SEA LEVEL CHANGES IN BANGLADESH NEW OBSERVATIONAL FACTS

by

Nils-Axel Mörner

Reprinted from

ENERGY & ENVIRONMENT

VOLUME 21 No. 3 2010

MULTI-SCIENCE PUBLISHING CO. LTD.
5 Wates Way, Brentwood, Essex CM15 9TB, United Kingdom

SEA LEVEL CHANGES IN BANGLADESH NEW OBSERVATIONAL FACTS

Nils-Axel Mörner
Paleogeophysics & Geodynamics, Rösundavägen 17, 13336 Saltsjöbaden, Sweden, morner@pog.nu

ABSTRACT
Morphological and stratigraphical observational facts in the Sundarban delta provide data for a novel sea level reconstruction of the area. This sea level documentation lacks traces of a global sea level rise. This implies totally new perspectives for the future of Bangladesh. No longer are there any reasons to fear an extensive sea level inundation in the near future. Sea level estimates based on linear trend analyses of tide gauge data should be avoided and seem often to be directly misleading, as was the case with previous, diver gent, claims of a strong global sea level rise component.

Keywords: Sea level changes, coastal erosion, no sea level rise, new future perspectives, delta environment, Sundarban, Bangladesh.

1. INTRODUCTION

The coast of Bangladesh is notorious for its frequent high-amplitude floods [1]. Those floods are primarily linked to the monsoonal regime (i.e. precipitation, air pressure, sea level, wind direction, storminess, currents, etc.) and frequent cyclone events. The flooding episodes may be caused both by river overflow (i.e. precipitation inlands) and by coastal and/or river flooding (Figure 1).

About 50% of the land lies less than 8 m above sea level making it highly vulnerable to coastal flooding. Long-term changes in the land/sea relation may be caused by local dif ferential subsidence and oceanic sea level rise. There are also factors linked to human activity , such as dams controlling the freshwater outflow by that af fecting the local marine environment, and mangrove deforestation (to make room for shrimp industry) which increases the vulnerability to negative flooding effects.

1.1. Multiple Interacting Sea Level Variables in the Indian Ocean

The Indian Ocean is like a gigantic sea level laboratory because of all the different sea level variables that interact in this region [2,3]. Any serious sea level analysis must consider all those variables. This is seldom the case, however . Our study in the Maldives [3,4] gives an example of how such a multiple analysis may be performed.

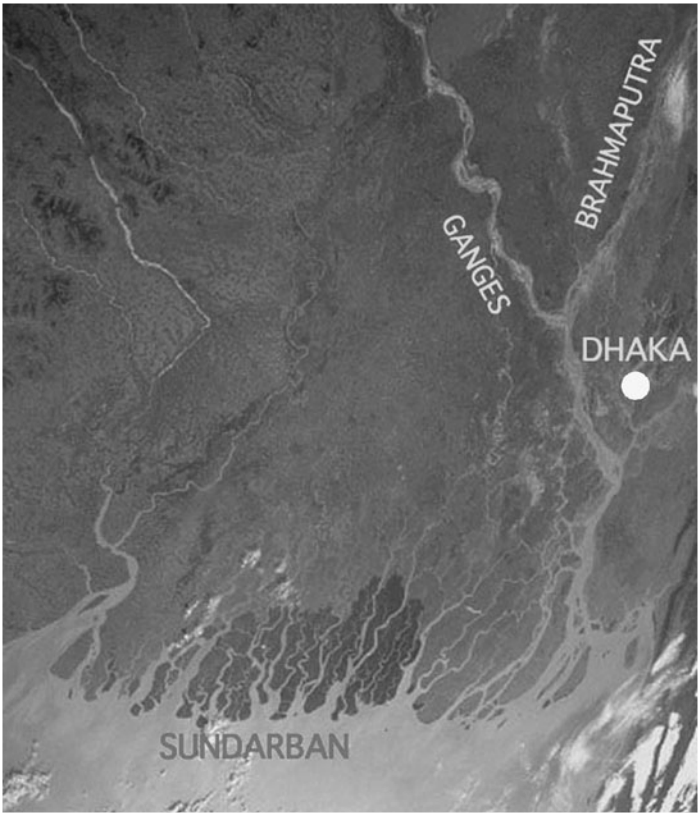

Figure 1. Bangladesh embracing the Ganges-Brahmaputra river systems and delta area, strongly vulnerable to river flooding as well as coastal flooding

