Application of numerical modelling for morphological changes in a high-energy beach during the south-west monsoon

V. R. Shamji, T. S. Shahul Hameed, N. P. Kurian* and K. V. Thomas

Marine Sciences Division, Centre for Earth Science Studies, Thiruvananthapuram 695 031, India

Study of beach morphological changes during monsoon and development of capabilities towards its prediction is of vital importance in coastal zone management. A study of the beach erosion/accretion processes during south-west monsoon and its numerical modelling is attempted in this communication for a micro-tidal and high-energy beach. Comprehensive hydrodynamic and beach profile data measured in the field were used for the study. The beach morphological changes as a result of the high intensity monsoon waves are found to be characterized by erosion of beach coupled with deposition in the offshore leading to formation and migration offshore longshore bar. The model LITPROF of the LITPACK software of DHI is found to simulate well the beach morphological changes by adjustment of the calibration parameters. The integrated cross-shore transport computed across the profile, using the model shows high erosion in the beach face coupled with an equivalent accretion in the offshore. The model performance computed using different statistical methods is found to be good.

Keywords: Beach morphology, LITPACK, monsoon, nearshore, numerical modelling.

NEARSHORE is a dynamic environment where the sediment transport is highly complex. The wave-induced sediment transport causes changes in beach morphology due to cross-shore as well as longshore sediment transport. Prediction of beach morphological changes is of paramount importance for various coastal engineering projects and proper management of coastal zone. Thus, coastal engineers and scientists have been involved in development of methodologies for prediction of beach morphological changes. Numerical models have gradually evolved as a powerful tool to predict beach morphological changes.

Swart[1,2], Kriebel[3], Kriebel and Dean[4], Larson *et al.*[5], Larson and Kraus[6] are some of the models available for prediction of beach profile changes. There are several commercially available models for the short/medium term prediction such as UNIBEST-TC[7], SBEACH[6], 2DH[8] and LITCROSS[9]. There has not been any effort in this country either in the development of numerical models or testing and validation of the available models for prediction of beach morphological changes, barring the preliminary work of Baba *et al.*[10]. The present study is carried out with the objective of numerically modelling beach morphological changes due to high-intensity monsoonal waves for a selected location off the Kerala coast using the LITPROF model of the LITPACK software.

Severe beach erosion is reported along the Kerala coast during the south-west monsoon season[11–14]. Rebuilding of beaches takes place during the latter part of monsoon and post-monsoon period. The important mechanism for high erosion during south-west monsoon is the cross-shore sediment transport than the longshore transport[15–17]. The present study is taken up at Valiathura, near Thiruvananthapuram (Figure 1), which is a high-energy coast with pronounced erosion during monsoon[11]. This coast has a micro-tidal regime of range less than 1 m. Beach at Valiathura is straight and inner shelf (<30 m contour) is steep with a slope of about 0.002.

The model LITPROF in the LITPACK software of DHI was used to model the morphological change. The model is a deterministic model to simulate beach morphological changes. The model can effectively handle complex morphological features like multi-barred profile with different grain size. The model assumes that in case of sloping beach there is a downward direction of current. The most important capability of the model is its ability to predict both erosion and accretion cases.

The LITPROF describes the cross-shore profile change based on time series wave data. The model assumes that

