

Upwelling & Sinking along Visakhapatnam Coast

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Stability and stratification of the water over the shelf disappear as cold saline waters characteristic of 60 m depth rise to the surface during March. Tilting of isopycnals and offshore displacement of isohalines suggest the surface divergence typical of a coastal upwelling driven by local wind stress. Upwelling is predominant off Visakhapatnam during premonsoon and monsoon periods. Waters from the deeper depths of the shelf appear to reach the surface causing considerable fall of temperature near the coast particularly during the premonsoon period.

Over the Bay of Bengal two distinct wind systems prevail during the year—the southwest monsoon winds which recurve over the Bay and become southeast and the northeast monsoon winds—and these wind systems cause sufficient wind stress on the surface waters giving rise to mass drift of the oceanic waters, which results in upwelling and sinking along the east coast of India^{1,2}.

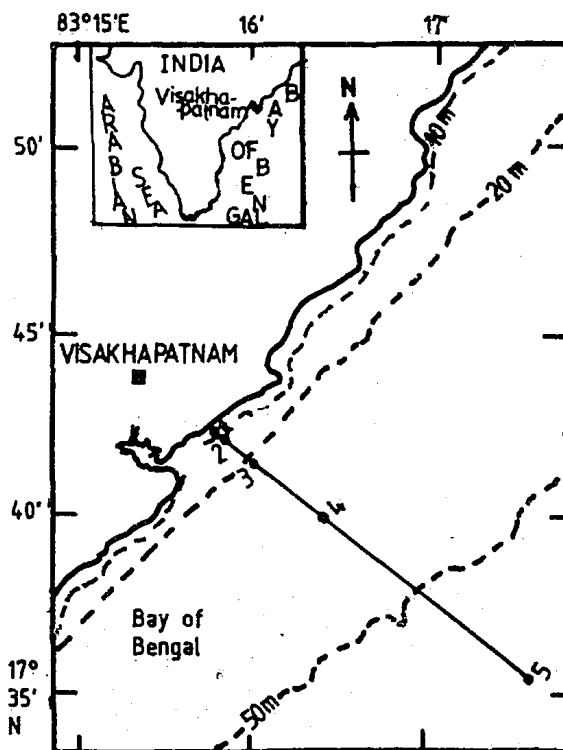
In the present study, upwelling and sinking on the central east coast of India near Visakhapatnam are studied using the observed temperature and salinity data.

Materials and Methods

Monthly sampling was made at 5 stations along a transect perpendicular to the coast off Visakhapatnam (Fig. 1) during April 1979 to March 1980. Temperature and salinity profiles were measured up to 60 m depth using T-S Bridge and Nansen casts. Data on meteorological parameters such as wind, air temperature—both wet and dry bulb temperatures—were recorded at each station. Knudsen's method was used to estimate the salinity of the water samples and cross-checked the values with T-S Bridge readings. The temperature data were processed by applying thermometric corrections to the readings of the reversing thermometers and cross-checked the values with T-S Bridge readings. The density values were evaluated from temperature and salinity data using the one atmosphere international equation of state of sea water³. Vertical profiles of temperature, salinity and density (σ_t) along the section were prepared for each month.

Results and Discussion

Seasonal variation of sea surface temperature—Sea surface temperatures (SST) show two peaks (Fig. 2), one in June and the other in October, which coincide more or less with the overhead positions of the sun at this latitude. The air temperature also shows two maxima one in June and the other in October. Earlier⁴⁻⁶ also similar variations in SST and air temperature have been reported along the Indian coasts.



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Fig. 1—Topographic chart of the coastal area off Visakhapatnam

There is a sudden drop of SST by about 3°C from February to March. Such a change cannot be ascribed to any change in the insolation or entirely to evaporation. This seems to be caused by advection of cold water into the region.

The air temperature is more than SST during Feb. to Oct. permitting sensible heat to flow from the atmosphere to the sea whereas in winter months the reverse is the case. This greatly influences the climatic conditions of the region.

