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Nearshore wave-tide hydrodynamics of Kuakata beach by numerical modelling

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Abstract

This research work has been conducted for nearshore wave-tide hydrodynamics analysis of Kuakata beach by numerical modelling 24 km long Kuakata beach is subdivided into three parts like Lebur Char (13 km), Gangamatir Char (4 km) and Kawar Char (7 km) stretching from west to east. A dedicated hydrodynamic model using MIKE 21 FM (with/without wave action) is developed, calibrated, and validated for studying nearshore hydrodynamic analysis. Model simulation for different critical hydrological and hydrodynamic conditions reveals that there develops longshore current along the beach and eastward current magnitude dominates over westward current magnitude. A dedicated wave model has been developed using MIKE 21 SW and the simulated wave result, wave rose analysis has been done, it is found that waves hit the Kuakata beach angularly and the eastward wave is most prominent, which generates longshore current from west to east. Simulated hydrodynamics of coupled wave-tide model can be used in another model to estimate the rate of longshore sediment transport. It is observed that the coastline is moving towards land with time.

Keywords: 2D hydrodynamic model, wave model, wave-tide hydrodynamics, longshore current, coastal erosion.

1. Introduction

Coastal erosion is one of the big challenges in Bangladesh. Many reasons are responsible for coastal erosion, among them strong tidal current, wave action, cyclonic storm surge and human interventions are prime reasons. Erosion has been happening in some places along the coastline of Bangladesh. Kuakata is one of those. There has been happening erosion along the main beach of Kuakata for last decades. This study has been conducted to analyze the nearshore hydrodynamics of Kuakata beach which will help a researcher to understand dominated wave direction which leads longshore sediment transport and obviously will provide the better insights regarding coastal erosion process.

1.1 Study area

This study is conducted for Kukata beach area and coastline. Kuakata is located in the southern part of Banaladesh and northern part of BoB. It is situated 320 km south of capital city Dhaka and 70 km away from Patuakhali district headquarter. The area lies between latitudes $21^0 48'$ and 21⁰55' N and longitudes $90^0 03'$ and $90^0 15'$ E. Kuakata is under Kalapara upazila of Patuakhali district. Study area (Kuakata) is shown in the Figure 1.1.

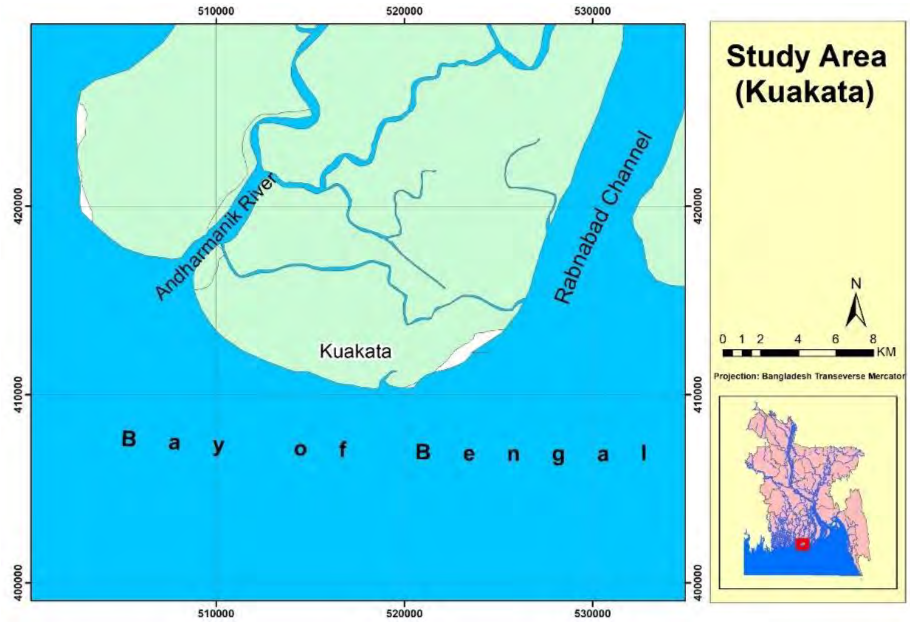

Fig. 1.1. Map showing study area.

Kuakata, also popularly known as Sagar Kannya (daughter of sea queen), located on the coastal zone of Bangladesh It is the only place of Bangladesh from where sun set, and sun rise can be enjoyed. A long narrow linear beach present in Kuakata. Kuakata beach is characterized by ridge and runnel topography. Deposits of the beach are mostly composed of sand. A dominant strong wind is present toward the onshore direction. A well-developed dune is present in Kawar Char area (Rashid and Mahmud, 2011).

Haque, (2018) conducted a study to assess the hydrodynamic changes during construction of a closure in a 4 km wide tidal channel between Subornachar and Swarnadip Island located in the Meghna Estuary. Two construction methods have been considered vertical and horizontal closing method. Model simulation shows that the maximum flow velocities during the construction of the closure were obtained during flood tide as 1.43 m/s (H1), 1.7 m/s (H3), 2.28 m/s(H5), 2.56 m/s (H6), 4.36 m/s (H7), 4.58 m/s (H8) and 4.76 m/s (H8).

A study work has been conducted by Nahiduzzamn, (2018) for simulation of storm surge level at a tidal channel due to coastal cyclone along the Bangladesh coast. Bay of Bengal hydrodynamic model (BoB) of IWM has been updated with finer mesh resolution at Baleshwar channel. An equation has been developed for estimating the storm surge height at Baleshwar estuary which is further verified with the simulated surge height of IWM and shows good agreement. Uddin et al., (2014) updated the BOB model with recent bathymetry data and shoreline of islands and coastline and upgrading from rectangular grid to finer size of mesh grids by using latest version of MIKE21 FM modeling system. This model is very useful for the hydrodynamic study in the coastal region of Bangladesh. Institute of Water Modelling (IWM) do have Bay of Bengal model, popularly known as BoB model, both for 2D hydrodynamic and 2D wave model and conducted many studies in the coastal zone of Bangladesh. Kuakata nearshore area is also included in BoB model but in this current research a dedicated model is developed and the Kuakata beach area updated and upgraded with available data. As it is dedicated model, domain is comparatively smaller than BoB model so it takes shorter time to simulate. Thus, simulation time is saved by setup of dedicated model. Wave action is considered incorporating the wave result file in the 2D hydrodynamic model setup as radiation stress, thus it is also called coupled HD model.

This study aims to setup, calibrate and validate hydrodynamic and wave model by MIKE 21 FM/SW and simulate the near shore wave-tide hydrodynamics to assess dominant current and wave direction through hydrodynamics analysis for occurring erosion which will help the researcher for further study. Moreover, wave rose, current rose and bed shear stress are also found out for different scenarios.

2. Materials and method

Two models (i.e., Hydrodynamic and wave) are used in this study. Both Hydrodynamic and wave model are setup, calibrated and validated. Ultimately using HD result file and wave result file results are extracted and analyzed.

2.1 Data collection

Various types of data have been collected for this study purpose like water level, wind data, sate, 1D hydrodynamic result file for the year 2010 to 2018, wave data for the year 2010 to 2018 and wind field for the same period from different sources. Data type, location, period, and source are shown in the following Table 2.1.

Table 2.1
List of data collection

Data type	Place/Location	Year/Period	Data source
Water Level	Kawarchar, Fakiraghat	2015-2017	IWM
Discharge	Tumchar (Tentulia) and Bamna(Bishkhali)	11/12/2017 and 16/12/2017 11/03/2015 and 12/03/2015	IWM
Wind data	Khepupara	2017	BMD
Wind field	BoB	01-01-2008 to 01-01-2019	EMCWF
Wave data	24 km offshore of Kuakata	07-03-2018 to 02-04-2018	IWM
Wave field	BoB	01-01-2008 to 01-01-2019	EMCWF
Sea Bathymetry	BoB	2014	GEBCO
River Bathymetry	Bishkhali, Baleswar, Rabnabad,Buriswar, Rabnabd, Andhar Manik	2019	IWM

2.2 2D-Hydrodynamic model

MIKE 21 flow model FM developed by DHI (Danish Hydraulic Institute) has been used for the Hydrodynamic Modeling of this research work. The Hydrodynamic Module is the basic computational component of the entire MIKE 21 Flow Model FM modelling system providing the hydrodynamic basis for the other Module. The Hydrodynamic Module is based on the numerical solution of the two-dimensional shallow water equations - the depth-integrated incompressible Reynolds averaged Navier-Stokes equations. The local continuity equation is written as

$$\frac{\partial \zeta}{\partial t} + \frac{\partial p}{\partial x} + \frac{\partial q}{\partial y} = \frac{\partial d}{\partial t} \tag{2-1}$$

And the two horizontal momentum equations for the x- and y- component, respectively

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial x}\left(\frac{p^2}{h}\right) + \frac{\partial}{\partial y}\left(\frac{pq}{h}\right) + gh\frac{\partial \zeta}{\partial x} + \frac{gp\sqrt{p^2+q^2}}{C^2.h^2} - \frac{1}{\rho_w}\left[\frac{\partial}{\partial x}(h\tau_{xx}) + \frac{\partial}{\partial y}(h\tau_{xy})\right] - \Omega q - fVV_x + \frac{h}{\rho_w}\frac{\partial}{\partial x}(p_a) = 0 \tag{2-2}$$

$$\frac{\partial q}{\partial t} + \frac{\partial}{\partial y}\left(\frac{q^2}{h}\right) + \frac{\partial}{\partial x}\left(\frac{pq}{h}\right) + gh\frac{\partial \zeta}{\partial y} + \frac{gq\sqrt{p^2+q^2}}{C^2.h^2} - \frac{1}{\rho_w}\left[\frac{\partial}{\partial y}(h\tau_{yy}) + \frac{\partial}{\partial x}(h\tau_{xy})\right] + \Omega p - fVV_y + \frac{h}{\rho_w}\frac{\partial}{\partial y}(p_a) = 0 \tag{2-3}$$

The following symbols are used in the equation.

