Tidal propagation on the continental shelves

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Introduction

- Tidal amplitude are relatively small in the open ocean, say, of the order of 30 to 40 cm.
- When tides enter on the shelf, various processes affect their propagation and at the coast, tidal heights reach upto several meters.

Refraction at the shelf edge

- While propagating from open ocean to shelf, tides undergo refraction, causing changes in orientation of tidal propagation, following Snells' law of refraction

$\sin i/\sin r = v1/v2 = \sqrt{4000}/\sqrt{200}$

v1 is the velocity in deep water and v2, that on the shelf

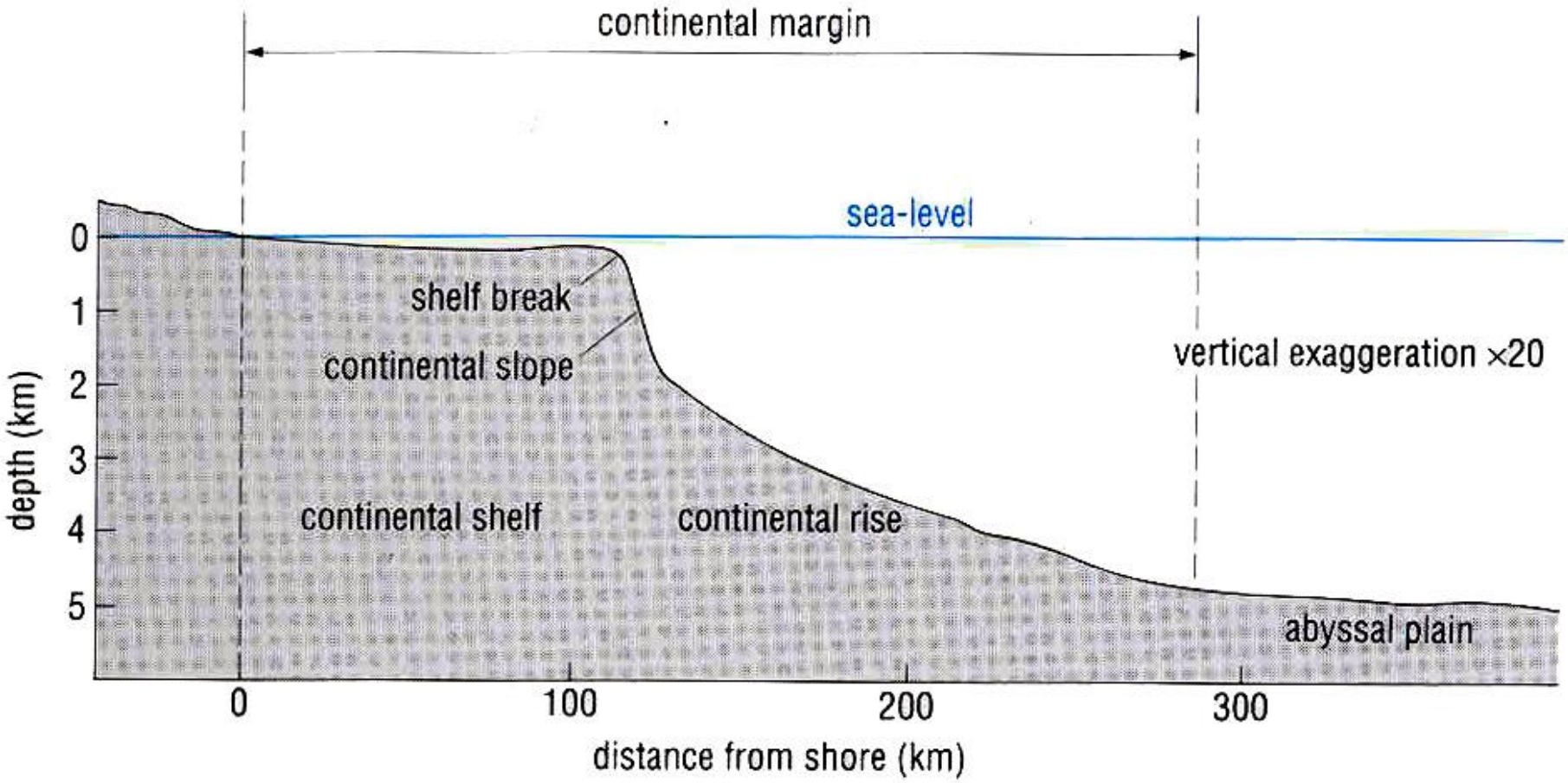
- Assume the case from 4000 m to 200 m, for a wave nearly parallel to the shelf edge (i=90), would refract through 13^0 The direction of propagation turns through 77^0

