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Studies on Sediment Size Distribution of North Karnataka Beaches, West Coast of India, Using Empirical Orthogonal Function Analysis

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Empirical orthogonal function technique was applied to beach sediment samples collected during different phases (premonsoon, monsoon and postmonsoon of 1983). The study revealed that the first ϕ dependent eigen function accounted for largest variation in the data set. This showed significant differences in the concentration of grain size across the beach covering high, mid and low tide strands during different seasons, i.e. dominance of relatively finer sediments during premonsoon season, coarser sediments during monsoon and less coarser sediments during postmonsoon season.

Grain size parameters are being used as indicators of sediment size distribution and depositional environments[1-4]. Different statistical parameters have been proposed to discriminate depositional environments. Because of the variety of statistical parameters proposed and lack of correlation between them empirical approaches utilising principal component analysis have been developed[5].

Empirical orthogonal function (EOF) analysis is a statistical technique for efficiently representing the variability in an array of geophysical data. The eigen vector approach facilitates the representation of a large quantity of data in terms of a small number of orthogonal components, accounting for a large fraction of the total variance in the original data, and has certain advantages for analytical work[5]. In the present study EOF analysis is used to examine the sediment size distribution during different seasons.

Methodology

Beach sediment samples were collected from backshore (berm) and foreshore (high, mid and low tide strands) pressing a plastic corer (5 cm diam) into the beach surface to a depth of 4 cm along each of the transects. The samples collected during April, July and September 1983 from 9 locations (Fig. 1) represented premonsoon, monsoon and postmonsoon phases of southwest monsoon. Samples were sieved on a Ro-Tap mechanical sieve shaker using ASTM sieves at intervals of 0.5 phi. The weights obtained were converted to percentages.

The overall grain size of the sediment samples was subjected to EOF anaysis to understand the variations accurately. The size distribution of these samples was represented in the form of a matrix $L(x,\phi)$ of discrete size class with x as the location and ϕ the grain size class. This matrix was converted to a normalised data matrix $X(x,\phi)$ following Lawson and Hanson[6] and the eigen functions obtained from

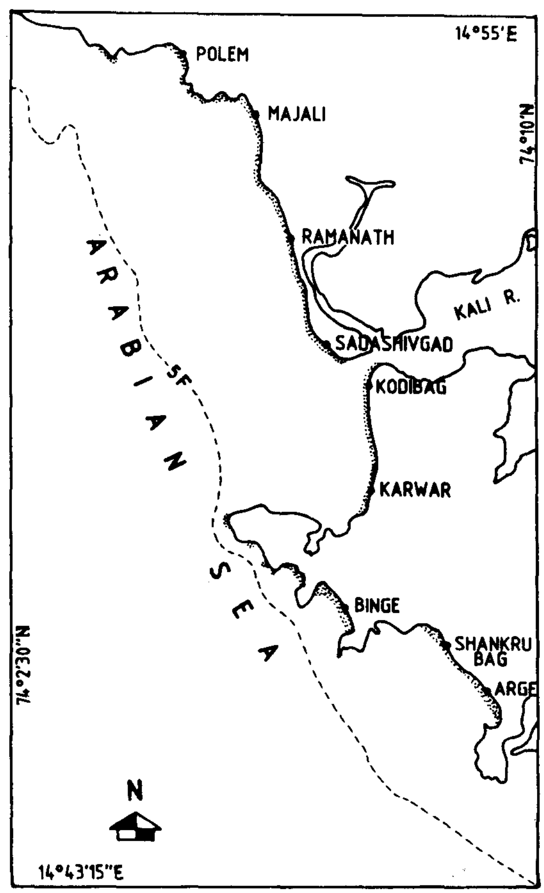

Fig. 1—Location of study area

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$$(A-\lambda^2 I)V=0 \text{ and } (B-\lambda^2 I)U=0$$

where A and B are co-variance matrices of X^TX and XX^T and λ the eigen values and I the identity matrix. Detailed methodology[7], computation of eigen values and vectors of square matrices[8] and statistical methods for selecting information rich eigen vectors[9] were reported.

Results and Discussion

The median values of sediments vary from 1.15 to 2.7 ϕ at berm, 1.3 to 2.68 ϕ at high tide, 1.63 to 2.82 ϕ at mid tide and 1 to 2.73 ϕ at low tide level, during fair weather season (April). These values reveal that across the beach, the grain size (mm) decreases from the upper foreshore (HT) towards the lower foreshore (LT). However, at low tide a mixture of coarse and fine material is observed. The sediments of the backshore (berm) are coarser in size than those of high and mid foreshore.

The average values of median of mid tide for April (2.354 ϕ), July (2.347 ϕ) and September (2.129 ϕ), show relatively coarser grain size during monsoon (July) and postmonsoon (September) period as compared to fair weather season (April). At high and low tide this relation is less significant.

