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Influence of Seasonal Changes on the Texture of Beach Sands, Southwest Coast of India

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ABSTRACT

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The variation in textural parameters and beach processes in relation to different seasons of southwest coast of India were studied on a 12 km stretch of the Mattul-Payangadi coast. On the basis of these sediment characteristics and beach morphologic changes, four distinct seasons relating to climatic conditions are identified: premonsoon, transitional, monsoon and postmonsoon. Seasonal wave energy differences are reflected in mean size distribution of sands. Corresponding to an increase in wave energy grain size increases from premonsoon to monsoon, through the transitional season. The kurtosis varies gradually from mesokurtic to platykurtic. On comparison, the sediments of the transitional and monsoonal season are moderately well sorted and tend towards platykurtic nature than the premonsoon and postmonsoon sediments. The sediments are negatively skewed to nearly symmetrical in all the seasons.

ADDITIONAL INDEX WORDS: *India, premonsoon, transitional, monsoon, postmonsoon, erosion, accretion, longshore currents, mean size, standard deviation, skewness, kurtosis, wave energy.*

INTRODUCTION

Kerala state, in the south western part of the Indian subcontinent has a coastline of 560 km long. The meteorology of Kerala is profoundly influenced by its orographic features, being broadly divided into highlands, midlands and lowlands. From the coastal lowlands the landscape rises steadily towards the east to the hilly midlands and further onto the highlands with peaks reaching 915 m to 2060 m. The tides in this area are semidiurnal and have a range less than 1.0 m.

The grain size data of sediments has been extensively used to identify the depositional environments and hydrodynamic conditions that exist/existed at the time of deposition (MASON and FOLK, 1958; FRIEDMAN, 1961; SEVON, 1966; GREENWOOD, 1969; VISHER, 1969). Attempts have been made to relate the textural characteristics to the probable mechanisms of deposition of the foreshore sediments (MILLER and ZEIGLER, 1958; SAMSUDDIN, 1985). The relationship between sediment movement and the beach erosion and accretion along the west coast of India has been discussed by many authors (REDDY and VARADACHARI, 1973; MURTHY *et al.* 1980). In this paper an attempt is made to evaluate the textural variation of the foreshore sediments in the light of the changes on wave energy and beach morphology during the different seasons of the southwest coast of India, *viz.*, (1) premonsoon (January-April); (2) transitional (May); (3) monsoon (June-August); (4) postmonsoon (September-December) (SAMSUDDIN and SUCHINDAN, 1985).

AREA OF STUDY, MATERIALS AND METHODS

The study area is a 12 km strip of beach along the northern Kerala coast between Mattul and Payangadi (Figure 1). The coast is bounded by the Elimala headland on the north and Valapatnam inlet on the south. This forms part of a strandplain, characterised by series of sub-parallel beach ridges, dunes and isolated hills (SAMSUDDIN and SUCHINDAN, 1986). The study period (November 80–October 82) represented an initial low-energy season of the premonsoon followed by a moderate energy tran-

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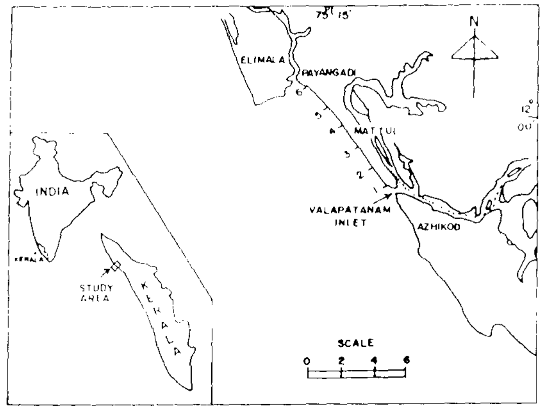

Figure 1. Location map of the study area in the Mattul Payangadi coast showing the beach-profile locations and sampling points.

sitional season, a high-energy monsoonal season and again a low-energy postmonsoonal season.

Six beach profiles spaced at 2 km interval were surveyed with reference to permanent reference marks to a point seaward, a few meters beyond the low water line using a dumpy level. The beach profile data was fed to a Keltron microprocessor to compute the beach volume changes. A computer program has been designed to assess the beach-volume changes in erosional and accretional format (m^3/linear meter) by superimposing the profiles of different seasons for the same location. This net volume represents the algebraic sum of erosion in one part of the profile and accretion in another part (GOLDSMITH *et al.* 1977).

