

**Seasonal variability of Tidal and Non-tidal Currents
off Beypore, SW Coast of India**

By

¹P K Dinesh Kumar, ¹K Srinivas and ²N Anil Kumar

¹National Institute of Oceanography, Regional Centre, P.B. NO. 1616,
Dr.Salim Ali Road, Cochin – 682 014.

²National Centre for Antarctic and Ocean Research, Vasco-da-Gama, Goa

e-mail : dineshku@niokochi.org

Abstract: Analyses of current meter records generated in the coastal waters off Beypore (11° 10'N; 75° 48'E) on the southwest coast of India have been made to understand the tidal and non-tidal variability during premonsoon and summer monsoon seasons of year 2000. Information on tidal signals contained in the currents were extracted using harmonic analysis - Least Squares Method and non-tidal component were analyzed using the X_0 filter. The study established that the signatures of the tidal currents are different at the surface and bottom waters in most of the records, suggesting the baroclinic nature of the tide and currents were dominated by diurnal and semi-diurnal tidal signals in the observed records. In general, the amplitudes of the diurnal and semi diurnal currents were found to be less than 7 cm/s in the region. Different signatures were displayed by the non tidal currents at surface and bottom layers of water column, thus suggesting the strong seasonal dominance of freshwater discharges of the region.

Key words: Current measurements, Tidal currents, Non-tidal currents, Beypore, southwest coast of India

1. Introduction

Though the general circulation pattern in the Arabian sea over the southwest continental shelf of India is reasonably well documented, the coastal current pattern adjoining the immediate coastline still remains virtually unknown. Recently a number of research initiatives are on in the region to understand the complexity of processes in the wake of varied coastal development projects (Anonymous, 1999, Anonymous, 2001, Anonymous 2002, Dinesh Kumar et al, 2004). Salient results of seasonal variability of tidal and non-tidal currents are presented here, based on field measurements carried out off Beypore (11°10'N; 75°48'E) during year 2000. Beypore, located near Calicut in the state of Kerala along the south west coast of India on the bank of the river Chaliyar, the third largest west flowing rivers in Kerala, which joins the Arabian sea (Fig 1).

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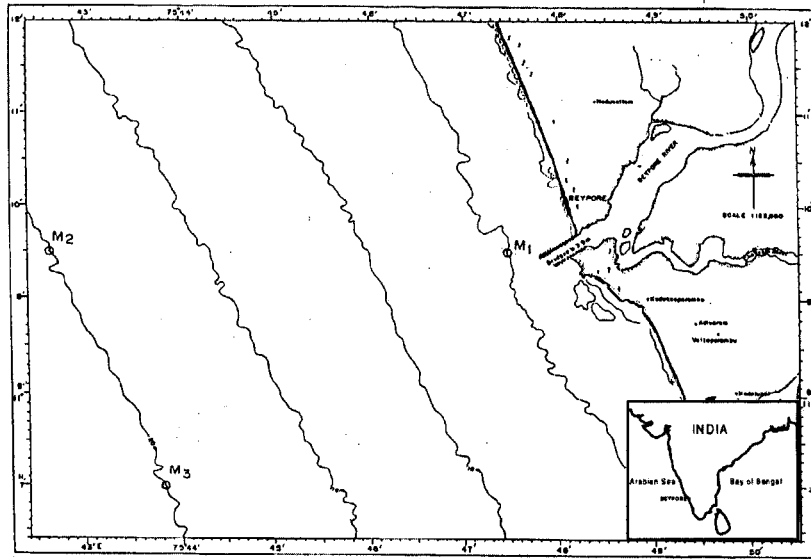


Figure 1. Current meter mooring locations M1, M2 & M3

The port facilities are located at the river mouth. Since time immemorial, the system has played a major role in shaping the socio-economic and cultural history of the region. Beypore port was one of the prominent ports and fishing harbours of ancient Kerala and an important trade and maritime centre – much sought after by the merchants of western Asia for its ship building industry. The estuarine habitat plays an important role in completing the life cycle of many of the commercially important prawns. Major industries of the region include coir retting and fish processing units. In addition to these and with various agricultural activities, the narrow coastal zone also accommodates several important residential locations.