The standard deviation values show an increasing trend from upper to lower foreshore corresponding to an increase in the median size (ϕ). The range of variation in standard deviation is more at backshore (berm: 0.259 ϕ to 0.92 ϕ) as compared to foreshore (0.237 ϕ to 0.879 ϕ) during April. It is also clear that the sediments are less well sorted during the monsoon and postmonsoon season as compared to fair weather season.

The ϕ-dependent functions and their variations are summarised in Table 1. First three energetic ϕ-

Table 1—Salient Features of EOF Analysis

Physiographic unit	Modal value			Percent dominance			Remarks
	$C_1(\phi)$	$C_2(\phi)$	$C_3(\phi)$	$C_1(\phi)$	$C_2(\phi)$	$C_3(\phi)$	
			April				
B	3	2 3	2.5	62.93	26.98	6	Asymmetric distribution with a prominent mode at 3 ϕ accounts for 5.47% of 62.93%. At $C_2(\phi)$ and $C_3(\phi)$ slightly coarser material is predominant.
HT	3	2 3	1.5 2.5 3	71.27	21.33	5.61	Asymmetric distribution with a sharp peak at 3 ϕ accounts for 5.87% of 71.27%. Relatively coarser and finer materials predominate in $C_2(\phi)$ and $C_3(\phi)$ indicating high frequency fluctuations.
MT	3	2.5 3.5	1.5 2.5	72.37	21.45	2.8	Symmetric within the interval of 2.5 and 3.5 ϕ with a sharp peak at 3 ϕ and asymmetric outside this interval, accounts for 6.27% of 72.37%. $C_2(\phi)$ and $C_3(\phi)$ functions show similar variations to that of high tide.
LT	3	3	2.5	69.28	18.06	10.4	Symmetric within the interval of 2.5 and 3.5 ϕ with sharp peak at 3 ϕ and asymmetric outside this interval, accounts for 6.74% of 69.28%. At $C_3(\phi)$ slightly coarser material is predominant.
			July				
HT	2.5	2 3	2 2.5 3.5	69.84	22.20	6.35	Asymmetric distribution with a broad band is seen in $C_1(\phi)$, the value is more at 2.5 ϕ accounting percent variability for 4.84% of 69.84%. Coarser and finer material is predominant at $C_2(\phi)$ and $C_3(\phi)$.
MT	2.5	2 3.5	2 2.5 3.5	71.99	17.81	8.48	Symmetric distribution with sharp peak at 2.5 ϕ accounting 5.31% of 71.99%. $C_2(\phi)$ and $C_3(\phi)$ show similar variation as at HT.
LT	3	2 3	2.5 3.5	64.53	21.99	7.24	Asymmetric with a sharp peak at 3 ϕ with wider variation occurring towards the coarser side, accounts 5.47% of 64.53%. Coarser and finer material is predominant at $C_2(\phi)$ and $C_3(\phi)$.
			September				
HT	3	2 3	2 3 3.5	68.06	23.93	6.33	Asymmetric distribution with sharp peak at 3 ϕ accounting for 5.79% of 68.06%. The material at $C_2(\phi)$ and $C_3(\phi)$ varies from 2 to 3.5 ϕ indicating high frequency fluctuations.
MT	2	2 3	2 2.5 3.5	72.20	19.18	6.81	Asymmetric distribution with sharp peaks at 2 ϕ accounting 5.27% of 72.20%. $C_2(\phi)$ and $C_3(\phi)$ show high frequency fluctuations.
LT	3	3.5	2.5 3.5	64.56	23.31	5.92	Asymmetric with a sharp peak at 3 ϕ with wider variation accounting towards the coarser side and 5.47% of 64.53%. Coarser and finer material is predominant at $C_2(\phi)$ and $C_3(\phi)$.

B = berm, HT = high tide, MT = mid tide, and LT = low tide
Overall variation 1 to 4 ϕ.

dependent eigen vectors at different physiographic units during different season are given in Fig. 2. The general distribution of these 3 functions compared with those of the variations at each of the physiographic units for all seasons is detailed below.

(1) Though all the first eigen vector component [$C_1(\phi)$] functions show asymmetric distribution, widei band width is seen during July (Fig. 2A) at high tide, indicating higher variability in grain size, as a result of relatively high wave energy prevailing. The variation is comparatively less during April indicating slightly finer (small range) sediments during fair weather season.

