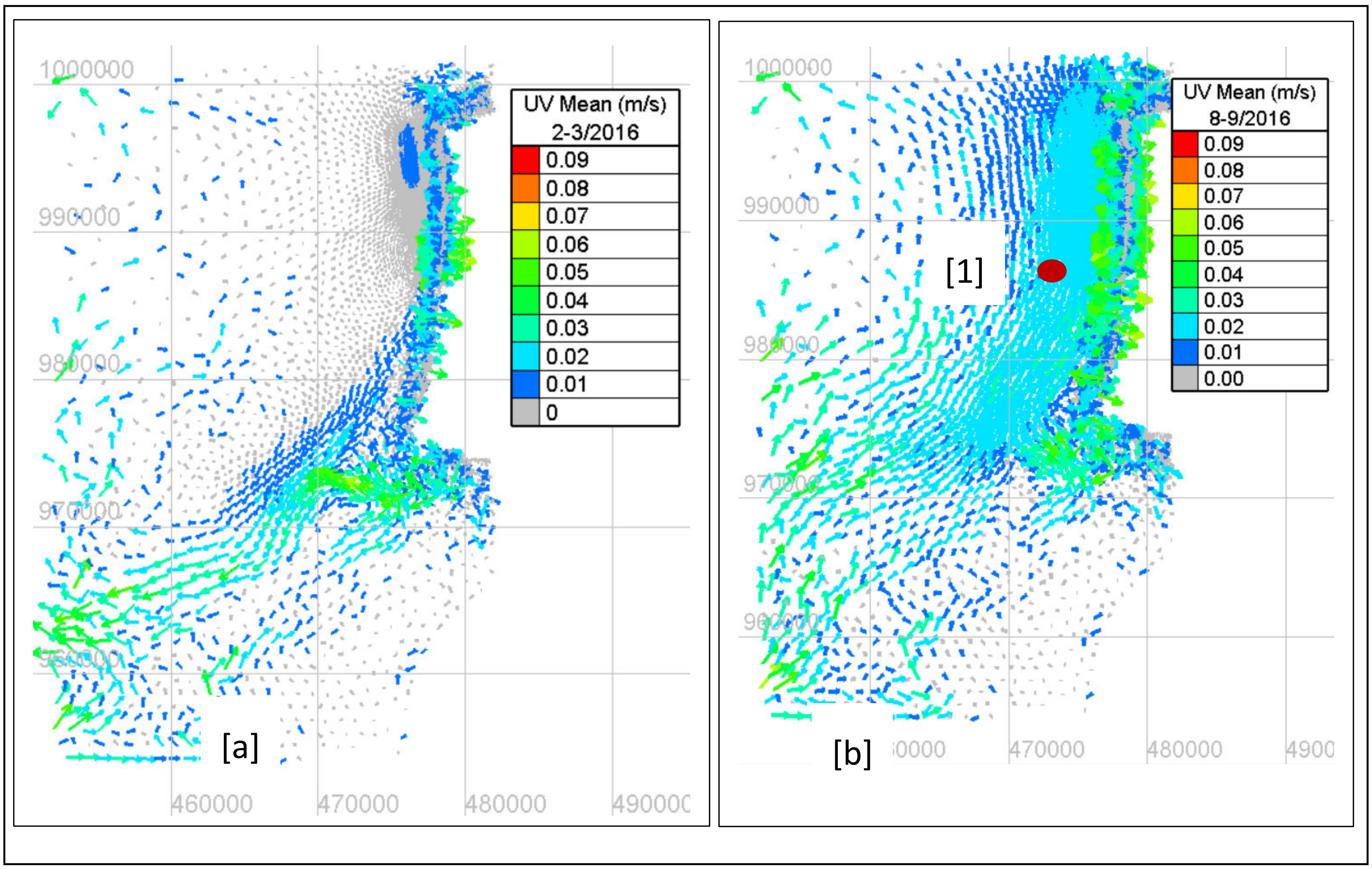

Figure 5.1: Field of average velocity in: (a) 2-3/2016 và (b) 8-9/2016

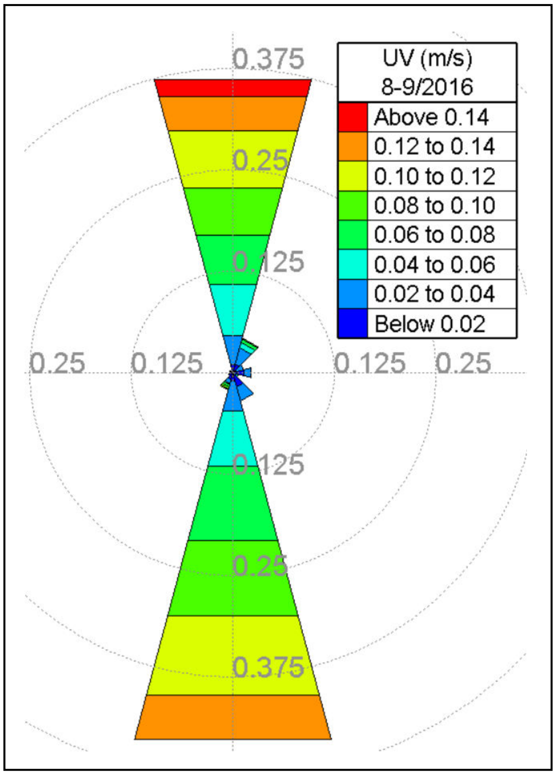

Figure 5.2: Distribution of flow velocity in 8-9/2016 at typical coastal position [1]