The wave period was measured as the average time (in seconds) required for ten successive wave crest to pass a point. Breaker height was measured visually. The longshore current velocity and direction were measured by drift bottles. Sediment samples were collected from the upper foreshore, approximately at the high waterline. The samples were washed, oven dried and sieved at ½ ϕ interval for 15 minutes in the Ro Tap sieve shaker, using ASTM sieves. The percentile values and the graphic measures (FOLK and WARD, 1957) were computed using the Keltron microprocessor. Range, scatter and frequency distribution of the size parameters were drawn to elucidate the significant textural variation of sediments in different seasons.

RESULTS AND DISCUSSION

As a dynamic environment, the beach is subjected to seasonal fluctuation, affecting its configuration and changes in the sediment distribution. Seasonal reversals in wind pattern plays significant role in inducing the changes in the wave parameters in the study area (Table 1). The general pattern of wind direction and speed in the study area are given in Figure 2.

The wave-induced longshore current shows significant temporal and spatial variation along the Mattul-Payangadi coast, resulting in the transport of sediment alternately in southerly and northerly direction (Figure 3). In the premonsoonal season, long period, low energy waves and northward-flowing low speed longshore currents are prevalent. Excepting for the profiles 1 and 2, the general tendency of the beach is to accrete during this season, where 36 m^3/m beach accumulated. Figure 4 shows the cumulative volume changes in the beach in different seasons. In the transitional season, with relatively higher energy waves (1 m to 1.5 m breakers of 10–14 sec. duration) and southward flowing longshore currents in majority of the stations, the beaches are either eroded or show an insignificant accretional trend. During this season 9 m^3/m of beach were eroded. In the monsoonal season, short-period high waves with maximum energy (1.5 m to 2.5 m breaker of 9–12 sec. duration) and rapid southward flowing longshore currents are generated resulting in the erosion of 94 m^3/m of beach (Figure 4). In the postmonsoonal season, long-period waves with small heights generate northward-flowing longshore currents of moderate to low intensity which led to an accretion of 57 m^3/m of beach.

The differences in wave energy and period of the ocean swell are important factors in determining the nature and distribution of the foreshore sediments. The frequency distribution diagram of mean size (Figure 5) shows that the premonsoonal sediments are fine grained and exhibit a major cluster of mean size at 2.9 ϕ and a tail at fines of 2.4 ϕ. The transitional sediments contain approximately equal proportions of medium to fine sand, which cluster around 2.2 ϕ. The monsoonal sediments are medium grained, with most of the mean size values at 1.6 ϕ and a comparatively smaller cluster at 2.0 ϕ. The clustering of mean size at 2.4 ϕ indicate that the postmonsoonal sands are fine grained.

Table 1. *Seasonal Changes in breaker height, wave period and foreshore slope in the Mattul-Payangadi coast.*

Station Number	Breaker Height (metres)			
	Premonsoon (Low energy)	Transitional (Moderate energy)	Monsoon (High energy)	Postmonsoon (Low energy)
1	0.8	0.8	1.5	0.7
2	0.8	1.6	1.7	0.6
3	1.1	1.2	2.2	1.0
4	0.9	1.5	2.5	0.8
5	0.9	1.5	2.5	1.1
6	0.7	1.3	2.5	1.2
	Wave Period (seconds)			
Station Number	Premonsoon (Low energy)	Transitional (Moderate energy)	Monsoon (High energy)	Postmonsoon (Low energy)
1	16	nd	nd	15
2	13	11	11	13
3	11	9	9	10
4	14	14	13	14
5	14	12	10	13
6	14	14	9	14
	Foreshore Slope (degrees)			
Station Number	Premonsoon (Low energy)	Transitional (Moderate energy)	Monsoon (High energy)	Postmonsoon (Low energy)
1	2.4	2.2	2.7	2.0
2	3.8	3.5	4.8	3.4
3	2.8	3.9	4.9	4.3
4	3.7	5.1	6.3	5.7
5	3.2	5.3	7.3	6.1
6	2.5	4.3	8.5	4.5