1.2. Sea Level Estimates from Tide Gauge Data

Tide gauges are far from ideal for recording sea level changes [5]. Often they are installed on harbour construction or landing bridges that are by no means stable, resting, as they often are, on unconsolidated sediments. Therefore, tide gauge records are already "a priori" likely to over-estimate rising trends. Secondly, ocean tidal changes are seldom uniform, but subjected to several different cyclic forces besides short-term deviations (like at ENSO events). Therefore, the application of linear regression lines is often directly wrong [6].

Singh [7] has assessed the problem of spatial variations in local sea level changes along the Bangladesh coasts. He limits his input data to the tide gauge records for 1977–1998 from Cox's Bazar, Char Changa and Hiron Point, and arrive at a relative sea level rise of 7.8, 6.0 and 4.0 mm/year, respectively. He ascribes the increasing trend eastwards in terms of subsidence, and the remaining about 4.0 mm/year rise in terms of local environmental changes in precipitation and water temperature. Singh limits his analysis to the 22-year trend analyses of the three tide gauge records. Nothing is said about cyclic changes that may prevent the application of trends, or about possible instabilities of the tide gauge stations. The decrease in high-tide level and increase in low-tide level seem rather to suggest a change in tidal amplitude as proposed by Wahid et al. [8].

A detailed plot of the tide gauge record from Hiron Poind (ranging from 1977 to 2003) seems to give a much more complicated picture of the interaction of different variables changing their relative effects over the time series available, by that making single trend analyses misleading (cf. below, section 2.3).

Unnikrishnan & Shankar [9] provided a regional analysis of 17 tide gauge stations along the northern coasts of the Indian Ocean, and arrived at a regional sea level rise component of 1.06–1.75 mm/year for five stations classified as reliable (including a GIA correction that may be questioned). Again we see an analysis confined to trends of tide gauge records [cf. 6]. The main reference site is Mumbai (Bombay) on the west cost of India with a mean trend of 0.77 ±0.08 mm/year rise from 1887 to 1993. This record, however, is much better understood if divided up in 5 parts, 1878–1903 recording stability 1903–1905 recording a drop of about 7 cm, 1905–1955 recording a rise of 17 cm (i.e. at a mean rate of about 3.4 mm/year), 1955–1962 recording a marked drop in the order of 12 cm (also present in the record from Vishakhapatnam), and 1965–1993 recording stability (cf. section 3 and Figure 12). Their second reference site is Vishakhapatnam on the eastern coast of India exhibiting a linear trend of 0.70 ±0.28 mm/year rise from 1937 to 2000. Even at this site, we see a 3-parted sequence; rise up to 1955, fall 1955–1961 and stability over the last 30 years. The mean of their five most conclusive site-trends gives a value of 0.92 mm/year sea level rise. This is considerably less than the 4.0 mm/year claimed by Singh [7].

1.3. Local Factors Affecting Coastal Environments

There are many different local factors that may affect local coastal environment. I will here discuss two; the effects of mangrove deforestation, and the downstream effects of dam building in the Ganges.

Rahman et al. [10] discussed the drastic deforestation of coastal mangrove in SE Bangladesh to give place for shrimp ponds. In one area, 4940 hectares of mangrove vegetation in 1988 had by year 2005 decreased to only 150 hectares. Coastal mangrove forests offer excellent protection for coastal erosion and negative flooding effects. Obviously such vast deforestation of coastal mangrove will drastically increase the vulnerability to severe effects of cyclones and coastal flooding.