Propagation of tides

- Tidal waves wave lengths are large compared to water depth. In this case, the speed is $c = \sqrt{gh}$, where h is the depth.
- Tides propagate as progressive waves, and sometimes stationary waves are also formed.

Shallow water processes

- Shallow depths
- Bottom Friction
- Effect of Continental boundaries
- River discharges
- Topographical features


continental margin
sea-level
shelf break
continental slope
vertical exaggeration ×20
depth (km)
0
1
2
3
4
5
continental shelf
continental rise
abyssal plain
0
100
200
300
distance from shore (km)

Tide-related processes on the shelf and the slope

- Amplification of tides on the shelf
- Internal tides
- Tidal mixing front
- Tidal rectification
- Topographic steering
- ROFI

Dissipation of tidal energy

- Dissipation occurs on the shelf occurs by bottom friction
- Conversion of energy from barotropic tides to internal tides on the continental shelf and slope

Internal tides

- Generated at the continental slope region when barotropic tides coming from the open ocean hit the continental slope region pushing the pycnocline up and down.
- Internal tides propagate offshore as well as onshore directions from the generating region.
- Internal tides have the same period as those of barotropic tides, but their amplitudes decrease towards the surface and as well as bottom

Internal tides as observed in vertical temperature time series on the shelf off Goa

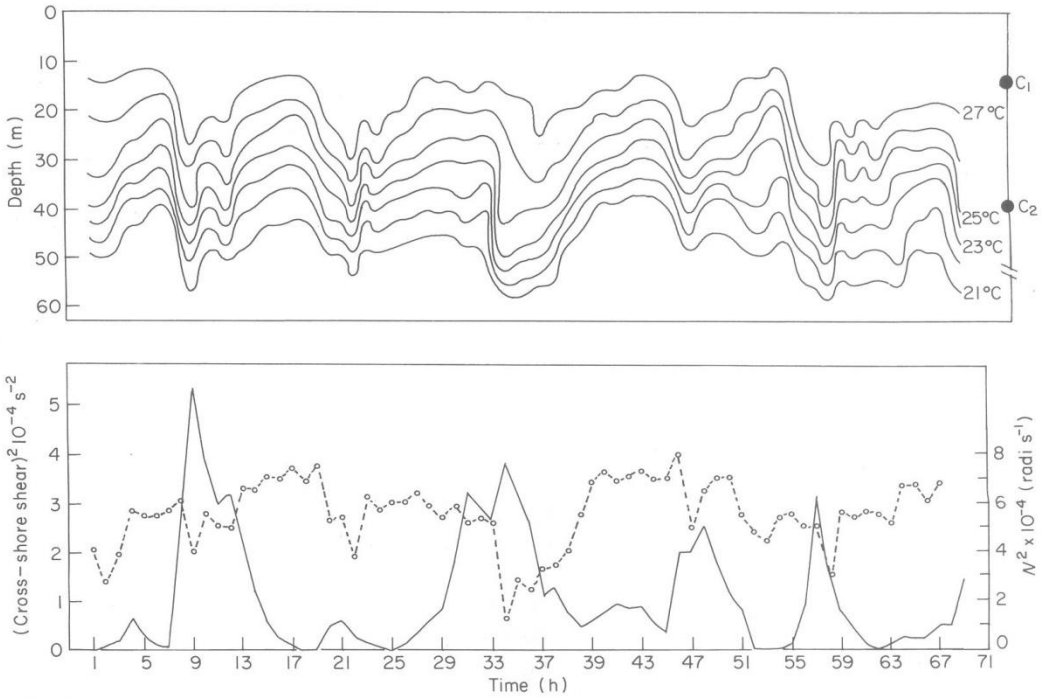


Figure 5. (a) Temperature–depth time series C_1 and C_2 are the depths of current meters. (b) ———, Cross-shore shear between the 15 and 40 m depths; ○– – –○, computed N^2.