Comments on field of average velocity are as follow:

- The average velocity field value in the 2-3/2016 is smaller than in 8-9/2016. The formation of coastal flows in monsoon is explained by the effects of wind. There is no clear formation of northward flow in the U-Minh coast.
- For the month of 8-9/2016, the above results show that the flows in the west coast are in two main directions north and south. The maximum instantaneous velocity can reach 0.18 m/s. The flow trend represents the formation of an average flow toward the north with a velocity of about 0.02 m - 0.03 m/s. This trend agrees with the results obtained from simulation of local areas including the coastal areas of the Mekong Delta.

b. Wave

Waves in the local model are described from boundary conditions in the West Sea extracted from the NOAA global wave data. In addition, the waves are also created by the effects of the wind on the surface of the domain. Wind data is also collected from NOAA. In this model, these wave and wind data are changed over time and space.

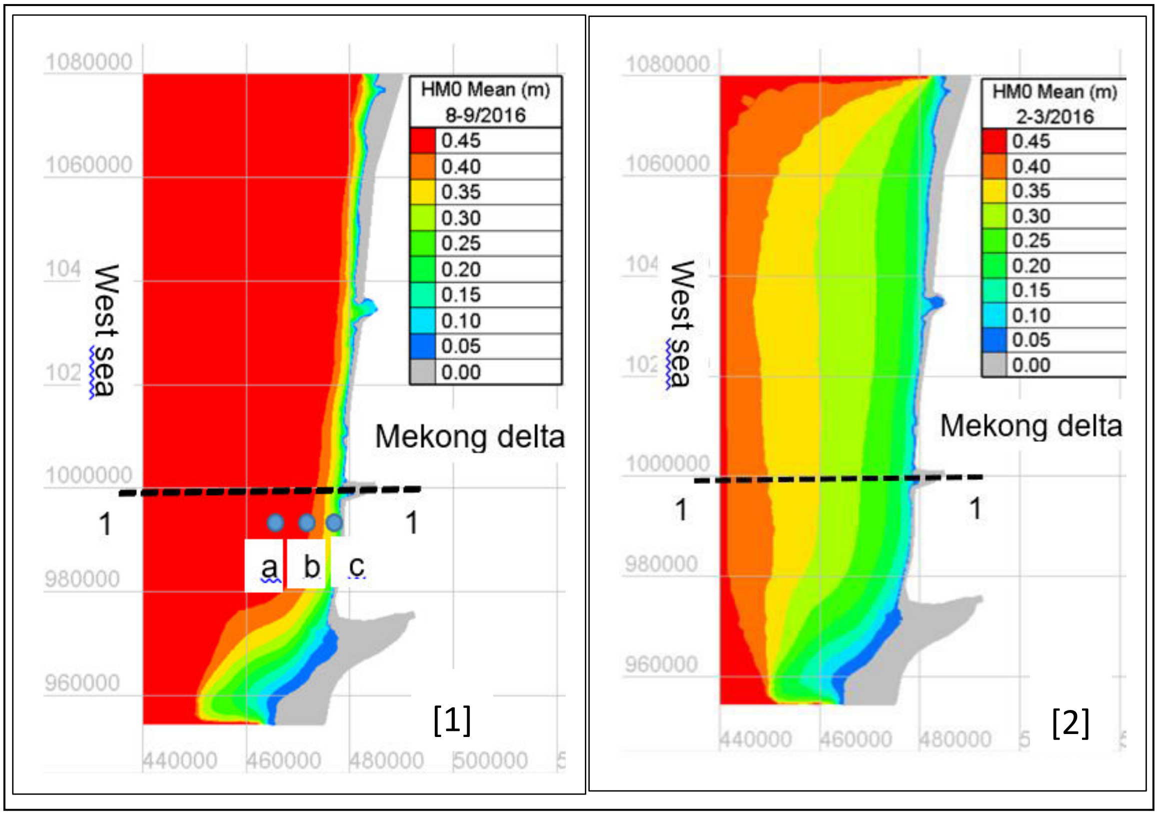

Figure 5.3: Average wave height (m): [1] in 8-9/2016 and [2] in 2-3/2016

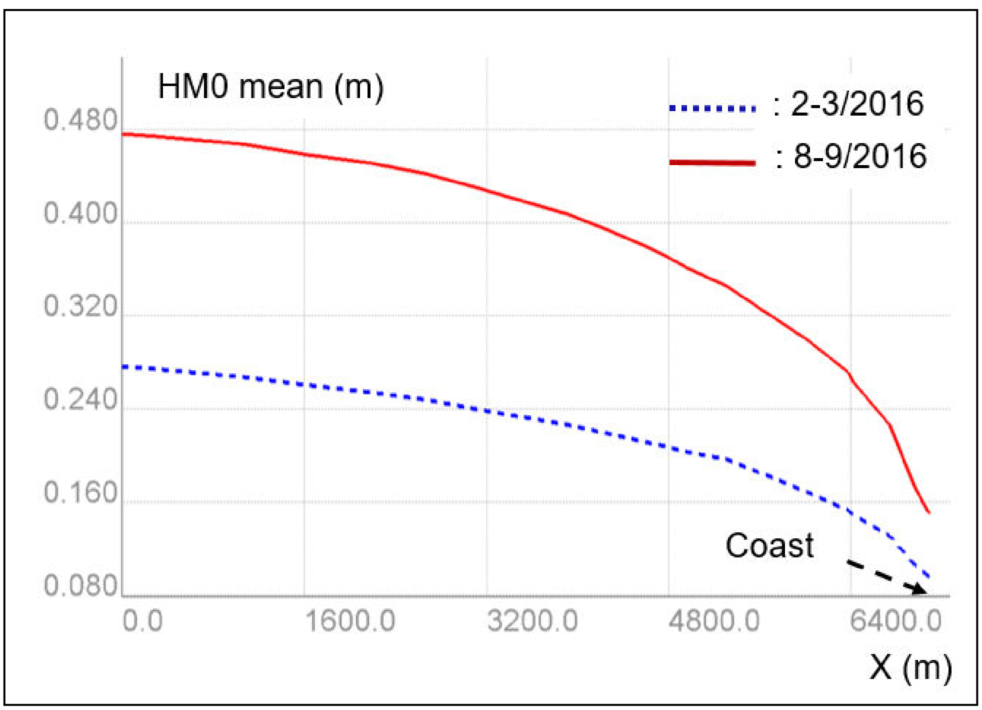

Figure 5.4: Variation of average wave height HM0 (m) at section 1-1

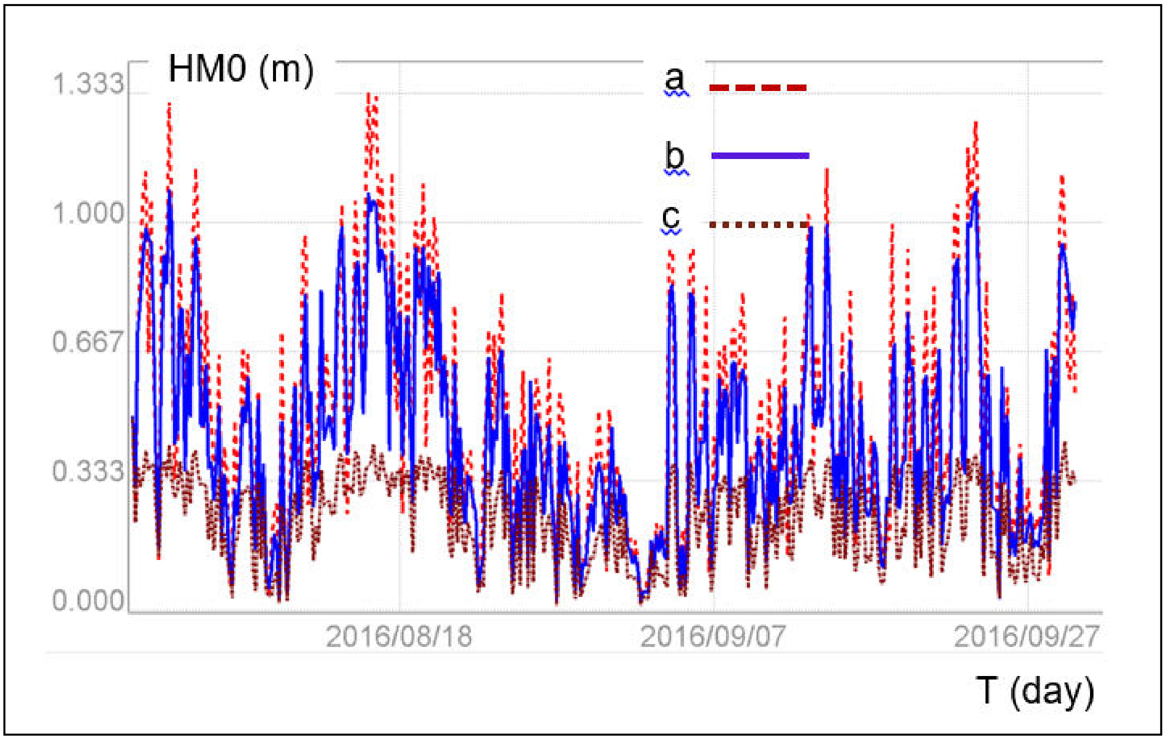

Figure 5.5: Variation of wave height HM0 over time at typical positions a, b and c

