

## CURRENT MEASUREMENTS OFF BOMBAY DURING MARCH 1976\*

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### ABSTRACT

An analysis of currents recorded continuously for about 24 hrs at four stations off Bombay revealed the dominance of periodic tidal flow on the current pattern. The frequency distributions (direction) are observed to be bimodal. The vector mean residual current is directed offshore in the surface layers (20 m) and onshore at relatively deeper (40 m) levels. Further, an analysis of the wind and current observations showed the influence of wind on current structure.

### INTRODUCTION

Recent developments in the Bombay High region necessitated comprehensive studies of the oceanographic parameters such as temperature, salinity, currents, waves,

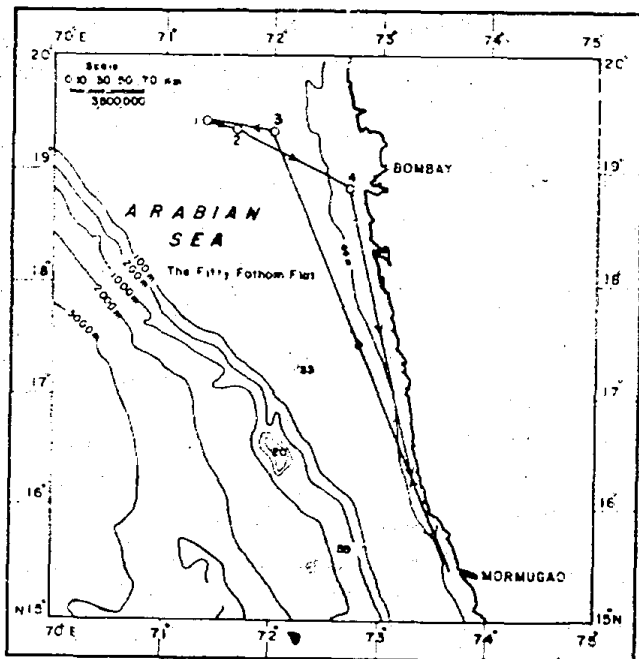


Fig. 1. Station location map.

bottom topography etc. In this connection, the Engineers India Limited had earlier carried out a limited survey on currents, tides, wind, temperature etc. in the Bombay High. (EIL 1976). As part of a more comprehensive study a short term survey of the hydrographic conditions had been carried out in this region during March 1976. These surveys included, amongst others, a study of the vertical current structure at four locations (Fig. 1). Current measurements at near-surface, mid-depth and near-bottom were made at hourly intervals for a period of 48 hours at each station (NIO, 1976). In addition to these spot observations, currents were also monitored by a continuous recording current meter and this

paper presents a preliminary analysis of the continuously recorded data.

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COLLECTION OF DATA

A T-S self recording current meter (Type-2, Tsurumi Precision Instruments Co., Japan) was used to obtain continuous records of current speed and direction. The instrument basically consists of sensing units for current speed and direction and a recording unit. When the instrument is lowered to the required depth, it orients itself in the direction of flow by vanes and is further stabilised by the stabilising fins. The flow sensing unit is a precalibrated propeller and for every five revolutions, a mark is drawn on the recording paper. The direction is printed at intervals of 4.5 minutes on the recording paper in tens of degrees by an engraved circular wheel encompassing a freely suspended magnet. The number of marks between two consecutive direction markings indicates the strength of the current. The current speed,  $V$  (m/sec), is computed from the formula,

$$V = \frac{GNK}{60D} + C$$

where  $G$  is ratio between propeller revolutions and current speed marks,  $N$  is the number of marks,  $K$  is the propeller co-efficient (0.383),  $D$  is time in minutes between two consecutive direction markings and  $C$  is the calibration constant of the propeller (-0.026).

When the current speeds are moderate to strong, the instrument gives fairly accurate readings with an accuracy of  $\pm 2\%$ . As the formula suggests at low current speeds the readings are not reliable.

Table I. Details regarding data collection and quality of records.