In: Unnikrishnan and Antony, 1991 ECSS

Internal tides observed off Jaigarh, west coast

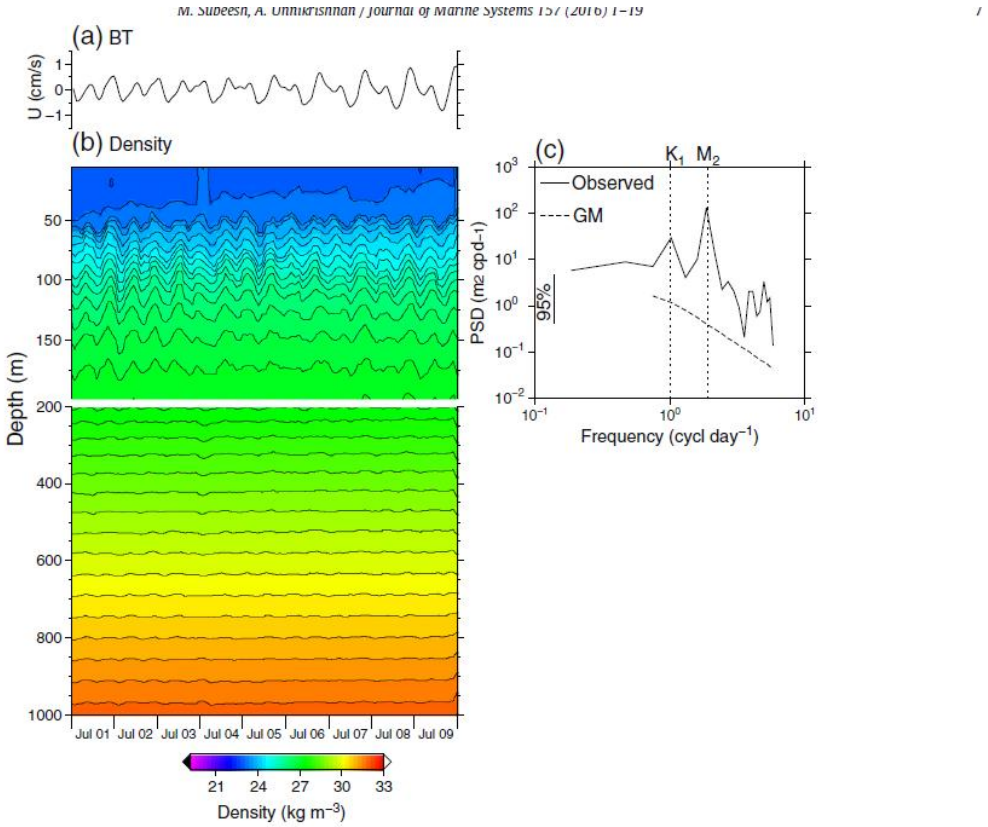
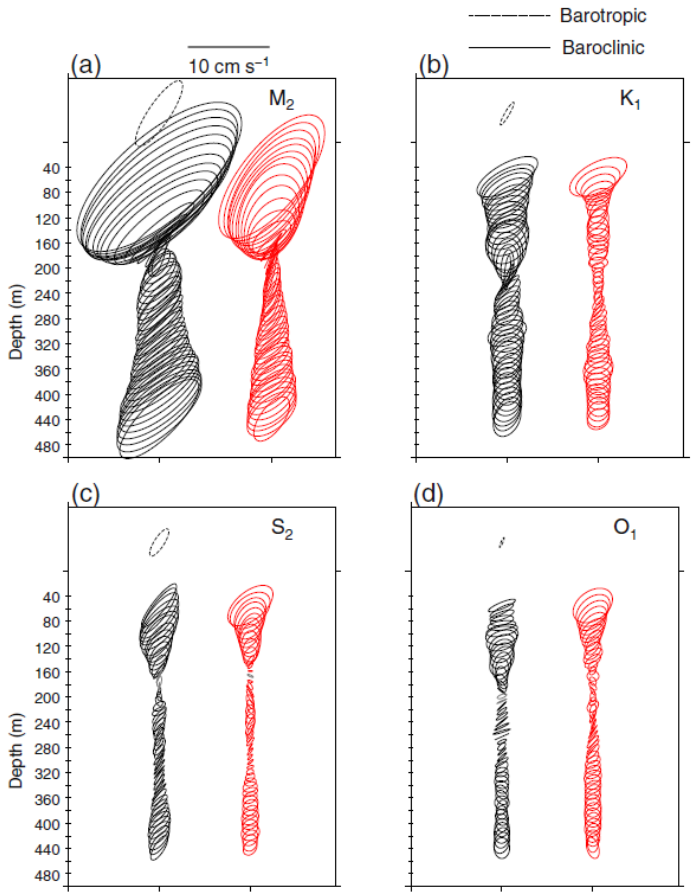


