

1537
ON AN UPWELLING FRONT ALONG THE WEST COAST
OF INDIA DURING LATER PART OF
SOUTHWEST MONSOON

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ABSTRACT

A coastal front, associated with upwelling, is identified from the observed thermal field along the west coast of India during September, 1987. The front, which is seen very clearly upto a depth of about 75 m, has a horizontal gradient of temperature of about 6°C over a width varying between 45 and 70 km. An alongshore temperature section passing through the offshore side of the front shows a north-south slope of the thermocline, which is shallow at the southern side and deep at the northern side. It is speculated from the observed features that upwelling along the west coast of India occurs first at the southern part and the signal gradually propagates towards north.

INTRODUCTION

Fronts associated with upwelling have been identified and studied in major upwelling regions such as off Oregon, west Africa (Canary), Peru etc. The dynamics of upwelling fronts, found off the coast of Oregon, had been described by Mooers et al. (1976). Upwelling along the west coast of India during SW monsoon was earlier studied by various workers mostly with the help of temperature sections at specific locations. A programme to investigate the spatial variability of upwelling process was initiated in September, 1987 with the help of closely spaced network of stations. In the present study, we describe the features of a front associated with upwelling based on the observed thermal field.

DATA AND METHODS

Vertical temperature profiles were collected using a digital bathythermograph (DBT) onboard RV 'Gaveshani' during 15-30 September, 1987 at stations separated by about 15'. In addition, towards the end of the cruise, three current meters of Aanderaa type were moored at 15, 40 and 75 m depths for a period of 72 hours. DBT stations and the mooring location are shown in Figure 1. Using the DBT data, horizontal distribution charts of temperature were prepared for 0, 25, 50, 75 and 100 m depths (Figs. 1 and 2). A vertical distribution of temperature along the north-south offshore section (Fig. 3) was prepared.

RESULTS AND DISCUSSION

Through the analysis of temperature field, a thermal front associated with upwelling has been identified along this coastline, the characteristics of which are discussed below.

Description of the front: In Fig. 1 and 2, a front, which is nearly parallel to the coastline, can be seen. In the frontal zone, sharp gradients of temperature of the order of 6°C over a distance varying between 45 and 70 km are found. The front is found to be closer to the shore in the northern part of the coast giving an impression that it is slowly moving away from the coast in the southern region. The front also appears to move away from the coast with depth. However, this could be a manifestation of upwelling, as the isopycnals (not presented) are tilted upwards. It is to be noted that temperature gradients in the frontal zone remain nearly the same at 25 and 50 m. The front is not clearly visible at the surface and below 75 m, as if the front is slowly disappearing with depth, as the horizontal gradients are diminishing downwards.

North-south section of temperature: Fig. 3 shows that the thermocline is shallow in the southern part of the coast and deeper in the northern region. This N-S slope