Stn. No.	Mean station depth (m)	Depth of observation (m)	Total duration of recording	Quality of records	
				Speed	Direction
1	75	20	0507 (26.3.76) to 0014 (27.3.76)	good	Recorded only for 0507 to 1742
		40	0234 (25.3.76) to 0340 (26.3.76)	good	good
2	65	20	0608 (28.3.76) to 0354 (29.3.76)	good	No registration
		40	0538 (27.3.76) to 0514 (28.3.76)	good	good
3	45	20	2102 (23.3.76) to 2005 (24.3.76)	good	good
4	15	40 8	— — 1322 (29.3.76) to 1424 (30.3.76)	— good	— good

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Continuous recording of currents for twenty four hours were made at depths of 20 and 40 m at stations 1, 2 and 3 while at station 4 (mean depth 15 m), the current was monitored at 8 m only. Table I gives the particulars and quality of recording.

During the entire observation period, wind speeds and directions were noted at hourly intervals.

#### ANALYSIS AND RESULTS

The current speeds were computed using the above formula from the total number of marks between two direction markings. Thus these values represent the average current speed over 4.5 minutes. Figs. 2(a), (b) and (c) show typical plots of current speed and direction against time. Fig 3. shows the hourly wind vectors at each of

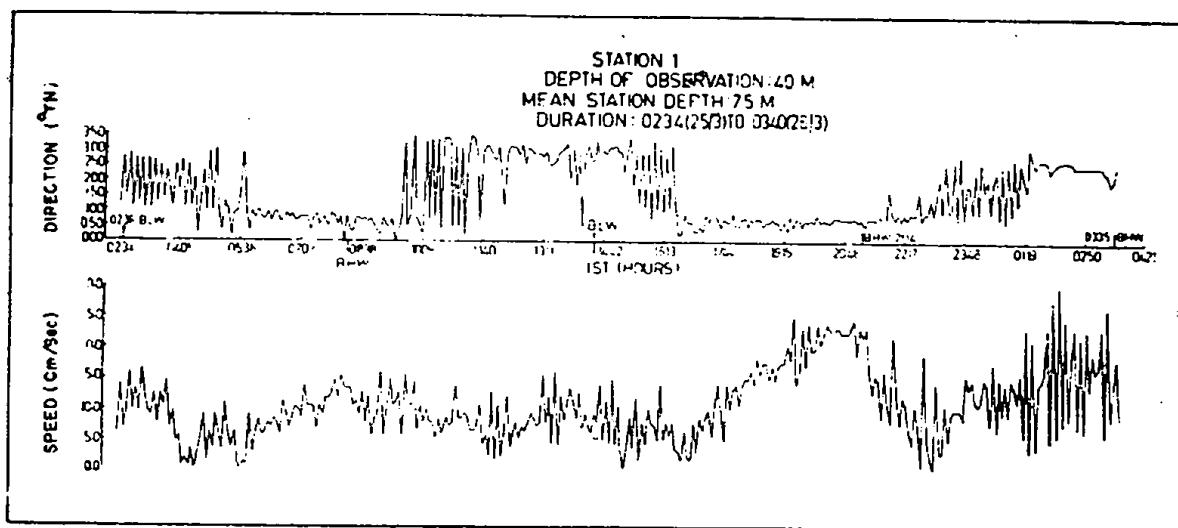


Fig. 2 (a). Continuous plot of current speed and direction at station 1, 40 m.