The plot of average value and scatter of mean size (Figure 6) shows that there are four distinct sub-populations which can be related to the different seasonal changes. The decreasing value of mean size from premonsoon to monsoon indicate an increase in grain size and can be explained if the wave energy level in different seasons are taken into consideration. The long period and low waves in the premonsoon indicate a low energy level, which in turn results in a flatter foreshore (Table 1) with finer sediments. Short period and higher waves of monsoon indicate a high energy level, which results in a steeper foreshore with coarser sediments. In the monsoon the steeper foreshore makes the backwash very effective which removes the finer sands in suspension leaving behind the coarser material on the beach face. The reduction in grain size and a flatter foreshore could be due to effect of the long period low energy waves in the postmonsoonal season, which build up the beach by resorting the medium grained sand and appear to have close resemblance to the postmonsoonal sediments. The generalisation that mean size is a function of amount of wave energy imparted to the sediment holds true for comparison of different seasons. GILES and PILKEY (1965), GORSLINE (1966) and KING (1972) also noted that the grain size increases as the wave energy increases along a coast line.

Kurtosis values are higher on the premonsoonal sands (mesokurtic) than on the transitional and monsoon, which indicate that the central sand mode is better sorted than the tails. The reduction in kurtosis with coarser mean size in monsoon (platykurtic) means that the coarser sample is increasing and the coarse tail is getting larger (ENGSTROM, 1974). With the end of monsoonal season the postmonsoonal sediments again produce a mesokurtic to platykurtic distribution. The transitional sands

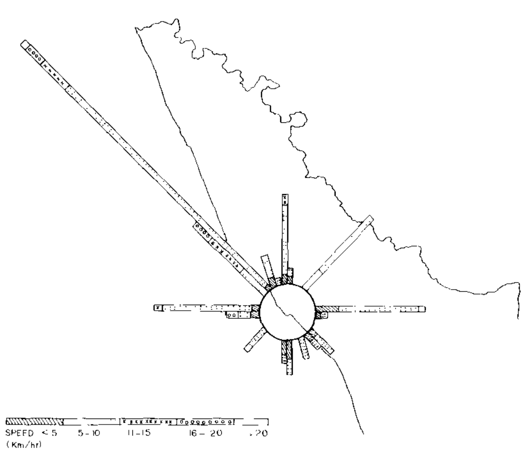

Figure 2. Rose diagram of general pattern of wind speed and direction in the study area.

are mesokurtic to platykurtic and appear to have more resemblance to the postmonsoonal sediments.

The standard deviation and skewness show imperceptible changes in different seasons. The sorting values show slight improvement towards the monsoon. The monsoonal sands are moderately well sorted than the premonsoonal and transitional period sands. With the cessation of the monsoonal season, the sorting is again found to be poorer in the postmonsoon. The overall similarity in sorting is not unexpected. FOLK (1967) has also noted that there seems to be little differences in sorting between beaches with gentle wave action as those of vigorous surf.

The sands of all seasons range from negatively skewed to nearly symmetrical. Selective removal of fines by backwash, truncating the fine end of the population is generally considered as the mechanism by which foreshore sediments become negatively skewed (FRIEDMAN, 1961; MARTINS, 1965).

Scrutinizing the above trends in the sediment distribution in different seasons, it can be suggested that the beaches behave in a seasonal manner in response to the changes on the wave energy. NORDSTORM (1977) considered energy and mobility as critical factors in determining whether the beach has behaved in a seasonal or cyclic manner. Energy referred to wave energy and mobility to the inputs of sediments into the system by any source (wind, wave current) with resulting changes in foreshore, grain size parameters and other response variables. The four season sands can thus be classified as follows:

(1). Premonsoon: Low energy—High mobility

(2). Transitional: Moderate energy—Low mobility

(3). Monsoon: High energy—Very low mobility

(4). Postmonsoon: Low energy—High mobility

Contrary to the observation by Nordstorm, the decrease in energy in postmonsoon and premonsoon resulted in a fine grained beach with a flatter foreshore. On the other hand greater energy in the transitional and monsoonal seasons has resulted in a coarse grained beach with a steeper foreshore. A decrease in beach mobility indicates a limited input of sediments (NORDSTORM, 1977) in the transitional and monsoonal season which is reflected in the occurrence of moderately well sorted sediments.