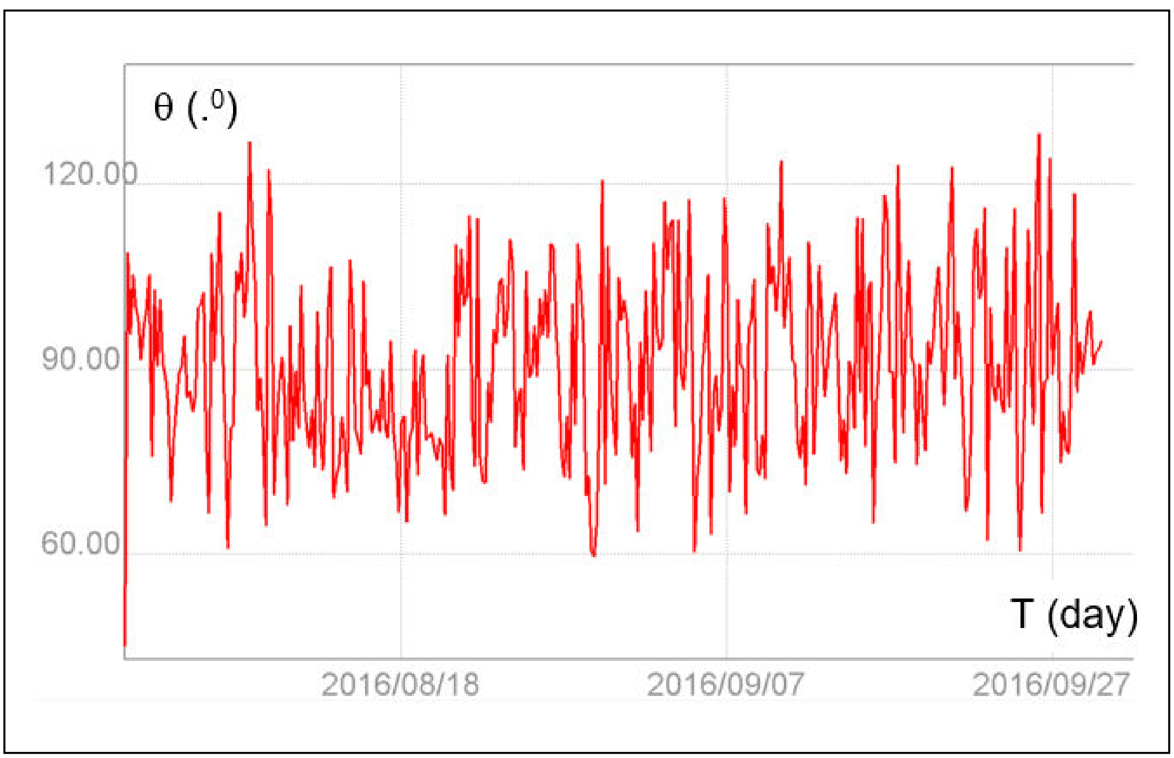

Figure 5.6: Average wave angle (compared to the north) at typical position [c]

Some general comments about waves in the domain area are as follows:

- The coastal area near Ca Mau cape, average wave height decreased faster when approaching the shore, compared with locations far to the north (Figure 5.3).
- The wave intensity drops rapidly within the 2000m range from the shore.
- Within 500m from the shore, the wave height is less than 0.3m (Fifure 5.5).
- The average wave angle shows nearly a straight direction (~ 90^0) waves on the west coast (Figure 5.6).

c. Sediment transport

The results of sediment transport are determined from the combination of three equations, including hydrodynamics, waves, and morphological change. The sediment boundary at the sea is considered as a free zone for the movement of bed load and suspended sediment. Due to the limit of field data (bathymetry and sediments), this model only considers the confluences Bay-Hap and Ong-Doc. Concentration of suspended sediment is set as 150 mg / l.

Under the influence of the hydrological regime and U Minh coastal shores, satellite data for suspended sediments for the month were recorded as follows:

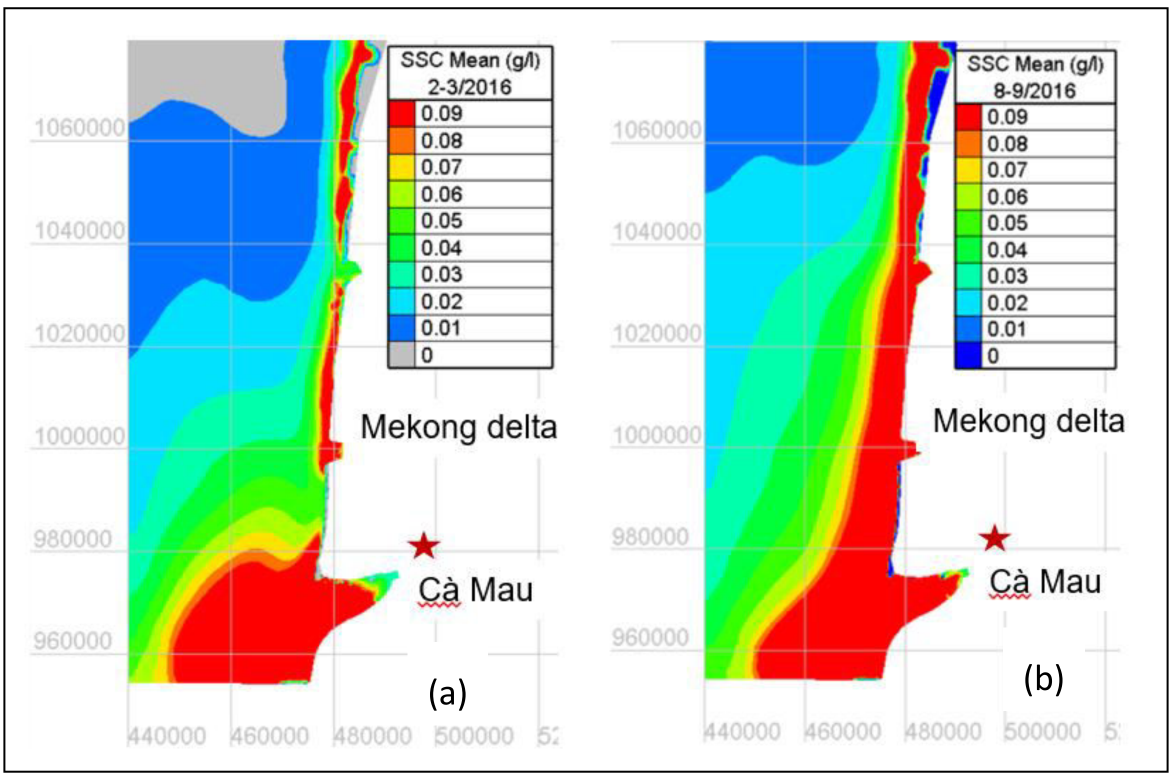

Figure 5.7: Average suspended sediment (a): month 2-3/2016; (b) month 8-9/2016

The above graph shows the effect of coastal waves on the concentration of suspended sediment in the area.