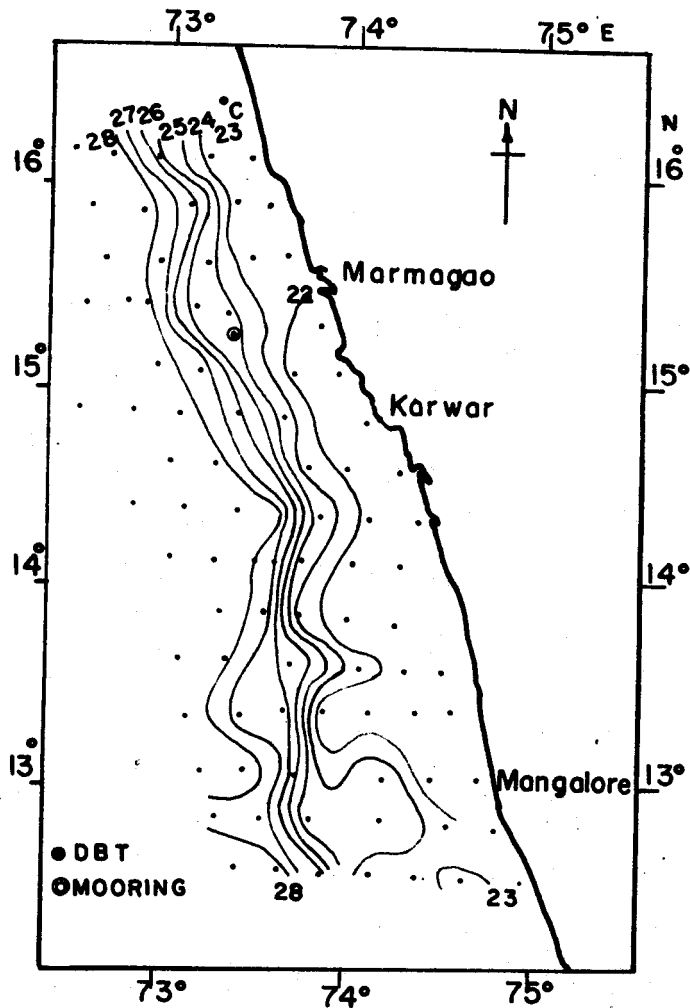


Fig. 1. Temperature section at 25 m depth

of isotherms shows that cold water is present very close to the surface in the southern region as compared to the northern side.

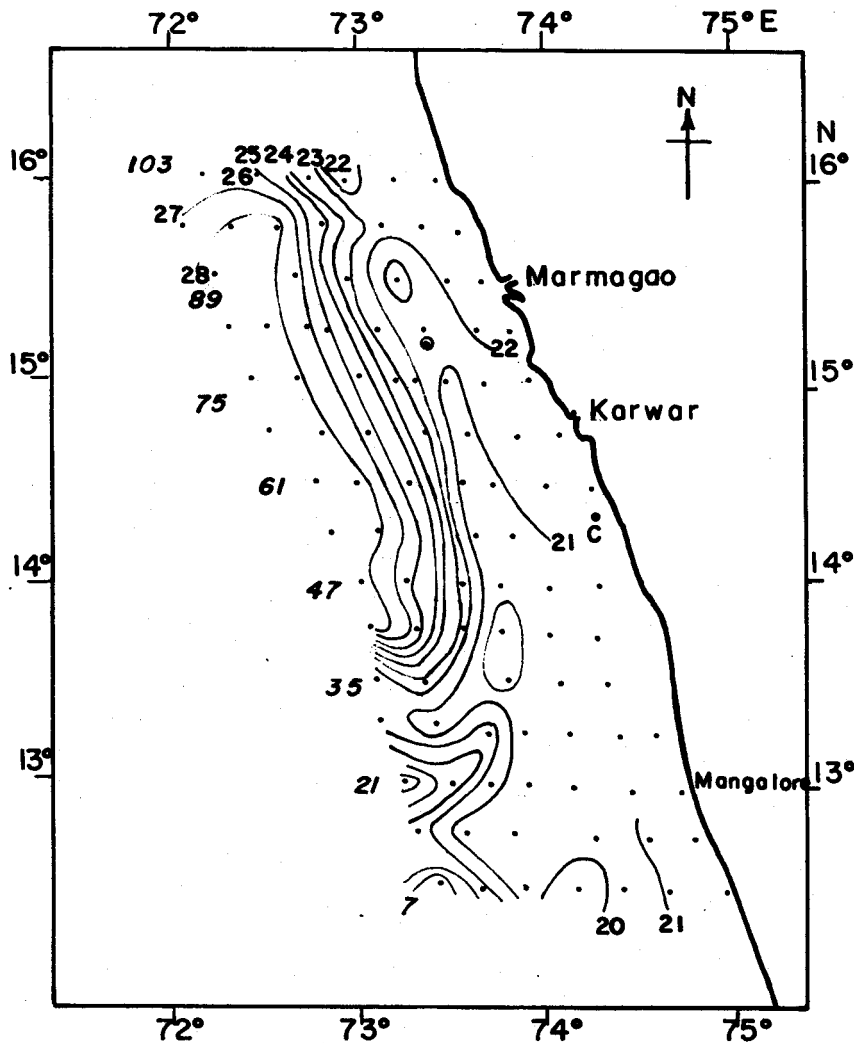


Fig. 2. Temperature section at 50 m depth. The numbers written in italics are station numbers.

Dynamical aspects: In order to examine the stability of the water column, Brunt Vaisala Frequency (N) and Richardson Number (Ri) were determined at the mooring station, which lies in the frontal zone. N^2 was found to oscillate with the period of semidiurnal internal tides, with values of the order of 10^{-4} (rad/sec) 2 . Ri was found to be always greater than one, indicating that the water column is dynamically stable.