Bivariate plots of mean size, standard deviation, skewness and kurtosis were drawn to elucidate the variation in size distribution of sands in different seasons (Figure 7). Due to the overlap of the postmonsoon and the transitional data the former is not plotted. These plots show good lateral separation between the sediments of different seasons and fall in particular fields in the scatter diagrams with minor departures. The range of skewness and mean size values exhibit certain degree of overlap between the monsoon and transitional sands, whereas the demarcation is almost perfect with the premonsoonal sands (Figure 7a). The range of kurtosis and mean size values exhibits good lateral separation between different seasons (Figure 7b). Figure 7c reveals that the monsoonal sands are coarser than the transitional and premonsoonal sands and are moderately well sorted. The former two seasons exhibit slight degree of overlap, whereas the premonsoonal sands are well separated. The plot of standard deviation versus kurtosis depicts a partial separation between three seasons and there is certain degree of overlap between all the seasons (Figure 7d).

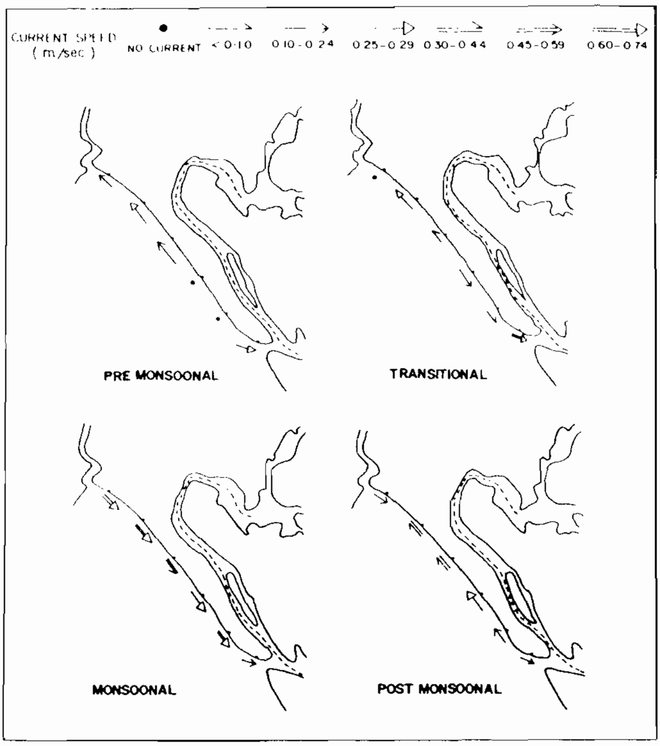

Figure 3. Longshore current (m/sec) pattern in the study area showing reversal of currents in different seasons.

CONCLUSIONS

Seasonal changes are apparent on the wave induced longshore current and beach volume changes. During the postmonsoon and premonsoon where the long-period, shorter wave and the northerly longshore currents are prevalent, the beaches show an accretionary trend. Under the influence of the short period high waves and southerly currents of transitional and monsoonal season, the beaches are erosional.

The mean size and kurtosis show significant variation in response to different seasons. The increase in grain size from premonsoon towards monsoon shows the increase in wave-energy conditions that prevailed at the time of deposition. The wave-energy factor evidently has an important effect on the foreshore slope and mean size. It has been observed that higher energy beach resulted in a steeper foreshore and coarser sediments. On the contrary the lower energy beach produces a flatter foreshore with finer sediments.

The beaches of the premonsoon are composed of fine sand which are moderately sorted and mesokurtic. The beaches of monsoon is marked by moderately well sorted platykurtic medium sand. In between these extremes falls the moderately sorted mesokurtic to platykurtic medium to fine sand of transitional season. With the end of the monsoonal season the postmonsoon phase returns to a flatter foreshore composed of moderately sorted mesokurtic medium to fine sands.

Bivariate plots of mean size, standard deviation, skewness and kurtosis shows good separation between the sediments of different seasons, with certain degree of overlap of transitional seasons with monsoonal season.

