Indian J. Met. Geophys.(1974), **25**, 3 & 4, 453-460

551.556 : 551.46

Waves in coastal waters off Mangalore Pt. I : Distribution of wave characteristics

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(Received 18 January 1973)

ABSTRACT. Wave records obtained from the pressure recorder for measuring sea waves, installed off Mangalore have been analysed and wave parameters like period, height etc. have been obtained for the period June 1968 to May 1969. Frequency distribution of wave heights and periods during various months have been drawn. Energy spectra obtained from the data are presented. From the study of the distributions of wave parameters it has been found that period follows normal distribution and the height follows Rayleigh distribution. The energy spectra are composite in nature giving the average condition for a month when the record for the whole month is considered as a single record.

1. Introduction

Coastal sea waves were earlier studied by Darbyshire J. (1956, 1959, 1963), Darbyshire M. (1958, 1960, 1962), Longuet Higgins (1952), Bretschneider (1961). Bretschneider (1966) reviewed the different theories regarding the wave generation by winds in deep and shallow waters. Coastal waves along the Indian coasts have not been recorded systematically so far. A capacitance type of wave recorder described by Harris and Tucker (1963) was installed off Mangalore at a distance of about 2.5 miles where the depth was about 30 ft. The location of the wave recorder is shown in Fig. 1 (a). A long series of wave records corresponding to a variety of wave conditions were obtained for the period June 1968 to May 1969. The results of the analysis of these data are presented in two parts. The present paper (Part I) deals with the frequency distribution of wave heights, wave periods and the spectral characteristics of the waves and their energy. In Part II of the paper we shall make an attempt to obtain relationships between wave parameters and the wind speed for shallow water conditions.

2. Method of analysis of data

2.1. Waves were recorded over a duration of 15 to 20 minutes at intervals of one hour during the period June to September 1968, while the interval between records was increased to three hours, keeping the duration of recording time same for the rest of the period. These records have been analysed following the method described by Putz (1952). From the records, the periods and heights of individual waves have been read off with an accuracy within ± 0.5 seconds and ± 4 inches respectively. The heights have been corrected for attenuation corresponding to the depth of installation and the respective periods using the graph giving the 'Relationship between pressure fluctuations on the sea bottom, surface wave height, wave period and depth of water' (Draper 1963). These results have been tabulated on a daily basis for all records. A sample wave record is shown in Fig. 1 (b).

2.2. The information obtained was subjected to a statistical analysis on a monthly basis. The relative frequency of occurrence of heights and periods for each of the months have been shown in the form of histograms in Figs. 2 and 3. Mean wave height, the mean height of the highest 10 per cent of waves, significant wave height (mean height of the highest one-third of the waves) and significant period (the mean period corresponding to the significant height) were evaluated for each of the days for which records have been obtained. Monthly grouped means of the above parameters, along with their respective standard deviations, the maximum wave height and period recorded during the month and the percentage of waves with heights less than 2 ft are summarised in Table 1.

2.3. Graphs have been drawn to show the variation of energy $S_H{}^2(w)$ with frequency (w) following the methods given by Bretschneider (1961). Theoretical curves of height distribution have been drawn for June and January based on the Rayleigh distribution law $P(H)=(2H/\overline{H}^2)\exp(-H^2/\overline{H}^2)$, where $P(H)$ is the probability of height H and $\overline{H}^2$ is the mean square height for comparison with the observed distribution