Severe siltation is an annual feature of the region and considerable sums are spent for the maintenance of navigational channels. Knowledge of currents is an important aspect for understanding the problem, as tidal currents play a very important role in suspended sediment transport.

2. Data and Methodology

Current measurements were carried out at 3 locations as shown in Fig 1. Details of these measurements are presented in Table 1. The total duration of the data available (station days) was 80. The longest series being of 14 days and the shortest being 6 days.

The currents at each station were resolved into east-west (u-component) and north-south (v-component) directions, with the flow to the north and to the east being defined as positive. These data on current components were subjected to harmonic analysis to determine the amplitudes and phases of the tidal constituents (Pugh,

1987). The tidal analysis (for the determination of the amplitudes and phases of the constituents) was carried out using the software of the Sea Level Center of the University of Hawaii. In the present study, only details pertaining to the amplitudes have been used. The tides were filtered using the X0 filter (Pugh, 1987). Spectral analysis was used to determine the predominant periodicities in the time series data on non-tidal currents (u- and v- components) using the Cooley-Tukey FFT algorithm (Gouveia and Mahadevan, 1983).

Table 1. Details of the current measurements

Station Number	Depth (m)	Level of current meter	From	To	Number of days of data
M1	5	Mid-depth	0900 h, 14/02/2000	0800 h, 28/02/2000	14
M1	5	Mid-depth	1200 h, 23/09/2000	1100 h, 29/09/2000	6
M2	20	Surface	1100 h, 28/02/2000	1000 h, 13/03/2000	14
M2	20	Bottom	1100 h, 28/02/2000	1000 h, 13/03/2000	14
M2	20	Surface	1100 h, 07/09/2000	1000 h, 15/09/2000	8
M2	20	Bottom	1100 h, 07/09/2000	1000 h, 15/09/2000	8
M3	20	Surface	1100 h, 15/09/2000	1000 h, 23/09/2000	8
M3	20	Bottom	1100 h, 15/09/2000	1000 h, 23/09/2000	8

3. Results and Discussion

Before any discussion regarding the tidal currents are presented, it is essential that we have some knowledge regarding the tides prevailing in the study area, as the basic forcing for the coastal currents is astronomical. Based on the sea level data for 1997, the amplitudes of the principal tidal constituents M_2 , K_1 , O_1 and S_2 were found to be 28.0, 20.3, 10.1 and 10.1 cm, respectively (Srinivas and Dinesh Kumar, 2002). The mean spring range was 76.3 cm and the mean neap range 35.9 cm. The type of tides at a given location can be determined using the Form Number, which is the ratio of the sums of the amplitudes of the diurnal constituents (K_1 and O_1) to that of the semi-diurnal constituents (M_2 and S_2). Based on the above information, the tides are classified as mixed and predominantly semi-diurnal in nature, having a Form Number of 0.80. In such regimes, two high and two low waters occur daily with large inequalities in range and time. The maxima in inequalities occur whenever the moon's declination has passed its maximum values. In the mixed tidal regime, the relative importance of the semi-diurnal and diurnal components keeps changing throughout the month. The diurnal tides have large magnitudes

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when the moon's declination is greatest but reduce to low values when the moon is passing through the equatorial plane. Semi-diurnal tides are most important after full and new moon and are only partly reduced during the period of neap tides.

The amplitudes of the diurnal and semi-diurnal bands of the tidal currents are presented in Table 2.