$h(x,y,t)$	water depth (= $\zeta - d, m$)
$d(x,y,t)$	time varying water depth (m)
$\zeta(x,y,t)$	Water surface elevation (m)
$p,q\ (x,y,t)$	flux densities in x- and y-directions ($m^3/s/m$) = (uh, vh); (u,v) = depth averaged velocity in x-and y-directions
$C(x,y)$	Chezy resistance ($m^{1/2}/s$)
g	acceleration due to gravity (m^2/s)
$f(V)$	wind friction factor
$V, V_x, V_y(x,y,t)$	wind speed and components in x-and y-direction (m/s)
$\Omega(x,y)$	Coriolis parameter, latitude dependent (s^{-1})
$p_a(x,y,t)$	atmospheric pressure ($kg/m/s^2$)
ρ_w	density of water (kg/m^3)
x,y	space coordinates (m)
t	time (s)
$\tau_{xx}, \tau_{xy}, \tau_{yy}$	components of effective shear stress

In the horizontal domain both Cartesian and spherical coordinates can be used. The spatial discretization of the primitive equations is performed using a cell centered finite volume method. The spatial domain is discretized by subdivision of the continuum into non-overlapping element/cells. In the horizontal plane, an unstructured grid is used comprising of triangles or quadrilateral element. An approximate Riemann solver is used for computation of the convective fluxes, which makes it possible to handle discontinuous solutions. For the time integration, an explicit scheme is used.

2.2.1 Dedicated hydrodynamic model setup

Concept of dedicated hydrodynamic model for Kuakata beach is brought under consideration because it is easy to handle, simulation time can be minimized, and high accuracy can be achieved through fine tuning of the model. Moreover, only one upstream boundary is required, which can be obtained from south-west regional model, to run the model. The flow chart of hydrodynamic model is illustrated in Figure 2.1.

2.2.1.1 Model domain

A smaller domain covering the area of interest was created based on the existing HD model of the Bay of Bengal. Figure 2.2 shows the model domain of study area. East, west and south boundary of the model domain are in the Bay of Bengal and upstream boundary is Hilisha river which has been originated from Lower Meghna. Moreover, the important rivers in the domain are Baleswar, Bishkhali, Buriswar-Payra, Andharmanik, Lohalia, Tentulia, Rabnabad Channel etc.

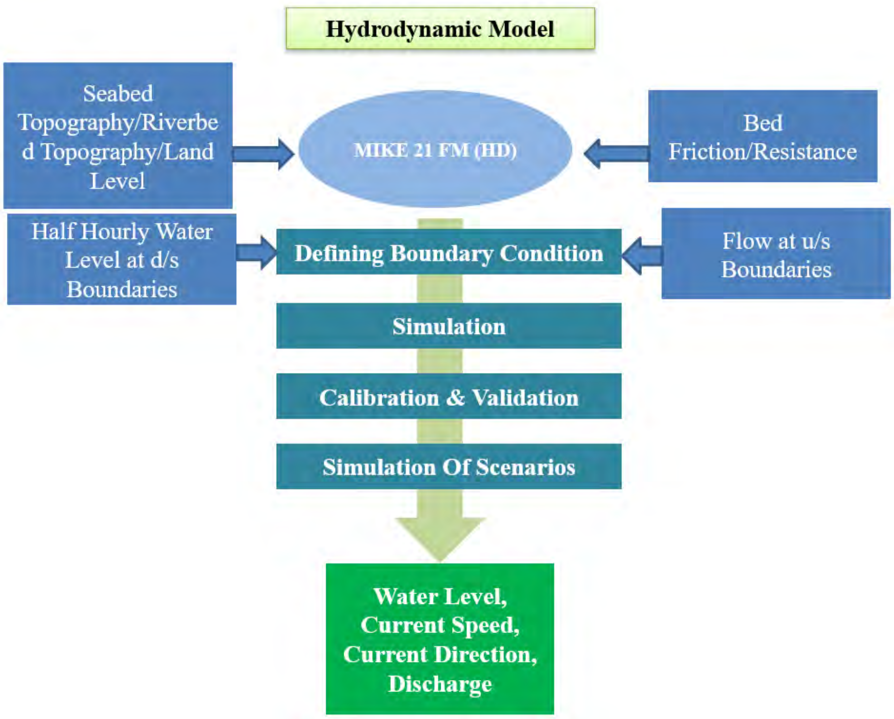

Fig. 2.1. Flow chart of a hydrodynamic model.

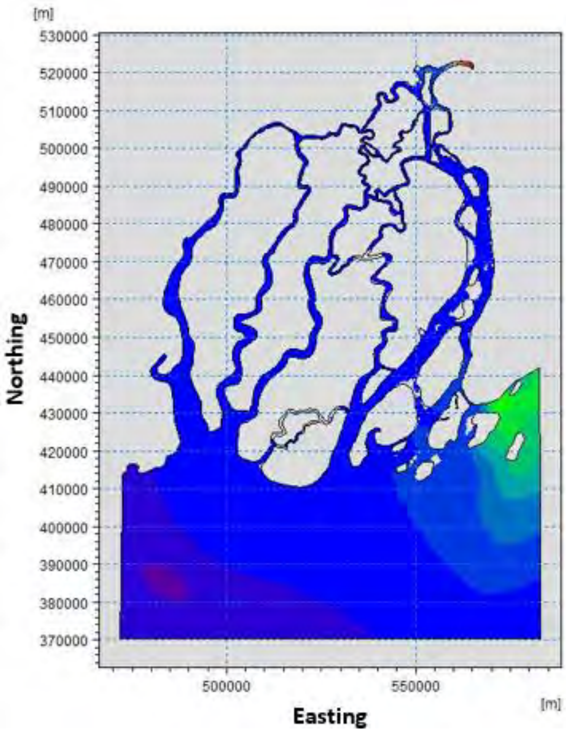

Fig. 2.2. Model domain of the Kuakata study area.

2.2.1.2 Model boundaries

This model has four boundaries. Upstream boundary is in Hilisha river, boundary is given as time series of discharge here. And discharge is extracted from the southwest regional model for the year 2015. Downstream boundaries are east west and south where water level is given as boundary here. These water levels are generated from global tide model.

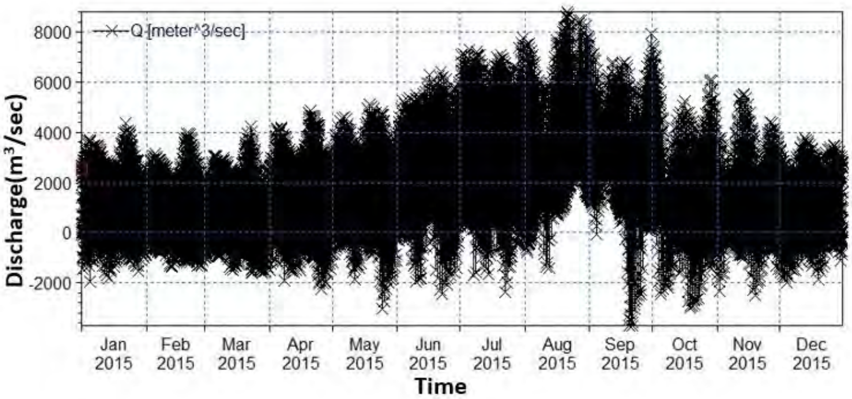

Fig. 2.3. Upstream boundary of hydrodynamic model (Hilisha river).

2.2.2 Upgrading of the hydrodynamic model

Upgrading of the hydrodynamic model comprises the improvement of mesh resolution specially for the area of interest. This study is focused on determining sediment budget. The mesh resolution of Kuakata beach area has been decresed from 13000 meters (Max^{m} area 80000000 m^{2}) to 100 meters (Max^{m} area 30000 m^{2}) under this research work. The upgraded mesh resolution and the bathymetry has been shown in Figure 2.5.

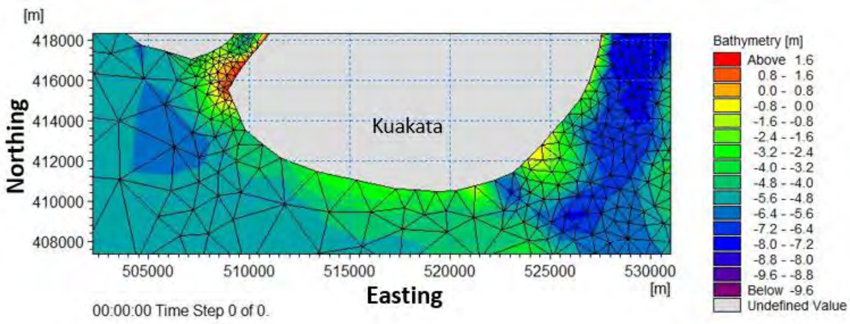

Fig. 2.4. Mesh size of existing BoB model of IWM in the Kuakata beach area.

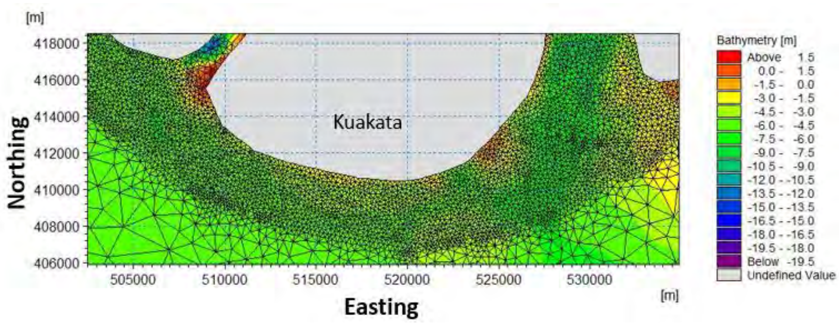

Fig. 2.5. Updated fine mesh used in the dedicated model under this study in the Kuakata beach area.

2.2.2.1 Bed resistance

To calibrate the model, it is necessary to adjust the bed resistance. A spatially varying map of bed resistance has been used for this research work. The relation between Manning number (M) and bed roughness length, K_s can be estimated using the following formula:

$$M = \frac{25.4}{Ks^{1/6}} \tag{2-4}$$

Initially the manning map was prepared based on the available water depth. Further correction has been made during the calibration process of the model. The applied Manning roughness (M) in the study area which is the reciprocal value of Manning's n is shown in Figure 2.6.

