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Semi-diurnal variability of Weligama beach due to tidal and wave actions

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Abstract
The effect of the tidal and wave action on the Weligama beach in the vicinity of the Polwatta River mouth is studied for the first time. The Weligama bay is located in the southern coast of Sri Lanka at approximate coordinates of 80.45E and 5.95N. The changes of the beach and the changing water level at the river mouth during the tide were monitored for two consecutive days in June 10-11, 2006. The high tide on June 10th was in the afternoon around 2.30. The water level was increased by about 20 cm at the high tide. Increase of the tidal action due to full moon was observed on the June 11th and the maximum rise of the water level was about 30 cm. The short-term variation of beach accretion/erosion due to wave action was measured at two location tracks on the beach and it was found to be within $\pm$ 10 cm. Accretion takes place onshore locations at both tracks during early afternoon on June 11th. Strong positive correlation (over 60%) between beach profile data and tide data is found at onshore locations during accretion on track B on June 11th. Negative correlation of around 50% between the two data sets is observed at onshore locations when more erosion takes place on track B on June 10th.

Keywords: Weligama bay beach, Polwatta river mouth, beach profile, semi-diurnal tidal variation, accretion and erosion, correlation

Introduction

Beaches change their size and shape from day to day, month to month and year to year mainly as a response to waves, currents and tides. Human actions also affect beaches, severely, in some instances. Beach deposits largely consist of sand particles comprise of land sediment brought by rivers, sediment produced by erosion of coastal landforms by waves, and offshore marine sediment that deposits onto the coast. After a severe storm strong waves can erode a beach due to flushing of sand out from the beach. As it is difficult to perform measurements of dynamic beach profiles, researchers extensively use beach models to study beach evolution. In general, such studies are carried out taking only the effects of wave action into consideration (She et. al, 2000). However, in reality, the combined effect of tides and waves change the shape of a beach and it has been found (Trim et. al, 2002) that beach model studies produce more realistic results when both these effects are taken into consideration. In this paper a beach on the southern coast of Sri Lanka is chosen to monitor the changes on the beach due to tidal and wave actions. Sri Lanka is an island with about 200 nautical miles of Exclusive Economic Zone (EEZ) and the legal continental margin extending to several hundreds of miles beyond EEZ. The coastline is characterized by sandy beaches, extensive lagoons, estuaries, mangroves, coastal marshes and dunes. Southern coast of Sri Lanka is subjected to activities that take place in the Bay of Bengal as well as in the Arabian Sea. Thus, effects from both Northeast and from Southwest monsoons on the southern coast can be expected. As a part of field work in a three-week long international workshop held in Sri Lanka from June 5 – 25, 2006, the beach in the Weligama bay was chosen for a study of the effect of the tide and the ocean waves on the beach.

Weligama is a coastal town located in southern Sri Lanka (Figure 1) where a great majority of fishermen living along the coast. The beach along the southern coast consists mainly of white sand. The Weligama bay is a spectacular natural bay with a width of about 2.8 km at the mouth. The Polwatta Ganga (Polwatta River) flows gently into the ocean on the eastern side of the bay (Figure 2). The bay is located at the coordinates of 80.45E and 5.95N, approximately.

It is a shallow water bay (< 10 m) and a habitat for coral reefs.

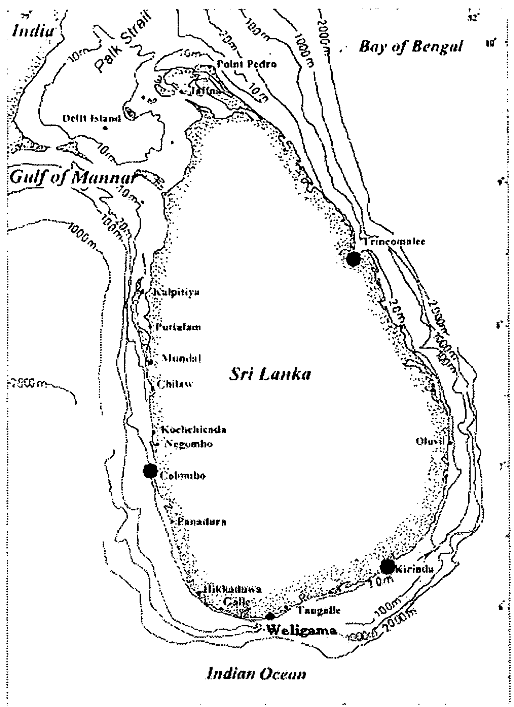

Figure 1. Map of Sri Lanka indicating Weligama and Kirinda.