Table 2. Details of the semi-diurnal and diurnal currents

Station Number / Period	Depth (m)	Position of current meter	U-component (cm/s)		V-component (cm/s)		Tidal variance (%)	
			Diurnal	Semi-diurnal	Diurnal	Semi-diurnal	u-component	v-component
M1 (Feb, 2000)	5	Mid-depth	3.70	0.83	6.19	3.85	34	51
M1 (Sep, 2000)	5	Mid-depth	0.35	0.61	1.44	3.42	4	9
M2 (Feb-Mar, 2000)	20	Surface	1.80	1.00	2.50	2.40	33	21
M2 (Feb-Mar, 2000)	20	Bottom	1.46	0.61	2.27	1.87	20	27
M2 (Sep, 2000)	20	Surface	5.48	0.75	4.26	0.97	46	18
M2 (Sep, 2000)	20	Bottom	2.83	2.94	4.43	2.03	18	22
M3 (Sep, 2000)	20	Surface	5.84	0.12	2.88	1.41	50	3
M3 (Sep, 2000)	20	Bottom	4.26	4.51	4.83	5.31	19	16

In general, the amplitudes of the diurnal and semi-diurnal currents were found to be less than 7 cm/s in all the stations. In station M2 and station M3, during the summer monsoon, the diurnal amplitudes strongly dominated the semi-diurnal amplitudes for the u component and v component at the surface as compared to the bottom, thus suggesting baroclinic nature of the tides at these locations. The percentage variance accounted by the tidal currents varied between 3% to 51%, suggesting the complex nature of the circulation pattern. Had the tides been a major forcing factor, the percentage variance accounted would have been much higher. At Station M1, during the summer monsoon, the tidal signatures were very poor (less than 10%). This could be due to the station's close proximity to the mouth of the estuary and hence directly under river discharge effects.

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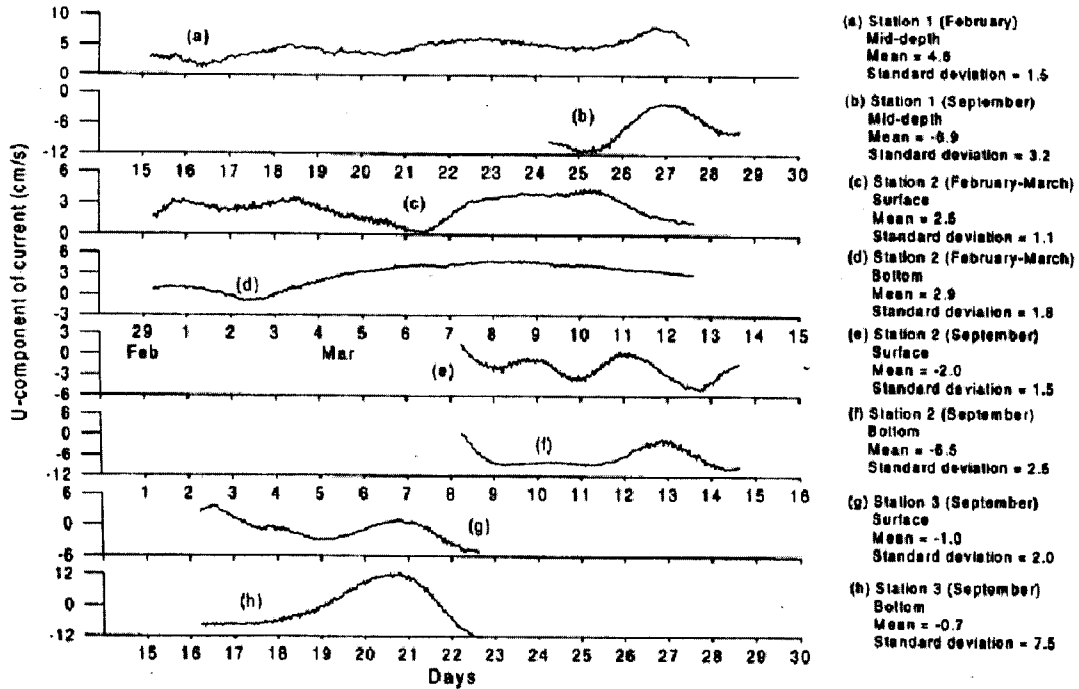


Figure 2. Variation of u-component of the non-tidal current. The means and standard deviations (cm/s) for the entire period are also indicated.