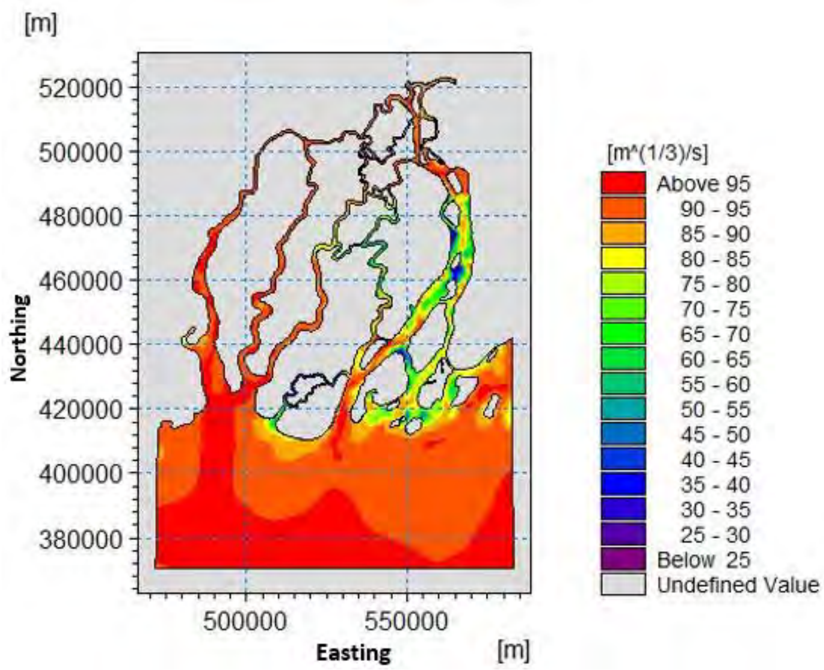

Fig. 2.6. Spatially varied manning M map used for model calibration.

2.2.3 Calibration and validation of hydrodynamic model

The hydrodynamic model has been simulated for a 20 days' period of March 2017. Model has been calibrated at two locations, i.e., Fakira Ghat and Kawar Char. Figure 2.7 shows the model calibration and validation locations.

2.2.3.1 Model parameter

The main model parameter used for the calibration of the hydrodynamic model is shown in the Table 2.2.

Table 2.2
The model parameters used for hydrodynamic calibration.

Model Parameter	Value
Numerical Scheme	Low
Eddy Viscosity	Smagorinsky formulation constant 0.28
Bed Resistance	Constant in time, varying in domain
Coriolis force	Varying in domain

An appropriate internationally accepted standard values of model parameters for the validation of hydrodynamic model performance can be found in the UK Foundation for Water Research Publication named “A framework for marine and estuarine model specification in the UK”.

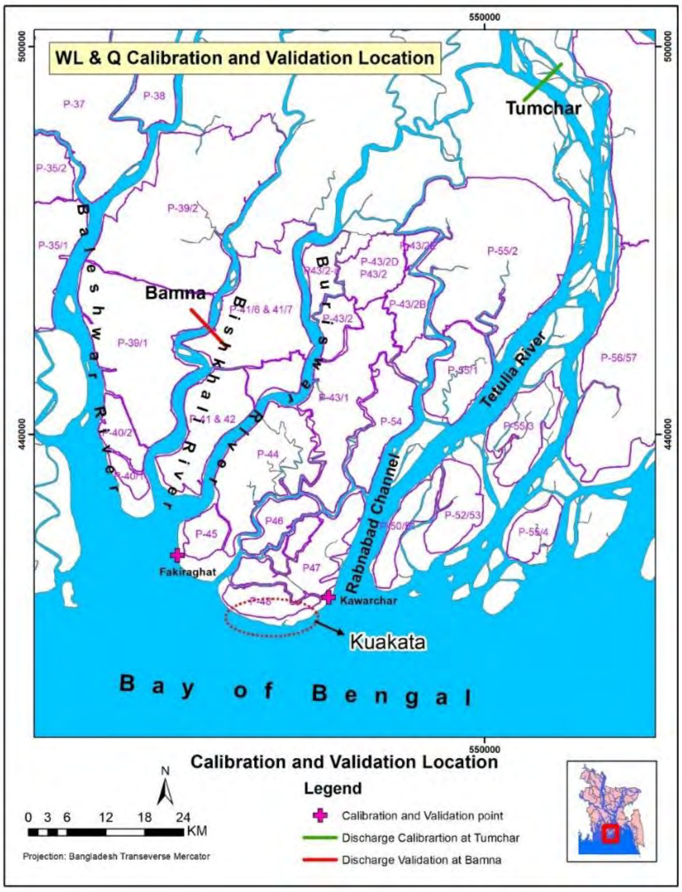

Fig. 2.7. Hydrodynamic model calibration and validation locations.

In broad terms, this can be categorized by the following performance limits:

Tidal elevations: Root Mean Square (RMS) error < 15% on spring tide and 20% on neap tide ranges (maximum deviation 0.1 m at marine estuarine boundary, 0.3 m at estuary head); Current speed deviation RMS error < 10 to 20% (maximum deviation 0.2 m/s); Direction error RMS error < 20 deg; and Timing of high water at marine estuarine boundary 15 minutes, 25 minutes at estuary head. Calibration results of water level at different locations are shown in Figure 2.8. From this figure it is seen that simulated water level and observed water level matched well.

There is tool named timeseries comparator which exists in MIKE Zero. By this tool performance measures can easily be found out result has good agreement. The performance measures result for Fakira Ghat calibration by time series comparator tool has good agreement also.

We have discharge measurement at Tumchar in Tentulia river of the year 2017. Discharge is calibrated with this measurement which is shown in the Figure 2.9. It is seen from the time series plot that simulated discharge and observed discharge matched well.

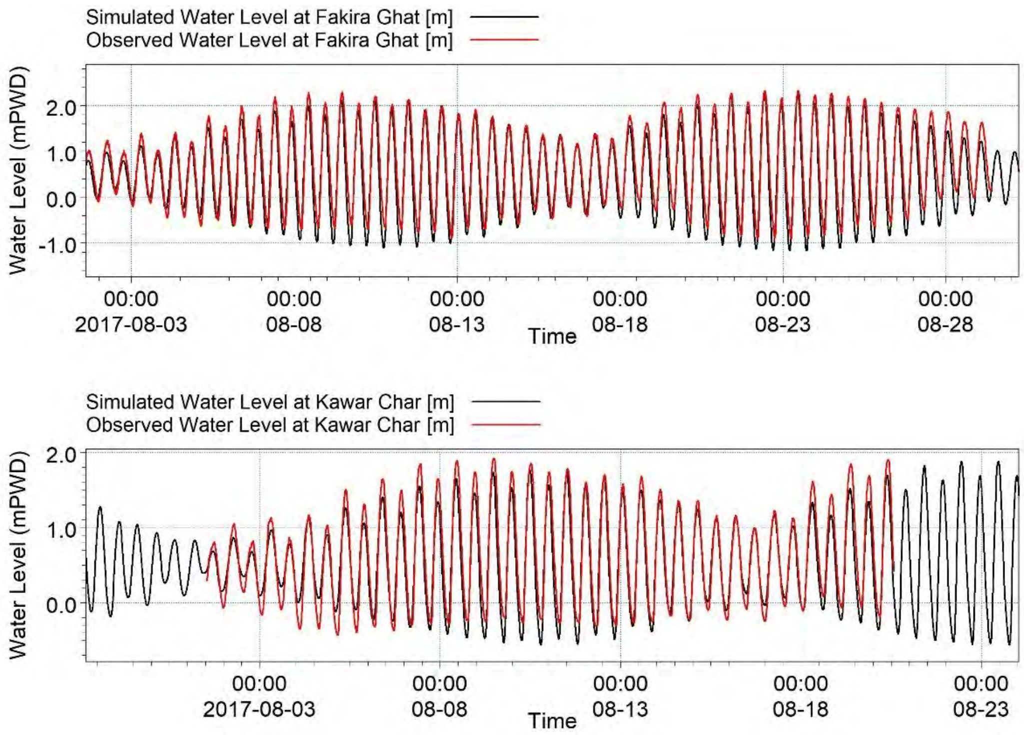

Fig. 2.8. Water level calibration at Fakirghat and Kawar Char.

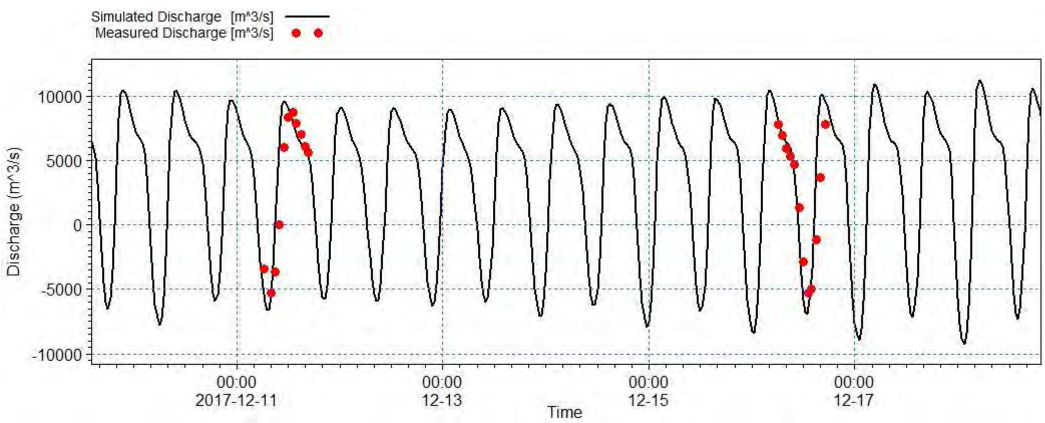

Fig. 2.9. Discharge calibration at Tumchar in Tentulia River.