A major fishing harbour is to the east of the bay, in Mirissa. During Southwest monsoon fishing is mainly restricted to the bay area.

There has been one study done in 1993 (Arulanthan, 1998) about salt-water intrusion into the Polwatta River. However, there have been no scientific observations carried out on tidal and wave actions on the Weligama bay beach until the present study discussed here. The data presented here is only a part of a long-term observation and monitoring plan of the southern coastal area. The beach profile was studied for two consecutive days in June 10-11, 2006. The tide was monitored during the day for the same two days as well. Sand accretion and erosion on the beach and the tidal action at the river mouth of Weligama bay is discussed in this paper. There is only one tide monitoring station located in the southern coast of Sri Lanka which is at Kirinda (see the map in Figure 1), about 150 km to the east of Weligama. Hourly tidal data from Kirinda for the same two days, June 10 and 11, 2006, is also presented for comparison.

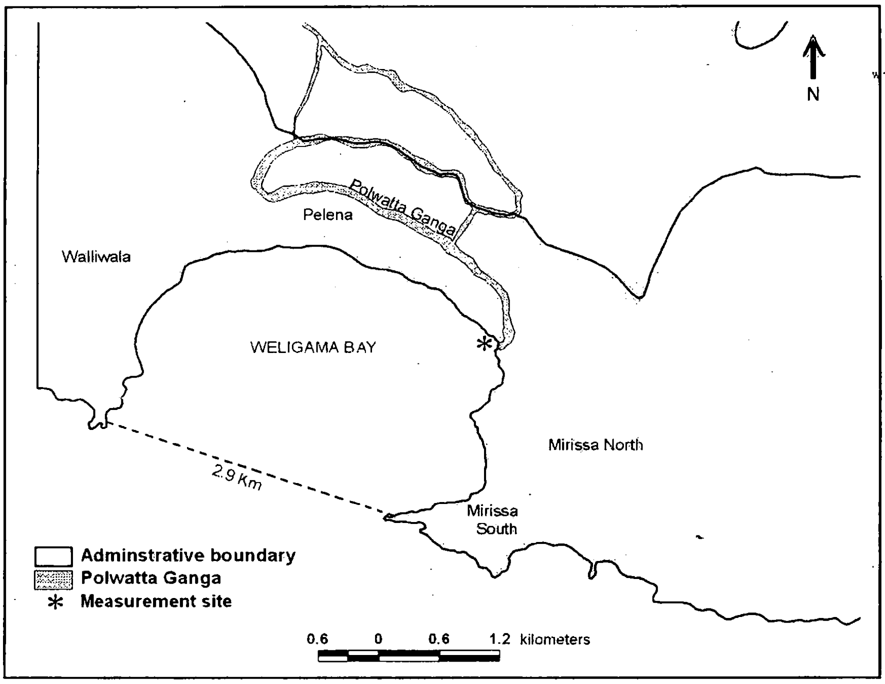

Figure 2. Map of the Weligama Bay. The * close to the river mouth is the measurement site.

Materials and Methods

The beach area close to Polwatta River mouth was chosen for this study. A tide pole (T, as shown in the Figure 3) was placed on the along-shore pathway about 5 m from the river mouth. Readings were taken at 5-minute intervals starting from 11:00 and ending at 17:00 on both June 10 and 11, 2006. Two track locations on the beach, A and B as shown in Figure 3, were chosen to study the beach profile due to wave action. The track closer to the river mouth (B) was about 20 m from the mouth and the distance between the two tracks A and B was about 8 m. At each track location 6 to 8 rods of 1m lengths were placed so that only 50 cm length was above the sand, initially. The rods at a track were aligned perpendicular to the beach and the distance between rods was kept at 1 m except for the last rod on the most offshore location, which was placed at 2 m distance from the preceding one.