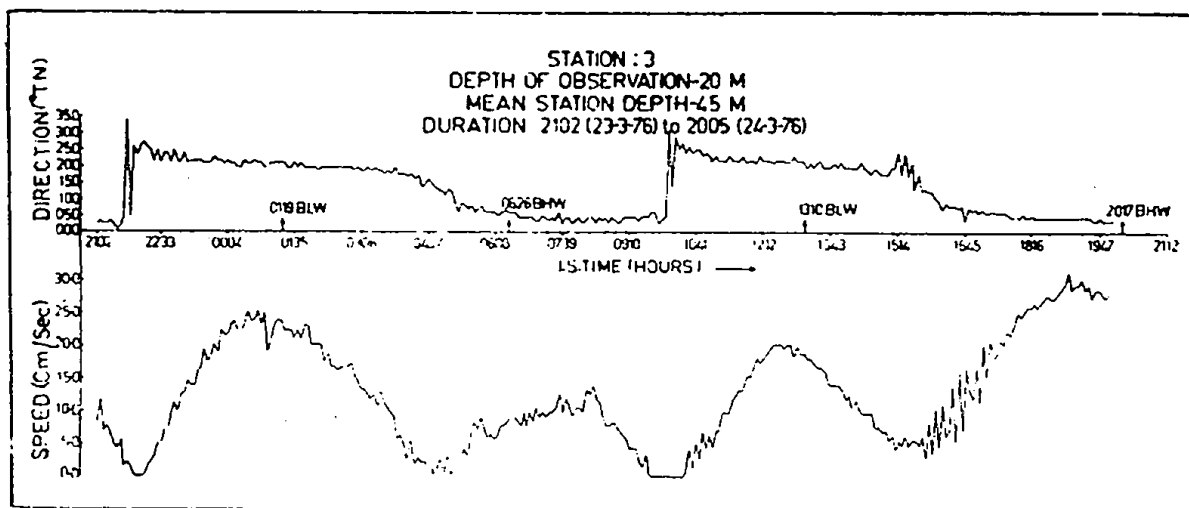


Fig. 2 (b). Continuous plot of current speed and direction at station 3, 20 m.

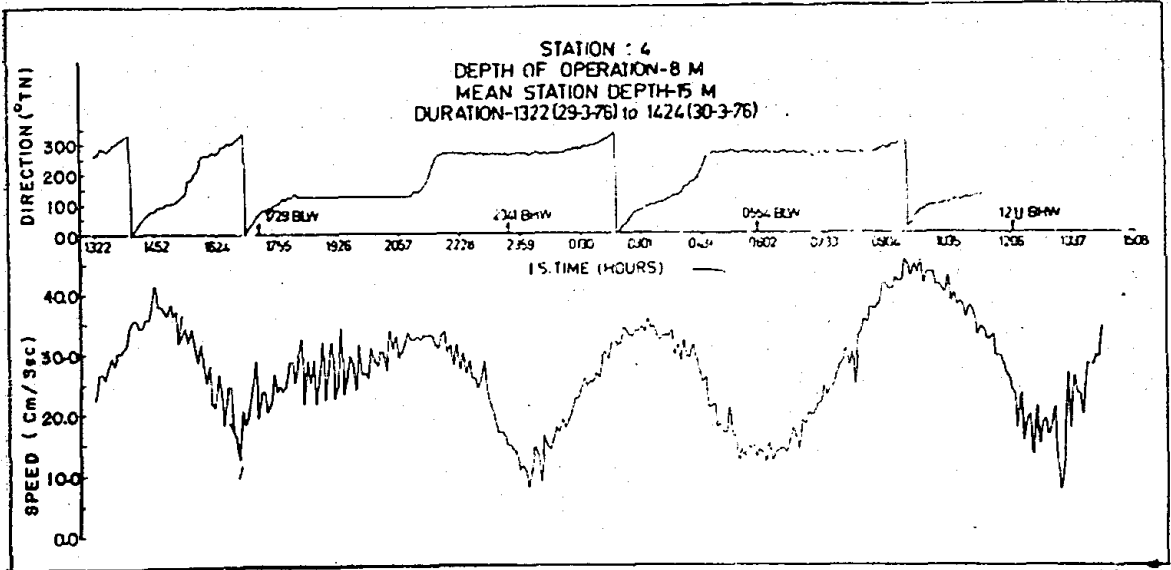


Fig. 2 (c). Continuous plot of current speed and direction at station 4, 8 m.

the stations. Frequency distributions of current speed and direction based on 4.5 minute average are shown in Figs. 4(a) and (b). Fig. 5 shows the hourly current vectors. Also shown in this figure is the mean current vector over a tidal cycle.

An examination of Figs. 2(a), (b) and (c) reveals that the influence of tide on the current structure even at 120 km offshore is considerable. When the currents are fairly strong (*e.g.* from 2300 to 0300 hr., station 3, 20 m), the direction remains fairly stable while at low current speeds (*e.g.* 0930 to 1030 hr, station 3, 20 m) as at slacks, significant fluctuations in direction are evident. A comparison of Fig. 2(a) with Figs. 2(b and c) shows that larger fluctuations both in speed and direction are superimposed on the basic current pattern at station 1. The regular fluctuations at station 1 with a periodicity of about 9 minutes appear to be closely related to the movements of the ship about the anchor due to wind, surface currents and waves. The long term more pronounced changes in the speed distribution (*e.g.* between 0600 and 1500 hr) are caused by the direct effect of wind drifts. Fig. 3 shows that during the entire observation period at station 1, the winds are fairly strong (often exceeding 5 m/sec) with directions varying from NW to NE. At stations 2 and 3, however, the winds are relatively weak with calms predominating for longer durations. As the depths of observations are relatively shallow the wind effect on the current could penetrate to these depths causing fluctuations. The yawing and swinging of an anchored ship associated with the gustiness of the wind could give rise to fluctuations in recorded current speed and direction. The fluctuations in speed and direction with a period of about 9 minutes observed at all stations (more pronounced at station 1) are clearly due to these extraneous ship movements. At station 4 the winds show a predominant diurnal variation with winds freshening from early afternoon hours. The larger fluctuations in speed at this station coincide with the freshening of the winds.