Fig. 4. (a) Barotropic tidal current (BT) from OTIS output. (b) First 9-day density record in July 2002 computed from the temperature and salinity time series observation over the deep location off Jaigarh (shown in Fig. 1). (c) Power spectra of isopycnal displacement at 100 m. The dotted curve denotes the Garrett–Munk spectrum for the vertical displacement based on N=2 cph.

Subeesh and Unnikrishnan, 2016, J. Mar. Syt.

Internal tides on the continetal slope off Jaigarh

M. Subeesh, A. Unnikrishnan / Journal of Marine Systems 157 (2016) 1–19



- Large oscillations caused by internal tides bring cooler waters to the surface layers.

- If the water column consists of an upper layer and a denser lower layer, the interface between the layers can undergo wave motion. This motion, which does not affect the surface and mostly is not observable at the surface, is an example of an internal wave.

- The restoring force for waves is proportional to the product of gravity and the density difference between the two layers (the relative buoyancy). largest near the surface and bottom and minimal at mid-depth.

Processes on the shelf

Processes on the shelf are determined by the alternate effects of stratification and mixing.

Vertical homogenity and stratification in coastal waters depend on many factors. (width of the shelf, river discharges etc.)

Amplification of tides on the shelf

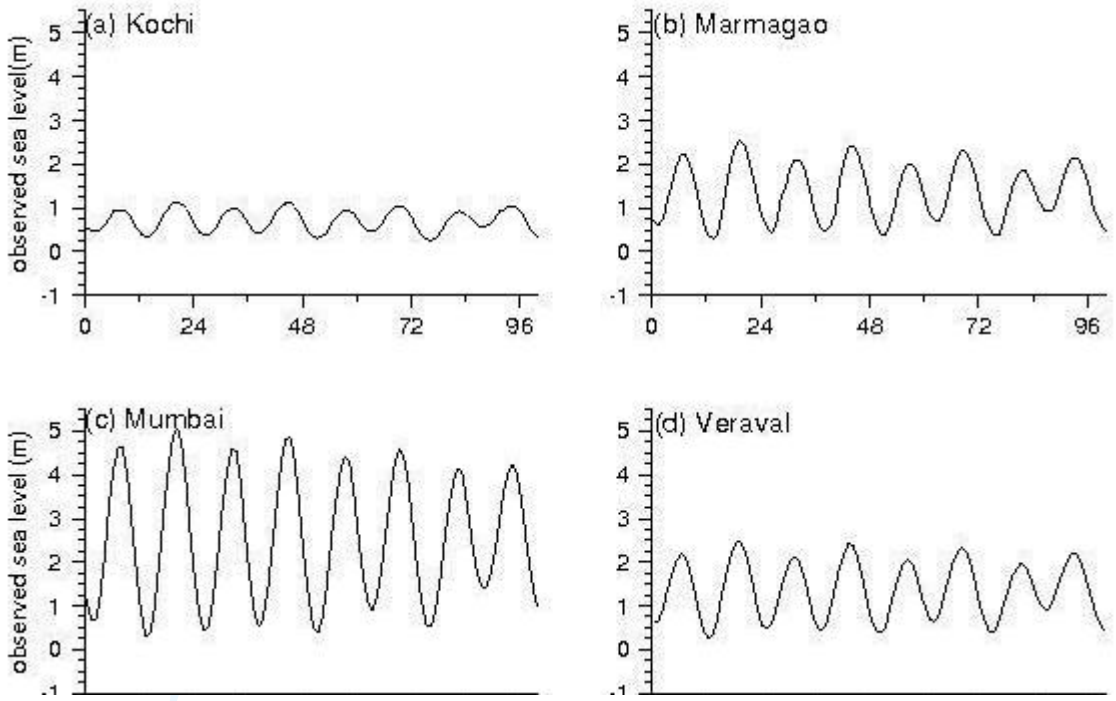
- Clarke and Battisti (1981) solved the above equations analytically and showed that wide shelves amplifiy (Clarke and Battisti, 1981) semi-diurnal tides in non-polar latitudes.
- This theory is often referred to as CB theory. Later, some improvements were made in subsequent works

