

Wave refraction and prediction of breaker parameters along the Kerala coast, India

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Numerical wave refraction study for the Kerala coast has been carried out for waves representing southwest monsoon (June - September), northeast monsoon (October - February) and fair weather period (February - May). Distribution of wave heights vary significantly from place to place due to wave refraction and shoaling. The convergence and divergence of wave energy induce non-uniform distribution of wave heights during the monsoon period. Ezhimala promontory causes waves to refract considerably along the coastline of Cannanore, Badagara and Mahe during October to February, whereas the headland at Thankasseri induces divergence of wave energy along Quilon and Varkallai. Yypin experiences convergence of wave energy almost throughout the year.

Wave action on the coast depends on deep water wave climate and its complex transformation processes in the nearshore. Depth induced shallow water wave refraction has significant influence in wave attenuation and in turn the distribution of wave energy along the coast. Computer based numerical wave refraction analysis is widely being used in recent days to study the nearshore wave transformation processes¹⁻⁶. Numerical wave refraction study for the Kerala coast with simultaneous wave measurements in deep and shallow waters was made by Kurian⁷. In India, most of the models have used linear wave theory. The regions of validity of various wave theories are indicated by Le Mehaute⁸. In shallow waters, particularly close to wave breaking zone, higher order wave theories would yield better accuracy in the analysis. In the present study, numerical wave refraction study has been carried out for the Kerala coast, using higher order wave theories and considering wave shoaling.

Materials and Methods

Based on the various wave atlas prepared for the Indian coast⁹⁻¹¹, the predominant deep water wave directions 270°, 290° and 210° representing

southwest monsoon (June-September), northeast monsoon (October-January) and fair weather seasons (February-May) respectively and of wave periods 6 and 8 s were selected for the refraction study along the Kerala coast (Fig. 1). Reflection and diffraction were assumed negligible as the coast is relatively straight and open. Naval Hydrographic Charts 217 to 221 were used for extracting seabed bathymetry. Numerical wave refraction procedure presented in Skovgaard *et al.*¹ has been followed in the present study. The details of solution of equations, various wave theories, grid configuration and operation of the models are explained in Chandramohan¹². Based on the shoaling (K_s) and refraction (K_r) coefficients obtained from the refraction model, the variation of breaker height (H_b) for the entire Kerala coast was estimated using the relationship,

$H_b = K_s K_r H_o$, where H_o is the deep water wave height.

Results and Discussion

Wave refraction

Southwest monsoon period—The refracted wave orthogonals for the incoming wave direction of 270° and for the wave periods 6 and 8 s are shown

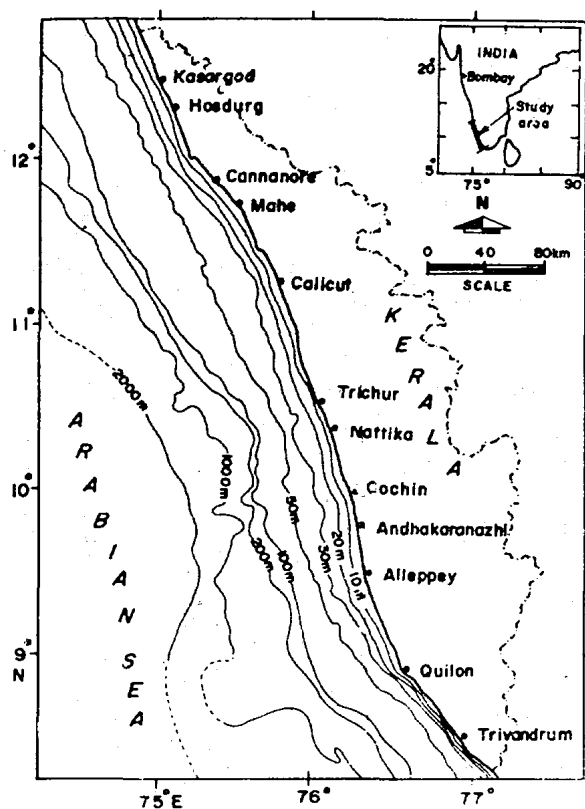


Fig. 1—Study location

in Fig. 2. For 6 s wave period, convergence of wave orthogonals is observed at Vypin and north of Cochin, and divergence is seen south of Ezhimala, south of Cannanore, at Quilandi, Quilon, Varkallai and Puvar. Waves of 8 s period show more convergence of energy along the coast than waves of 6 s period. Convergence of wave energy is observed at Kasargod, south of Cannanore, north of Quilandi, south of Beypore, at Ponnani, Vypin, north of Alleppey, north of Karunagapalli and at Neendakara. Divergence of wave orthogonals is seen south of Ezhimala, at Andhakaranazhi and Quilon. Along the rest of the coastal stretch, the wave energy is uniformly distributed.

