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The role of environmental forcing on tidal dynamics along complex near-shore waters off Bangladesh

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ABSTRACT

In a geomorphic sense, the Bangladesh located in the head Bay region comprises of numerous tidal creeks, waterway inlets, and complex coastline geometry. This region encompassing the world's largest deltaic system is thickly populated and extremely low-lying, and therefore highly susceptible to coastal flooding and sea level rise. High tidal range existent in this region primarily governs the hydrodynamic behavior and coastal processes. The present study deals on a comprehensive tidal analysis, understanding the variations in tidal behavior over spatial and temporal scales in the near-shore region off Bangladesh. The harmonic tidal analysis using SLPR2 estimates the tidal constituents using linear least squares with respective nodal correction. Tide gauge observations from five different stations viz; Hiron Point, Khepupara, Charchanga, Khal No-10, and Cox's Bazaar were used for tidal analysis. The results from SLPR2 signify considerable seasonal variations in water level attributed due to meteorological factors and excess river discharge. Tidal pattern at all these five stations are primarily mixed semi-diurnal with M_2 as the dominant constituent. The t-tide toolbox computed the equilibrium tidal amplitude for the study area. Some of the components known to be influenced by meteorological aspects such as Solar Annual component (Sa), Semi-Annual component (Ssa), and Solar Radiational component (S_1) have higher amplitudes than expected, in the study area. The shallowness of the delta cause severe deviations in the tidal behavior from equilibrium tides. Interaction of tides with river discharge also dominant in this region indicates the role of hydrological forcing. Interestingly, the study also reveals the existence of compound tidal constituent Msf in this region. Monthly analysis of Msf component, using FFT, revealed peaks corresponding to the monsoon, Kal-Baisakhi months and to the seasonal changes in atmospheric pressure, thereby unfolding the seasonal influence on Msf. The funnel shaped head Bay plays an important role in amplification of tidal constituents, wherein the form factor and maximum tide levels showed an increasing trend. This study also demonstrates how tidal dynamics can be elucidated using location specific water-level observations. Investigations on the annual variations in observed and predicted water levels clearly signify the seasonal patterns. The correlation analysis show a reasonable match with skill level exceeding 93%, and the overall prediction by SLPR2 is highly satisfactory.

1. Introduction

The sea level variation along a coast attributes from various physical factors such as astronomical tides and currents, meteorological forcing, and hydrological aspects (Chen et al., 2000; Douglas, 2001). It in turn dominates the water level elevation in estuaries and river channels (Thain et al., 2004). In this context, the Sunderbans situated in the head Bay of Bengal (BoB) is a low-lying deltaic environment that is highly vulnerable to the effects of sea-level rise. The Intergovernmental Panel for Climate Change (IPCC, 2007) report ascertains that the global mean air and ocean temperature have increased in the recent past. Numerous studies based on measurements and numerical model projections portrays on increased atmospheric temperature in the near future. Hence, there is a growing concern that coastal areas and especially the low-lying areas such as the deltaic environment in head Bay region is highly susceptible to direct threat from increased total water level elevations (TWLE). The TWLE is a combined effect due to increased storm surge activity from high intense cyclones, wave-induced setup, and astronomical tides that occurs during the landfall of energetic cyclones. A paradigm shift in climate change during the recent decades have increased the probability of high-energetic events like cyclones leading to widespread storm surge, flooding, and wave induced setup along near-shore areas. This activity in conjunction with a permanent rise in sea level for low-