TABLE 1

Monthly Wave Characteristics

	Total No. of waves	†Waves less than 2 ft (%)	Max. ht (ft)	All waves		Highest 10% waves		Highest 33% waves		Significant period		Max. period recorded (sec)
				Mean ht (ft)	S.D.	Mean ht (ft)	S.D.	Mean significant ht (ft)	S.D.	Mean period (sec)	S.D.	
1969												
Jan	14390	100	3·0	1·3	0·26	1·3	0·44	1·3	0·44	6·4	0·65	7
Feb	12543	99	4·0	1·3	0·30	1·4	0·50	1·4	0·50	6·6	0·70	8
Mar	11246	100	2·0	1·3	0·28	1·8	0·40	1·4	0·49	7·0	0·80	9
Apr	10323	100	3·0	1·3	0·26	2·0	0·25	1·6	0·49	8·7	1·74	12
May	15023	91	5·0	1·5	0·72	2·4	0·70	2·0	0·60	8·7	1·52	13
1968												
Jun	31858	32	17·0	3·8	2·17	5·8	2·24	4·8	1·54	9·4	1·33	12
Jul	28592	33	15·0	3·7	2·23	5·5	1·74	4·7	1·45	10·6	0·56	12
Aug	19067	56	11·0	2·5	1·38	4·6	1·22	3·7	1·12	9·7	0·64	11
Sep	18011	80	7·0	1·8	0·89	2·9	1·34	2·7	0·36	9·1	1·04	11
Oct	10908	92	6·0	1·6	0·75	1·8	0·59	1·8	0·59	9·5	1·25	11
Nov	7445	100	3·0	1·3	0·26	1·6	0·49	1·2	0·44	10·6	1·60	14
Dec	13007	100	3·0	1·3	0·20	1·5	0·50	1·2	0·41	7·0	1·10	10

†Percentage corrected to 1%

S.D.=Standard Deviation

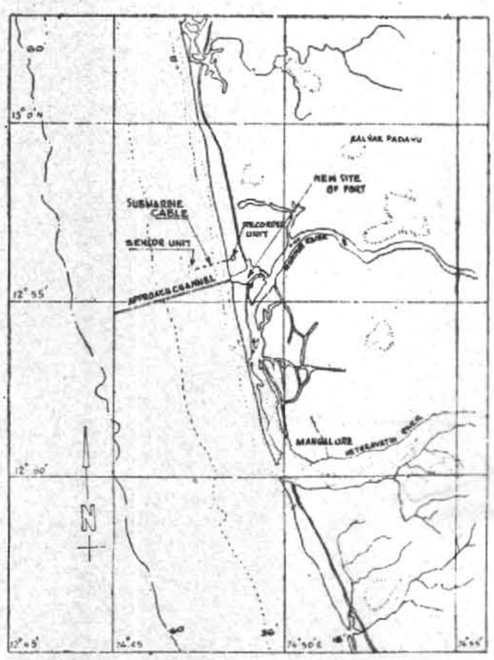

Fig. 1 (a). Location of wave height recorder at Mangalore harbour

TABLE 2

Physical characteristics of the disribution of observed heights

Physical property		Jan 1969	Jun 1968
Central moments	1	0	0
	2	0·0696	4·7067
	3	0·0016	12·7926
	4	0·0092	106·8634
Skewness		0·0910	1·2519
Kurtosis		−0·9869	1·8194

Physical characteristics of the distribution of the observed height are given in Table 2.

3. Discussion of the results

3.1. *Relative frequency distribution* — The relative frequency corresponding to a particular period is the ratio of the number of times the waves of that period repeated to the total number of waves of different periods occurred during a month. The relative frequency distribution of period and height is given below.