2.2.3.2 Validation of hydrodynamic model

Validation for hydrodynamic model is required to verify the model or to validate that the model works good in a different year time period rather than calibration period. The model has been validated for tidal water level at different locations for the year 2015. Validation locations are shown in Figure 2.7.

Usually, validation location is chosen such way that it differs from calibration locations. In this study water level calibration and validation locations are same that means calibration and validation have been done for same location.

Validation Results are shown in Figure 2.10. From this time series plot it seen that for both locations (i.e., Fakira Ghat and Kawar Char) simulated and observed water level matched well. Correlation factors for hydrodynamic model validation are found quite satisfactory.

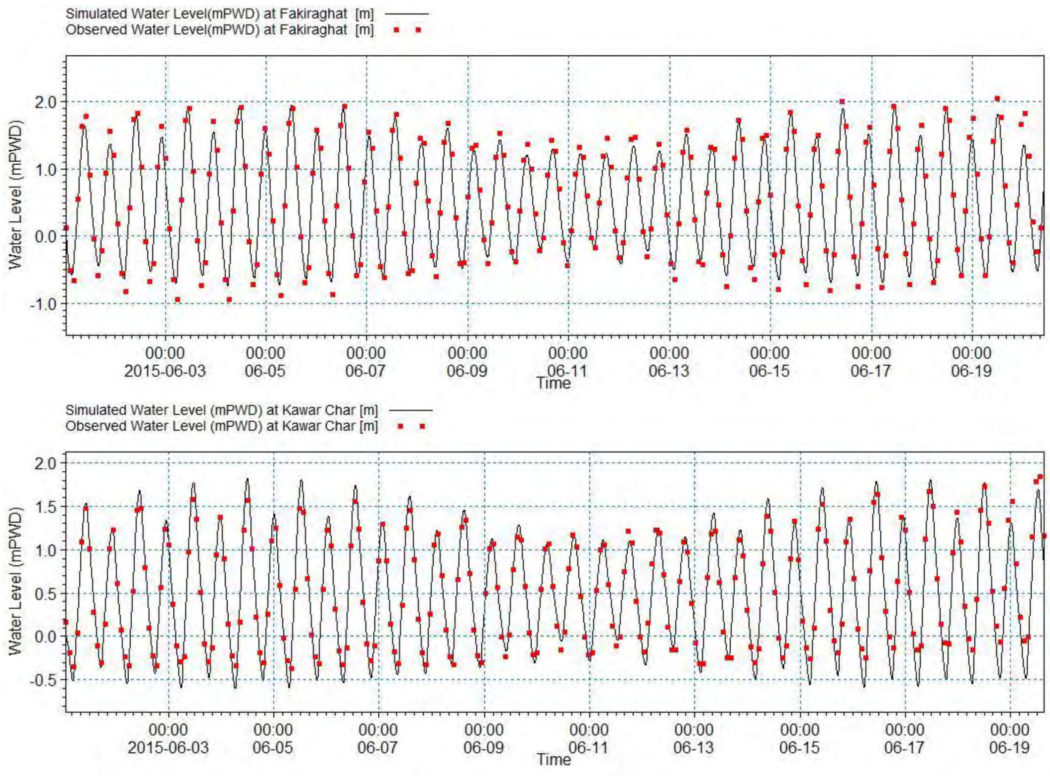

Fig. 2.10. Water level validation at Fakiraghat and Kawar Char.

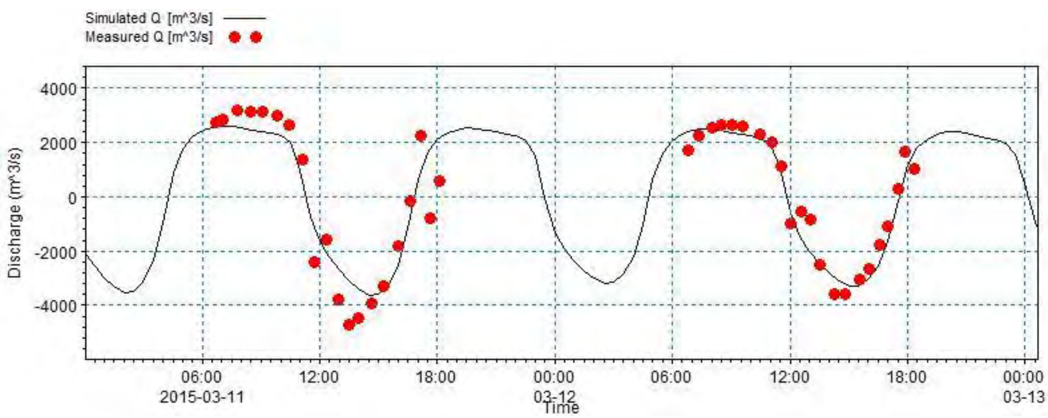

Fig. 2.11. Discharge validation at Bamna of Bishkhali River.

2.3 Wave model

The spectral wave module of Mike 21 (MIKE 21 SW) is based on the wave action balance equation where the wave field is represented by the wave action density spectrum *N (σ,θ)*. The relation between the wave energy density spectrum *E(σ,θ)* and the wave action density spectrum is given by

$$N = E/\sigma \tag{2-5}$$

The spectral wave module includes two different formulations

- Directionally decoupled parametric formulation
- Fully spectral formulation

The fully spectral formulation is based on the wave action conservation equation as described in e.g., Komen et al. (1994) and Young (1999), where the directional-frequency wave action spectrum is the dependent variable.

In horizontal Cartesian co-ordinates, the conservation equation for wave action can be written as

$$\frac{\partial N}{\partial t} + \nabla.(\vec{v}N) = \frac{S}{\sigma} \tag{2-6}$$

Where,
$N(\vec{x}, \sigma, \theta, t)$ is the action density
t is the time, $\vec{x} = (x, y)$ is the Cartesian co-ordinates
$\vec{v} = (c_x, c_y, c_\sigma, c_\theta)$ is the propagation velocity of a wave group in the four-dimensional phase space $\vec{x}$, σ and θ
S is the source term for the energy balance equation
∇ is the four-dimensional differential operator in the $\vec{x}, \sigma, \theta$-space

Spectral Wave module has been applied for the study. MIKE 21 SW is a new generation spectral wind-wave model based on unstructured flexible mesh. The model simulates the growth, decay and transformation of wind generated waves and swells in the offshore and coastal areas. MIKE 21 SW includes the following physical phenomena:

The existing bathymetry that has been used for wave model are given in Figure 2.12.

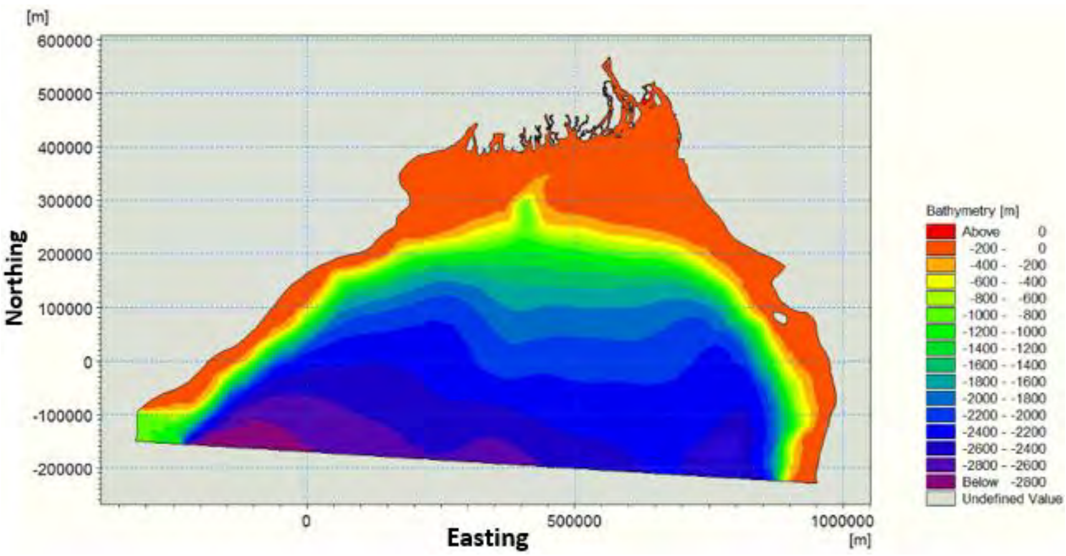

Fig. 2.12. Bay of Bengal spectral wave model.

The existing mesh resolution has been further upgraded for the study area and also bathymetry is updated in Rabnabad Channel, Andharmanik River and the vicinity of Kuakata beach under this research work. The boundary conditions for the upgraded model are extracted from the existing Wave Model of IWM.

A dfs1 file as wave boundary of Bay of Bengal (BoB wave model domain) is collected from IWM for the year 2008 to 2018. This dfs1 file is actually prepared from ECMWF. Existing

BoB wave model is run using this boundary for long term. For dedicated wave model east west and south wave boundary is created from simulating BoB model. Dedicated wave model result is more accurate as higher resolution mesh is used and bathymetry is updated in the study area. Then wave result is analyzed and used for littoral drift and coastline evolution model. Parameters used at the boundary data for the upgraded wave model are significant wave height, peak wave period, mean wave direction and directional standard deviation.

2.3.1 Model parameters

For the local spectral wave model, the model parameters are shown in Table 2.3. MIKE 21 SW includes two different formulations: 1) Directional decoupled parametric formulation and 2) Fully spectral formulation. The directional decoupled parametric formulation is based on a parameterization of the wave action conservation equation. The parameterization is made in the frequency domain by introducing the zeroth and first moment of the wave action spectrum as dependent variables following Holthuijsen (1989). The fully spectral formulation is based on the wave action conservation equation, as described in e.g., Komen et al. (1994) and Young (1999), where the directional-frequency wave action spectrum is the dependent variable. The number of discrete directions should be large enough to resolve the directional variation of the waves. For swell with a relative narrow directional distribution of the wave action/energy a relatively small directional resolution is needed.

Table 2.3
Model parameters for local wave model.