On my visit to Sundarban, I was told that the salinity had increased in recent years. This affected some less salt-tolerant trees and the number of months per year they could drink water from the rivers. This rise in salinity increased from the east to the west. This was explained in terms of a rising sea level. The real reason, however, seems to be the dams in the Ganges (the latest completed in 1974) by that decreasing the outflow of freshwater, allowing the salinity to rise away from the main outflow tributary. This agrees well with the records of Wahid et al. [8] which document a very strong decrease in freshwater outflow after 1974 in the Sibsa and Pussur Rivers.

1.4. Local Differential Subsidence

Any delta is, because of the sediment accumulation, susceptible to subsidence. The origin may be in sediment compaction or isostatic adjustment to the sediment loading. Compaction varies over a delta region and is therefore differential. The long-term Holocene coastal evolution [e.g. 11,12] is not covered in this paper, however.

At the GeoDev meeting in Dhaka, Kudrass & Akhter [13] proposed that the Bangladesh delta was subjected to a subsidence in the order of 15 mm per year.

In the SE side of the coast, there is an excellent record dating the submergence of the –56 m level at about 10,000 BP [14]. This suggests no subsidence factor in that region.

2. NEW OBSERVATIONAL FACTS

The GeoDev conference ended with an excursion in the Sundarban delta (October 29–31) with boat from Mongla Port at the Passur River and with visits at a number of field stops (Figure 2); Karamjaol, Harbaria, Kotka and Hiron Point. Below follows a report of my findings with the main information achieved at the Kotka site.

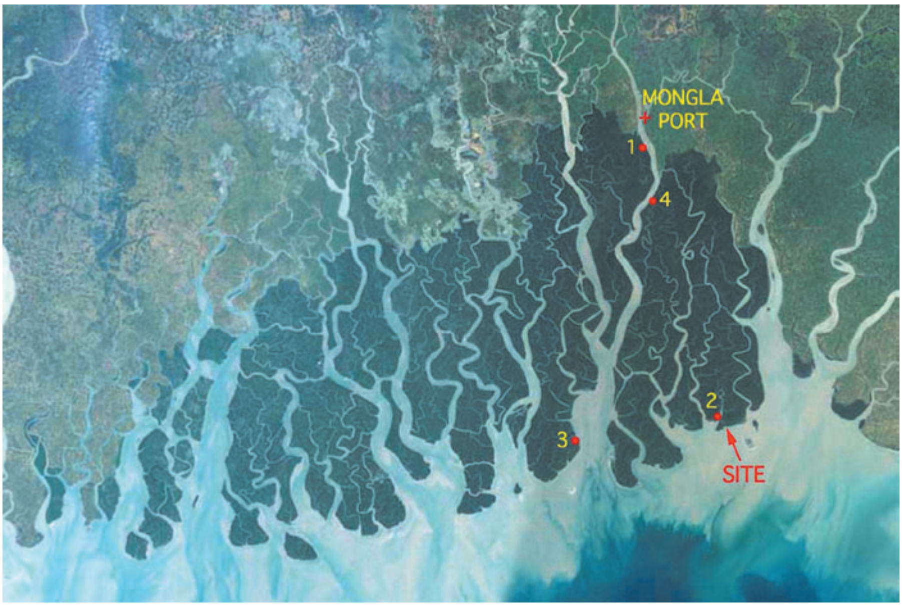

Figure 2. The Sunderban delta region and natural resort with the investigation sites marked; (1) Karamjaol, (2) Kotka, (3) Hiron Point and (4) Harbaria

2.1. The Karamjaol Natural Resort

At this site buildings and crocodile farming are established where the ground is somewhat higher and generally dry. The surrounding mangrove forest is intermittently flooded. The outlet channel of concrete from the crocodile farm ends at about HTL. It shows no sign of becoming flooded or filled with sediments. This gave the first hint of a virtually stable sea level in this area.