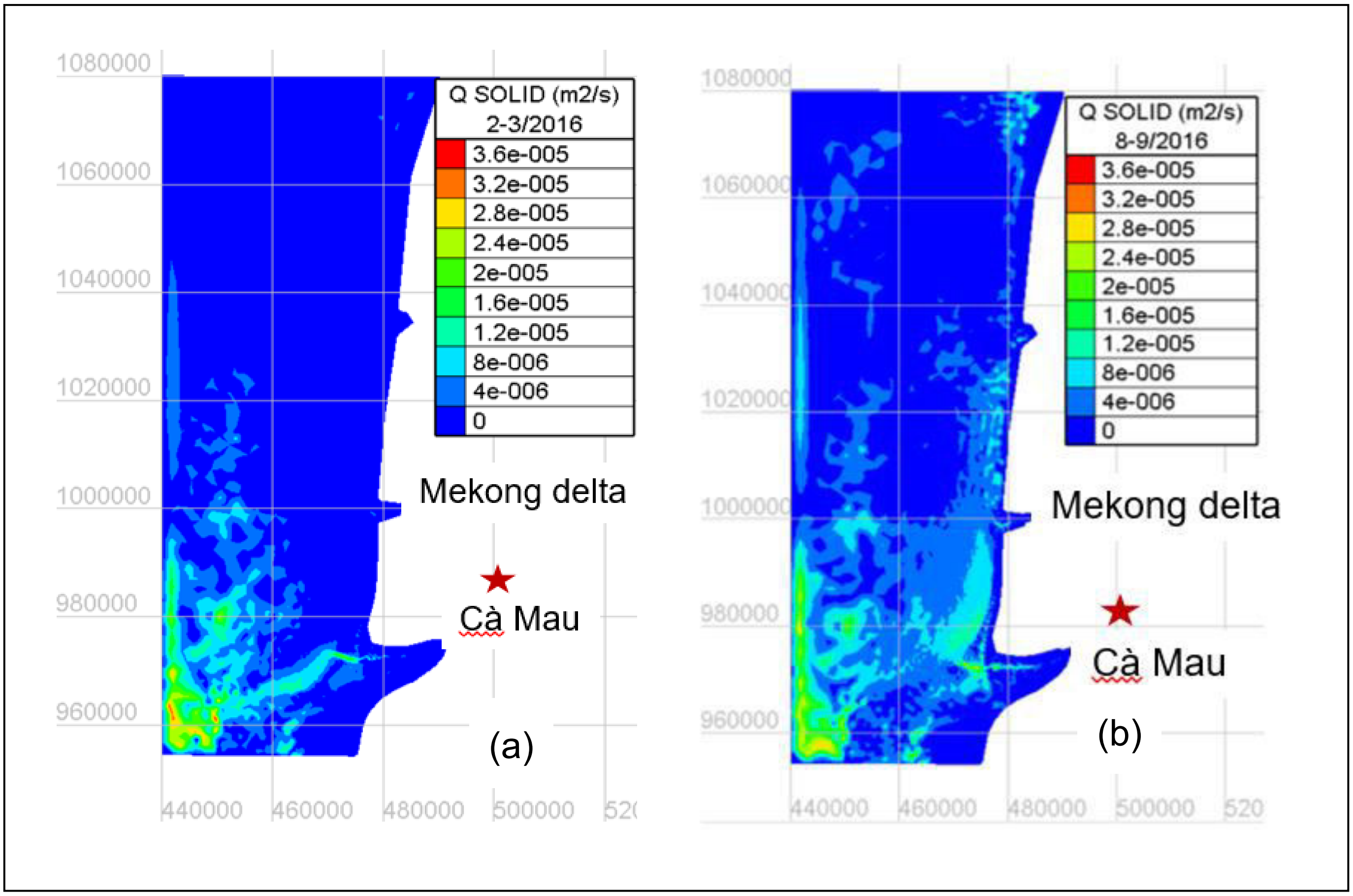

Figure 5.8: Average sediment fluxes (a): month 2-3/2016; (b) month 8-9/2016

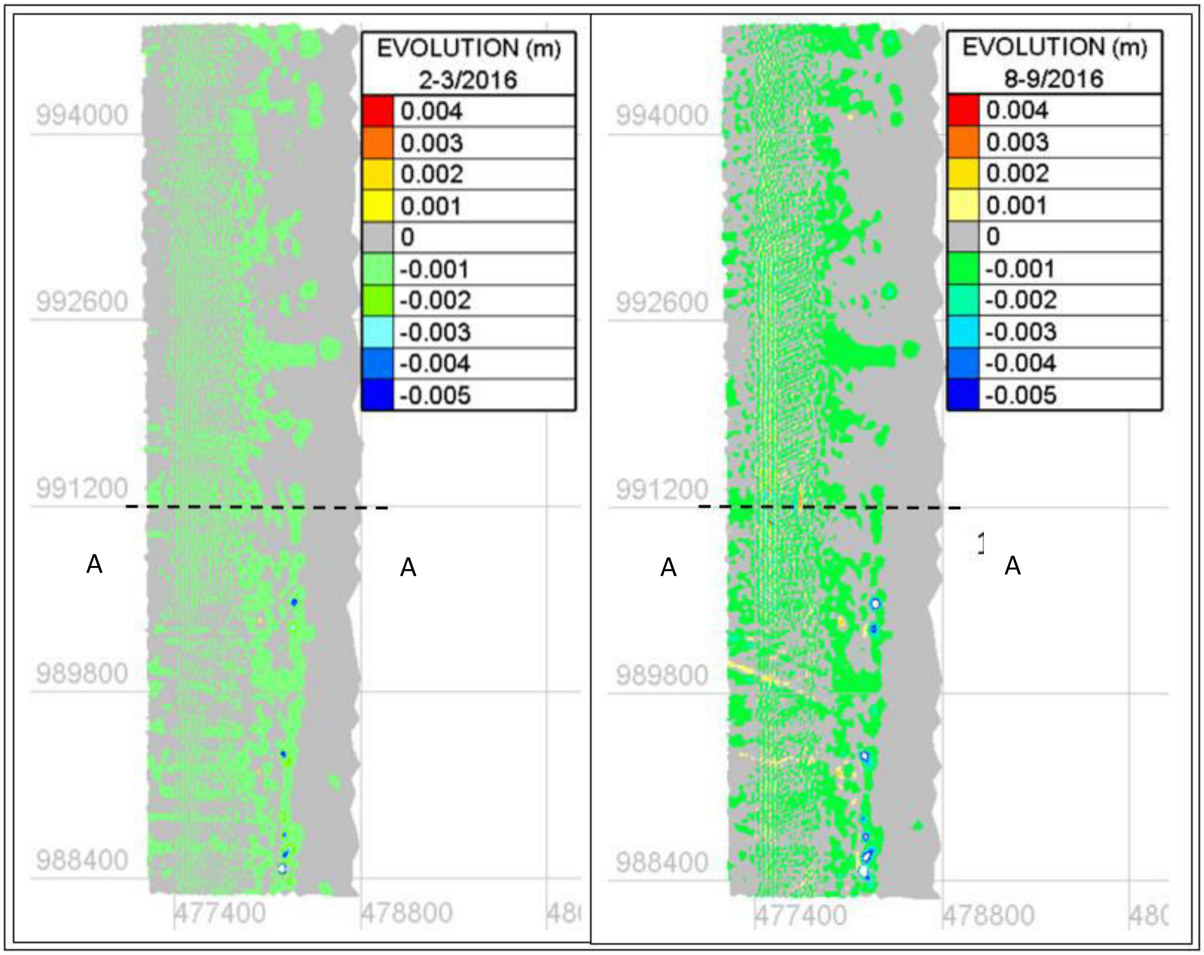

Figure 5.9: Erosion/accretion after 2 months: (a) 2-3/2016; (b) 8-9/2016 in case without measure

To quantify the sediment transport in the study periods for the coast from the Bay-Hap River to the Ong-Doc River, the simulation results in typical sections 1-1 (1km in length), 2-2 (1km in length), 1-2 (7km in length) are noted as follows:

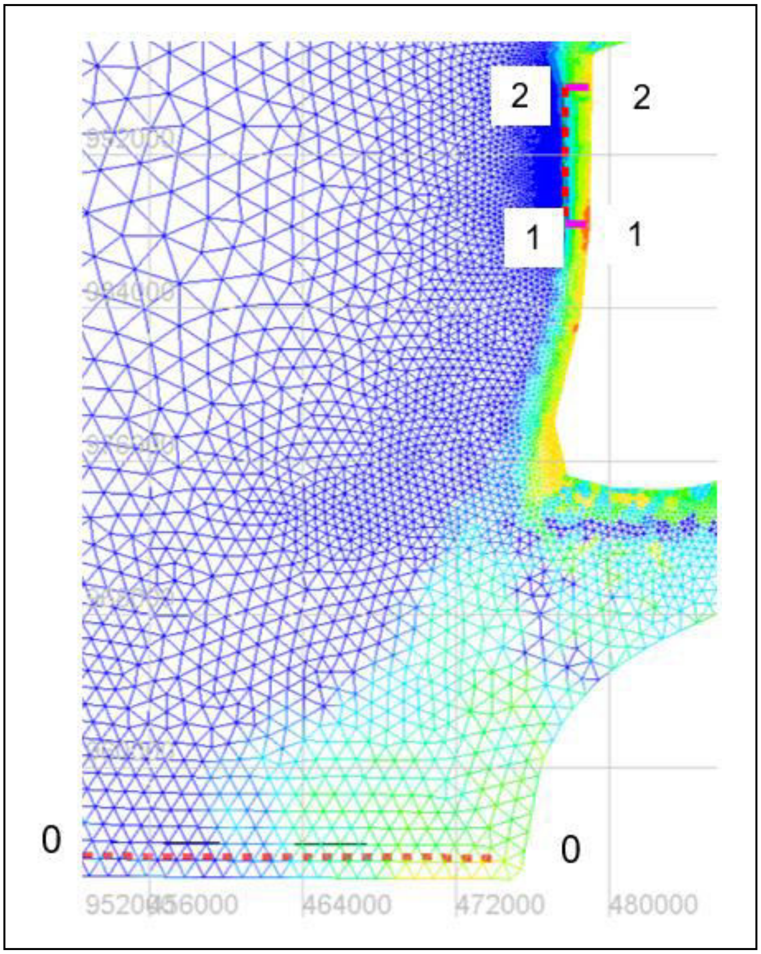

Figure 5.9: Position of representative sections and subdivisions

The sediment transport passing through the study sections is presented in the following table:

Table 5.1: Sediment fluxes through sections 0-0 (1000 m^3)

Section	1-1	2-2	1-2
Month 2-3 /2016	0.69	-0.59	-0.73
Month 8-9 /2016	5.47	-2.66	-6.40
Comments	(+ : north; - : south)	(+ : north; - : south)	(+ : east; - : west)

Comments:

- The above results at section 1-2 show that the sediment going to offshore (toward west).
- The above results at section 1-1 show that the sediment going to the north
- The trend of accretion in the months of Aug - Sep 2016 may be related to the average flow to the north in this season (Figure 5.1 b).
- There is a slight erosion in the study area.
- The erosion in Aug - Sep 2016 has a slightly higher erosion in compared to March - September 2016

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The following results show the change of sediment flux through the cross section 0-0. This is the section to study the trend of sediments moving in and out of Ca Mau cape:

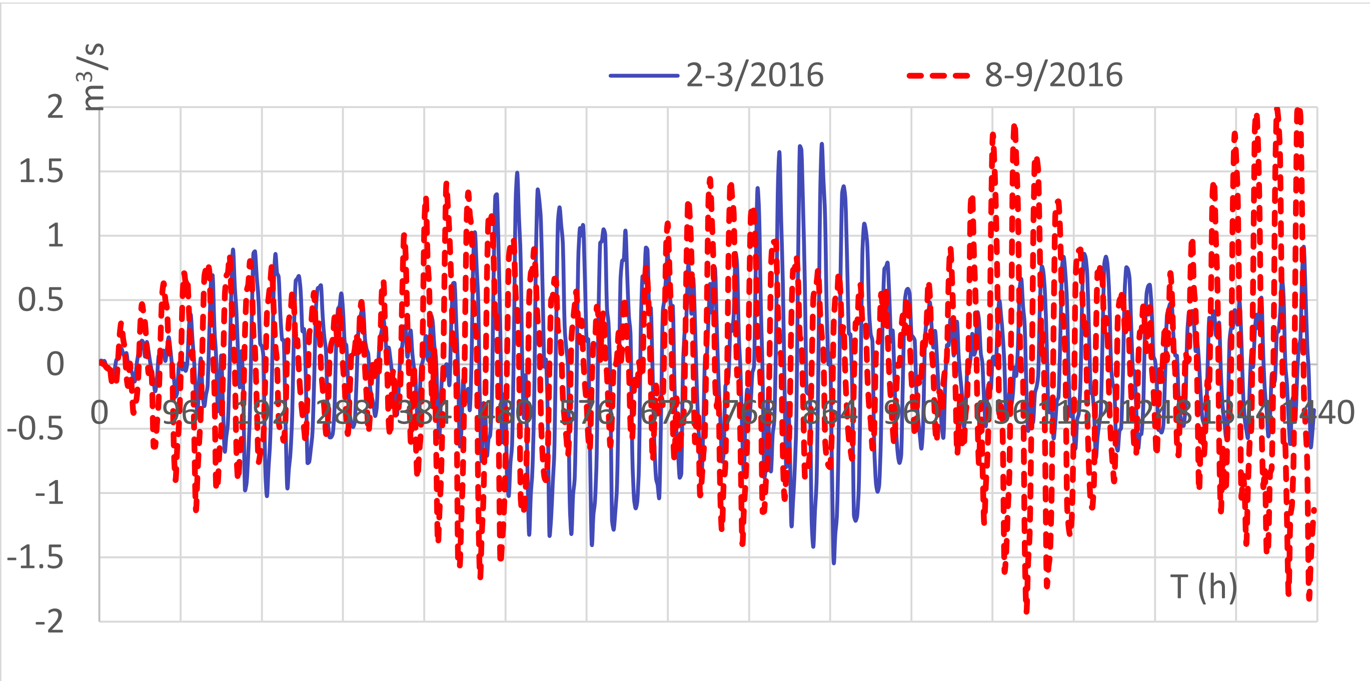

Figure 5.10: Sediment fluxes through cross section 0-0 over time.