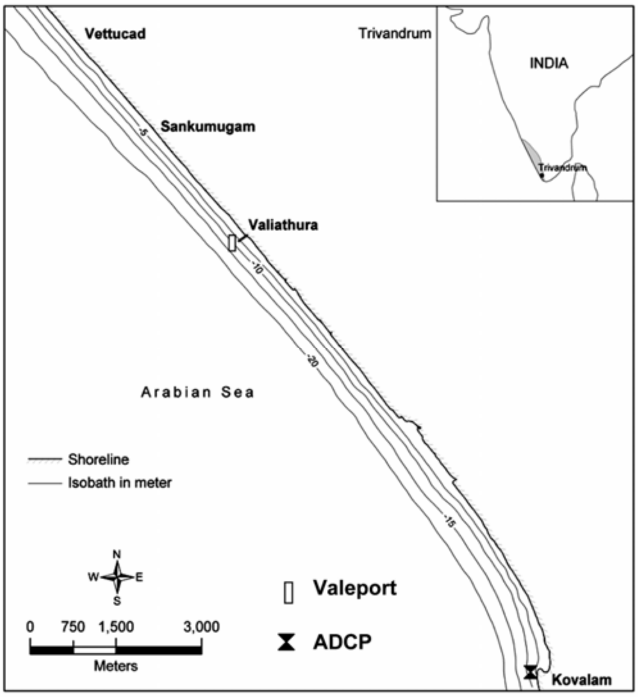

Figure 1. Valiathura coast near Thiruvananthapuram, the site chosen for the study.

*For correspondence. (e-mail: npkurian@gmail.com) longshore gradients of sediment transport are negligible and nearshore bathymetry is almost parallel to the coast. At the offshore boundary, time-varying wave conditions are specified in terms of wave height, mean wave period and mean wave direction. Sediment transport is calculated from an intra-wave hydrodynamic model where the time evolution of the bed boundary layer is resolved. The bed level change is described by the continuity equation:

$$D(z)/D(t) = -1/(1-n)\mathrm{d}(Q_s)/\mathrm{d}(x), \quad (1)$$

where z is the depth, Q_s the cross-shore transport and n the porosity of the bed material. The model consists of different modules; first, wave and current profiles across the coastal zone are calculated, followed by calculation of cross-shore sediment transport rate. The cross-shore profile changes are calculated by solution of the bottom sediment continuity equation.

Among the data requirements for model running, the first was the hydrodynamic data, which were collected using field instruments. The wave and current in the nearshore site were measured by deploying a pressure gauge manufactured by Valeport and an Acoustic Doppler Current Profiler (ADCP) off Valiathura and nearby area at a depth of 8 m (Figure 1) during 5–26 June 2005. Beach profile measurements using dumpy level and staff, together with surficial sediment sampling were carried out twice – first, on the early stage of deployment and second, on the later stage of retrieval of the equipment. The wave parameters like significant wave height (H_s), wave period (T_z) and mean wave direction were derived from recorded data by FFT method of analysis. The foreshore slope was derived from the profiles of the beach. The statistics of the wave for the measured period is given in Table 1. The frequency distributions of wave parameters during the period are given in Figures 2–4.

Table 1. Statistics of input wave parameters

Parameter	Range	Mean	Standard deviation
Wave height, H_s (m)	0.94–2.78	1.88	0.44
Wave period, T_z (s)	6.80–9.8	8.28	0.75

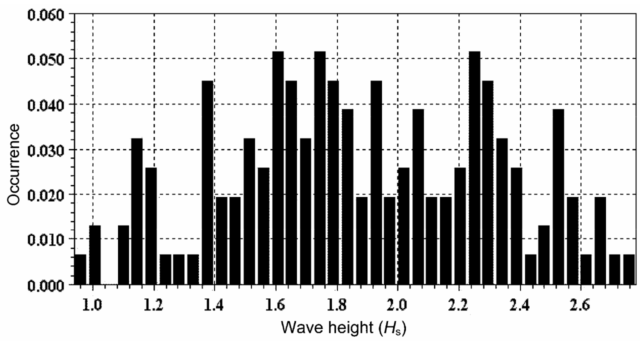

Figure 2. Frequency distribution of wave height (H_s).

The size characteristics of sediments derived from analysis following Folk[18] are given in Table 2.

As the measurement period pertained to the period of onset of monsoon, as expected, wave heights show higher values, with a minimum significant wave height (H_s) of 0.94 m and a maximum of 2.78 m. Standard deviation of H_s is 0.44 pointing to a wider spreading of wave height. Frequency distributions of wave heights (Figure 2) show that about 10% of the H_s are below 1.2 m, 38% in the range 1.2–1.8 m, 41% in the range 1.8–2.4 m and 11% above 2.4 m.