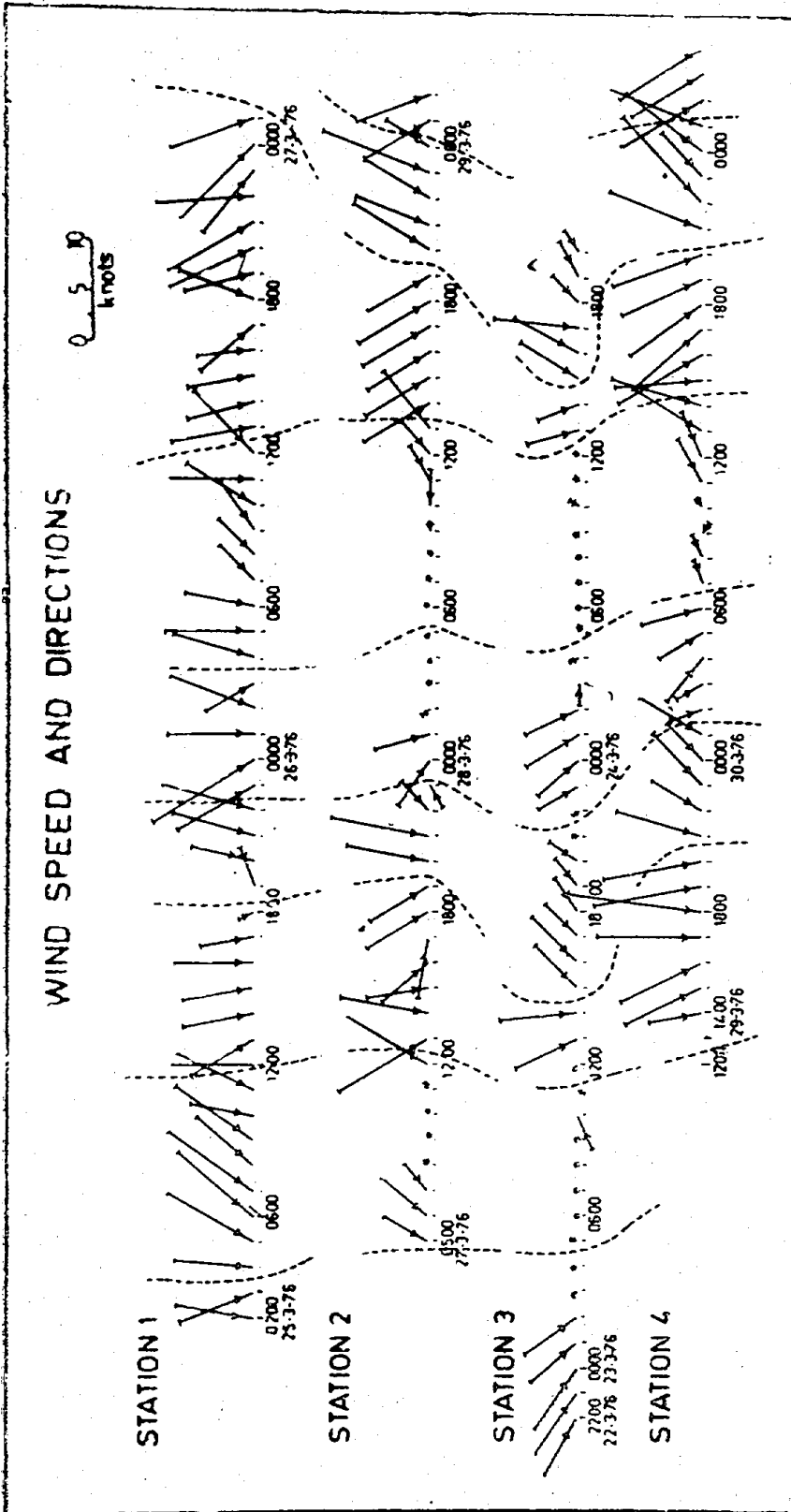


Fig. 3. Wind vectors at hourly intervals for the periods of observation at the four stations.  
(The dashed lines indicate alternating phases of wind.)