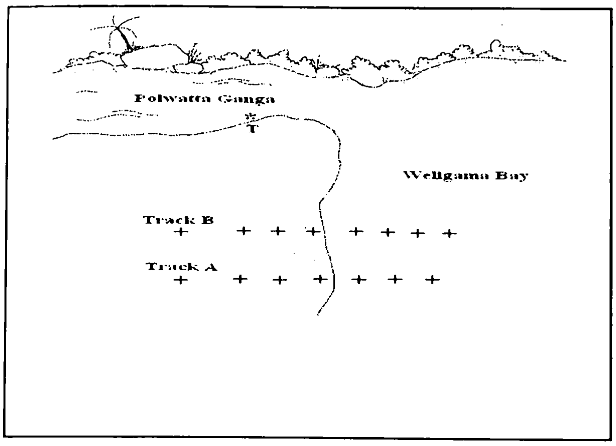

Figure 3. A sketch of the measurement site. Tide measurements were taken at the site marked T. The beach profiles were taken at the two track locations marked as A and B. The locations of the rods are marked with + signs.

Before the rods were placed, the mean sea level was located and at least 4 to 5 rods were positioned onshore (towards ocean) from the mean sea level. At every 30-minute interval starting from 11:00 till 17:00 (the first reading was taken at 10:45), the height of each rod from beach floor at both track locations, A and B, was recorded. Beach measurements due to wave action were recorded for the two days on June 10 and 11, 2006 along with tidal data.

Results and Discussion

The tidal variation of the Weligama bay is shown in Figure 4 along with hourly data from Kirinda tidal station for comparison. The high tide on June 10th was around 2.30pm while the same on June 11th was around 3.20pm in accordance with the period of rotation of the moon of 24hr and 50min. The water levels at high tide for the 10th and 11th are about 30 cm and 40 cm, respectively. June 11th was a full moon day and thus, the increase of the high water level by about 10 cm from that of 10th can be due to the stronger gravitation pull. However, there is no significant difference in the tidal levels from Kirinda. As the Weligama tidal data were taken at every five minutes, small oscillations of the wave action in the bay is apparent from the two plots in Figure 4. The oscillations could be due to wind. Figures 5 and 6 show changes of the beach at the two track locations A and B, during the day for June 10th and 11th.

Figure 5 shows the contour maps of accretion and erosion of the beach at each rod during the day for the two consecutive days. Track A was farthest from the river mouth. The rod labeled 1 was at the most offshore location whereas rod labeled #7 was located at the most onshore (in water) location with respect to rod #1. It is interesting to note from the four plots, Figure 5 (a) to (d), that the two beach locations A and B are rather dynamic and short-term accretion and erosion features are not similar even though the two sites are only few meters apart from each other.

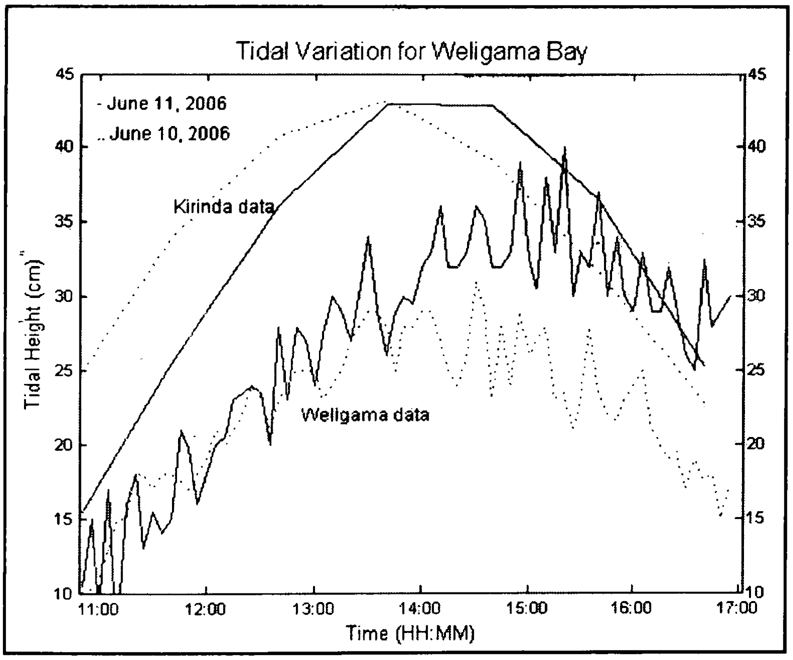

Figure 4. Tidal variation at Weligama bay for June 10th (dash curve) and 11th (solid curve) are shown in the figure. Hourly tidal data from Kirinda for the same two days is shown as well.