Fair weather period—Wave orthogonals approaching the coast at 210° for the wave periods 6 and 8 s are presented in Fig. 3. Waves of 6 s period, show convergence of wave energy north of Kanjangad, at Vypin and Purakkad, and divergence at Ezhimala, between Cannanore and Mahe, Quilandi, and Quilon. Waves of 8 s period show convergence along south of Kasargod, Kanjangad,

north of Ponnani, Azhikod, Vypin, north of Alleppey, Purakkad and Neendakara, and divergence of wave orthogonals between Cannanore and Badagara, Mahe, south of Nattika, Andhakaranazhi and north of Karunagappalli. The wave energy is uniformly distributed along the other parts of the stretch of this coast.

Northeast monsoon—The refraction of wave orthogonals for the direction 290° with respect to north for wave periods 6 and 8 s are presented in Fig. 4. Waves of 6 s period show convergence along north of Bekal, south of Ponnani, at Vypin and Purakkad, and divergence at Ezhimala to Mahe, Quilandi, Nattika, Andhakaranazhi, Quilon to Varkallai and Puvar. Waves of 8 s period show converge at south of Bekal, Kanjangad, just north of Cannanore, south of Quilandi, south of Beypore, south of Ponnani, Azhikod, Vypin, north of Alleppey, north of Purakkad and at Neendakara. Divergence is observed at north of Ezhimala, Cannanore to Tellichery, Nattika, Andhakaranazhi, north of Karunagappalli, Quilon to Varkallai and at Puvar. The remaining part of the coast experiences uniform distribution of wave energy.

Variation of breaker parameters

Variation of shoaling and refraction coefficients, and the ratio of breaking wave height to deep water wave height for the selected three wave directions, and for 6 and 8 s wave periods are shown in Figs. 5 to 7.

Southwest monsoon period—Shoaling coefficient was relatively large (>0.95) at Ezhimala, Cannanore, Quilandi, Cochin and, between Quilon and Trivandrum, and low (<0.9) at other places (Fig. 5). Refraction coefficient at wave breaking point for 6 s period was more than 1 at north of Ezhimala, Vypin, Andhakaranazhi, Alleppey and north of Quilon, and less than 1 at south of Ezhimala and south of Quilon. The refraction coefficient for 8 s period, was more than 1 at north and south of Ezhimala, Kanjangad, south of Beypore, south of Bekal, between Vypin and south of Alleppey and Quilon. It was around 0.6 at north of Quilon and at Varkallai. Minimum value of 0.5 was observed near Puvar. The breaker wave height ratio, i.e., the ratio of breaking wave height to deep water wave height, for 6 s waves is around 1 at Quilandi, Vypin, north of Alleppey and Quilon, 1.5