2.2. The Kotka Sites

The Kotka area consists of two sites (Figure 3); the village with surrounding costal area, and the natural resort area to the south where my main investigation site is located. We start with the main site to the south; a 1 km long shore segment facing the open sea.

The southern shore, facing the Bay of Bengal, is full of dead tree trunks in growing position (Figure 4). Many persons would directly interpret such a view in terms of a rising sea level generating erosion. A closer look (Figure 5) will reveal

Figure 3. Aerial view of the two sites at Kotka: (1) the main investigation site on the south side of the neighbouring island (Figures 4-8), and (2) the Kotka village site (Figures 9-10)

Figure 4. The eastern part of the beach at the main site at Kotka is full of dead tree trunks in growing position. Obviously, this coastal segment has suffered extensive erosion

details that provide a totally different story, however. Several of the dead tree trunks on the beach have a horizontal root system some 60–80 cm above the shore surface (Figure 5).

Figure 5. A closer examination of individual trees reveals that several of the tree trunks have horizontal root systems hanging some 80 cm above the shore. Such root systems are found just below the mud surface (see Figure 6). Consequently, they seem to indicate a stable sea level despite the strong erosion

Those roots represents the surface root system that is spread laterally just below the mudflat. At the western side of the beach, we can see this in a vertical section (Figure 6). This implies that the former mudflat (delta surface) must have been just above the horizontal root system in Figure 5; that is at the same level as in the forest behind, as illustrated in Figure 7. Consequently, we have clear observational evidence of very strong coastal erosion despite absolutely no rise in sea level.

The erosion of the former delta deposits has lead to a concentration of coarse silt and fine sand grains that has accumulated as a beach-bar above the HTL (Figure 8). The new , present-day HTL lies somewhat below the inland delta surface. The difference is in the order of 10 to 20 cm. Also, the old delta surface is densely vegetated not only by mangrove but also be some less salt tolerant species. Some parts are fully dry and clearly above present HTL (partly visible in Figure 3). The trees are up to 50, maybe 100, years old according to our guide.

Figure 6. Section of the delta clay and a rooted tree with its horizontal roots spread just below the mud surface (from the western side of the shore segment investigated)

Figure 7. Reconstruction of the former mud surface before the erosion (blue). This surface has the same level as the delta surface in the forest. Hence, it indicates heavy horizontal (about 50 m) and vertical (about 0.8–1.0 m) erosion, despite zero change in sea level

Figure 8. Whilst the fine particles are removed in suspension, the coarser grains (fine sand) were concentrated on the beach and accumulated in a shallow beach-bar just above HTL. The wreck is stranded at HTL. This new HTL lies some 10–20 cm below the delta mud flat, hence suggesting a minor fall in sea level in sub-recent time

The Kotka village was heavily affected by the Sidar Cyclone in 2007. A large part of the coast was eroded, leaving isolated trees on the beach (Figure 9). At high-tide, the eroded ground is below sea level and the trees left are surrounded by the sea (Figure 10). Like in the previous site, this has nothing to do with a rise in sea level, just strong erosion.

Kudrass [13] has described finds of salt ovens below present sea level that were dated at around 240 BP. During our visit to Kotka, Professor Kudrass was able to find additional evidence of salt working at a level now below sea level [Kudrass, personal communication at lecture during the excursion]. Whilst Kudrass & Akhter [13] interpreted this low level in terms of a sea level position in a continuous subsidence, I find it more reasonable to see it as a sea level low-stand in the 18th century just as is the case in the Maldives [3]. This is further discussed under section 3 in respect to an intra-clay unconformity at Kotka.

2.3. The Hiron Point

The settlement at Hiron Point was severely affected by the Sidar Cyclone in 2007, which destroyed most of the houses.