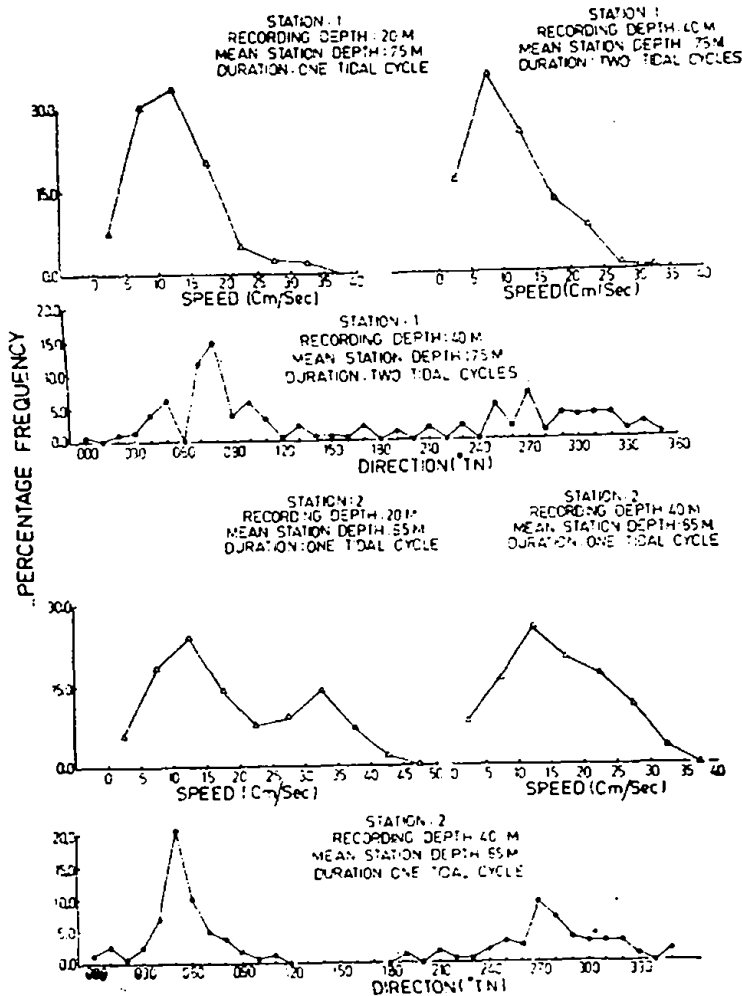


Fig. 4 (a). Percentage frequency distributions of current speed and direction at stations 1 and 2.

The frequency distributions of direction shown in Figs-4 (a and b) are bi-modal in character at all stations and this is clearly due to the dominance of the tidal flow on the current field. The directions during both the phases of ebb and flood are spread over a wide range around the two modes. At station 4, the modes are of the largest magnitude and the distribution is peaked maximum compared to other stations.

The frequency distributions of speed are generally sharply peaked. However, they show widely varying features. In some cases the distributions show small flat side lobes towards higher values. At station 1, both at 20 m and 40 m (Fig. 4a) the distributions are unimodal and are sharply peaked at 12.5 cm/sec and 7.5 cm/sec respectively. At 20 m, at station 2, the distribution is bi-modal with a pronounced peak at 12.5 cm/sec and a weak secondary one at 32.5 cm/sec (Fig. 4 a). In contrast, the 40 m plot is uni-modal (12.5 cm/sec) and flat. The frequency distribution at station 3 shows a much varied feature in its monotonic nature. This is due to the fact that the flow is very weak ( $< 5$  cm/sec) for long periods.