Model Parameter	Value
Basic equations	Fully spectral formulation Instationary formulation
Spectral discretization	16 directions
Solution technique	Low order fast algorithm Max. number of levels in transport calculation = 32 Minimum time step = 0.01 sec Maximum time step = 600 sec
Water level conditions	Calculated using HD model
Wind forcing	U and V wind field from ECMWF
Wave breaking	Specified gamma Gamma = 0.8 Alpha = 1 Gamma (wave steepness) = 1 Effect on mean frequency not included
Bottom friction	Nikuradse roughness height. Kn = 0.04 m Effect on mean wave frequency was included
Current conditions, ice coverage, diffraction	Excluded

The discretization in geographical and spectral space is performed using a cell-centered finite volume method. In the geographical domain, an unstructured mesh is used. The spatial domain is discretized by subdivision of the continuum into non-overlapping elements. The convective fluxes are calculated using a first order upwinding scheme. Depth-induced wave breaking is the process by which waves dissipate energy when the waves are too high to be supported by the water depth, i.e., reach a limiting wave height/depth-ratio. The formulation used in the spectral wave module is based on the formulation of Battjes and Janssen (1978). This model has been used successfully in the past in fully spectral models as well as in parameterized versions. As waves propagate into shallow water, the orbital wave velocities penetrate the water depth, and the source function due to wave-bottom interaction become important. The dissipation source function used in the spectral wave module is based on the quadratic friction law and linear wave kinematic theory.

2.3.2 Dedicated wave model

Concept of dedicated wave model is deployed in this study due to ease of handling the model, it minimizes the simulation time, provides good result incorporating the finer mesh. Plenty of scenarios can be investigated in limited time. The flow chart in the Figure 2.13 indicates how a wave model works by MIKE 21 SW.

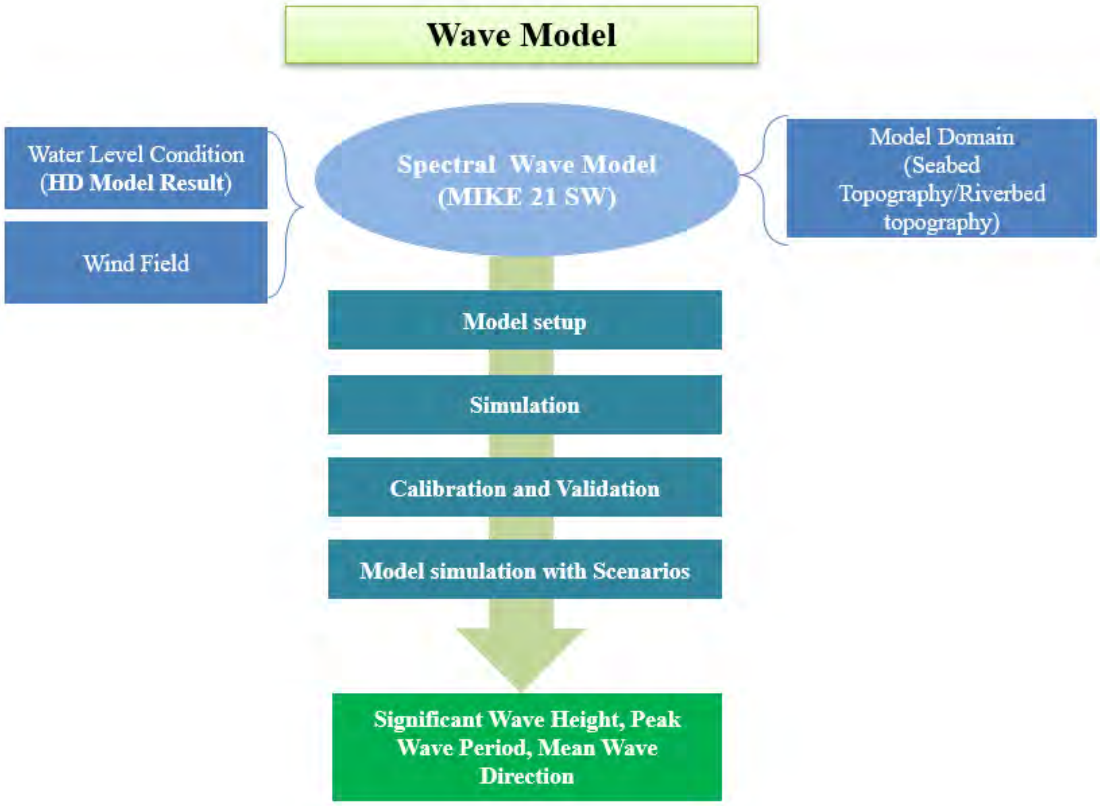

Fig. 2.13. Flow chart of wave model using MIKE 21 SW.

2.3.2.1 Model domain

In the present study, a dedicated model has been developed which is cut from the existing IWM wave model. Mesh is improved in the vicinity of Kuakata beach.

In IWM wave model very coarse mesh was used, here in this study finer mesh is used as sediment budget calculation is involved. Figure 2.14 shows the model domain of study area. East, west and south boundary of the model domain are in the Bay of Bengal and upstream boundary is Hilisha river which has been originated from Lower Meghna. Moreover, the important rivers in the domain are Baleswar, Bishkhali, Buriswar-Payra, Andharmanik, Lohalia, Tentulia, Rabnabad Channel etc.

2.3.2.2 Water level conditions

For the same domain hydrodynamic model was run for the year 2018. Result file of hydrodynamic simulation is used as water level condition. So, Water level is used as varying in time, varying in domain.

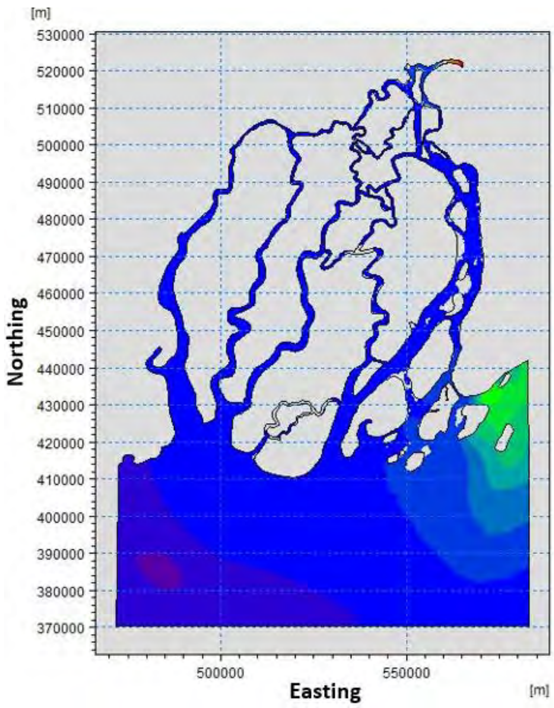

Fig. 2.14. Dedicated wave model domain of the Kuakata study area.

2.3.2.3 Wind

Accurate predictions of extreme values of waves are essential when determining design data for marine structure. The safety of structures, as well as the possibility of developing an economic design, relies above all on reliability and accuracy of the underlying design data. European Centre for Medium-Range Weather Forecasts (ECMWF) has carried out global forecast model for different part of the world. In this study, wind and wave data will be extracted from this global model from ERA5 for forecasting wind and wave in the project area. Figure 2.15 shows the coverage of the global model data for existing Bay of Bengal model. The detailed description of the wind field data is furnished below:

Area: 81^o E to 95^o E and 16^o N to 25^o N
Period: 1 Jan 2008 to 1 Jan 2019 with resolution 0.125 x 0.125 degrees
Parameters: Atmospheric pressure and wind components (X and Y)
Format: DFS2 (structured grid)
The wind data is variable in space/time and inserted in the model as velocity components. Figure 2.15 shows y component of a sample wind data.

2.3.2.4 Development of boundary condition

The model has three open boundaries namely the south, west and east boundary where offshore wave conditions are specified for the period 2008-2018 and the other boundary is absorbing land boundary. The offshore wave conditions defined in the Mike 21 SW model are

- Significant wave height (meters)
- Peak wave period (seconds)
- Mean wave direction (degrees)
- Directional standard deviation (degrees)

These integrated wave parameters have been extracted from Global Wave Model.

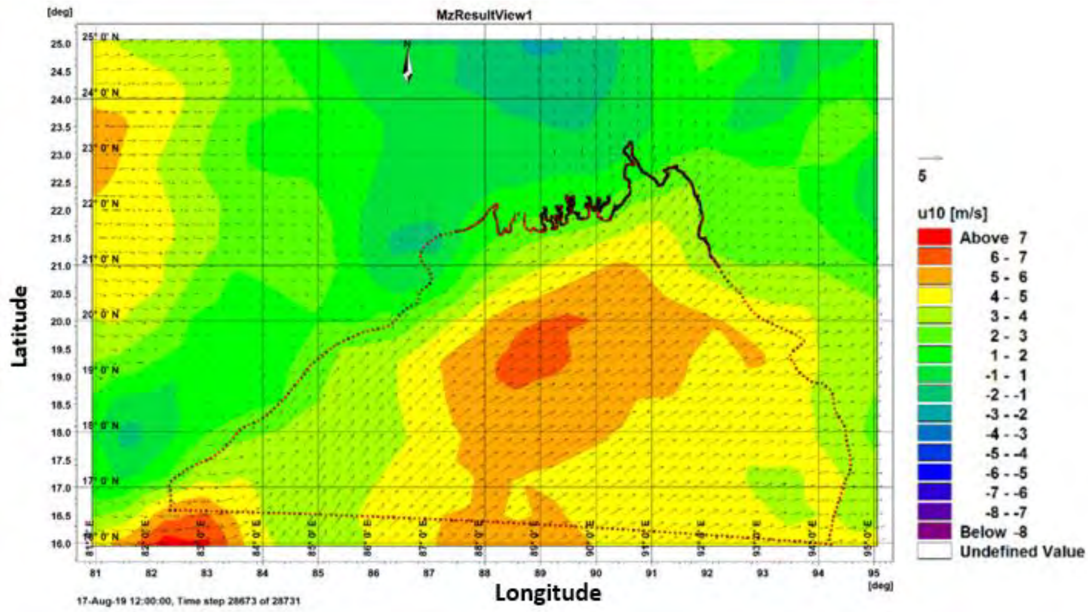

Fig. 2.15. Y-component of wind speed at a particular time covering the Bay of Bengal model area.