Fig.3 shows variation of temperature, salinity and density at depths 0, 20, 40 and 60 m. Variation of temperature is more at 60 m depth and least at the surface (Fig.3a). Such a large variation of temperature at 60 m depth can be accounted for only by the advection of cold waters from below. This is further confirmed by the variation of temperature at shallower depths, which decreases indicating that bottom waters are being advected to different depths causing different temperatures.

Changes in salinity at 60 m depth during different months (Fig.3b) are least whereas the salinity variations at surface are high with intermediate values at depths in between.

Density variations (Fig.3c) are similar to the salinity variations except that the densities show peak values during March at all depths confirming that the cold saline bottom waters are upwelling resulting in increase in density.

Vertical sections of temperature, salinity and density at different distances from coast are given in Fig.4. In March, the divergence of the isotherms takes place at 30 m within 7 km of the coast, and below 40 m and over 20 km from the coast there is a notable deepening of the isotherms and isopycnals. In April, the picture is different even though the upwelling takes place above 30 m and over 20 km from the coast. It may be inferred from this that upwelling centre (cooler water) appears first close to the coast during March and then migrates

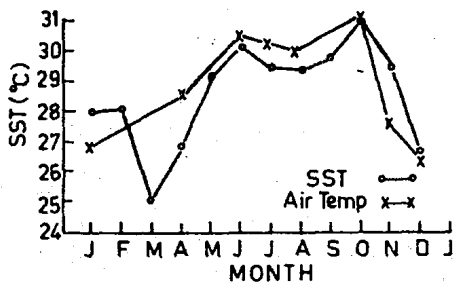


Fig. 2— Monthly variations of mean sea surface temperature at coastal station off Visakhapatnam

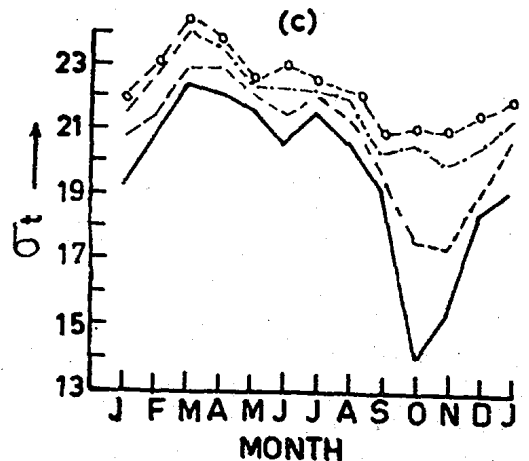
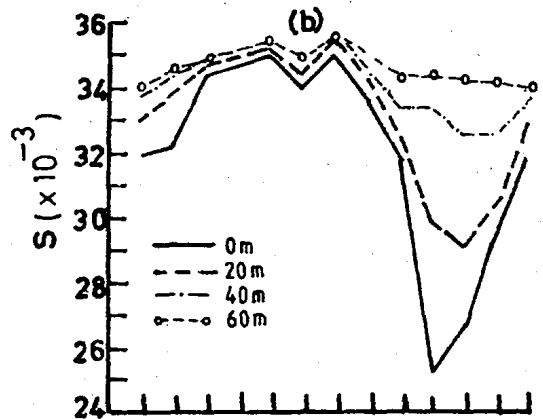
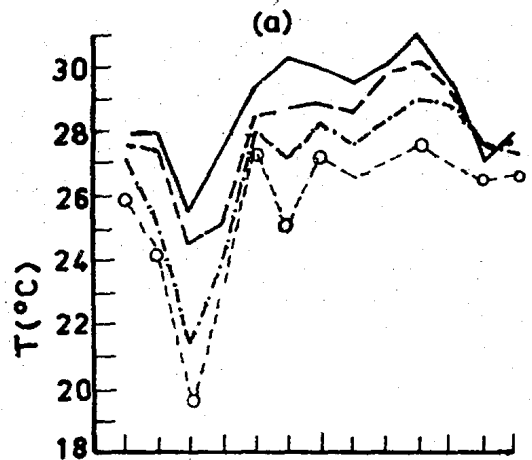