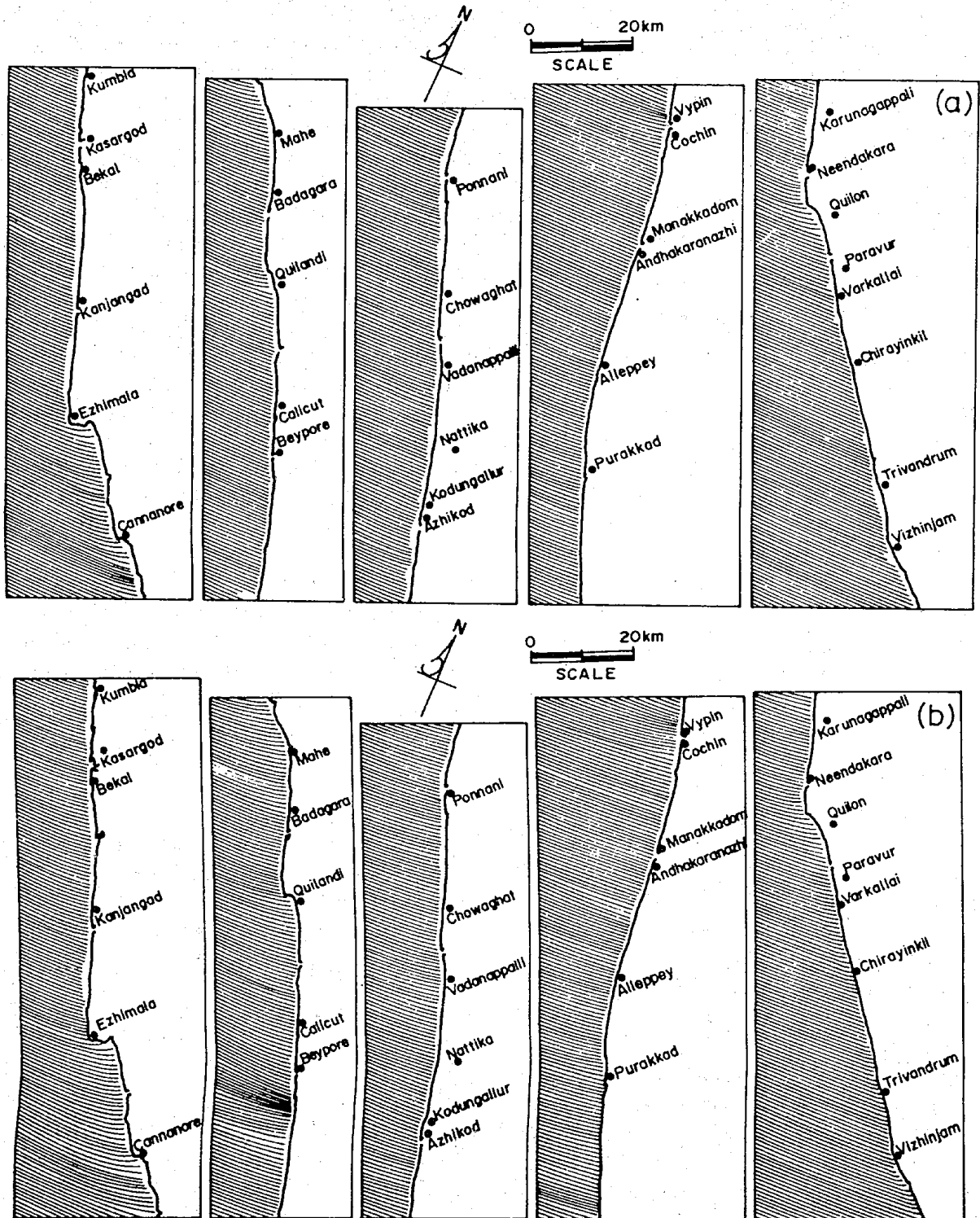


Fig. 2—Wave refraction for 270° direction for : a) 6 s period, b) and 8 s period..