2.3.3 Calibration of dedicated wave model (MIKE 21 SW)

2.3.3.1 Simulation

A number of simulations were carried out to establish the nearshore wave conditions in the study area. The simulations have been carried out using the following conditions:

- Fully spectral formulation
- Quasi-stationary time formulation
- Directional discretization 360 degrees
- Bottom friction $k_n = 0.015$
- Wave breaking $\gamma = 0.8$ and $\alpha = 1.0$

The bottom friction is specified as Nikuradse roughness, k_n. The default value k_n is 0.04 m which is usually too high for nearshore applications using the fully spectral formulation. The value of k_n is selected 0.015 m for the SW model of Kuakata beach by trial-and-error process.

2.3.3.2 Calibration

Calibration means adjustment of the model parameters so that simulated and observed data match within the desired accuracy. The spectral wave model was calibrated using recorded wave data from 7th March – 2nd April of year 2018. The location of the wave measurement was 24 km offshore from Kuakata beach and is illustrated in Figure 2.16. The simulated significant wave height, peak wave period & peak wave direction is compared with the observed data at the available location in Figure 2.16. It is seen in Figure 2.16 that the significant wave height, peak wave period & peak wave direction is well represented by the spectral wave model. For validation the wave models no observed wave data is found for the study area. So, it can be treated as a limitation of this thesis work.

3. Data analysis, result and discussion

In this chapter current analysis from hydrodynamic model, wave rose analysis from wave model are explained in the following sections.

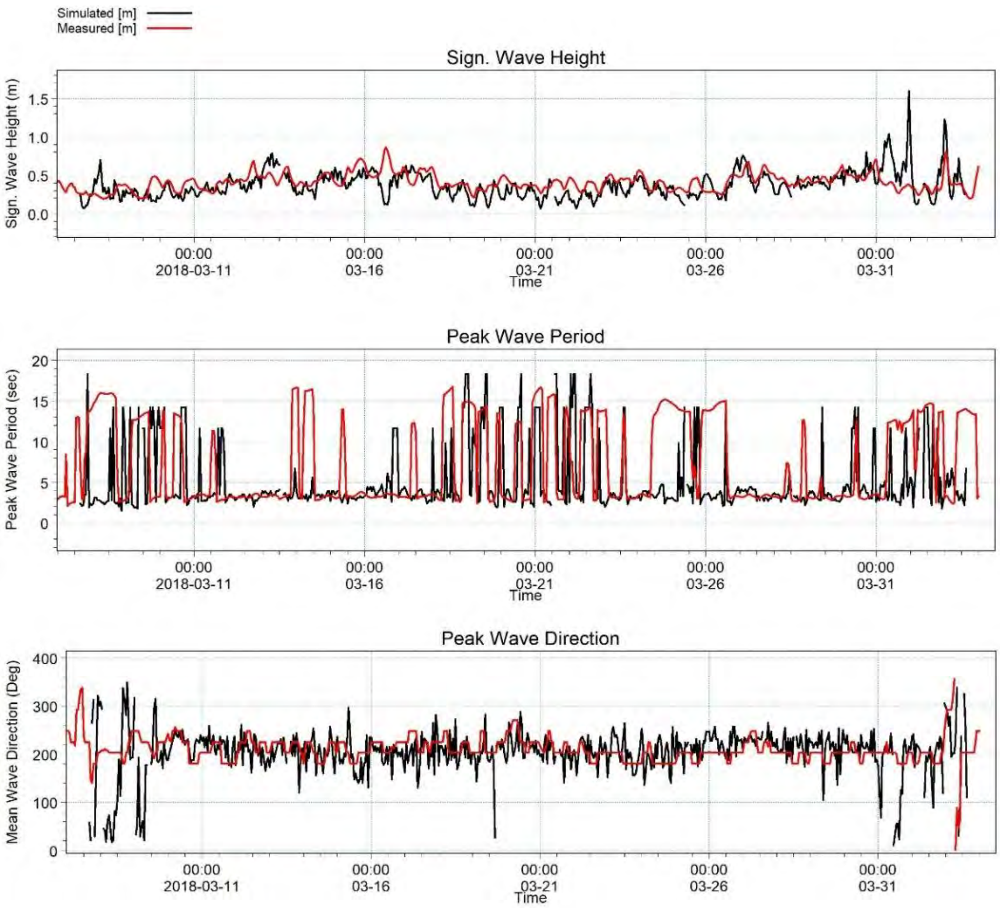

Fig. 2.16. Calibration plot of significant wave height, peak wave period and peak wave direction.

3.1 *Nearshore wave-tide hydrodynamics*

It is very important to analyze the current and wave properties to understand the reasons behind the coastal erosion at Kuakata beach area. Current direction and speed in different water level condition, current rose analysis from HD model and wave rose analysis from wave model result file will determine whether longshore or cross shore current is dominant in Kuakata. Moreover, current directions and magnitudes due to combined effect of tide and wave (i.e., coupled HD model with wave radiation stress) for both ebb tide and flood tide were analyzed for the existing condition (without incorporating protective structures) for different periods of the year 2017. The results from the simulations helped to understand the existing governing nearshore hydrodynamic conditions in the study area. This section will accomplish the 2nd objective of the study.

3.1.1 *Current analysis from HD model result*

Current analysis has been carried out for three different periods like monsoon, dry and normal period. For every period water level was found out. Four points have been identified in water level hydrograph in day. Point-1 is identified as when water level move from low tide to high tide. Point-2 is identified as when water level is in equilibrium condition (low tide to high tide). Point-3 is identified as when water level move from high tide to low tide and point-4 is identified as when water level is in equilibrium condition (high tide to low tide). These are illustrated in Figure 3.1 and Figure 3.2. Current direction and speed were extracted in the vicinity of Kuakata beach for every point. It is found that for point-1 and point-2, the current direction is eastward and for point-3 and point-4 current direction is westward.

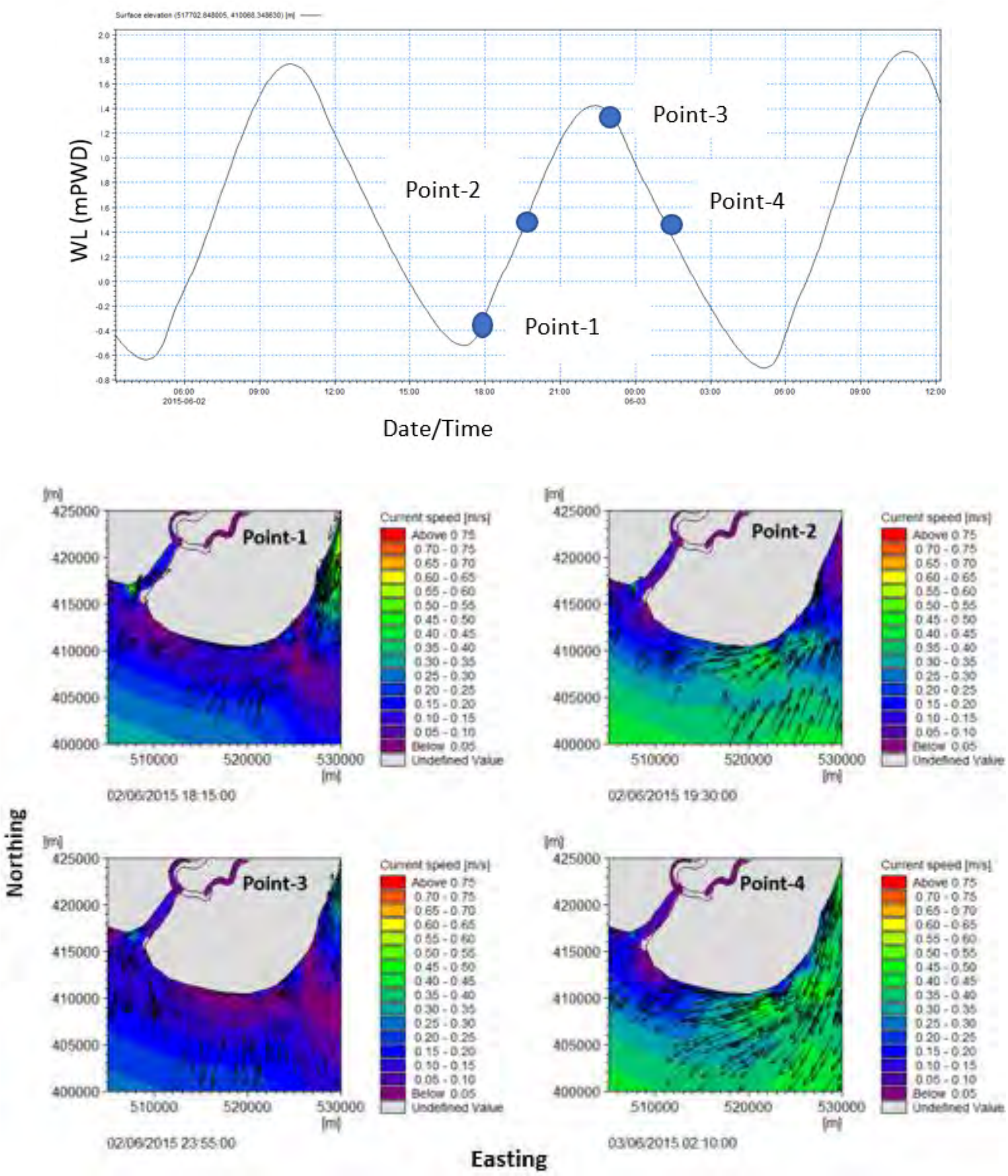

Fig. 3.1. Current direction and speed at Kuakata nearshore in monsoon period at different water level condition.

It is because of the presence of tide is there and which is semi diurnal. It is also found from the analysis that eastward current speed is higher than westward current speed. So, sediment moves toward right, which means sediment transport occurs Lebur Char to Kawar Char. In Data view manager of MIKE, there is a statistical analysis tool which show the maximum current speed in the Kuakata beach area.

