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Observed salinity changes in the Alappuzha mud bank, southwest coast of India and its implication to hypothesis of mudbank formation

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ABSTRACT

Alappuzha mud bank draws special attention among the twenty-mud bank locations reported along the Kerala coast by its remoteness from riverine sources. Among several hypotheses proposed for the formation of mud bank, the subterranean hypothesis was most accepted because of the occurrence of low salinity in the bottom layers. The present study provides evidence to show that occurrence of low salinity waters near the bottom in the mud bank region is an artifact of measuring technique employed for the measurement of salinity. The usual technique of conductivity based salinity determination completely fails in the presence of water laden with high amount of suspended sediment. Laboratory experiments were conducted to determine the response of electrode and conductivity cell sensor types to determine the salinity using a range of suspended sediment in the water column. Actual sediment samples from the mud bank region were utilized for the above studies. Based on field observations and experiments, we conclude that the low salinity was the manifestation of the presence highly turbid fluid mud formation in the mud bank region rather than the influence of fresh water.

1. Introduction

Mud banks are of region of calm, turbid water with high-suspended sediments that occurs close to the shore during southwest monsoon (June to September) along the Kerala coast (Nair, 1976). Mud banks are seen within a water depth of 15 m, often in a semi-circular shape with a radius ranging from 4 to 8 km. Due to the prevalence of calm waters within the mud bank during south west monsoon, which is a period of very high wind and wave activity, fishermen use this region for launching and landing of small boats for fishing activities. At the same time due to the calmness of this region, the adjacent shore is usually protected from erosion due to high waves. There are nearly 20 locations along the Kerala coast, where mud banks have appeared some time or the other in the past (Fig. 1). Though mud banks are reported at several places along the Kerala coast, the most prominent and persistent one occurs at Alappuzha. Studies by Gopinathan and Qasim (1974) reported the presence of small elevation of 1–2 m in the sea bottom within the Allappuzha mud bank, which consisted of consolidated mud. Subsequent study showed that the sediment density in this region varied from 1080 to 1300 kg/m^3 with suspended particle size ranging between 0.5 and 3 µm (Faas, 1995).

Various hypotheses have been postulated for explaining the formation of mud banks along the Kerala coast, which can be broadly classified into two – local water-column dynamics in the near shore region, and remotely mediated processes such as subterranean flow of mud and fresh water from hinterlands or adjacent lagoons. Under the former there are four hypothesis, which are (1) formation of fluid mud due to upwelling and Ekman divergence at the bottom (Ramasastry and Myrland, 1959; Philip et al., 2013), (2) suspended sediment transport under littoral current and rip current system (Varma and Kurup, 1969; Kurup, 1977), (3) wave-induced oscillation and wave dampening (Pherson and Kurup, 1981; Mathew and Baba, 1995), and (4) infra-gravity waves interacting with undertow and reflections from shore leading to mud suspension (Tatavarti et al., 1996, 1999; Tatavarti and Narayana, 2006). Under the remotely-mediated processes, there are five hypothesis, which are (1) passage for soft mud from rivers and backwater during monsoon through subterranean channels as evidenced by the mud cones observed in the beaches of Alappuzha (Crawford, 1860; King, 1881; Menon, 1924), (2) water-bearing subsurface strata churning up mud within the region of mud bank (Rhode, 1886; Bristow, 1938), (3) seepage of methane gas, produced by marsh deposit, due to injection of fresh water from lagoon following heavy monsoonal rain (Narayana et al., 2008) or due to the pressure fluctuations of the short-period storm waves associated with

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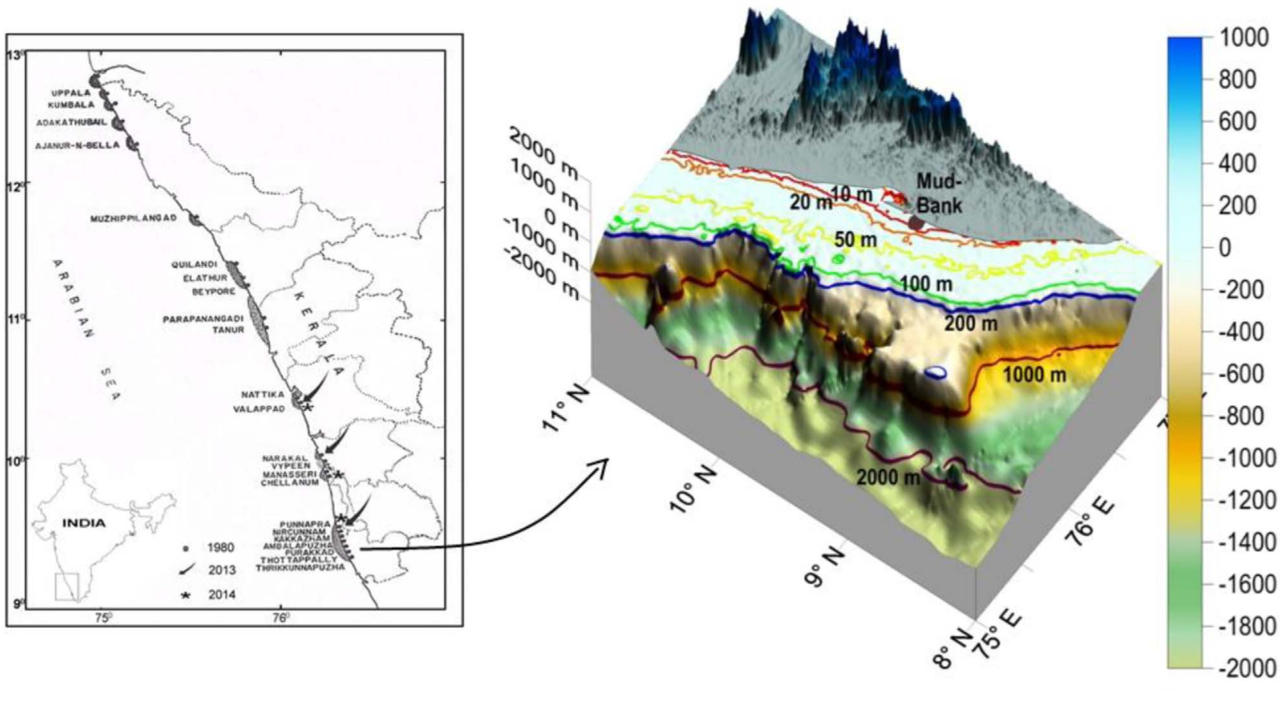