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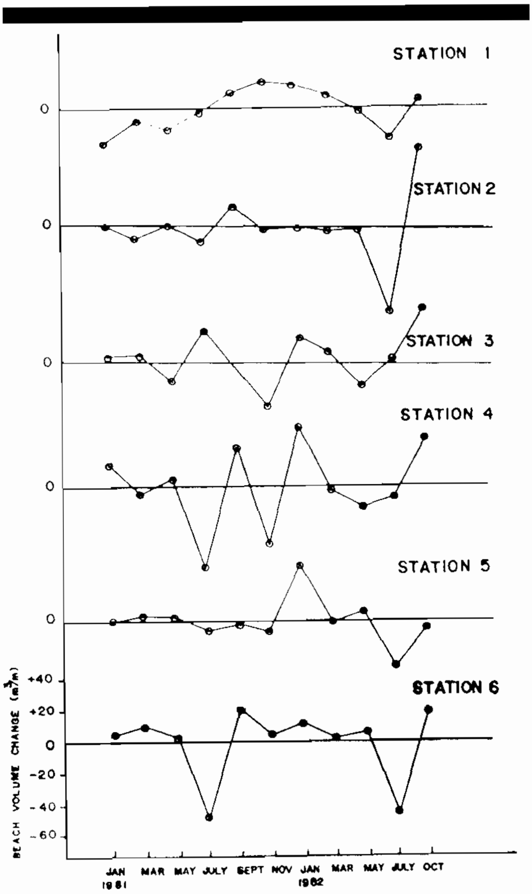

Figure 4. Graphical representation of cumulative beach volume changes (m^3/linear meter) during different periods from November 1980–October 1982.

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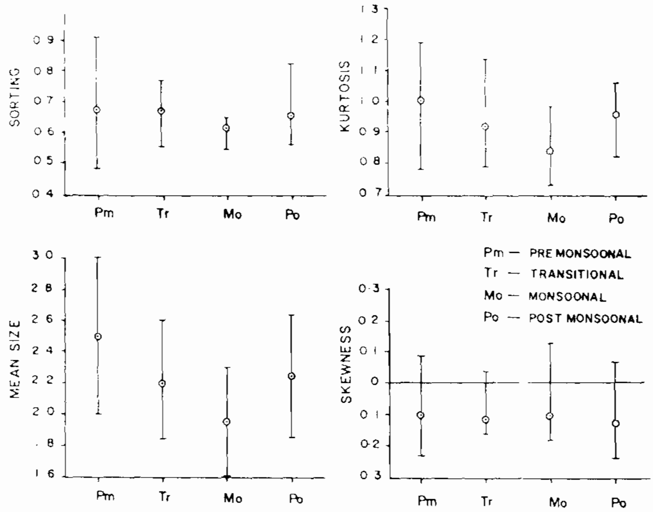

Figure 5. Plot of average value of mean size, standard deviation, skewness and kurtosis showing both spatial and temporal variation.

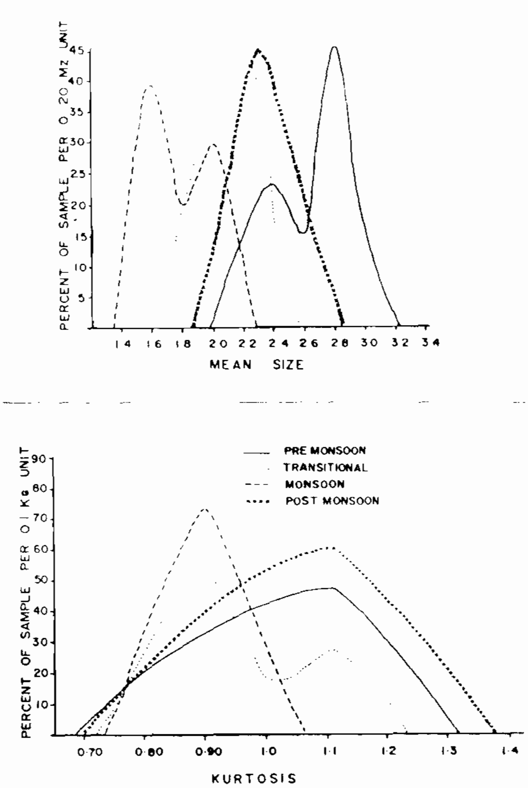

Figure 6. Frequency distribution diagram of mean size showing the nature of sediment in different seasons.