3.1.2 Current rose analysis

From one-year hydrodynamic result file current speed and direction data are extracted in three different point. By plot composer tool of MIKE current roses are prepared for the study area which is shown in the Figure 3.3. There extraction points (i.e., point-1, point-2 and point-3) are shown in the map (Figure 3.3). This current rose for point-1 is in left portion of the beach which is marked by red dot on the map. Here eastward current is dominant. Current rose for point-2 is for the middle portion of the beach. Here current is in both directions. But in eastward direction current speed is higher. This current rose indicates that most of the currents are slightly angular to left direction in a year. We will see later, there will be very little annul drift in westward direction.

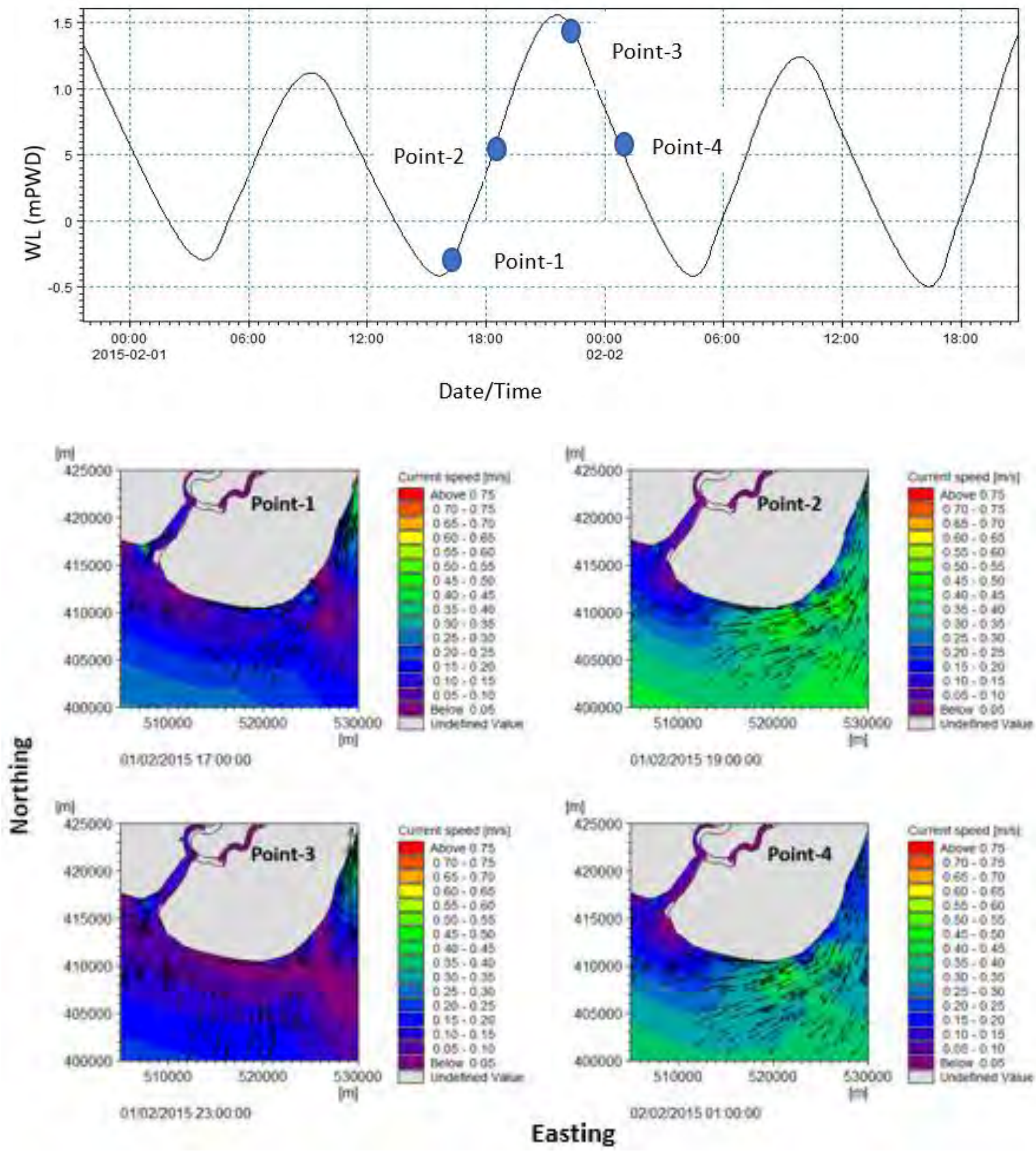

Fig. 3.2. Current direction and speed at Kuakata nearshore in dry period at different water level condition.

3.1.3 Wave rose analysis from wave model result

Wave roses are prepared from wave model result. The components of making a wave rose are significant wave height and mean wave direction. From Plot Composer of MIKE wave rose can be prepared. Wave result is extracted in three different locations i.e., transect no. 2,4 and 6. From wave rose analysis or pattern it is found that most of the waves come angularly and hit the beach. It is also found that right ward angular waves are more prominent which is also an indicator of transporting sediment more than the left.

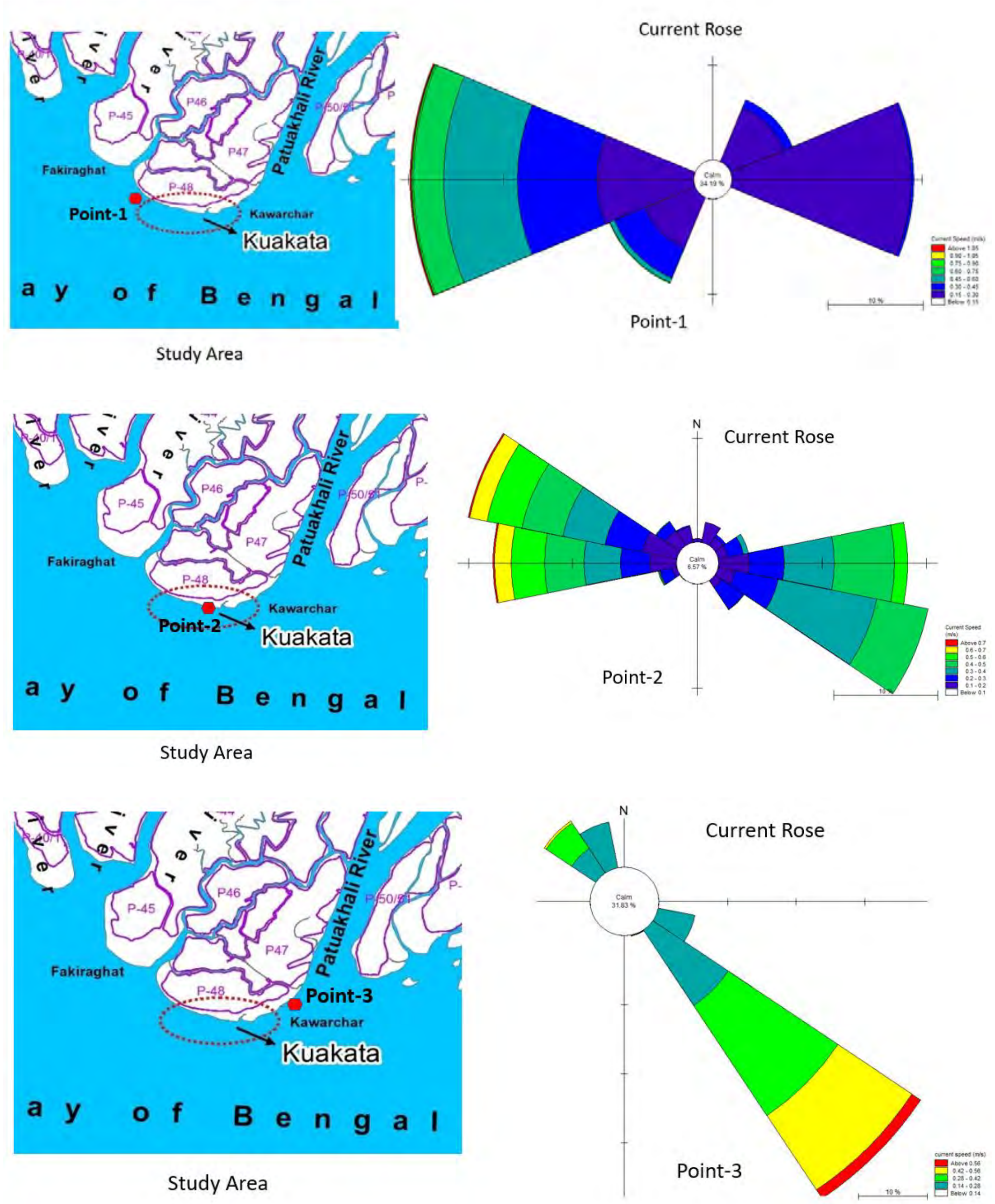

Fig. 3.3. Current Rose at different location of the beach (i.e., Point-1, Point-2 and Point-3 shown on the left map).

3.1.4 Current speed diagram analysis

Current speed diagrams for Kuakata nearshore are prepared from hydrodynamic result file for spring tide and with wave action which shown in Figure 3.5. Tide and seasonal information are marked on each diagram. If we couple wave with HD model (i.e., incorporate wave radiation stress in pure tide model) current speed increases (Figure 3.5). In monsoon flood tide current speed varies 1.65 m/s to 1.95 m/s and ebb tide varies 0.3 m/s to 1.2 m/s. on the other hand for dry season flood tide current speed 0.6 to 1.8 m/s and ebb tide current speed varies from 0.1 m/s to 1 m/s.

By statistical tool of MIKE data manager maximum current speed and bed shear stress are found out for Kuakata nearshore in different wave and tide condition which are shown in the Table 3.1. Bed shear stress increases with the increase of current speed. During Flood tide current direction is eastward and during ebb tide current direction is left ward. Flood tide always govern here to cause longshore littoral transport to eastward (i.e., to east direction).