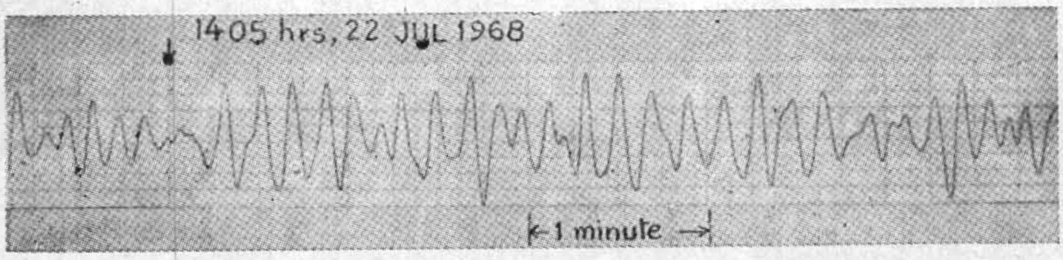

Fig. 1 (b). Sample wave record

Period — The period disbtriution during December 1968 — February 1969 (Figs. 2 l, 2 a, 2 b) has two peaks in the relative frequency of occurrrence, namely, one at a period of 8 seconds and another at a period of 12 seconds. The peak corresponding to 8 seconds is higher than that corresponding to 12 seconds. The frequency of occurrence of 8 seconds period waves remain almost the same during March-April 1968 (Figs. 2 c and 2 d) as in December-February, but the frequencies of 12 seconds and 13 seconds period increase from those during December-February. The maximum frequency around 8 seconds period may be due to the locally generated waves from low winds during this season. The relative frequency of occurrence of swells of 12 seconds period, which remains small during December-February, increases towards March-April. The frequency distribution of period almost resembles a normal distribution during May-September (Figs. 2 e, 2 f, 2 g, 2 h and 2 i).

3.2. The histogram for July (Fig. 2 g) suggests a uniform distribution of relative frequency of the wave period. Long periods of the order of 16 seconds have also been observed. The relative frequency of occurrence of long period waves with period around 13 seconds is increased during the post monsoon season, namely, October and November (Figs. 2 j and 2 k).

3.3. The state of the sea during winter months (December-February) is marked by waves of low periods due to local winds. Swells start appearing towards the beginning of the southwest monsoon due to relatively moderate and long persisting winds, and their frequency increases with the development of the southwest monsoon. It may be seen that the frequency distribution for the period during the southwest monsoon is flat. The almost equal distribution of the relative frequency over a relatively large bandwidth of wave periods shows that the period of sea *and swell become continuous with equal frequency* of occurrence. Waves with wide variation in their periods prevail during this season.

3.4. The frequency of swells during post monsoon season (October and November) it increased because of the presence of depressions in the sea during this period. A cursory glance at the frequency distribution of depressions and cyclones published by India Meteorological Department confirms the presence of depressions during this season.

3.5. *Height* — The relative frequency of wave height is maximum around 1.5 ft during the period November-February (Figs. 3 k, 3 l, 3 a and 3 b). The width of the distribution is very narrow, ranging from 1 ft to 2.5 ft. A similar narrow band is also observed during March-April (Figs. 3 c and 3 d). The height starts increasing from May onwards. The wave height corresponding to maximum frequency is shifted towards 2 or 3 ft during June-August. The relative frequency distributions (Figs. 3 f and 3 g) show that heights of the order of 10 ft occur during June and July. The nature of the distribution suggests that it does not follow a normal distribution; as the peak is shifted towards the lower side. The shape of the histogram during the monsoon season resembles a Rayleigh distribution. Theoretical curves (Figs. 4 and 5) for the height distribution were drawn for June and January respectively using Rayleigh distribution law. On comparing the theoretical and observed distributions, it was noticed that the observed distribution had a larger peak, during both June and January.

3.6. From Table 1 it may be seen that percentage of occurrence of waves below 2 ft height is always more than 90 per cent, except during the period from June to September. Mean height during all months except during June-September, varied from 1.3 to 1.6 ft, with a standard deviation from 0.2 to 0.8 ft respectively. During the southwest monsoon season the mean height varied from 1.8 to 3.8 ft, with a standard deviation from 0.9 to 2.2 ft respectively. The variation of mean height during southwest