There is a tide gauge at this site with a record for the period 1977–2003. This tide gauge has a very unstable position on a landing bridge resting on delta clay. Hence any

Figure 9. The shore just west of Kotka village was heavily eroded at the Sidar Cyclon in 2007. The erosion has removed large quantities of clay, leaving single trees on the shore (in the foreground) and a sharp boundary to the forest segment in the background

Figure 10. At high-tide the eroded shore west of Kotka village is submerged leaving isolated trees standing in the water. This is a function of the removal of sediments with no changes in sea level. The horizontal width is about 500 m

analysis with respect to trends of sea level changes [7,9] must be considered unsafe and risky, if not directly misleading. Furthermore, the record seems to include different factors (cycles, episodes, independent segments, etc) preventing meaningful linear trend analysis.

The tidal amplitude is around 2 m. The annual variability is in the order of 70 cm. The mean inter-annual variability is in the order of 20 cm. Obviously , different forces and factors are interacting. This prevents a meaningful application of a long-term trend [as in 7 and 9].

Whilst the coast on the opposite side of the river experience local erosion with isolated trees standing in the water at high-tide, the coast to the east of the village has experienced coastal growth seawards. This is well recorded in an aerial view of the area (Figure 11). This implies that sea is no longer in a rising mode, and may even have fallen some 10–20 cm in the last 50-80 years, judging from the age of the trees, the stepwise evolution of the village and the coastal progradation recorded (Figure 1 1).

Figure 11. Aerial view of the Hiron Point settlement. Three phases of settlement are seen (becoming successively younger from right to left). The shore to the right exhibits a seaward progradation indicating no sea level rise in the past decades and probably even a minor lowering in sub-recent time. The progradation was nourished by sediment supply along the river. The horizontal width is about 700 m

2.4. The Harbaria Site

South of the river inlet, there is a coastal segment with trees under water at high-tide. This might be interpreted in terms of flooding. The truth is dif ferent, however.

The coast north of the river inlet and just west of the Harbaria site is growing seawards (as in the case of Hiron Point; Figure 11). This indicates a present coastal stability.

After the documentation at Kotka, the evolution of this area can be understood in terms of heavy coastal erosion on the south side (leaving some single trees now being flooded at high-tide) and deposition of sediments on the northern side where the coast has grown seaward. This is consistent with a stable sea level (besides sediment availability).

3. DISCUSSION

The physiographic future of Bangladesh is strongly dependent on the stability of the present sea level. There are two means of assessing this problem; viz. via analyses of available tide gauge records [e.g. 7,9] or via morphological –sedimentological studies in the field [cf. 3,4]. In this paper, I present new data representing observational field studies.

Analyses of tide gauge data have two major shortcomings; one is the instability of the recording tide gauge [5], and another is the application of statistical trends over incomplete cycles, signals of different origin and segments that need independent treatment [6]. In order to give an example of the latter shortcoming, I will use the records from Mumbai (Bombay) on the mid west coast of India and from Visakhapatnam (Vizagapatam) on the mid east coast of India in the analysis of Unnikrishnan & Shankar [9]. Whilst they apply a single trend line, I identify individual segments (above, section 1.2) that call for individual treatment as illustrated in Figure 12. The difference is remarkable; whilst they give a present rise of 0.77 mm/year, I get stability for the last 30 years.

The 10 cm fall in sea level recorded at 1955–1962 (Figure 12) is likely to be a correlative to the fall recorded at Kotka and Hiron Point.

The tide gauge at Hiron Point seems not suitable for detailed sea level analyses (cf. above).