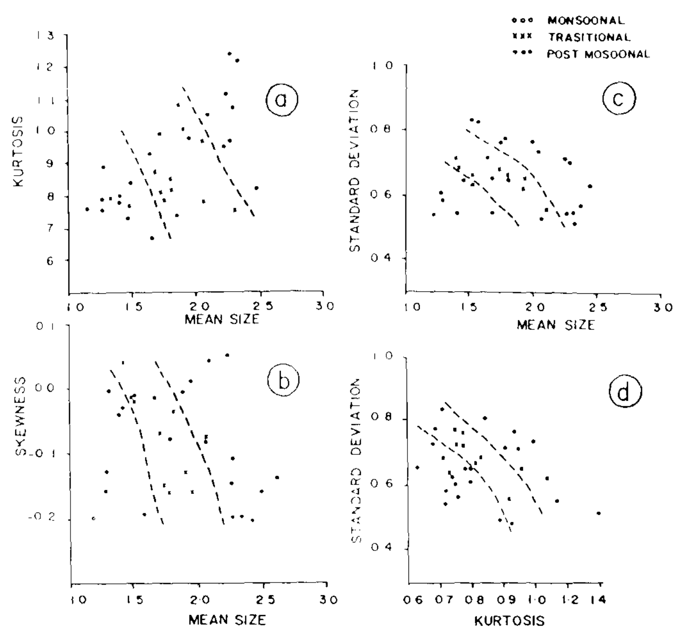

Figure 7. Scatter plots of (a) mean size vs. kurtosis; (b) mean size vs. skewness; (c) mean size vs. standard deviation, showing the separation of premonsoonal, transitional and monsoonal sands.

☐ RESUMEN ☐

Se han estudiado las variciones de los parámetros de textura y procesos de playa en relación con diferentes estaciones anuales en la costa Suroeste de la India, a 12 Km de la costa del Estrecho de Matlul-Payangadi. Con base en las caracteristicas de los sedimentos y los cambios morfológicos de la playa se han identificado cuatro estaciones climáticas: pre-monzón, transición, monzón y post-monzón. Las variaciones de energia incidente del oleaje se reflejan en la distribución de tamaños de las arenas. A mayores energias de oleaje se corresponde un incremento de tamaño desde el pre-monzón hasta el post-monzón pasando por la estación de transición. Curtosis varia gradualmente de mesocurtosis a platicurtosis. En comparación, los sedimentos de las estaciones de transición y monzón son moderadamente bien distribuidos y tiende más a platicurtosis que los correspondientes a premonzón y post-monzón. Los sedimentos presentan en todas las estaciones un sesgo negativo cuasi simétrico.—*Department of Water Sciences, University of Santander, Cantabria, Spain.*

☐ RÉSUMÉ ☐

Les variations dans la texture des sédiments et la morphologie des plages, en fonction des saisons, ont été étudiées sur 12 km de la côte de Mattul-Payangadi, dans le Sud-Ouest de l'Inde. En se basant sur les caractéristiques des sédiments et les changements morhpologiques de la plage, quatre saisons ont été identifiées en relation avec les mousson. Les différences dans l'énergie des vagues suivant les saisons se réflètent dans la granulométrie des sables. La taille des grains augmente avec l'accroissement de l'énergie des vagues depuis la pre-mousson jusq'à la mousson en passant par la période de transition. La classification des sables varie elle aussi. Les sables sont mieux triés pendant la période de transition et la mousson que pendant la pré-mousson ou la post-mousson.—*Roland Paskoff, Université Lumière de Lyon, France.*

☐ ZUSAMMENFASSUNG ☐

Die von den verscheidenen Jahreszeiten abhängigen Änderungen der Korngrößenparameter und der Strandprozesse an der Südwestküste Indiens wurden an einem 12 km langen Abschnitt der Küste von Mattul-Payangadi untersucht. Aufgrund der Sedimentmerkmale und der küstenmorphologischen Veränderungen werden vier Jahreszeiten in Abhängigkeit von den Klimabedingungen ausgegliedert: Vormonsun-, Übergans-, Monsun- und Nachmonsunzeit. Saisonale Unterschiede in der Wellenenergie spiegeln sich in der Verteilung der durchschnittlichen Korngröße der Strandsande wider. Entsprechend der Zunahme der Wellenenergie erhöht sich auch die Korngröße in der Übergangszeit von der Vormonsun- zur Monsunsaison. In den Änderungen des Kurtosiskoeffizienten kommt der Übergang von mittlerer zu flacher Hüaufung zum Ausdruck. Im Vergleich zu den vor- und nachmonsunalen Seidmenten sind die der Übergangs- und Monsunsaison mäßig gut sortiert und tendieren zu flacherer Häufung. In allen Jahreszeiten ist die Schiefe negativ bis fast symmetrisch.—*Helmut Brückner, Geographisches Institut, Universität Düsseldorf, F.R.G.*