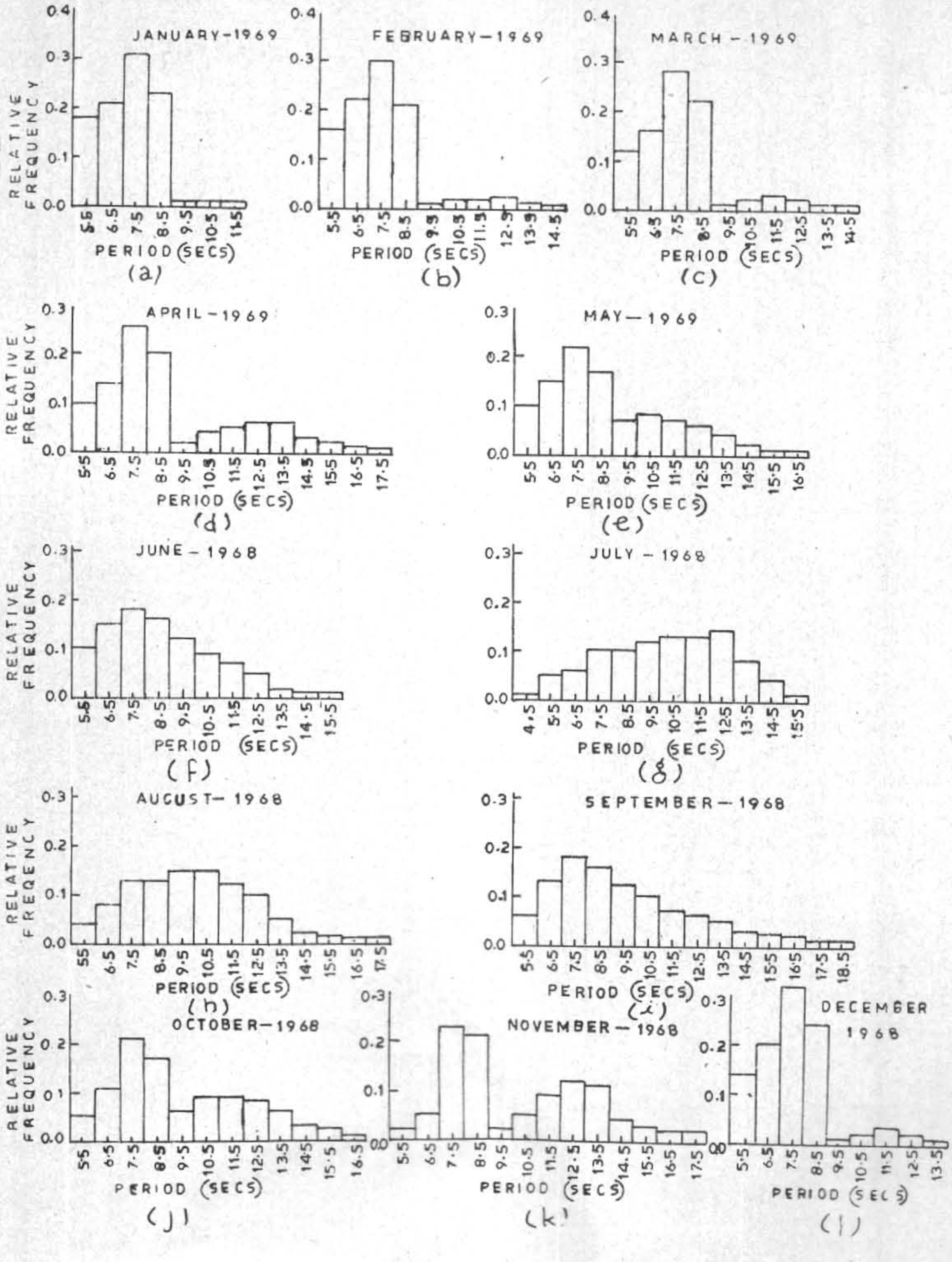

Fig. 2. Period distribution

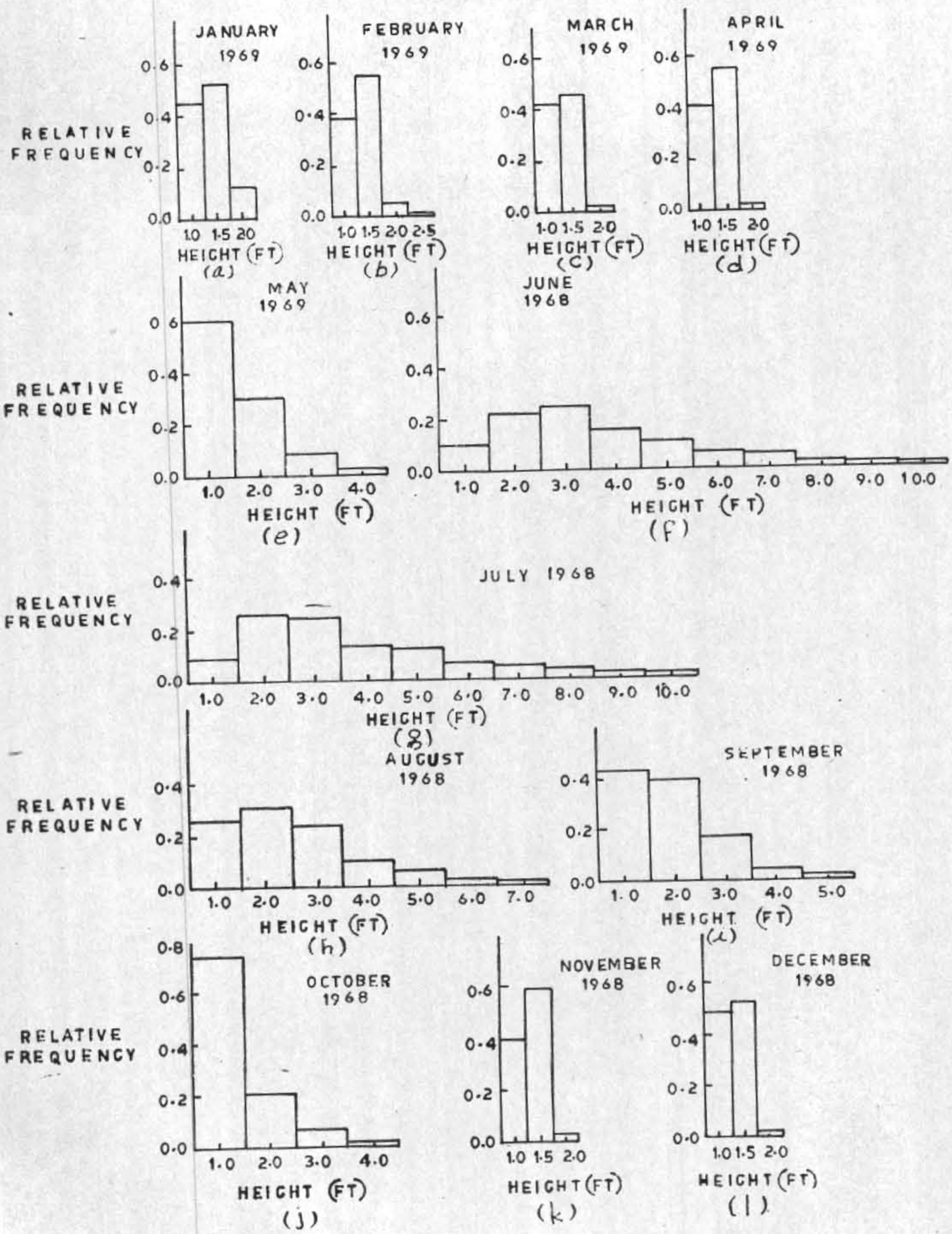

Fig. 3. Height distribution

monsoon is higher than that during the rest of the year.

3.7. From the analysis of daily records it was found that the highest daily maximum height occurred on 13 June 1968 with a height of 17 ft. It was also observed that the daily maximum