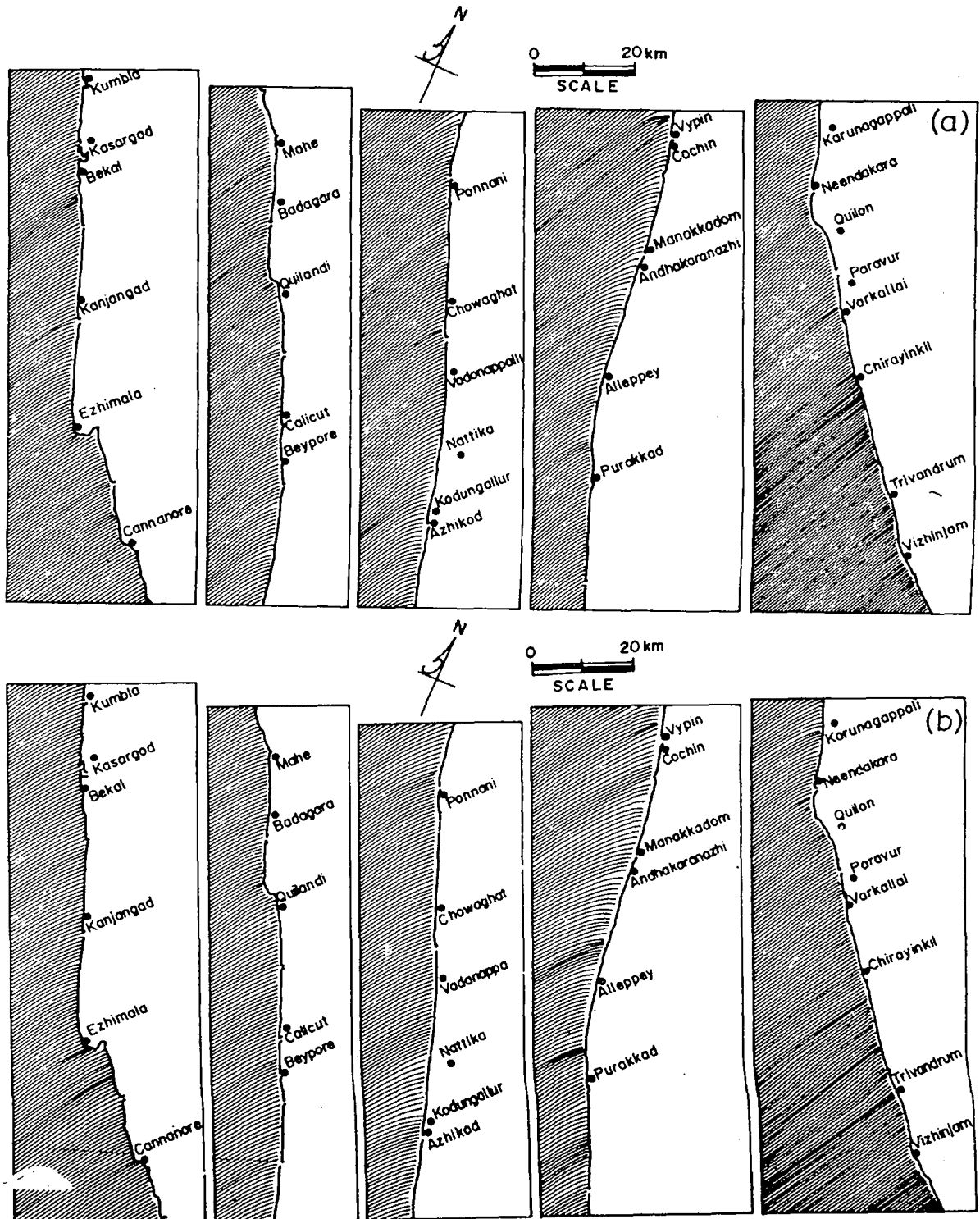


Fig. 3—Wave refraction for 210° direction for : a) 6 s period, b) 8 s period.

