

Alongshore Velocity Field Off Visakhapatnam, East Coast of India during Premonsoon Season

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Received 16 October 1986; revised received 19 October 1988

Using direct current measurements made during February-May 1982, alongshore currents over the innershelf off Visakhapatnam (water depth ≈ 45 m) have been discussed. Significant mean alongshore flow (20 to 50 $\text{cm}\cdot\text{sec}^{-1}$) occurs in the innershelf regime and is towards northeast. The intensity of observed mean flow has negligible variability. Mean alongshore flow appears to be related to the baroclinic pressure gradients associated with upwelling system. The relatively strong alongshore velocity shear observed during March-May induces upwelling. The onshore-offshore component of the current is weak during March-May.

Upwelling along the Visakhapatnam coast, a seasonal event occurring from March to July, is important to local fishing industry. The wind and current cause the upwelling which is manifest in the variations in surface temperatures and salinities¹. Theoretical study² indicates the occurrence of upwelling from January to July due to the northeasterly current. Earlier investigations^{3,4} on the temperature, salinity, density and nutrients proved conclusively the existence of upwelling and its dependence on the northeasterly current flowing along this coast. Several earlier studies provide surface currents off Visakhapatnam using double theodolite method⁵, geostrophic method⁶, density distribution^{7,8} and ship drift data⁹. Direct current measurements have been made over the innershelf region off Visakhapatnam for the first time.

The central theme of this paper has been the variability of alongshore velocity field off Visakhapatnam and how the variability of alongshore velocity field effects upwelling during premonsoon season.

Materials and Methods

The present study (February-May 1982) was made at closely spaced hydrographic stations (sts 1-5) and at a station (water depth ≈ 45 m; st 6) off the Visakhapatnam coast (Fig. 1). Temperature and salinity profiles were measured up to 60 m depth using T-S bridge and Nansen casts. The density values were evaluated from temperature and salinity data using the one atmosphere international equation of state of seawater¹⁰. Current measurements were made at every 5 m up to 40 m depth from an anchored boat with digital current meter (accuracy: ± 1 $\text{cm}\cdot\text{sec}^{-1}$, $\pm 1^\circ$), designed by NIO, Goa. These readings were repeated every hour, 10-12 times

during the day. Data on winds and air temperature - both wet and dry bulb temperatures - were recorded at each station.

The hourly current vectors were plotted in a time sequence i.e. the end of the one being taken for the beginning of the next vector (Fig. 2). As a result, the average vector was calculated and the current variation was estimated by a quantity called stability¹¹, (B).

$$B (\%) = 100 |V| / v$$

where $|V|$ is the length of the average vector and v is the arithmetic mean velocity.

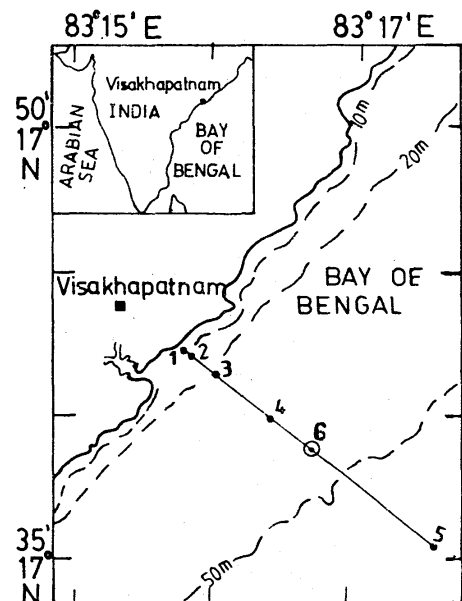


Fig. 1—Study area off Visakhapatnam (1-5, hydrographic stations and 6, current observation station)

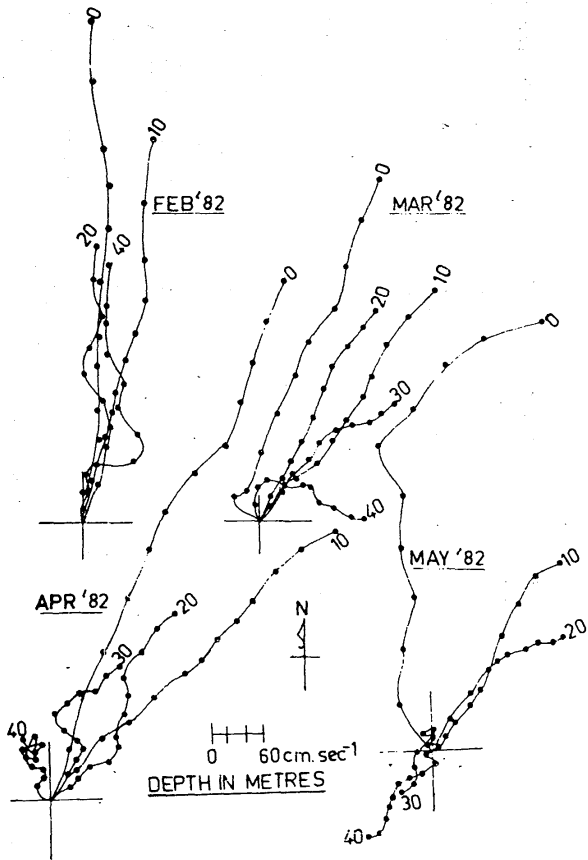


Fig. 2—Successive vector diagrams for February-May 1982

The currents at the station were averaged over a day to obtain daily estimates of the residual flow. The vector mean of horizontal velocity from hourly data were computed¹¹ (Fig. 2). Three depth classes - surface (0-15 m), intermediate (15 - 30 m) and deep (30-45 m) layers of the water column were considered.