The zero crossing periods (T_z) for this season range from 6.8 to 9.8 s and have a standard deviation of 0.75, indicating a narrow spreading of wave period. Frequency distribution of T_z (Figure 3) shows that 33.3% of the values occur in the range 6.8–7.9 s, 33.4% in the range 8.0–8.6 s and 33.3% in the range 8.7–9.8 s.

The wave directions fall in the range 180–298°N with a standard deviation of 16.29. Frequency distribution of wave direction (Figure 4) shows that about 32% of the values occur in the range 180–220°N, 56% in the range

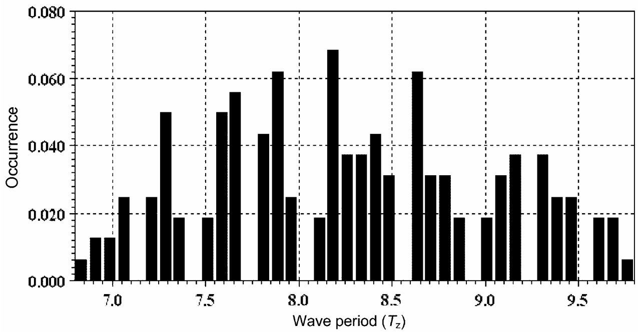

Figure 3. Frequency distribution of zero crossing wave periods (T_z).

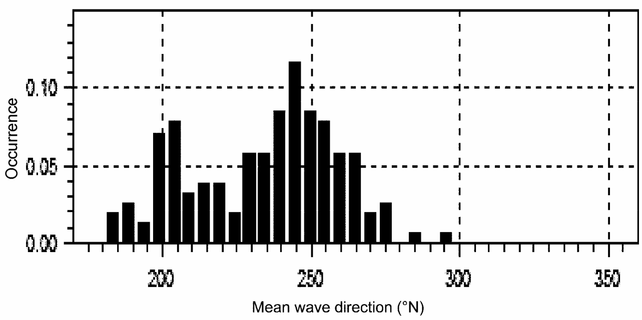

Figure 4. Frequency distribution of mean wave direction.

Table 2. Statistical parameters of the sediment samples

Parameters	Beach face	Berm
Mean (mm)	0.37	0.25
Sorting (mm)	0.74	0.65
Skewness	0.81	0.99
Kurtosis	0.45	0.57

220–260°N and 12% above 260°N indicating that wave directions are normal to the shore for most part of the period.

The initial and final beach profile for the study period is given in Figure 5. The initial profile is characteristic of a beach with the impact of the first monsoonal spell. The fair weather seaward berm is already eroded and the eroded sediment deposited as longshore bar just seaward of the shoreline. The final profile shows high erosion during this period with offshore movement of bar.

The size characteristics (Table 2) reveal that the berm sediments during monsoon are fine sand with a mean size of 0.25 mm, moderately well sorted, symmetrical and platykurtic in nature. Along the beach face, the sediments are medium sand with a size of 0.37 mm, well sorted, fine skewed and leptokurtic in nature (Table 2).

The size characteristics can be attributed to the high wave energy conditions prevailing in the region during this period.

Numerical models need to be refined to match the site, and the decision-making leading to any modification occurs during the calibration phase. The process of calibration also involves adjustment of calibration factors in the models. To minimize the difference between measured and computed values, the model has been run for many cases in the present study.