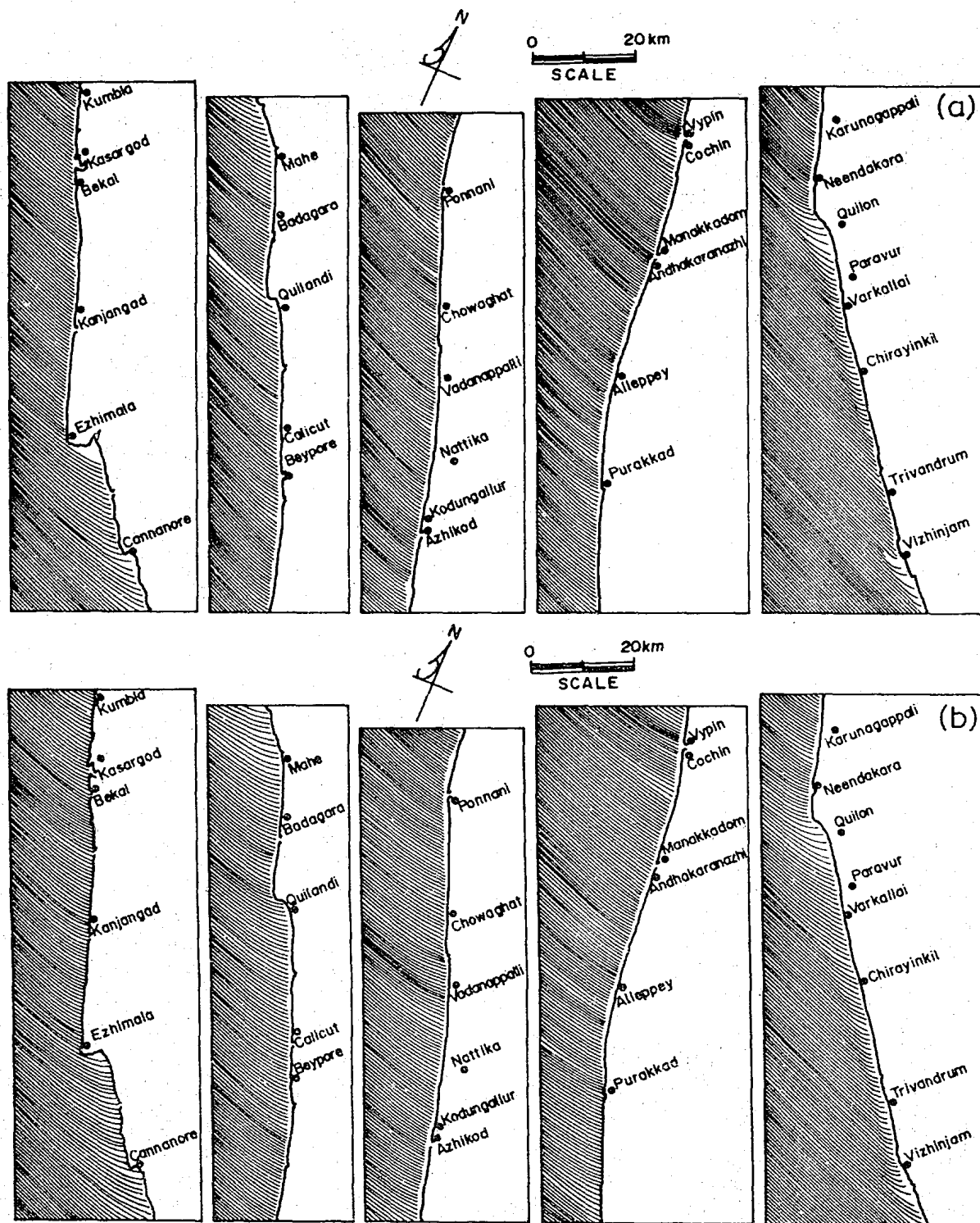


Fig. 4—Wave refraction for 290° direction for : a) 6 s period, b) 8 s period.

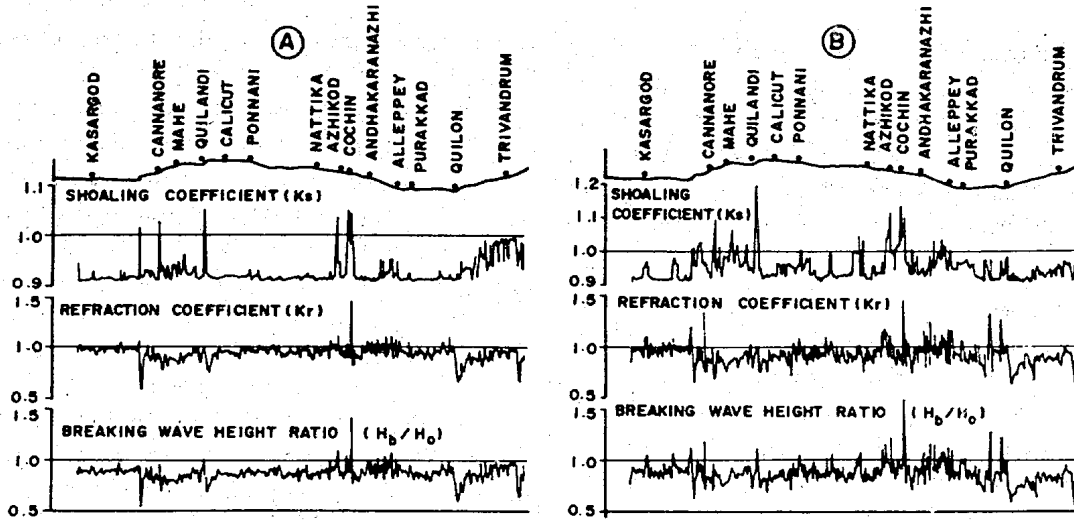


Fig. 5—Variation of nearshore parameters for 270° direction.