The alongshore flow was represented in terms of the component parallel to the local isobath and the onshore - offshore flow was perpendicular to it. Along the Visakhapatnam coast 045°T and 315°T were taken as the alongshore and onshore-offshore axes respectively. The hourly current observations were resolved into alongshore and onshore-offshore components along these axes.

Results and Discussion

Measurements of the current from surface to 40 m depth (Fig. 2) show that the current magnitude decreases rapidly with depth. In general the vector mean flow (Fig. 2) has larger alongshore (u) components than onshore-offshore components (v) except in February. During February the onshore-offshore flow is considerably strong as the current is towards north. The discussion has been restricted to the

alongshore flow only. From Table 1 the characteristic feature of the currents during February to May is distinguished by high stability of current velocity and direction. During April the stability is less (34%) at the bottom and may be attributed to the weaker upwelling during this month (Fig. 3). The mean direction of currents during February to May are 7°, 45°, 30° and 101° with corresponding mean velocities of 42, 27, 30 and 31 cm.sec⁻¹ respectively. During March, the mean currents are parallel to the coast and is towards northeast indicating predominant upwelling (see Fig. 3 also). The upwelling as reported earlier¹² becomes vigorous during March.

Fig. 4 shows the alongshore component of the hourly data from st 6. From February to May (Fig. 4

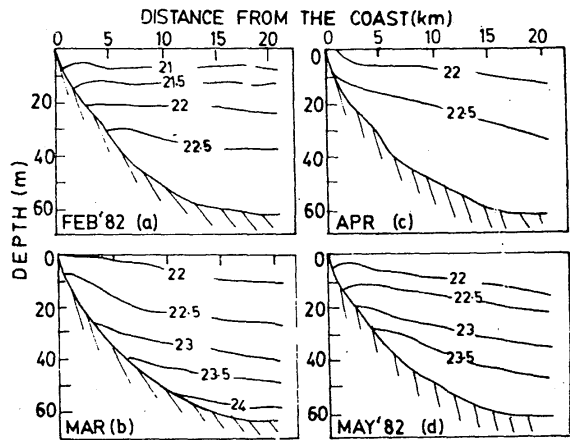


Fig. 3—Density (sigma-t) sections over inner continental shelf observed during February-May 1982

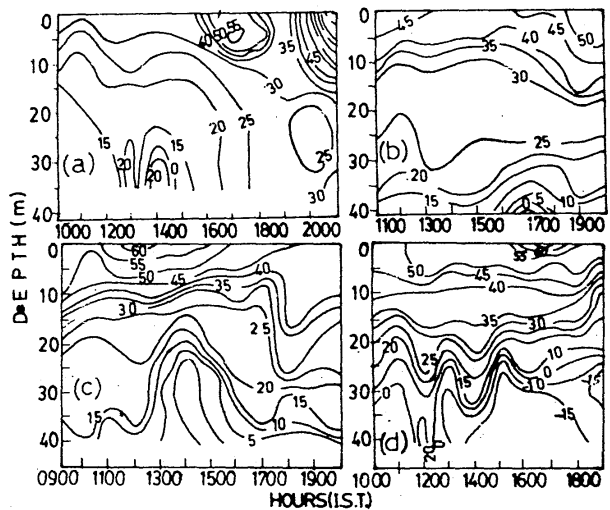


Fig. 4—Hourly variation of alongshore current with depth for (a) February (b) March (c) April and (d) May 1982 (+ ve northeastward, - ve southwestward)

Table 1—Flow Statistics from Direct Current Measurements Off Visakhapatnam from February to May 1982
(Water depth = 45 m)