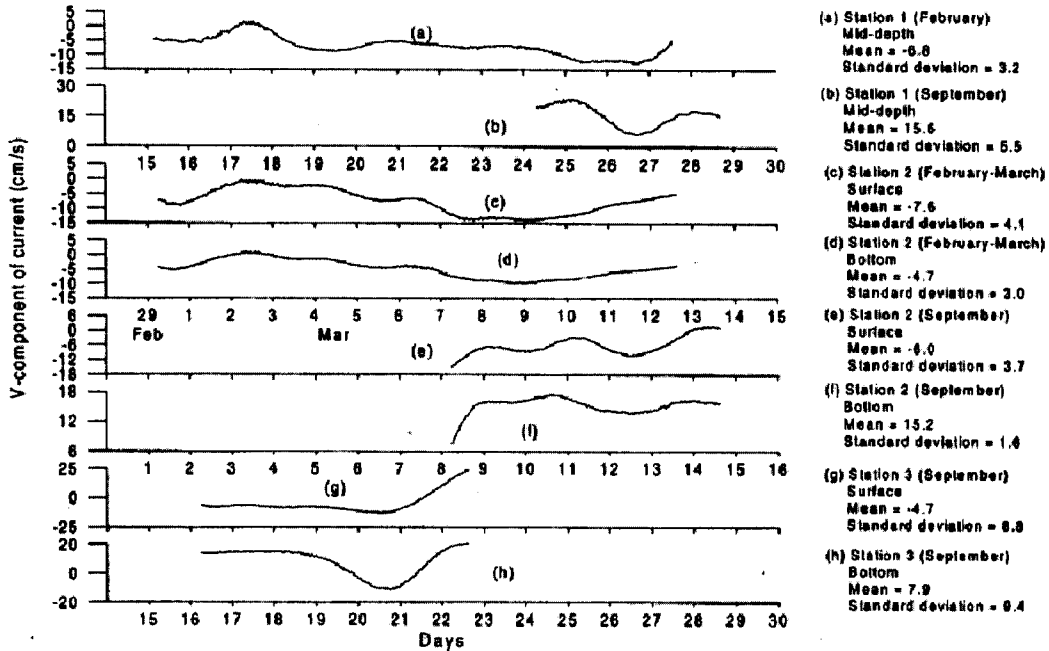


Figure 3. Variation of v-component of the non-tidal current. The means and standard deviations (cm/s) for the entire period are also indicated.

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The time series of non-tidal currents are presented in Fig. 2 for the u-component and in Fig. 3 for the v-component, along with associated statistics - means and standard deviations. The v-component of currents at most of the stations very much dominates that of the u-component, in terms of means and standard deviations. One interesting feature is that the surface and bottom currents have quite different mean directions as is evident in the case of stations M2 and M3 during summer monsoon season (Fig. 3 e-f and g-h). This was, however, not seen for the u-component at these two stations for the same period (Fig. 2 e-f and g-h). The time series of the v-component of currents at the surface and bottom showed very high correlation, which was not seen in the case of the u-component. The variance explained by the correlation between surface and bottom currents in the case of data presented in Figs. 3 c and d was 96%, whereas for that in Fig. 3 e and f and in Fig. 3 g and h, it was 36% and 28%, respectively (in the case of the u-component, the variance was less than 3% in all the three cases). The correlations in all the above six cases were, however, found to be positive. Premonsoon season is a season with minimal freshwater discharge and this could probably be the reason for the high correlation observed in the case of Figs. 3 c and d. We are not sure regarding the role bathymetry plays in the above mentioned relationship, the effects of which could be less in the case of the v-component and more in the case of the u-component, because of the bathymetry (sharp gradients in the x-direction and comparatively lesser gradients in the y-direction).