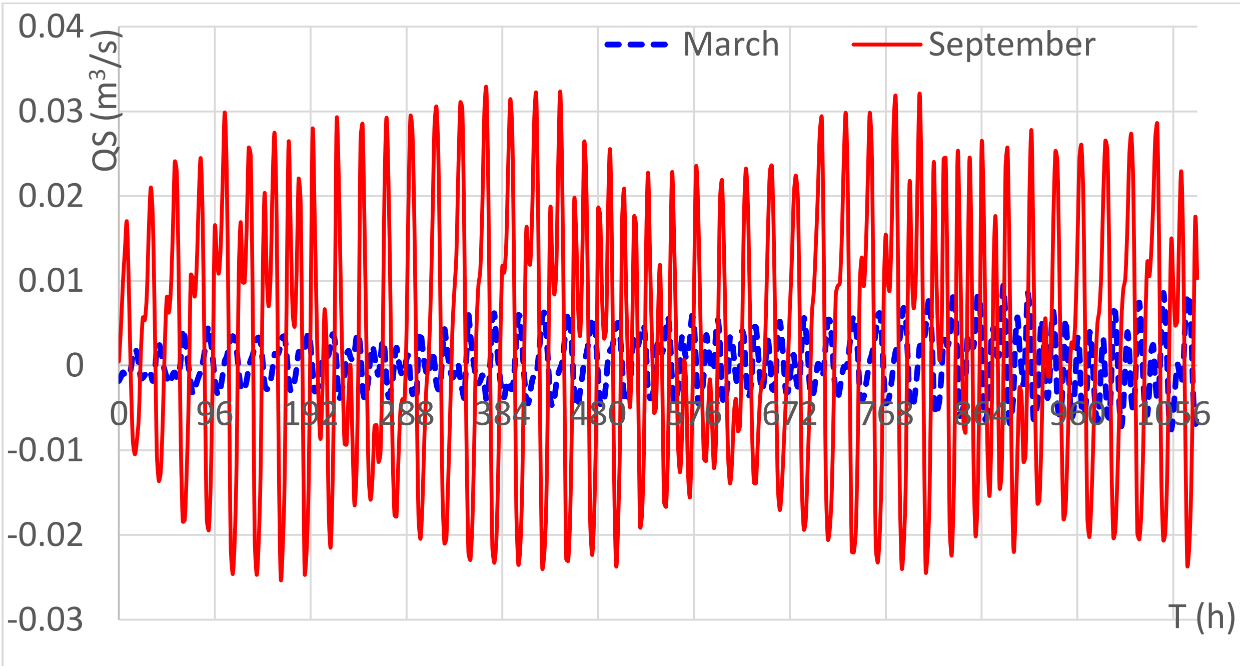

Figure 5.11: Sediment fluxes through cross section A-A (Figure 5.9) over time in case without measure.

(+: towards the north, - : towards the south)

Table 5.2: Sediment fluxes through cross section 1-1 in case without measure

	Sum (m^3)	Notes
From 15/2/2016 to 31/3/2016	699.5	(+) : towards the north
From 15/8/2016 to 30/9/2016	10907.4	(-) : towards the south

Some main observations on the sediment transport at the cross-sectional site crossing the Ca Mau cape are as follows:

- Time-varying results reflect the change in direction of the instantaneous flow.
- The average sediment transport rate corresponding to the above graph is $+85.4x10^3$ m^3 (towards the north) in Feb - Mars 2016 and $+28.3x10^3$ (towards the north) in Aug - Sep 2016. These values are relatively small. This trend can be explained by the formation of the coastal sediment and their movement from east coast to the West Sea in the same period.
- Sediment transport tends to move towards the north at 1-1 cross-sections
- Fluxes through cross section 1-1 over time in August-September 2016 are much larger than February-March 2016. This trend may explain by the effects of wind direction in August-September 2016 and the wave intensity is greater than in February-March 2016.
- There is a strong correlation between the sediment fluxes through a cross section over time and the tides.

6. CONCLUSION:

The simulation in the U-Minh area during the 2 representative periods of 2-3/2016 and 8-9/2016 showed the following results:

- The results of model calibration in 10/2016 and model validation in 2/2017 for hydrodynamics, waves and sedimentation showed quite good results.
- Formation of the mean flow in the coastal zone (Figure 5.1) in accordance with the wind direction in February 2016 and August 2016 (Figure 2.5).
- The wave intensity in study area depends mainly on the wind intensity on the surface. Waves once reaching the shore tend to rapidly decrease in intensity within about 1000m from the shore (Figure 5.4). The average wave height HM0 tends to slightly increase towards the north (Figure 5.5).
- Waves have a great influence on the intensity of suspended sediment (Figure 5.3 and Figure 5.7).
- The trend of moving sediment offshore increases as coastal waves increase (Table 5.1, section 1-2)
- The sediment flux across the section O-O going north during February-March 2016 is greater than the sediment during August-September 2016. This result may explained by the movement of sediment from East coast of the Mekong Delta in the same period (Fifgure 5.10).

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