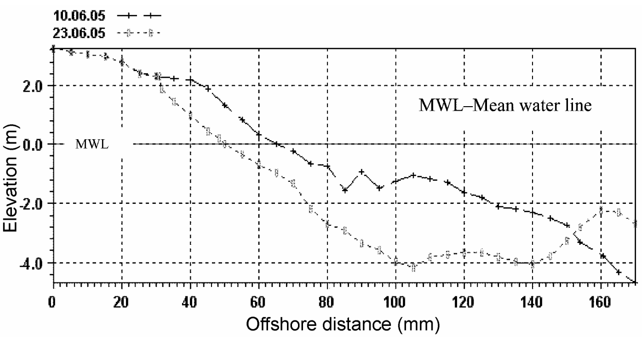

Figure 5. Measured beach profiles at Valiathura.

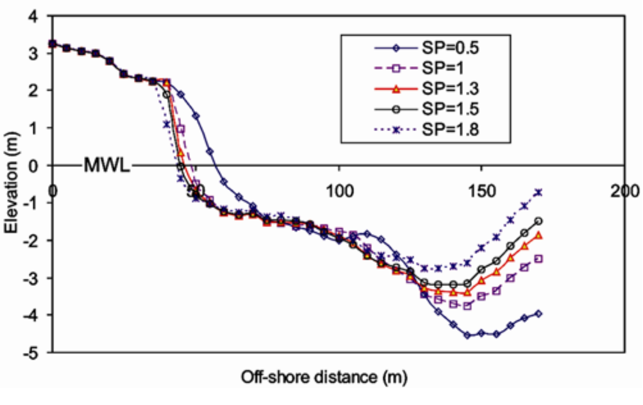

Figure 6. Simulated profiles for different values of scale parameters (SP); wave-breaking parameters are maintained constant at G1 = 0.88 and G2 = 0.6.

The scale parameter (SP) and wave-breaking parameters Gamma1 (G1) and Gamma2 (G2) are the calibration parameters used. The SP reflects the cross-shore exchange of momentum and is proportional to a characteristic length scale over which the sediment transport is smoothed. It will to some degree affect the shape of the developing bars. The higher the SP, the broader is the bar formed (Figure 6). The wave-breaking parameters are the common parameters used in the calibration process in most of the models. The linear shoaling wave outside the breaker point is governed by height to depth ratio, which is given by wave breaking parameters. These parameters are used by Battjes and Janssen[19] in their wave energy dissipation study due to wave breaking. The values of these parameters were varied in the calibration process. It becomes apparent that values of some calibration parameter would have to be modified to achieve agreement between measured and computed profiles.

During the calibration process, the SP is varied at first by keeping the wave-breaking parameters as default value. Figure 7 presents a comparison of the measured profile with the simulated profiles for two different SP values, viz. 0.95 and 1.8. As the value of scale parameter is decreased, the profile comes closer to the measured value. If the value of SP is further decreased to 0.9, it can be seen that the computed profile falls closer to the measured one (Figure 8).

If the other calibration parameter, viz. wave breaking parameters is also adjusted (G1 is 0.88 and G2 is 0.8) the

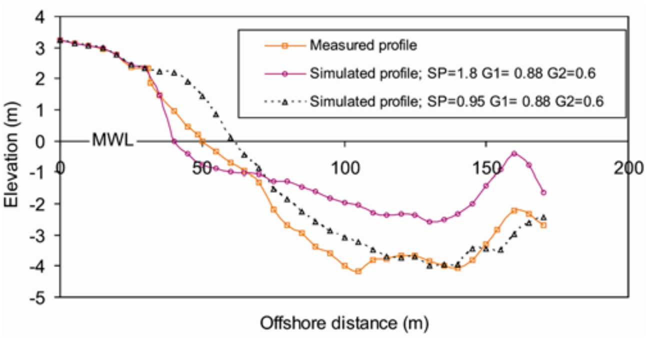

Figure 7. Comparison of the simulated profiles with the measured.