Water depth (m)	Mean current		Vector mean velocity (cm.sec ⁻¹)	\bar{u} (cm.sec ⁻¹)	\bar{v} (cm.sec ⁻¹)	SD(u)	Stability (%)
	speed (cm.sec ⁻¹)	Direction (deg.True N)					
February 1982							
0	50	5	50	33	36	11	99
5	47	15		38	23	12	
10	37	11	37	29	21	11	98
15	31	7		24	22	9	
20	27	6	26	19	17	8	98
25	29	5		19	18	8	
30	29	4	24	17	17	8	84
35	31	353		17	19	8	
40	33	8	25	20	15	11	82
March 1982							
0	47	30	42	40	17	8	90
5	44	39		44	8	6	
10	29	40	34	35	4	8	99
15	30	40		30	2	6	
20	29	32	28	28	7	2	98
25	27	35		26	5	2	
30	22	54	21	21	2	3	97
35	20	61		16	-2	5	
40	18	79	13	9	-8	3	72
April 1982							
0	55	26	55	51	18	7	99
5	49	48		45	01	4	
10	39	49	38	38	00	7	99
15	28	46		26	02	8	
20	24	35	22	21	02	8	92
25	22	25		18	04	10	
30	19	40	14	14	03	8	76
35	19	8		11	00	12	
40	18	358	06	02	06	13	34
May 1982							
0	62	18	51	41	23	18	82
5	51	44		47	00	6	
10	40	48	39	37	-01	7	98
15	35	52		33	-01	6	
20	22	56	21	21	-02	8	92
25	19	112		4	00	16	
30	17	153	06	-6	-02	13	37
35	16	205		-11	01	11	
40	15	221	12	-8	-04	11	83

\bar{u} positive to the northeast, \bar{v} positive to the northwest.

a-d) there is considerable difference or shear, between the deep and shallow currents.

In February (Fig. 4a) the difference between the shallow and deep currents seems to be less (13 cm.sec⁻¹) and are almost northeastward except at 1400 hrs, wherein deep currents are towards southwest. In March, the difference between shallow and deep currents seems to be appreciable (25 cm.sec⁻¹)

and are almost northeastward. There is further increase in the difference between shallow and deep currents (34 cm.sec⁻¹) during April. The shear increased from February to May (0.004 to 0.016 sec⁻¹) and reached maximum in May (0.016 sec⁻¹). The southwest currents observed in the deeper layer during February at 1400 hrs have been noticed at the same time during April whereas the deep currents are always towards southwest during May.

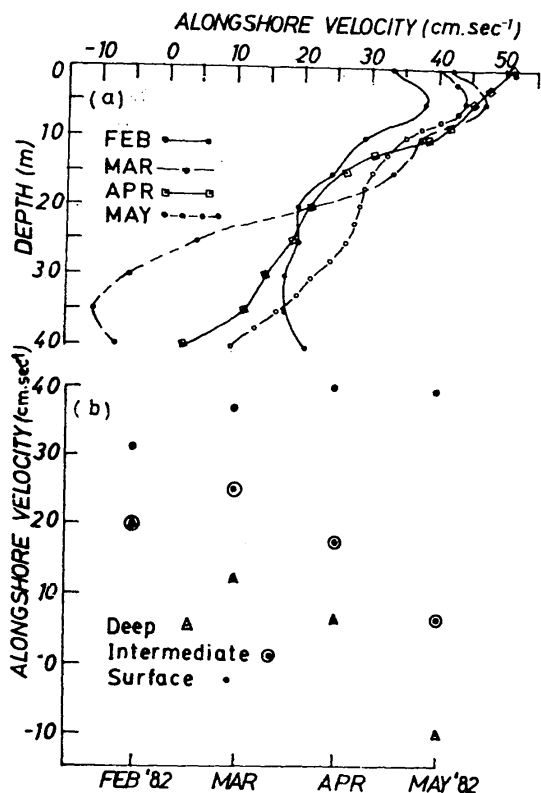


Fig. 5—Monthly variation of (a) alongshore current with depth and (b) alongshore current field for February-May 1982

Alongshore component of the monthly mean (Fig. 5a) shows that the shear is nearly absent during February. The surface and deep currents are northeastward during February to April. A mean vertical shear with surface flow towards northeast and deep currents towards southwest is established in May. The northeastward flow (Fig. 5a) is maximum at surface during April. It is maximum at the deeper layer in February. During May at 27 m the alongshore flow changes from northeast to southwest.

The variation of the alongshore flow with time (Fig. 5b) indicates greatest vertical shear in March-May, presumably because horizontal density gradients occur in this region (Fig. 3). The variation of the currents over the inner continental shelf is undoubtedly related to the variations in the winds, sea level and hydrographic regime. Winds become favourable for upwelling from the middle of February when the northeast wind gives place to south-south-

west winds¹², the month in which the observed alongshore velocity shear develops. Associated with this is a change in the hydrographic regime, as indicated by the density sections across the continental shelf (Fig. 3). A horizontal gradient of density results from the isopycnals sloping upward towards the coast during upwelling. Under the geostrophic assumption (thermal wind relation), this is consistent with the vertical shear observed during March-May (Fig. 5b). The lowest mean sea level observed at the coast during March as reported earlier¹³ correspond to the period of strong northeastward flow, consistent with the geostrophic assumption.

The results of this study indicate that the northeastward alongshore flow (20 to 50 cm.sec⁻¹) and the relatively strong alongshore shear (0.008 to 0.016 sec⁻¹) are responsible for upwelling during March-May.

Acknowledgement

The authors thank Dr. B.N. Desai, Director, Dr. J.S. Sastry and Mr V.S. Rama Raju for their keen interest and encouragement.

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