The present sea level analysis is based on morphology and stratigraphy. The main site is at Kotka (Figure 3). Here, there is a strong coastal erosion in the order of 50 m horizontal and 0.8 m vertical removal of sediments. Horizontal roots (Figure 5) and vertical sections of rooted trees (Figure 6) provide firm evidence that the erosion is linked to a zero rise in sea level (Figure 7). The removal of the silty clay sediments implied that the clay and fine silt particles were suspended and deposited elsewhere, whilst the coarse silt and fine sand particles were concentrated on the beach and accumulated as a very shallow "beach ridge" (or rather bar) above mean HTL (Figure 8). This morphologically identified HTL lies some 10–20 cm below the delta clay surface. Hence, it may signify a minor regression of the sea.

The base of the erosion recorded (Figures 5 and 6) seems to be controlled by an intra-clay structure or unconformity located some 0.8 –1.0 m below the original delta surface. This structure may represent the unconformity (land surface) upon which the salt "industry" took place [13 and section 2.2 above]. If this level represents a low sea level at around 240 BP, it was followed by a sea level rise of about 1 m with the continual building up of the delta. This transgression must later have ceased allowing the delta to be overgrown also by less salt-tolerant species, and the settlement of people to be established.

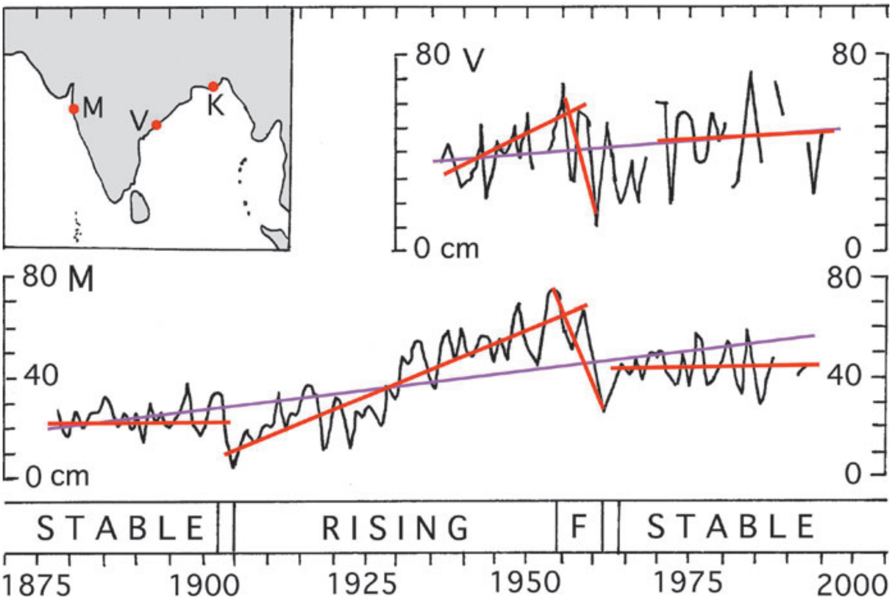

Figure 12. Tide gauge records from Mombai (M) and Visakhapatnam (V) on each coast of India (location in the inserted map, where K stands for Kotka and the present study area). The Mombai (Bombay) record goes from 1878 to 1993. Unnikrishnan & Shankar [9] used a linear trend analysis (pink line) despite the fact that the records are composed of individual segments that must be treated individually (red lines). The individual segment analysis gives a totally different sea level story in 5 steps (division at base); stable, minor fall, general rise of 17 cm, rapid fall of 12 cm between 1955 and 1962, and full stability for the period after 1965. The last 3 steps are also recorded at Visakhapatnom (V).

The forest is about 50 to 100 years old. The habitation at Hiron Point started in the 1950s (the first boat entering on December 11, 1950). The post-erosional HTL at Kotka lies some 10–20 cm below the delta surface. These facts suggest that we may be dealing with a minor regression. The coastal seaward extension at Hiron Point (Figure 11) is indicative of a stop of the vertical building up of the delta and suggests a stabilization or even minor fall in sea level over the past 50 years or so. This fall in sea level may be a correlative to the one recorded in Figure 12 at 1955–1962.