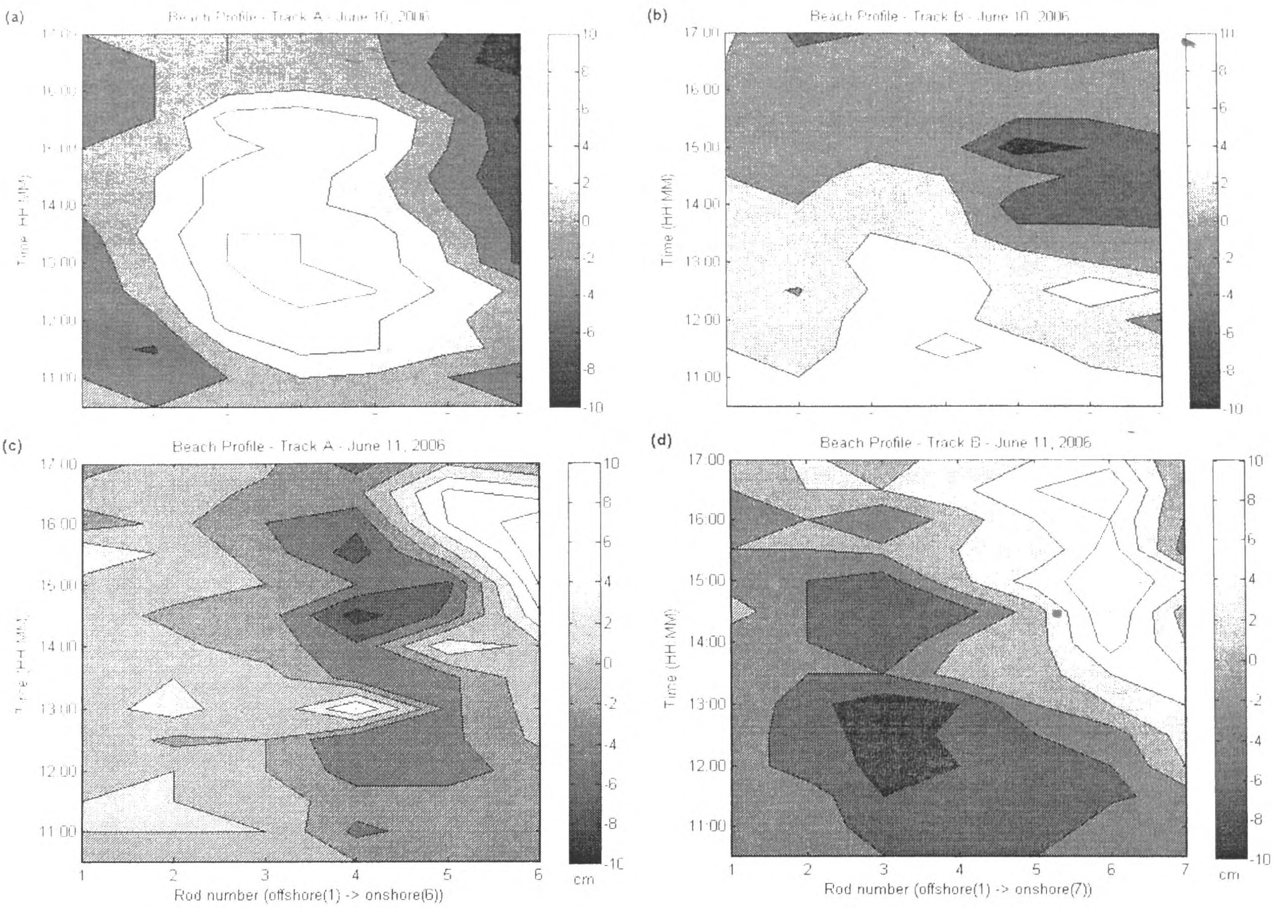

Figure 5. Beach profile data for the two track locations, A and B, for June 10th and 11th are shown in the figure. Contour plot of beach profile at 7-rod locations for Track A on June 10th from 10:45 to 17:00 is shown in (a). Similarly, plots for Track B on June 10th, Track A and Track B on June 11th are shown in plots (b), (c) and (d), respectively.

