

## An Overview of Physics

Satish R. Shetye  
National Institute of Oceanography, Dona Paula, Goa  
(Email: [shetye@nio.org](mailto:shetye@nio.org))

The Mandovi and Zuari estuaries in Goa are coastal plain estuaries located between the Sahyadris (Western Ghats) and the Arabian Sea. Each estuary is about 50 km long. On the basis of their geometry, they can be divided into two distinct regimes. The first, on the seaward side, is the bay. It is about 10 km (5 km) long in case of the Zuari (Mandovi). The width at the mouth of Zuari is about 5 km; mouth of Mandovi is narrower. Depth in each bay decreases from about 8 metres at the mouth to about 3 m. The second regime is the channel that connects the bay to the head of each estuary. Each is less than a kilometer wide and narrows in the upstream direction. Due to their wide opening and small length, each bay comes under strong influence of the conditions on the open coast. The channels, on the other hand, mark the transition between the bays and the heads of the two estuaries.

Tides in the two estuaries are mixed with semi-diurnal dominance. Amplitude of the most important component,  $M_2$ , increases in the upstream direction due to narrowing of the cross-section of the two channels. The most dominant semi-diurnal component too increases in the upstream direction, but at a rate that is smaller than that of the  $M_2$ .

The annual cycle of salinity and other fields in the estuary have two distinct periods: the wet period during roughly June-September, the time of the Indian Summer Monsoon; and, the dry period from November to May. October marks the transition from the wet period to the dry. During the wet period the runoff in the Mandovi and Zuari estuaries is much greater than the volume of the estuaries. The volume of freshwater flowing through the Mandovi exceeds the volume of the estuary by a factor of at least 20. Though this figure is smaller for the Zuari, both estuaries are flushed many times over during the wet period. It is the flushing that determines the variability of fields like salinity during this period. During the dry period, the runoff decreases to negligible levels soon after withdrawal of the monsoon, and salt intrudes into the channels during the entire period. The process of intrusion is typical of that found in partially-mixed estuaries. Vertical stratification, resulting from formation of gravity currents, is high during the neaps. It breaks down once the currents pick up. As a result, a distinct periodicity related to tides is seen in vertical stratification in the estuaries.

In the literature on estuaries in India there has often been mention of “monsoonal estuaries”. The evolution of salinity field in the Mandovi and Zuari estuaries allows us to define the special characteristics of such estuaries.