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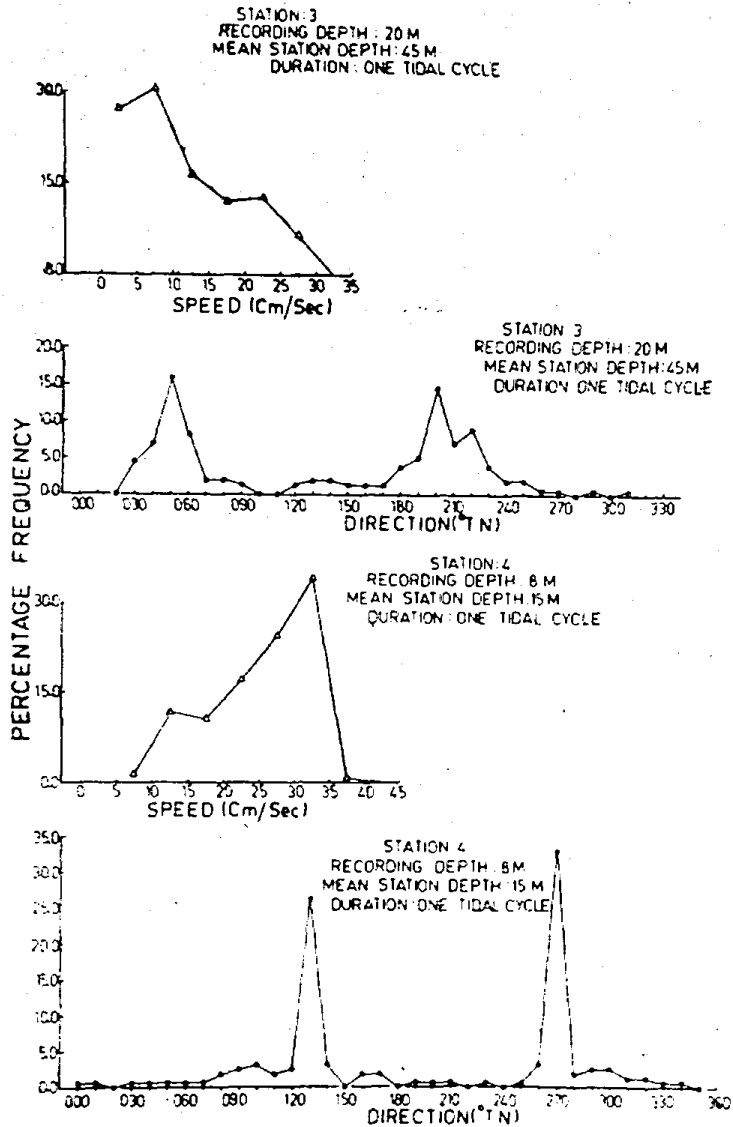


Fig. 4 (b). Percentage frequency distributions of current speed and direction at stations 3 and 4.

It may be noted that at station 1 and 2, the velocity class (0-5 cm/sec) has relatively small percentage values. As shown in table I, station 3 is located in shallow waters (45 m) compared to station 1 and 2 where it is possible that the prevailing general circulation extends deeper and probably more stronger. The nature of the continuous plots of the current speed and direction, Figs. 2 (a) and (b) suggest the above reasoning. At station 4, the distribution is largely skewed towards higher speeds. This is clearly due to the dominance of strong nearshore tidal currents.

Fig. 5 shows hourly smoothed current vectors over a tidal cycle. The computed vector mean residual current is also shown for each station. Table II lists the directions and magnitudes of these residual currents, along with the characteristics of the frequency distributions. The main feature is that the directions of the residual