The dot plots of the non-tidal currents are shown in Fig. 4 a-h. Each point represents the speed and direction at a particular instant of time. The scatter plots indicate a complicated nature in the flow characteristics. The currents at the surface have quite different characteristics as compared to the bottom as is evident at Stations 2 and 3 during summer monsoon season (Fig. 4 e-h). Currents in estuarine channels are constrained to flow either up or down the channel axis, but in more open waters, all directions of flow are possible. The mean direction of the currents at the surface and bottom at Stations 2 and 3, during summer monsoon season (Figs. 4 e-f and g-h) were found to be quite different. A difference in the mean direction between surface and bottom of 139° was seen at Station 2 and 163° at station 3, respectively. The surface currents have a southerly orientation, whereas the bottom currents have a northerly orientation. The currents at Station 2 during premonsoon (Fig. 4 c and d), however, did not show any conspicuous change in direction at the surface and bottom. The difference in direction between the surface and bottom currents being 14° . The summer monsoon season is a season with copious rainfall along the southwest coast of India and results in very heavy river discharge. The substantial river discharge (there are no hydroelectric projects to trap the water discharge, upstream of the Chaliyar river) during the summer monsoon season can cause density stratification and these, in turn, are responsible for the different signatures of the non-tidal currents at the surface and bottom levels.