On the 10th, accretion takes place around rod #4 at track A in the early afternoon (Figure 5 (a)) and erosion happens in the late afternoon. At both sites erosion is highest at the most onshore location (rod #6) in the late afternoon. The features on the 11th at both tracks (Figure 5 (c) and (d)) are quite opposite to that on the 10th. During early afternoon on the 11th, erosion takes place at both tracks and accretion starts during late afternoon and it is highest at the most onshore rods (#6 at A and #7 at B). The long shore current at measurement site was towards track B (or towards the river mouth).

The plots in Figure 6 depict beach elevation at the two track locations. Elevation is computed as the difference between beach profiles of two consecutive rods starting from the most offshore rod location, which is taken as the initial reference point. The elevations shown in the plots (a) to (d) in Figure 6 are starting from location of rod #2 as rod #1 is the reference point (elevation at rod #3 is given as the profile difference between rod #3 and rod #2, etc.). A positive value at a rod location represents more accretion compared to the preceding rod located towards offshore from the rod of interest and similarly, a negative value represents more erosion. From these plots, it is clear that there is a significant difference in beach action on the 11th compared to that on the 10th. On the 11th more accretion takes place onshore whereas more erosion occurs at about same locations on the 10th. Correlation coefficient between the tide data and beach profile data calculated at both track locations A and B for both June 10th and 11th are shown in Table 1. It was found that on June 10th there is over 50% positive correlation at offshore locations (rod #s 2, 3 and 4) at track A whereas at track B there is around 50% negative correlation at onshore locations (rod #s5,6 and 7). On June 11th there is over 60% positive correlation at onshore locations (rod #s 4, 5 and 6) at track B and week negative correlation (~ 40%) at offshore locations at track A. In general, these observations suggest that a positive correlation could be attributed to accretion on the beach where as negative correlation could be attributed to erosion on the beach.