Brammer [15] correctly stated that "a gradual rising sea level would be matched by a rise in levels of river levees and of tidal and estuarine floodplain land near the coast". Our observations indicate that this balance is no longer operating in the area studied, but altered to create ground dry enough for the establishment of forest vegetation including less salt-tolerant species and the establishment of sites for human habitation.

In Figure 13, I have combined the available data into a tentative sea level curve of the area. It is based on three main observational facts: (1) a sea level low in the 18th century [13], a sea level rise and delta accretion to a surface level 10–20cm above the present HTL, and a subsequent stabilization and sea level lowering to the present

HTL well recorded in the field (e.g. Figures 8 and 11) and probably also recorded in India (Figure 12).

This curve indicates that there is no global sea level rise component present. If such a component is absent here, it should be so also for the rest of the region. This means that we can free Bangladesh from the condemnation of becoming flooded in the near future (as, for example, the scenario of a 3 m rise by year 2100 proposed by Broadus [16]).

Subsidence is a factor common to most delta areas. It is usually differentially imposed. In the southeastern coast of Bangladesh there may be a significant component of subsidence [13]. In this part of the Sundarban delta (Kotka, Hiron Point, Harbario, Karamjaol) no such subsidence factor can be determined, however.

The sea level changes hereby recorded in Sundarban (Figure 13) are very similar to those recorded in the Maldives [3,17], which has a low level in the 18th century (peat below sea level), a high level from 1790, a minor fall in the 1970s, and full stability in the last 30 years (the last two steps may also be seen in Figure 12).

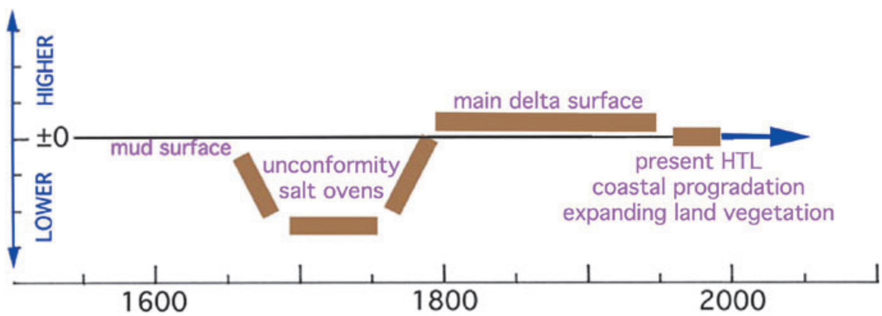

Figure 13. Sea level changes for the last 400 years as based on novel morphological and stratigraphical evidence in the region of Kotka, Hiron Point and the Sibsa-Passur river-system composed of the following facts: (1) a low sea level in the 18th century recorded by the inter-clay unconformity and the findings of salt ovens, (2) a major sea level rise giving rise to the delta surface and mangrove ecosystem, (3) a sea level fall in the order of 10–20 cm as indicated by a lower present HTL, and (4) a period of stability indicated by segments of dry land, habitation, vegetation by species of low salt tolerance, progradation of costal segments at Hiron Point and Herbaria and the stratigraphy at Kotka. This curve exhibits many similarities with the sea level curve of the Maldives [3,17]. The last steps are also present in the revised Indian records of Figure 12

4. CONCLUSIONS

In this paper, I have presented novel observational facts indicating that there is no global sea level rise component present in the evolution of the Sundarban delta. This has wide implications for realistic estimates of the future of Bangladesh.

No longer should we fear a vast coastal flooding in the near future with – as has repeatedly being claimed – a huge number of casualties and millions of flooding refugees. There are far too many urgent local problems to cope with to waste time, efforts and money on a fabricated threat.

It seems significant that the sea level story recorded in the Sundarban is almost identical to the one documented in the Maldives [3].

The high vulnerability to flooding episodes and disastrous cyclone events is, of course, not affected by the novel sea level perspectives.