Fig. 1. Map showing prominent mud bank stations along the Kerala coast (left panel) and location map showing Alappuzha mud bank observation station for the year 2014 (right). The scale is for the elevation/depression in meters.

the monsoon (Nair, 1976), (4) existence of submerged trending faults from AchanKovil shear zone to Alappuzha (Hedberg, 1974; Mallik et al., 1988), (5) a combination of subterranean fresh water flow from the adjacent Vembanad Lake through the shallow trending faults over the lime shell bed during summer monsoon (Balachandran, 2004). The central premise of the remotely mediated process hypothesis is that the fresh water from either the adjacent lagoon or from hinterland through underground facilitates mud suspension in the mud bank region. Therefore several authors have endeavored to seek the evidence for this through changes in the bottom salinity within the mud bank, but with limited success (Mallik et al., 1988; Mathew and Gopinathan, 2000; Balachandran, 2004; Nair et al., 2013).

The present study focuses on capturing the bottom salinity changes associated with the initiation of mud bank at Alappuzha with the help of targeted measurements using more than one technique. We show that the observed lowering of salinity near the sea bed associated with the initiation of mud bank at Alappuzha was not actually due to the introduction/addition of subterranean fresh water; rather it was the manifestation of the interaction of high quantity of suspended bottom mud in the salinity measurements.

2. Materials and method

The objective of study being the testing of the hypothesis of subterranean flow of freshwater and mud triggering the mud bank formation, a filed measurement programme was initiated to collect water samples and temperature and salinity profiles from a station located at 76° 22′ 16.8′′ E longitude and 9° 25′ 21.4′′ N latitude, where the water depth was 6 m (Fig. 1). The station was chosen in such a way that it was located within the reported occurrence of mud bank in the Alappuzha region (Silas, 1984).

2.1. Sampling

The field measurement consisted of weekly profiling of temperature, salinity, turbidity and photosynthetically active radiation (PAR), which was initiated on 24th April 2014 well ahead of the southwest monsoon onset and continued until 20th October 2014. A Seabird SBE 19plus conductivity-temperature-depth (CTD) profiler with Turbidity and PAR sensor was used for the profiling. The instrument was well calibrated and having measuring range for conductivity 0-9S/m (accuracy of +−0.0005 S/m), for temperature −5 to 35°C (+−0.005°C) and 0.1% of full scale for a pressure rating of 100 m depth. Bio-spherical PAR sensor was used to measure the quantum of solar radiation (μE/cm^2. s) ranging from 400 to 700 nm with a flatness of ± 10%. WET Labs ECO-FLNTURt Turbidity sensor, 0–25 NTU ranges with a sensitivity of 0.01% was used to measure turbidity of water column.

To capture the onset of southwest monsoon an Automatic Weather Station (AWS) developed at CSIR-National Institute of Oceanography (CSIR-NIO, Goa), was mounted at 10 m height on a building located close to the station to measure wind speed (range 0–60 m/s, accuracy 0.2 m/s) & direction (range 0–360°, accuracy 3°), barometric pressure (range 800-1060mbar, accuracy 0.4mbar) and relative humidity (range 0–100%, accuracy 3%), at 10 min intervals. For rainfall data, we have used daily averaged precipitation data from Tropical Rainfall Measuring Mission (TRMM) (https://mirador.gsfc.nasa.gov).

2.2. Experimental Setup for measurement of salinity under varying suspended sediment

The characteristic of the mud bank is the suspension of sediment in the water column, with an increasing concentration towards bottom. As the measurement of salinity is based on the electrical conductivity of the medium, it is expected to be impacted by the presence of suspended sediment in the medium. In order to decipher the impact of suspended sediment in the water column to the electrical conductivity measurements, we conducted 3 sets of experiments namely, concentration, filtration and desorption, the details of which are listed below.

2.2.1. Concentration experiment

To find out the response of electrode and conductive cell to the