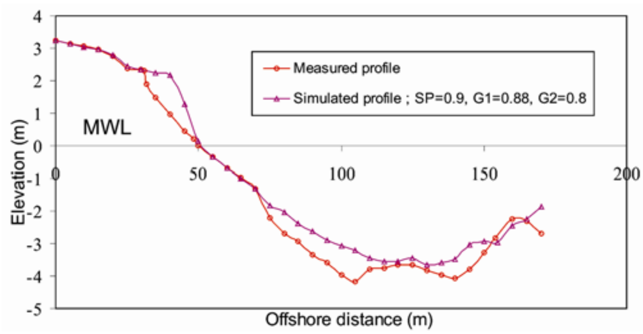

Figure 8. Comparison of the calibrated model output with the measured profile.

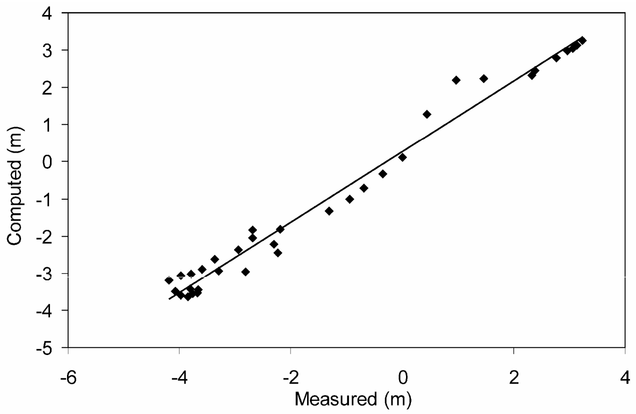

Figure 9. Plot of computed beach elevation against observed.

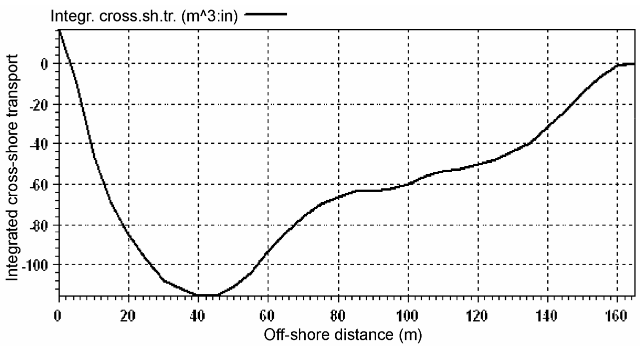

Figure 10. Simulated integrated cross-shore transport in the model domain.

Table 3. Statistical parameters of the calibrated model

Parameter	Value
Bias	0.33
Root mean square	0.50
Correlation coefficient	0.99

model gives the best results and the computed profile falls more or less close to the measured one (Figure 8).

The predicted elevations at different locations of the profile are plotted against the observed in Figure 9. It is seen that the observed values are close to those predicted with a correlation coefficient of 0.99. Hence, the model in its present form can be used to make prediction of beach morphological changes.

The integrated cross-shore transport, which indicates erosion/accretion zones in the profile, was calculated from the model results and is given in Figure 10. It shows high erosion in the beach face and an equivalent accretion in the offshore region due to the deposition of eroded material from the beach face. The results conform to the findings of the earlier researchers for the south-west coast[11–14].

Model performance depends on mathematical stability of the model and the quality of the model, evaluated through the parameters such as root mean square (RMS), bias, correlation coefficient, from the model results. Bias measures the difference in central tendencies of the predictions and observations. The correlation coefficient measures the linear relationship between the two variables and the RMS error gives a measure of the differences between the predicted and observed values. These model parameters have been calculated from the model results and are given in Table 3. It can be seen from the values that the performance of the model is good.

Measurements of nearshore hydrodynamics and beach profiles during the south-west monsoon at a high energy, micro tidal beach in south-west coast of India have provided insight into beach morphodynamics in response to high-intensity monsoonal wave. The morphological changes during the period of measurements, which is typical of the first phase of monsoon, are characterized by erosion of the beach and deposition in the offshore leading to bar formation and its migration. Simulation of the morphological changes using the LITPROF module of the LITPACK software, calibrated with field data provided outputs of good accuracy. The numerical modelling study also confirms the high erosion of the beach coupled with accretion in the offshore. The good performance of the model points to its applicability for other coastal locations subject to its validation.