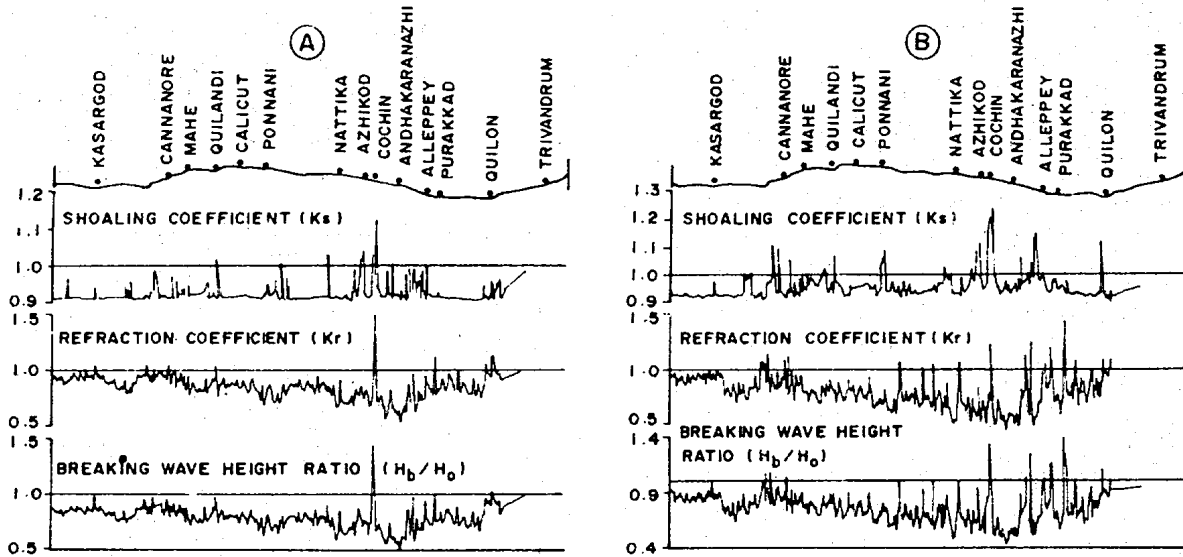


Fig. 6—Variation of nearshore parameters for 210° direction.

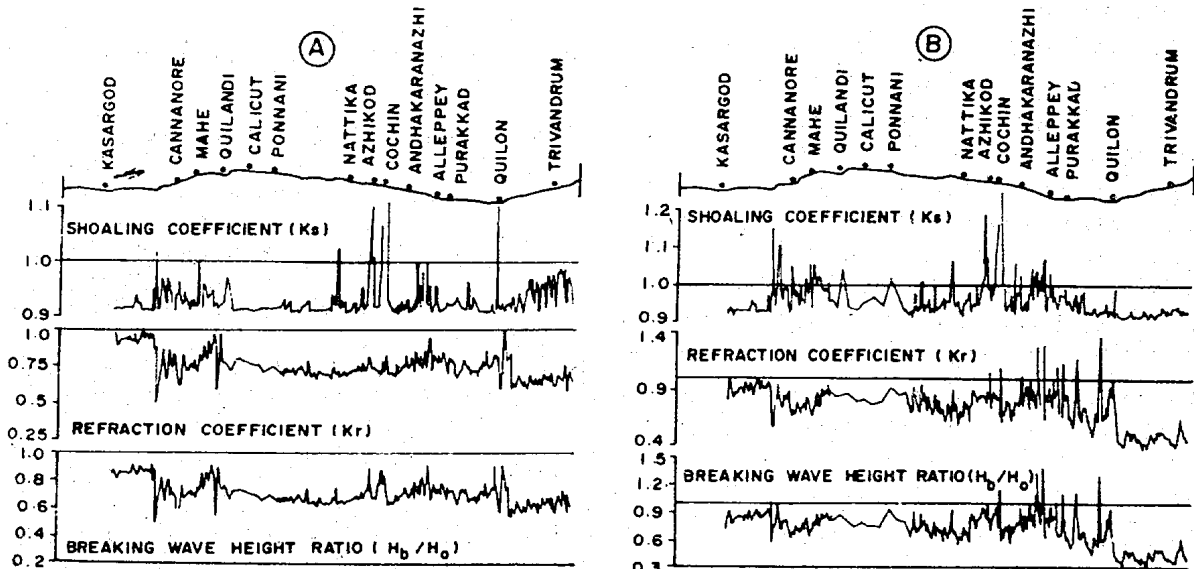


Fig. 7—Variation of nearshore parameters for 290° direction.

near Vypin and 0.8 along the remaining stretch of the coast. For 8 s period, it is more than 1 at Kasargod, Kanjangad, north of Ezhimala, south of Bekal, Quilandi, south of Beypore, Ponnani, Nattika, Vypin, Andhakaranazhi, Alleppey and Quilon, and between 0.6-0.9 along the rest of the coast.