(2) At mid tide the variation in the mode is very clear (Fig. 2B). During April, the mode occurs at 3 ϕ while during July and September it prevails at 2.5 and 2 ϕ respectively. The distribution clearly indicates predominance of fine material during fair

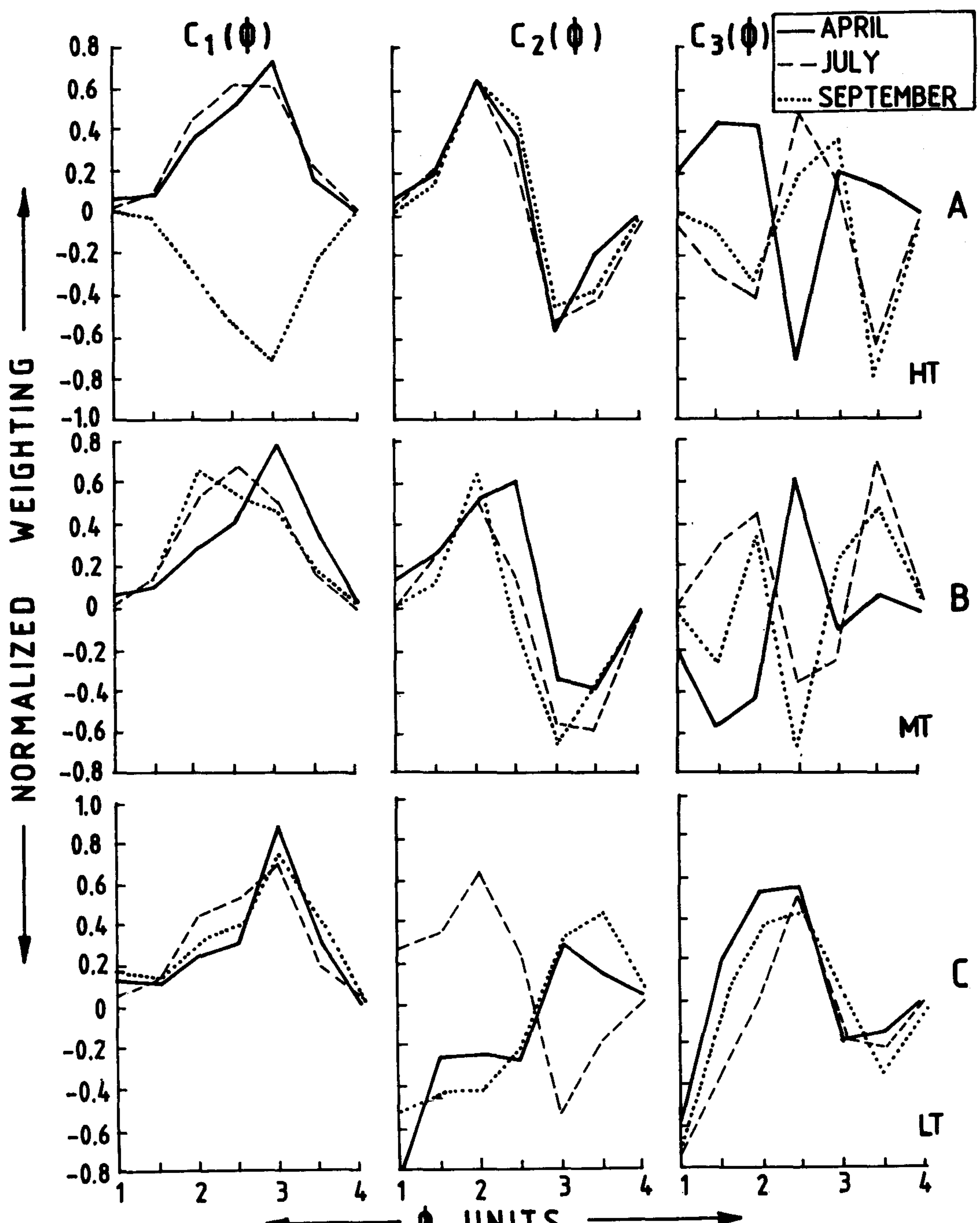

Fig. 2—The 3 most energetic ϕ dependent eigen vectors for beach sediments of high tide (A), mid tide (B) and low tide (C)—comparison of premonsoon (April), monsoon (July) and postmonsoon (September)

weather season (April) and coarser material during July and September at this location.

(3) At low tide though the mode occurs at 3 ϕ for all the 3 months (Fig. 2C), variation in the band width towards coarser side is very clear and this shows more coarser material during July as compared to other two months.

The variations at $C_2(\phi)$ and $C_3(\phi)$ are very large indicating high frequency fluctuations. At high and mid tide some symmetry is seen during April and September though at low tide the variation is very high.

From this it can clearly be seen that the first eigen function explains the maximum percent variance of the data set, though the mode values clearly define the peaks centered around 2.5 to 3 ϕ. This fact is also found to be true when Md ϕ values only are considered.

Study of sediment size distribution of the beach and nearshore environs using EOF analysis along the Goan coast[10] has distinguished clearly different environments of deposition i.e. foreshore, backshore, dune and nearshore. The study also reflects the impact of the changing character of the transportational and depositional processes affecting the sediments, thus implying different energy environments. In the present study EOF helps in separating the sediment size distribution temporally.

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