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Geopathic stress: a study to understand its nature using Light Interference Technique

N. P. Dharmadhikari[1], D. C. Meshram[2], S. D. Kulkarni[3], S. M. Hambarde[4], A. P. Rao[4], S. S. Pimplikar[5], A. G. Kharat[6] and P. T. Patil[7]

[1]Department of Applied Physics, JSPM'S Jayawantrao Sawant College of Engineering, Hadapsar, Pune 411 028, India
[2]Department of Geology, University of Pune, Pune 411 007, India
[3]Department of Environmental Science, New Arts Commerce and Science College, Ahmednagar 414 001, India
[4]Department of Electronic and Telecommunication, JSPM'S Jayawantrao Sawant College of Engineering, Hadapsar, Pune 411 028, India
[5]Department of Civil Engineering, Maharashtra Institute of Technology, Kothrud, Pune 411 038, India
[6]Department of Civil Engineering, Sinhgad Academy of Engineering, Kondhwa (Bk.), Pune 411 048, India
[7]Department of Civil Engineering, PVPIT, Budhgoan, Sangli 416 304, India

The energy emitted by the earth at a specific location on the surface, which affects the normal human body function, is termed as geopathic stress (GS). Studies of the exact nature and characteristic of GS are sparse. Some studies indicate that GS may be of electromagnetic nature or subtle energy (Jane Thurnell-Read). The archaic method to identify GS is by dowsing. This communication attempts to make use of 'Light Interference Technique' to study the nature of GS in and around the pre-detected GS location on the Mumbai–Pune expressway and some residential areas of Pune. The results indicate that this stress may be due to concentrated low energy at the respective locations.

*For correspondence. (e-mail: sejalrohit2007@gmail.com)

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DURING the archaic time, a site for dwelling or work place was located after several tests like 'Bhumi Pariksha' (examining the location for typical characteristic). This was done to avoid specific locations where people do not sleep well, get sick more easily or where the efficiency of people is lowered[1–4]. Energies from earth at specific locations, that have an ability to change the normal functions of the human system, are termed as geopathic stress (GS)[5]. There are several sources that generate GS[6]. The archaic method for selecting a site for dwelling considered the presence of bushes, colour of land, presence of water bodies and the development of trees. GS is directly linked with groundwater. It is a common practice to locate groundwater with the help of dowsing[7]. The major cause of natural origin of GS is associated with the subterranean groundwater flows at various depths, with geological faults, fissures, joints and lineaments[8–10].

Extensive studies have been made to understand the nature and effect of GS on the built environment[11–20]. Literature survey reveals that GS may be a form of imbalanced electromagnetic energy spectrum or subtle energy[21–23]. The effect of GS is obvious on humans, animals and even on plants. However, a systematic scientific device is required to study the nature of GS. Therefore, an attempt is made to study the interaction of laser light beam with GS using Light Interference Technique (LIT).

In ancient times, detection of GS was traditionally done by using dowsing or biolocation and kinesiology[24]. Though these techniques have been successful based on their statistical success ratios, and are also simple, fast and inexpensive; there is a continued skepticism about their acceptance by the scientific community. Dowsing is a crude technique and does not give any numerical value or a reading. GS locations identified were confirmed for the existence of groundwater using resistivity method and seismic refraction method[25]. All these methods are lengthy, time consuming and complicated as compared to dowsing. An attempt is made here to design simple, low cost and easy handling device to study the nature of GS.

Light has electromagnetic nature and discrete bundle of energy. These packets are called quanta and particle of light is photon[26]. According to Jane Thurnell-Read, GS may be of electromagnetic nature or subtle energy. The ray diagram of the set-up of LIT is shown in Figure 1,