Fairweather period—The estimated shoaling coefficient was found to be more than 1 at Quilandi, north of Nattika, Vypin and at Alleppey, and was about 0.95 at other places (Fig. 6). Refraction coefficient for 6 s period waves was more than 1 at Kasargod, Ezhimala, Cannanore, Quilandi, Vypin, south of Alleppey and Quilon, and between 0.5-0.9 at other places. For 8 s wave period, it was more than 1 at Ezhimala, Cannanore, south of Chawaghat, North of Nattika, Vypin, north of Alleppey, Purakkad and Quilon. The breaker height ratio for the waves of 6 s period, indicates higher values (>1) at Vypin and Quilon, lower values (<0.6) between Andhakaranazhi and Alleppey and about 0.75 at other places. The ratio is highest about 1.4 at north of Cochin. For waves of 8 s period, the breaker height ratio is more than 1 at Ezhimala, Cannanore, Vypin, north of Alleppey, Purakkad and north of Quilon, 1.3 at Vypin, 0.5 between Nattika and Andhakaranazhi and 0.9 at Kasargod.

Northeast monsoon—The shoaling coefficient showed more than 1 at Ezhimala, north of Nattika, Cochin and Quilon, and about 0.95 at other places (Fig. 7). Refraction coefficient for 6 s period showed low values (<0.75) along the entire stretch of the Kerala coast, except south of Kasargod, Quilandi, Alleppey and Quilon. For 8 s period, it was more than 1 at Cochin, south of Andhakaranazhi, south of Alleppey (Purakkad), Karunagappalli and at Neendakara. Large value of 1.4 near Neendakara and low value of 0.5 near Ezhimala were observed. Breaker height ratio for 6 s wave period shows about 0.8 along the stretch of the Kerala coast with low values about 0.5 at Ezhimala and Quilandi. For 8 s period, the ratio is 1 at Cochin, 1.4 at north of Alleppey and Quilon.

At the southern end of the Kerala coast, the breaker height ratio was only 0.4.

The study indicated that the breaking wave heights along the coastline of Kerala are higher at few locations and lower at few locations, attributed due to the wave convergence and divergence. The presence of Ezhimala promontory appears to cause waves to refract considerably along the coastline of Cannanore, Badagara and Mahe during October to February. Similarly, the headland at Thankasseri, causes divergence of wave energy along Quilon and Varkallai during this period. It is observed that Vypin experiences convergence of wave energy almost throughout the year.

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References

- 1 Skovgaard O, Jonsson I G & Bertelsen J A, *JWW Harb & Coast Engrg Div*, ASCE, 101 (1975) 15.
- 2 Griswold G M, *J Geophy Res*, 68, (1963) 1715.
- 3 Jen Y, *JWW Harb & Coast Engrg Div*, ASCE, 95 (1969) 379.
- 4 Wilson W S, *CERC Technical Memo*, No. 17 (U.S. Army Corps of Engineers, Washington), 1966, pp 57.
- 5 Dobson R S, *Technical Report*, No.80 (Dept. of Civil Engineering, Stanford University), 1967, pp.115.
- 6 Mahadevan R & Renukaradhya P S, *Proc II Indian Conf. in Ocean Engineering*, (1983) 71.
- 7 Kurian N P, *Wave height and spectral transformation in the shallow water of Kerala coast and their prediction*, Ph.D. Thesis, Cochin University of Science & Technology, India, 1987.
- 8 Le Mahaute B, *Water wave theories*, Vol. 2, (U.S. Dept. of Commerce, Washington D.C), 1969, pp.118.
- 9 Anonymous, *Wave statistics of the Arabian Sea*, (Naval Phys. Oceanogr. Lab., Cochin, India), 1978, pp.204.
- 10 Varkey M J, Kesava Das V, Narayanaswamy G, Joseph P S & Sastry J S, *Wave (swell) Atlas for Arabian Sea and Bay of Bengal*, (Natn. Inst. Oceagr., Goa, India), 1982
- 11 Chandramohan P, Sanil Kumar V, Nayak B U & Anand N M, *Wave Atlas for the Indian Coast (Based on ship observations, 1968-1986)*, (Natn. Inst. Oceagr. Goa, India), 1990, pp.312.
- 12 Chandramohan P, *Longshore sediment transport model with particular reference to Indian coast*, Ph.D thesis, Indian Institute of Technology, Madras, India, 1988.