Fig. 3— Monthly variations of temperature (a), salinity (b) and density (c) at four standard depths (0-60 m) for the coastal area off Visakhapatnam

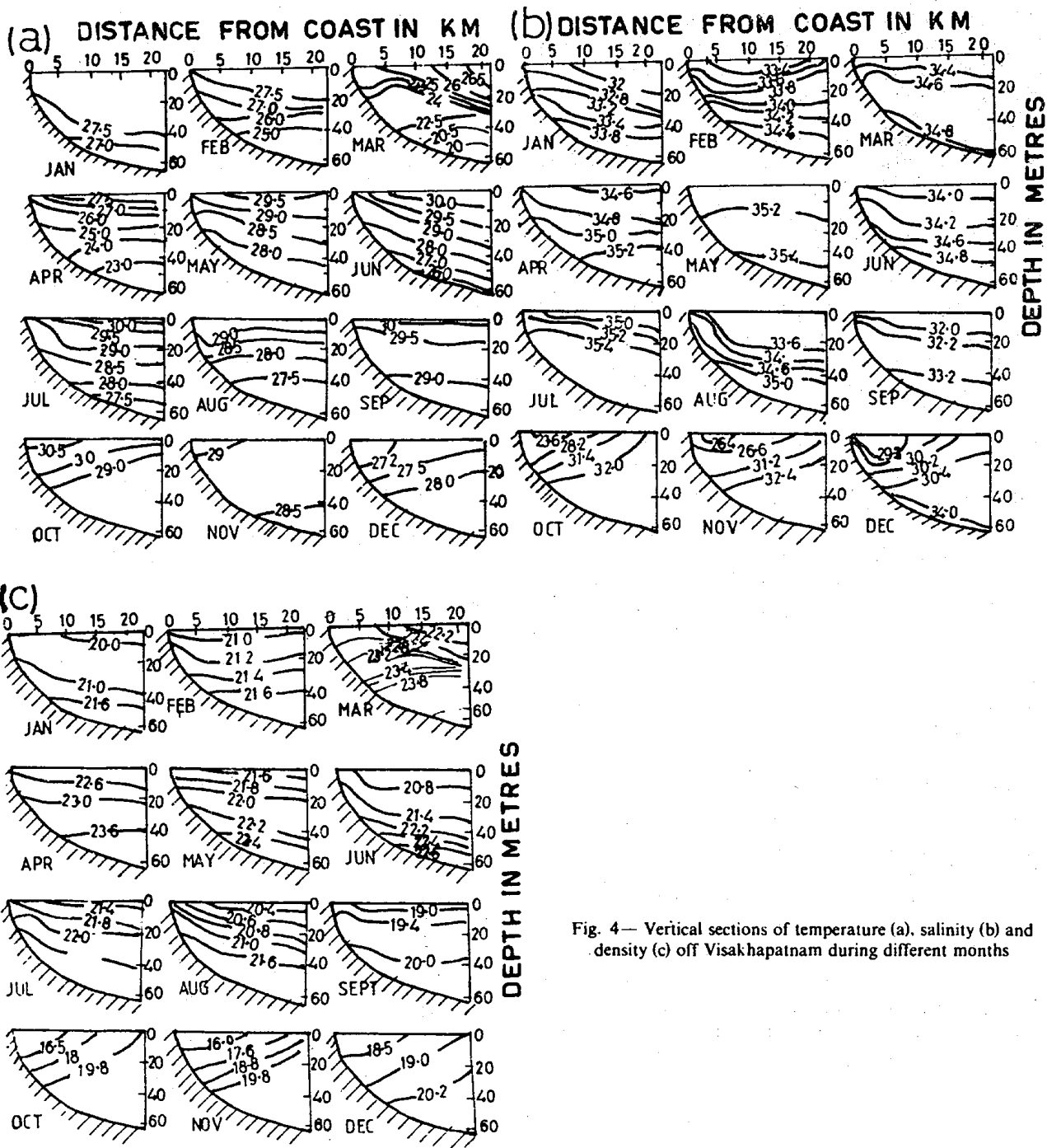


Fig. 4— Vertical sections of temperature (a), salinity (b) and density (c) off Visakhapatnam during different months