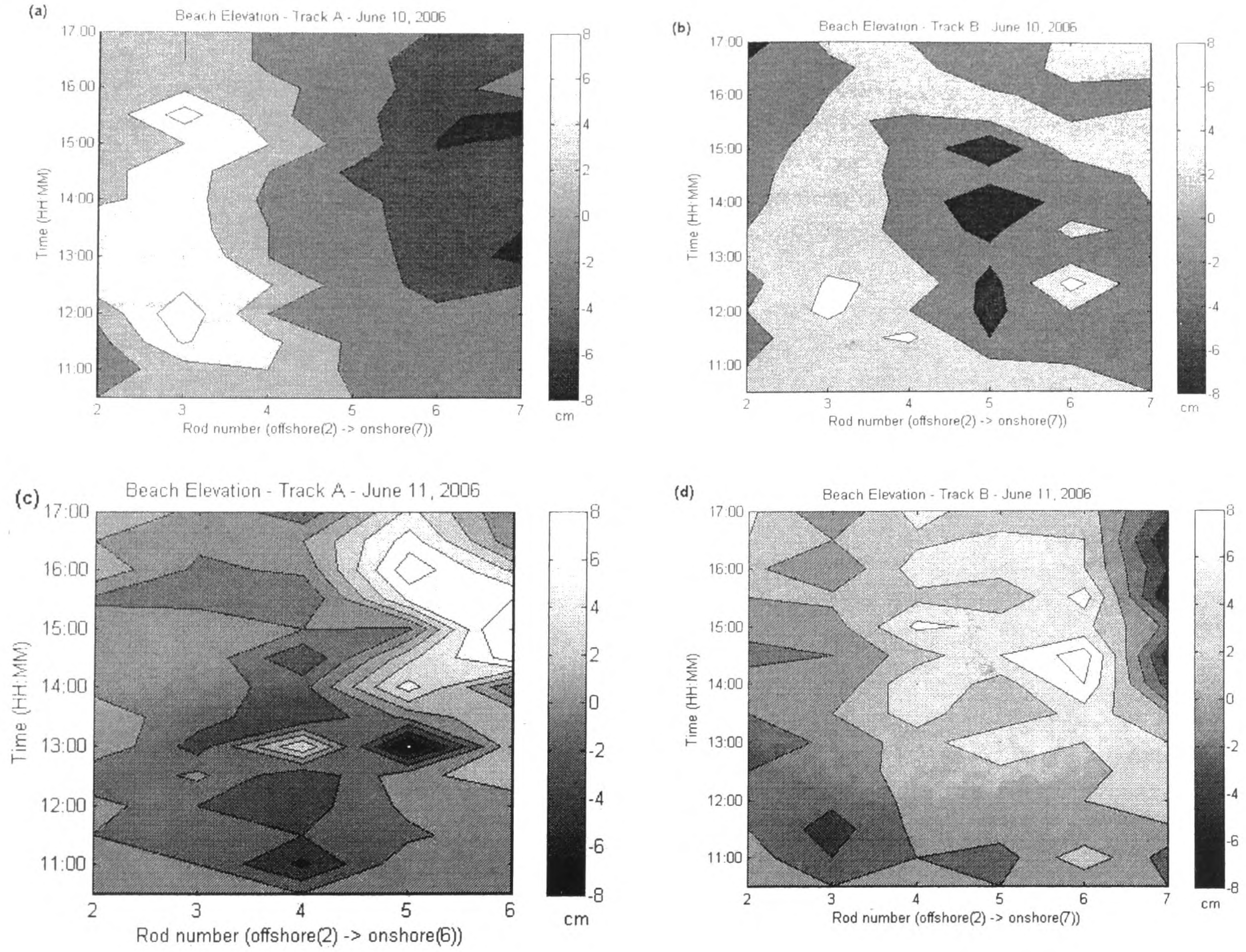

Figure 6. Beach elevation data for the two track locations, A and B, for June 10th and 11th are shown in the figure. Contour plot of beach elevation at rod locations starting from rod #2 for Track A on June 10th from 10:45 to 17:00 is shown in (a). (Elevation at rod #2 is measured with respect to rod #1). Similarly, beach elevation plots for Track B on June 10th, Track A and Track B on June 11th are shown in plots (b), (c) and (d), respectively.

Table 1. Correlation coefficients between tide and beach profile data for both track locations.

		offshore						onshore
		Rod #1	Rod #2	Rod #3	Rod #4	Rod #5	Rod #6	Rod #7
10-Jun	track A	0.0433	0.799	0.66	0.73	0.463	0.093	-0.139
	track B	-0.704	-0.294	-0.091	-0.151	-0.485	-0.475	-0.616
11-Jun	track A	-0.259	-0.411	-0.543	-0.1583	0.1023	0.665	
	track B	0.516	0.155	0.3235	0.622	0.83	0.884	0.449

Conclusion

For the first time, beach activity due to coastal ocean waves and the tidal variation during the day were studied at Weligama bay beach for two consecutive days in the month of June 2006. The tidal measurements indicate an increase of water level for about 20-30 cm during the high tide. The highest tide measured in the southern coastal ocean is at Kirinda about 150 km towards east from Weligama, which is between 40-45 cm during the same period. Spring tide with an increase of about 10 cm water level was observed on the full moon day of June 11th in Weligama.

Short-term beach activity measurements show accretion and erosion taking place during the tidal cycle. The two track locations show different beach behaviour and correlation between tidal and beach profile data show that accretion (+ve correlation with the tidal height) and erosion (-ve correlation with the tidal height) on the beach due to wave action is affected by the tidal action. Even though the data were limited, the results show some interesting phenomena, which encourage scientists for further studies in the area.

The preliminary study presented here highlights the effect of the tidal cycle and the wave action on the beach profile. This study shows that both wave action on the beach and tidal variation need to be considered when developing beach models as they are correlated.

Further continuous measurements during Southwest and Northeast monsoon periods, in particular, on the tide and the wave activities on the beach and at the river mouth for a longer time period will help scientists to understand the changes thoroughly in the Weligama bay beach.

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