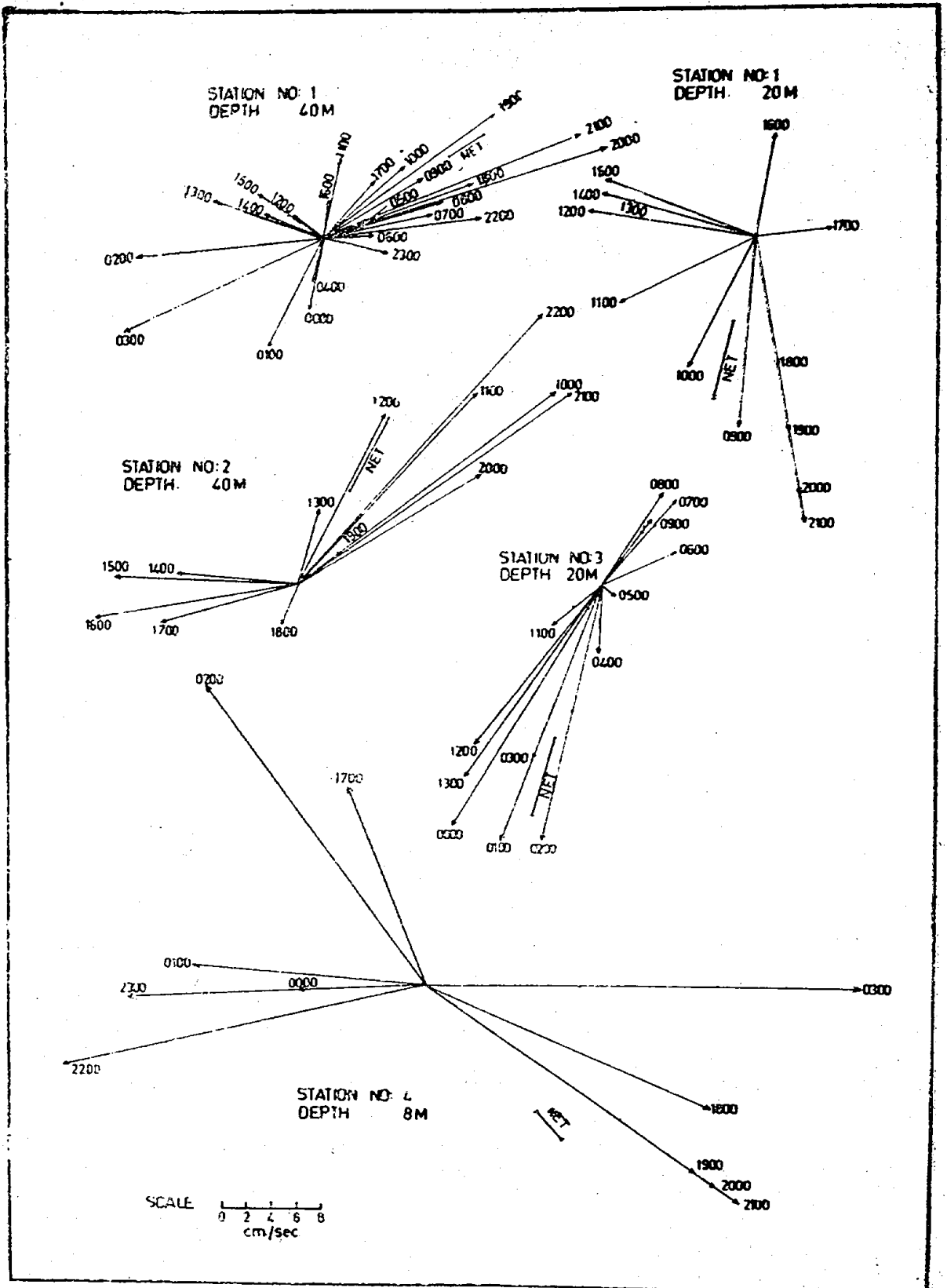


Fig. 5. Hourly current vectors and mean residual currents over tidal cycles at stations 1, 2, 3 and 4.



*Current measurements off Bombay*

**Table II.** Important features computed and delineated from the recorded data.

Stn. No.	Depth of observation (m)	Vector mean residual current		Length of averaging record	Mode Values		
		Speed (cm/sec)	Direction (°TN)		Speed (cm/sec)	Direction (°TN) Flood      Ebb	
1	20	6.2	195.0°	One tidal cycle	12.5	80°	270°
	40	3.4	58.0°	Two tidal cycles	7.5	—	—
2	20	—	—	—	12.5	—	—
	40	6.9	28.0°	One tidal cycle	12.5	50°	270°
3	20	6.7	198.0°	One tidal cycle	—	50°	200°
	40	—	—	—	—	—	—
4	8	3.0	139.0°	One tidal cycle	32.5	130°	270°

flow at 20 m at stations 1 and 3 is about 195° (offshore) and is around 43° (onshore) at stations 1 and 2 at 40 m. For station 4 (Fig. 5), the residual current is directed to about 139°. This layering may possibly be due to the Ekman effect on the vertical current structure.

CONCLUSIONS

- (i) The recorded current values are affected by the movements of the anchored ship, due to wind, wave and surface currents.
- (ii) Even in Bombay High region about 120 km offshore, the effect of tidal currents is significant.
- (iii) The vector mean residual currents are directed almost in opposite directions at 20 m and 40 m depths in the Bombay High region.

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