Flow and wind characteristics: Instantaneous wind measurements made at different stations show that the wind is mostly northerly to north westerly. From the

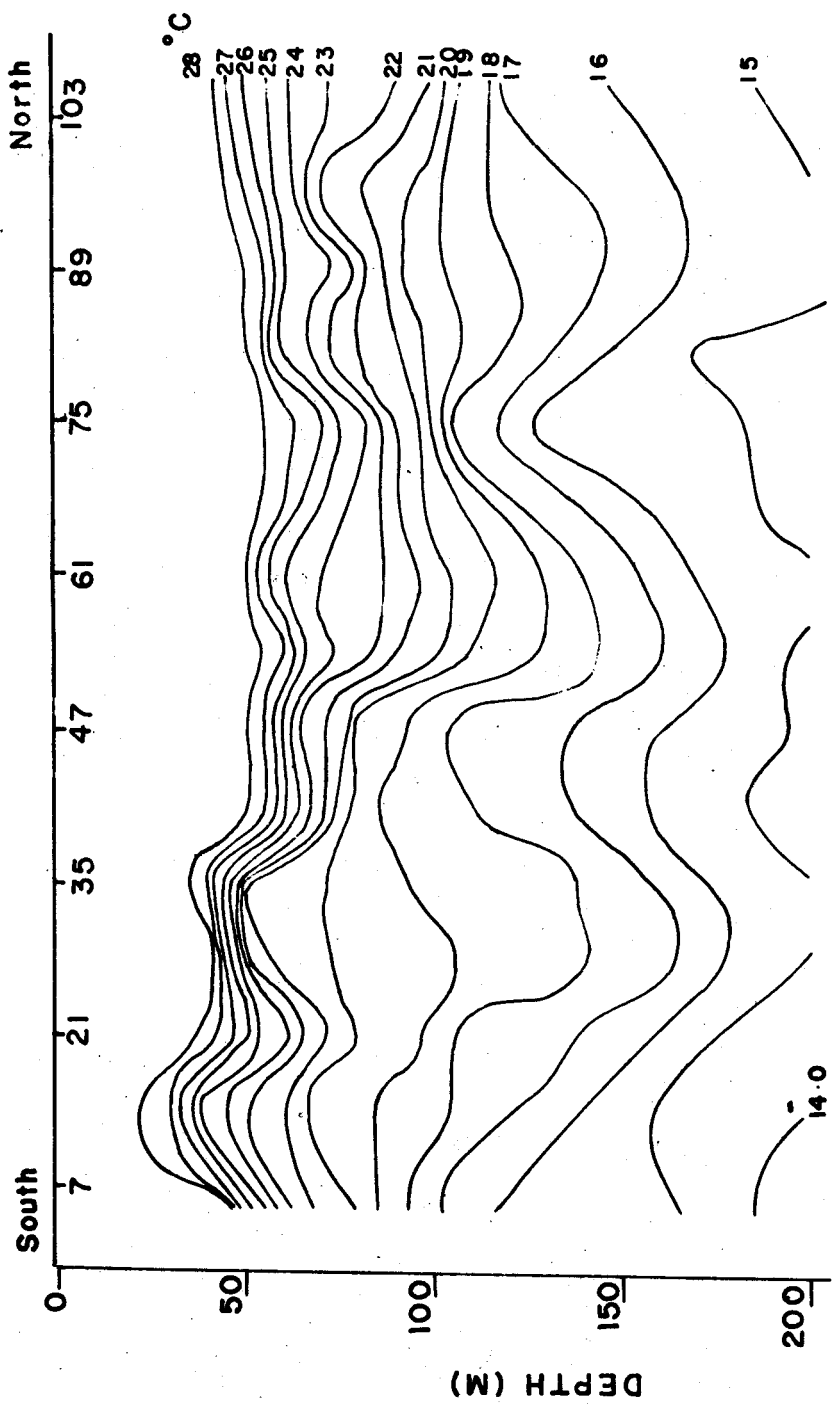


Fig. 3. North-south section of temperature. In the x-axis, station numbers are shown.

current meter observations made at a location in the frontal zone, it is found that alongshore flow at 15 m depth is southward. This suggests that alongshore flow near the surface is driven by local winds and the reversal of flow, which is expected during early October, has not yet taken place. The alongshore component of wind is found to be favourable for upwelling. This along with southward surface flow, constitutes a typical eastern boundary phenomenon.

Sharma (1967) had shown that upwelling along the west coast of India starts during February-March in deeper layers and reaches the surface by May. However, Sankaranarayanan et al. (1978) observed the presence of cold water in the surface layers off Goa even in early October. The present observations confirm that along the Goa coast, upwelling features are seen much later than those in the southern region. Under these circumstances, one would speculate that the upwelling phenomenon occurs first in the southern part of the coast and the signal gradually propagates towards north.

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