ACKNOWLEDGEMENTS

This study was undertaken during an excursion organized as a part of the GeoDev Conference in Dhaka, October 26-31, 2009. I am indebted to Professor Afia Akhtar for assisting me in attending this meeting. Professor Paul Kay followed me at the documentation of the main coastal site at Kotka. I acknowledge important discussions with our local guide Nazrul Islam Bachchu.

REFERENCES

1. Floods in Bangladesh. *Wikipedia*.
2. Mörner, N.-A. Sea level changes and coastal dynamics in the Indian Ocean. *Integrated Coastal Zone Management*, 2000, Spring,17–20, IGC Publ. Ltd.
3. Mörner, N.-A. Sea level changes and tsunamis, environmental stress and migration overseas. The case of the Maldives and Sri Lanka. *Internationales Asienforum*, 2007, 38, 353–374.
4. Mörner, N.-A., Tooley, M. & Possnert, G. New perspectives for the future of the Maldives. *Global Planetary Change*, 2004, 40, 177–182.
5. Mörner, N.-A. Estimating future sea level changes. *Global Planetary Change*, 2004, 40, 49–54.
6. Mörner, N.-A. Some problems in the reconstruction of mean sea level and its changes with time. *Quaternary International*, 2010, http://dx.doi.org/10.1016/j.quaint.2009.10.044
7. Singh, O.P . Statial variation of sea level trend along the Bangladesh coast. *Marine Geodesy*, 2002, 25, 205–212.
8. Wahid, S., Babel, M.S. & Bhuiyan, A.R. Hydrologic monitoring and analysis in the Sundarban's mangrove ecosystem, Bangladesh. *Journal of Hydrology*, 2007, 332 (3-4), 381–395.
9. Unnikrishnan, A.S. & Shankar , D. Are sea-level-rise trends along the coasts of the north Indian Ocean consistent with global estimates? *Global Planetary Change*, 2007, 57, 301–307.
10. Raman, F., Haque, F., Bhulyan, A.H. & Rahman, S. Study of landuse changes impact on environment in Chokoria Upazilla using remote sensing and GIS techniques. Int. Conf. GeoDev, Dhaka, Oct. 26-31, 2009, *Abstract Volume*,120.
11. Islam, S. & Tooley, M.J. Coastal and sea-level changes during the Holocene in Bangladesh. *Quaternary International*, 1999, 55, 61–75.
12. Umitsu, M. Late Quaternary sedimentary environment and landforms in the Ganges delta. *Sedimentary Geology*, 1993, 83, 177–186.

13. Kudrass, H.R. & Akhter, S.H. Geoscientific view and considerations on the stability of the Ganges-Brahmaputra delta. Int. Conf. GeoDev, Dhaka, Oct. 26-31, 2009, *Abstract Volume*,128.

14. Pate, R.D., Goodbred J:r, S.L. & Khan, S.R. Delta double-stock: juxtaposed Holocene and Pleistocene sequences from Bengal Basin, Bangladesh. *The Sedimentary Record*, 2009, 7 (3), 4–9.

15. Brammer, H. Geographical complexities of detailed impact assessment for the Ganges-Brahmaputra-Meghan delta of Bangladesh. *In*: R.A. Warrick, E.M. Barrow & T.M. Wigley, Eds, Climate and Sea Level Change: Observations Projections and Implications, Cambridge Univ. Press, 1993, 246–262.

16. Broadus, J.M. Possible impact of, and sdjustment to, sea level rise: the cases of Bangladesh and Egypt. *In:* R.A. Warrick, E.M. Barrow & T.M. Wigley, Eds, Climate and Sea Level Change: Observations Projections and Implications, Cambridge Univ. Press, 1993, 263–274.

17. Mörner, N.-A. Open letter to the President of the Maldives. *New Concepts in Global Tectonics Newsletter*, 2009, 53, 80–83.