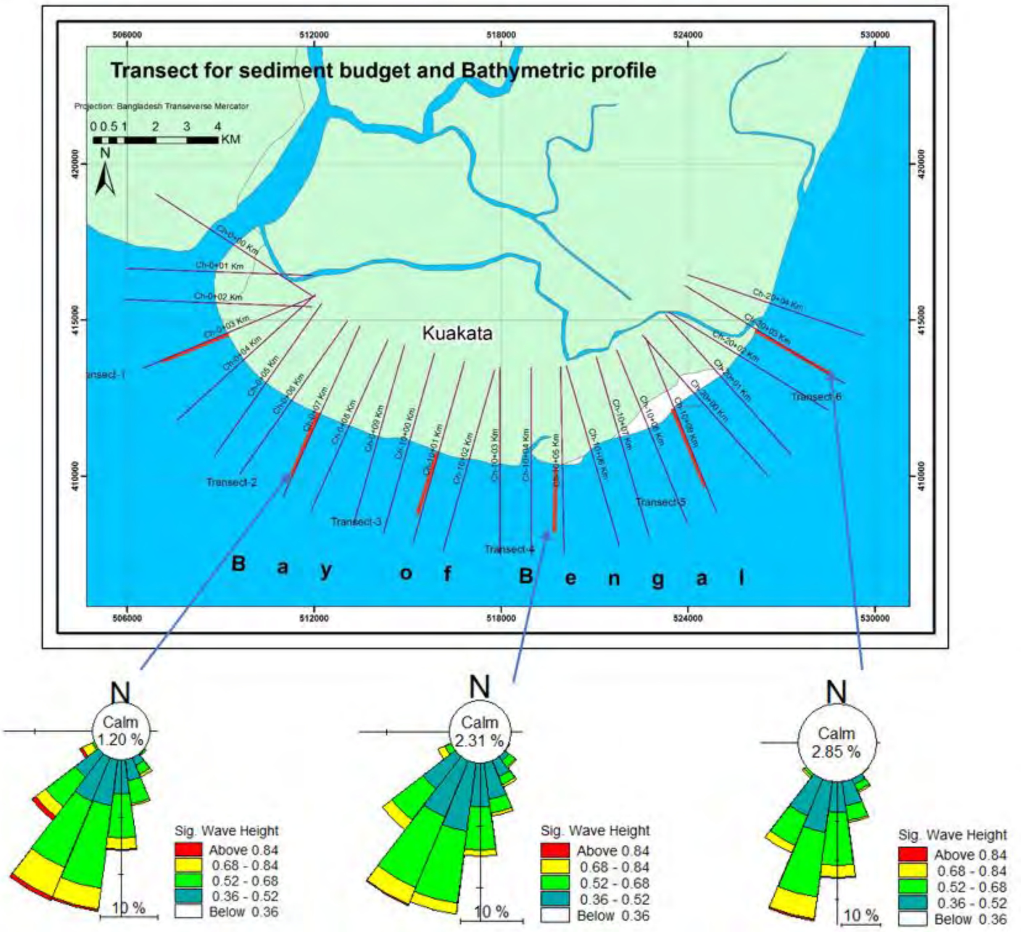

Fig. 3.4. Wave rose at different location, at transect no. 2,4 & 6.

From the above Table 3.1, for spring tide, monsoon flood tide is with wave condition is governing for longshore current. Maximum current speed and Maximum bed shear stress are 1.2 m/s and 2.8 N/m^2, respectively. It can be concluded from the above article 4.3 that current speed and direction for different water level condition and current speed analysis confirms that eastward (i.e., to east) littoral transport occurs. Current rose and wave rose analysis confirms longshore current is dominant in Kuakata. Wet season flood tide with wave action during spring tide is the governing situation for littoral transport. Bed shear stress increases with increase on current speed. Maximum current speed increases as we go offshore from the beach consequently maximum bed shear stress follow the same.

3.2 *Summary of the results*

Following major findings have been found from this study:

– From 2D hydrodynamic model current analysis is done in the vicinity of Kuakata beach two seasons like monsoon and dry period. In four scenarios current direction and magnitude is observed in a day in monsoon and dry season. It is seen that current direction is eastward at starting point of flood tide and equilibrium condition during flood tide. It is also seen that current direction is westward at starting point of ebb tide and equilibrium condition during ebb tide because of tidal characteristics of the sea. During flood tide current direction is eastward and during ebb tide current direction is westward. The magnitude of eastward current is higher than westward current, so sediment is transported from west to east.

– From wave roses it is seen that most of the time wave direction is eastward in angel. That means longshore current is dominant. Sediment is transported from west to eastward. Current rose prepared from HD model also conforms the same.

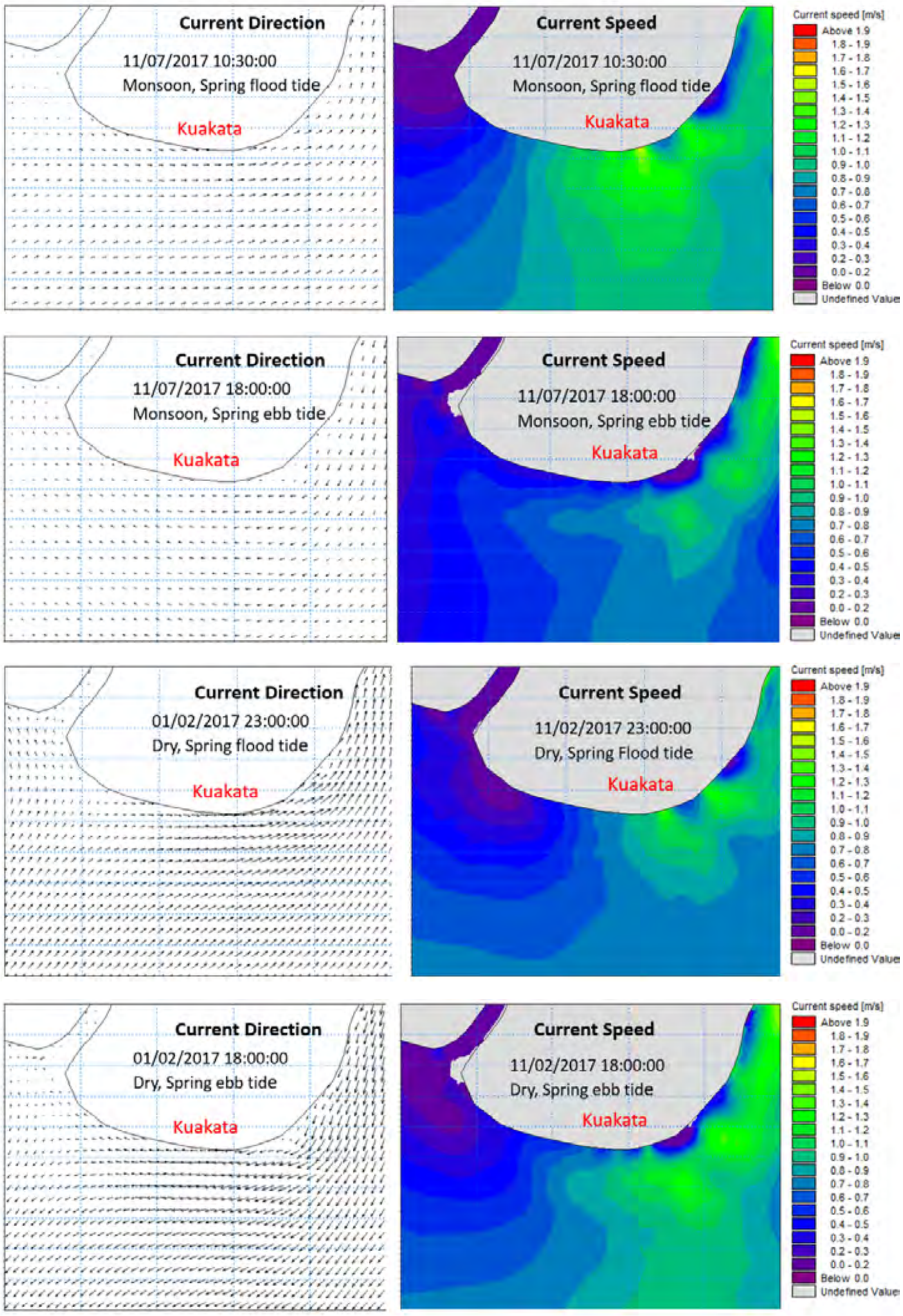

Fig. 3.5. Current speed diagram with wave action at spring tide.

Table 3.1
Maximum speed and maximum bed shear stress matrix.

Season	Wave condition	Tide condition	Max Current speed(m/s)	Max bed shear stress (N/m^2)
Dry (February-2017)	without	flood	0.8	1.4
		ebb	0.1	0.01
	with	flood	1.1	1.7
		ebb	0.2	0.1
Monsoon (July-2017)	without	flood	0.95	1.7
		ebb	0.15	0.05
	with	flood	1.2	2.8
		ebb	0.25	0.17

4. Conclusion

Two types of models have been used in this study. These are 2D hydrodynamic model, wave model. Wave model is coupled with hydrodynamic model. Result from wave model is used in littoral drift model and LITLINE model. Following major findings have been found from the current study:

- Around 13 km western side of Kuakata beach (i.e., Lebur Char) faces serious erosion and on the other hand 7 km eastern side (i.e., Kawar Char) accretes over the last 4 decades which is found from historical satellite images.
- A dedicated hydrodynamic and a wave model are setup, calibrated and validated for the Kuakata study area and nearshore wave-tide hydrodynamics analyzed. It is found that longshore current governs in the nearshore of Kuakata and wet season, spring tide, flood tide with wave action is the governing condition for littoral transport.

Based on this study some recommendations have been summarized below:

- As we know the dominant current direction and wave direction in the Kuakata beach, mainly longshore current occurs here. Groynes can be incorporated in the model. Nearshore hydraulics can be studied after incorporating groyne in the hydrodynamic and wave model.
- Coarser bathymetry is used from C-map and GEBCO in the vicinity of Kuakata beach. Better result can be expected if fine bathymetry would be used. Further study can be carried out using fine bathymetry (if available) and compared with present result.

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