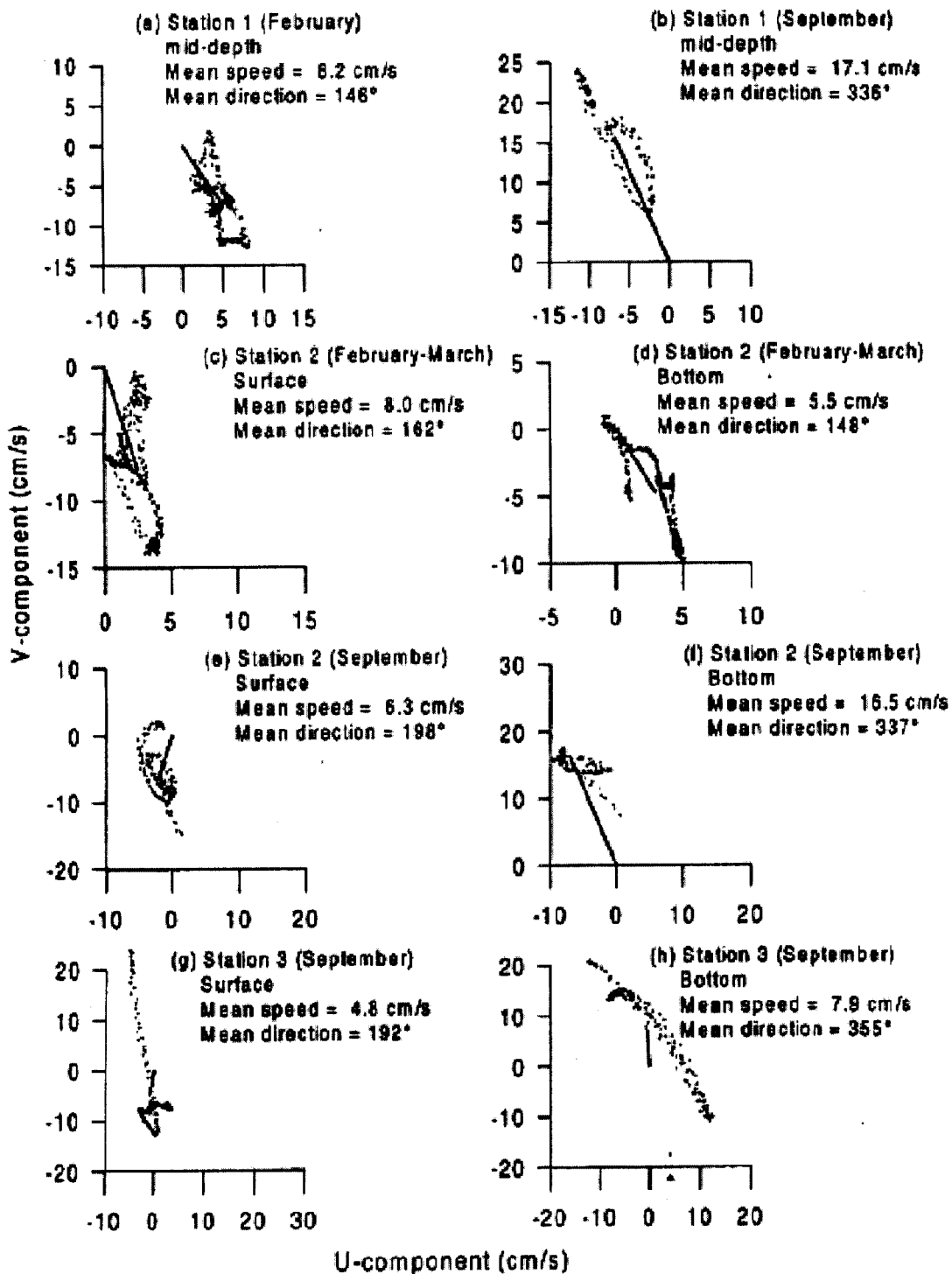


Figure 4. Scatter diagrams of the non-tidal current components. The mean speed and mean direction are also given. The mean speed and mean direction are also given. The mean vector is also shown as a thick line.

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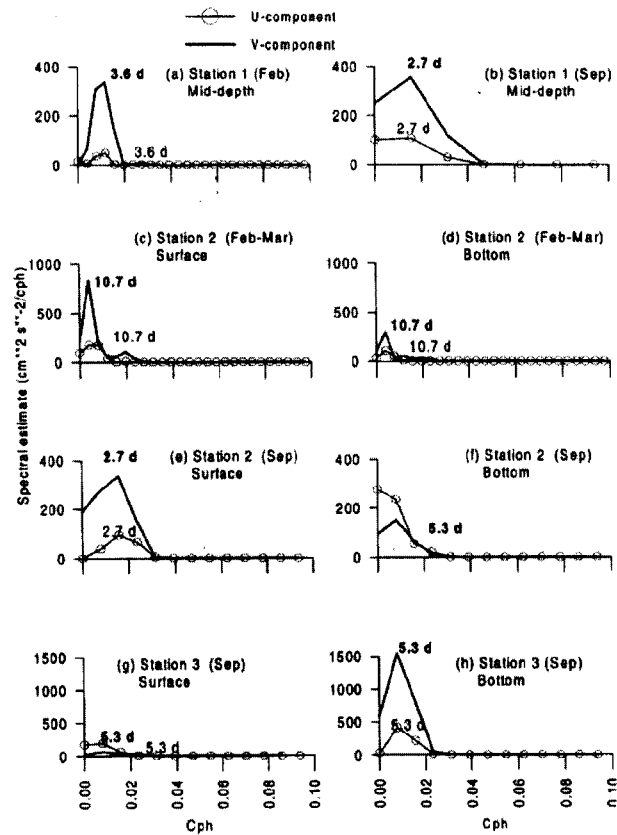


Figure 5. Spectra of the u- and v-component of the non-tidal currents.

The spectra of the u- and v- components of the non-tidal currents for the different stations are presented in Fig. 5. One conspicuous feature seen is that u- and v-components of currents show similar periodicities in all the records, although the spectral estimates are different. The 10.7-day period wave phenomena conspicuously seen in some of the records (Fig. 5 c and d) could be signatures of coastally trapped phenomena (Geyer, 1997).

4. Conclusion

Tidal and non-tidal currents were studied for the premonsoon and summer monsoon seasons of 2000 for the coastal waters off Beypore, southwest coast of India. Amplitudes of the diurnal and semi-diurnal currents were much less than 7 cm/s. The characteristics of the tidal currents were quite different at the surface and bottom, during the summer monsoon season at a couple of stations, suggesting baroclinic nature of the tide. Different signatures were displayed by the non-tidal currents at surface and bottom layers of water column, thus suggesting the strong seasonal dominance of fresh water discharge in the region.

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