Amplification of tides on the shelf

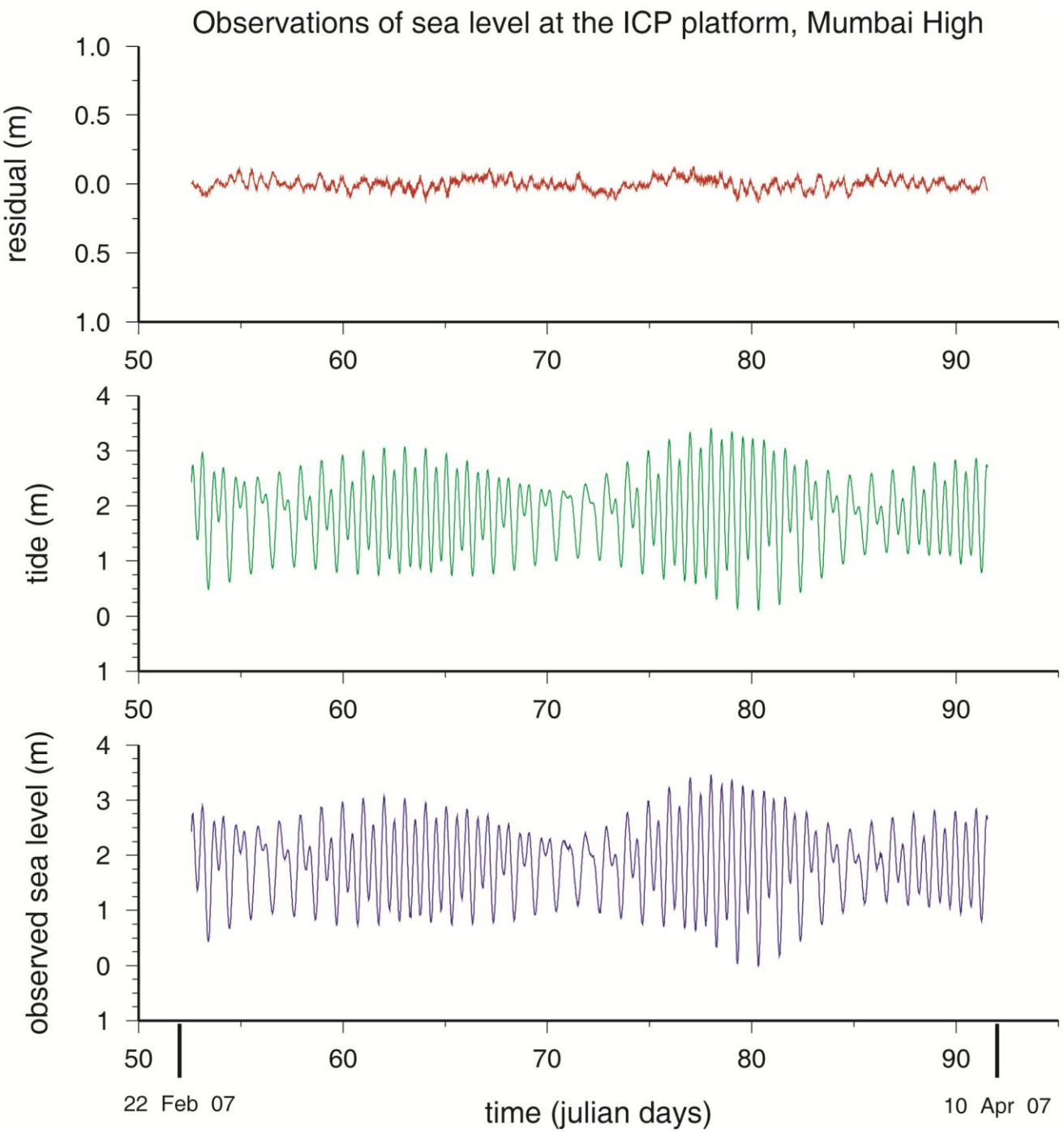
- Wider shelves amplifiy (Clarke and Battisti, 1981) semi-diurnal tides in non-polar latitudes.