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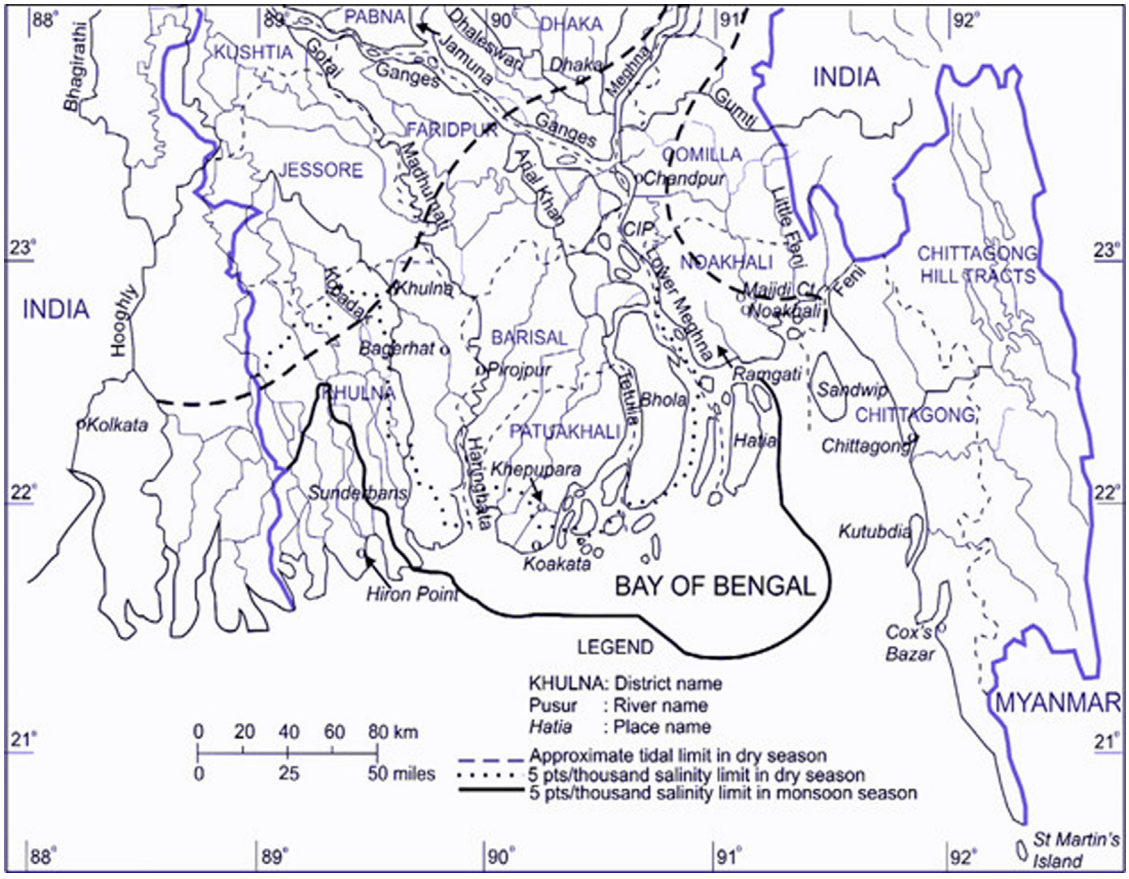

Fig. 1. Map of the coastal region of Bangladesh.

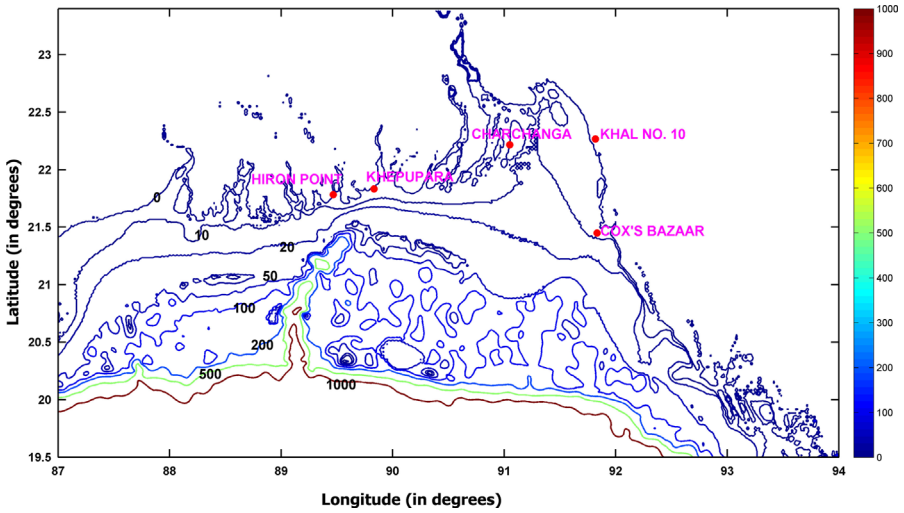

Fig. 2. Study area with location of tide stations and bathymetry contours.

lying coastal areas is a subject of major concern. Tidal variation is an integral part of TWLE, and therefore tidal analysis in coastal and near-shore waters is very important to understand the dynamics and residual effects.

Tidal information along the coast is very important for planning shoreline management plan, navigation, coastal engineering and protection works, port and harbor activities, a better understanding on near-shore ocean dynamics etc. For the west coast of India, the tidal propagation for the Gulf of Khambhat and surrounding areas in Gujarat state was studied by Unnikrishnan et al. (1999), Nayak and Shetye (2003). Srinivas et al. (2003) investigated the tidal propagation for the Cochin estuary located in south India. In comparison to several studies conducted for the west coast of India, attempts to understand tidal dynamics for the east coast bordering the BoB is very limited. For this region, Murty and Henry (1983) developed co-tidal charts for major tidal constituents using a numerical model. Recently for the BoB region, Sindhu and Unnikrishnan (2013) developed a vertically integrated two-dimensional numerical model to simulate major tidal constituents. Their work signify that the broad continental shelf (approximately 200 km) in the head Bay region is responsible for the amplification of semi-diurnal tides. Recently, Chatterjee et al. (2013) provided a