to offshore with the progress of time. During May to July the distribution is similar to that during April, but with weaker upwelling. During Oct. and Nov., the vertical and horizontal displacement of the isotherms and isopycnals indicates a vertical circulation downward the shelf slope and onshore at the surface, characteristic of sinking along this coast during these months. However, during the rest of the upwelling and sinking period the isopycnals are horizontal and the

inclination that is characteristic of coastal upwelling and sinking is absent.

Upwelling in the coastal waters off Visakhapatnam— Distribution of isotherms, isohalines and isopycnals (Fig.5) shows that cold bottom waters upwell from the middle of Feb. when the northeast winds give place to south-southwest winds. The upwelling becomes vigorous during March and continues up to July and then decreases with the withdrawal of the southwest

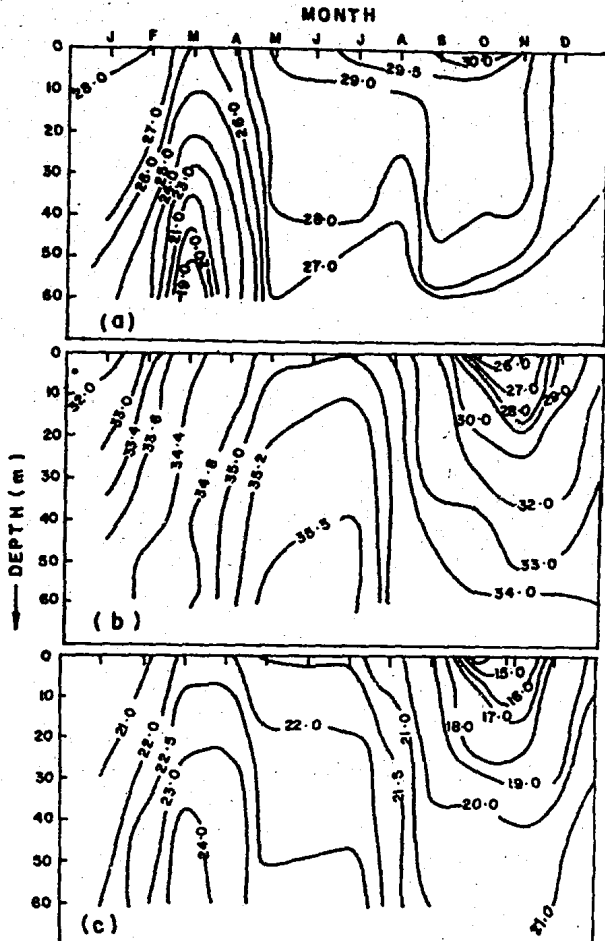


Fig. 5— Monthly distribution of temperature (a), salinity (b) and density (c) for the coastal area off Visakhapatnam

monsoon. With the onset of the northeast monsoon, when north-northeast winds prevail and the wind stress transports offshore waters to the coast where sinking takes place. The sinking is not as vigorous as that of upwelling since the wind stress during the northeast monsoon is much weaker than that in southwest monsoon season. An estimation of the movement of the 22-24 σ_t isopycnals give upwelling speed of 9.6×10^{-4} cm.sec⁻¹ during March to April and 7.7×10^{-4} cm.sec⁻¹ during May to July. Similar estimation of the movement of the 18-19 σ_t isopycnals give downwelling or sinking speed of 5.77×10^{-4} cm.sec⁻¹ for October and November.

Acknowledgement

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