- Large tides imply increased vertical mixing

Tides along the west coast of India



Observed Tides at Mumbai High (Joseph et al., In : Current Science, 2009)



- Observed currents at Mumbai High show that they are largely driven by tides and are vertically homogenous
- Large tides imply increased vertical mixing

Tidal propagation in estuaries

- Changes occur due to the bottom topography

  The crests move faster than the troughs (phase speed $=\sqrt{gh}$, where h is the depth)

  Duration of trough increases, compared to the duration of crest of the tidal wave

Modifications in tidal propagation in estuaries

- The shape of the tidal curve changes as one moves in the upstream direction, the flood duration increases

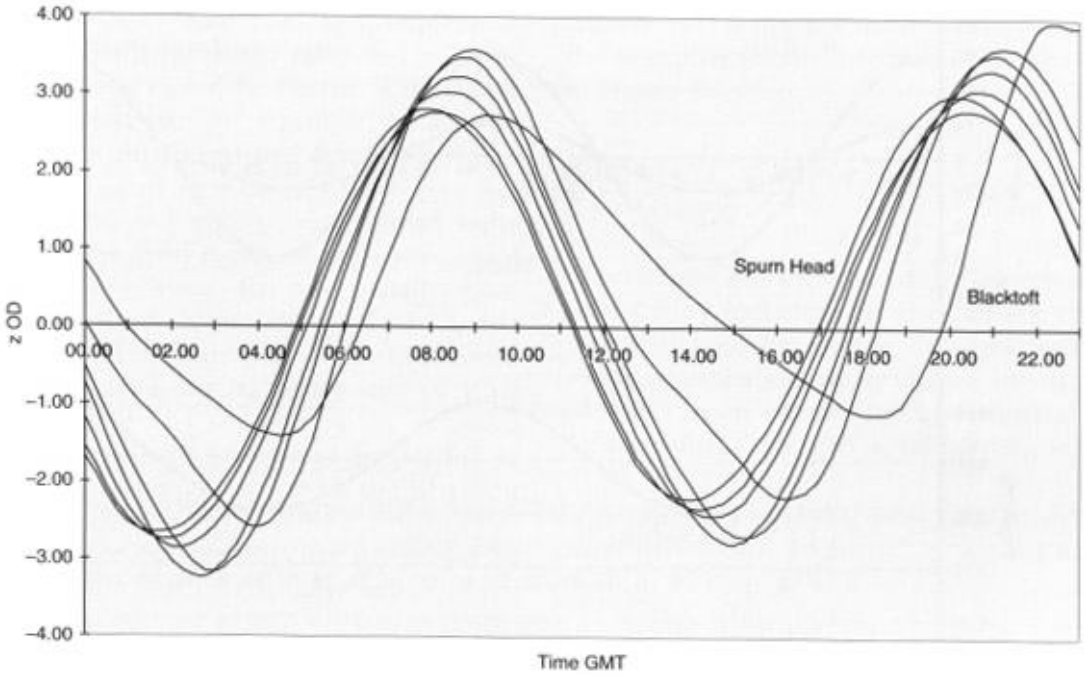
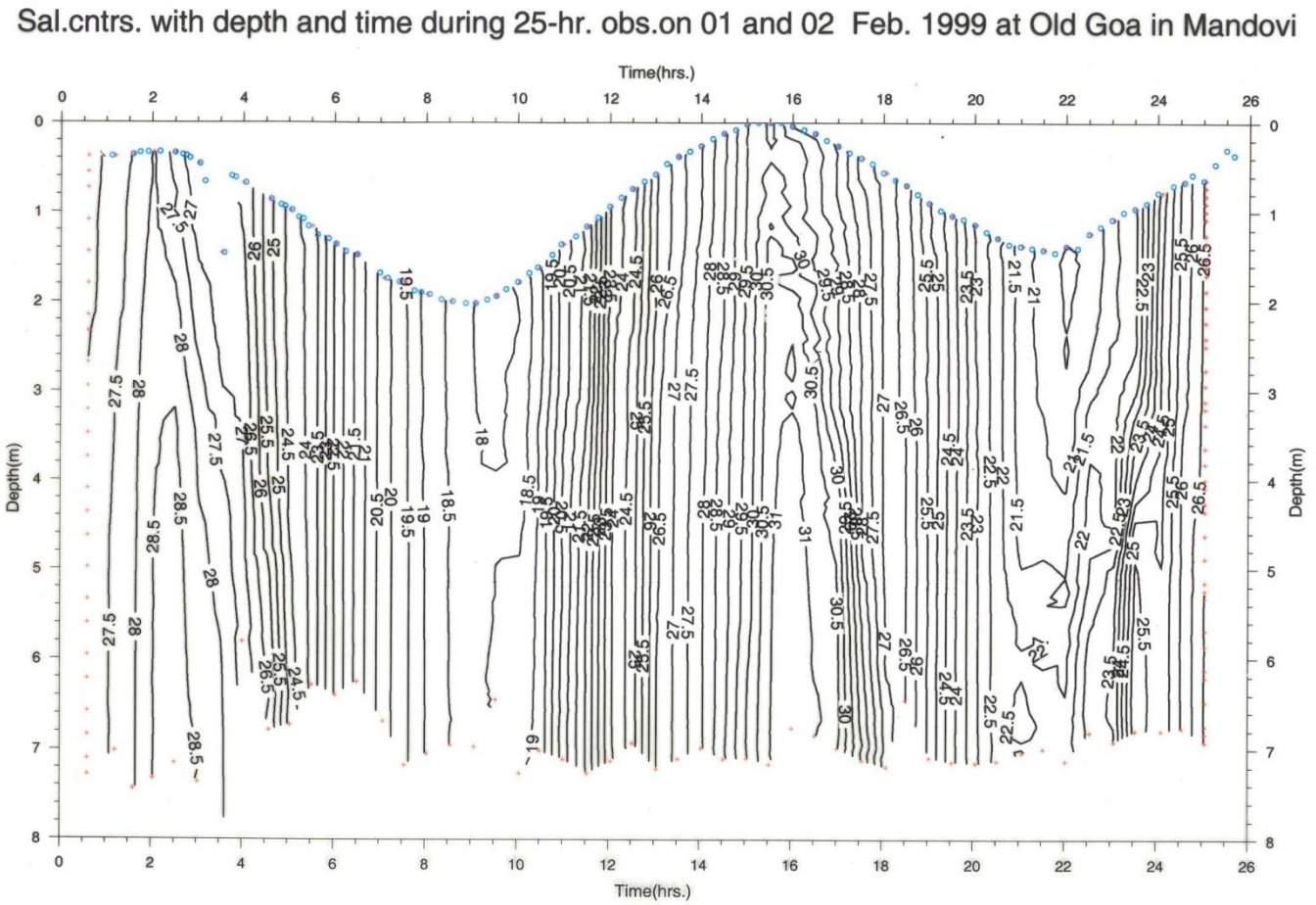


FIGURE 5.8 Increasing asymmetry upstream for the tidal wave in the Humber Estuary plotted from Spurn Head to Blacktoft.

Tidal phase and Salinity distribution in Mandovi estuary, Goa



Tidal bore

- Tidal bores have been reported in some estuaries (geomorphological conditions), where tidal ranges are large and particulalry during spring tide.
- Tidal bores manifest as ‘a very rapid rise in level as the front advances past an observer; from the river bank it often appears as a breaking wall of water a metre or even higher with speeds of 20 km/hr’

- A **tidal bore**, often simply given as **bore** in context, is a **tidal** phenomenon in which the leading edge of the incoming **tide** forms a wave (or waves) of water that travels up a river or narrow bay against the direction of the river or bay's current.

Suggested Reading

- Open University Course Team Waves, Tides and Shallow water processes
- Naqvi and Unnikrishnan (2009). Hydrography and biogeochemistry of coastal ocean. In :*Geophysical Monograph Series.*