is higher than 10 ft for most of the south-west monsoon period, while the average daily significant wave height is more than 4 ft. The difference between the daily maximum and daily average significant wave height decreases during December-February.

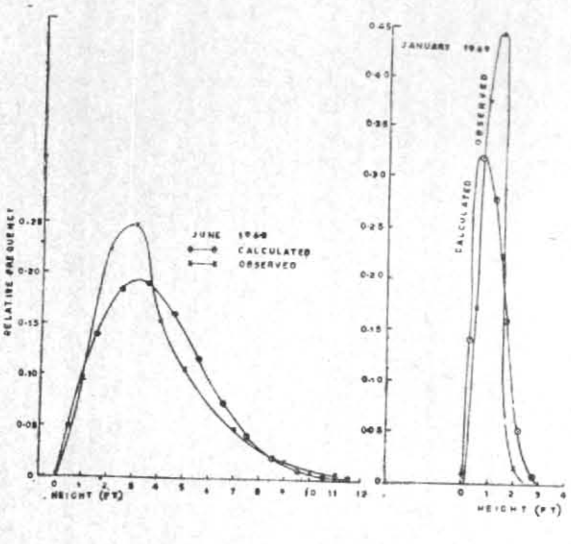

Fig. 4

Theoretical and observed height distribution in June 1968 and January 1969

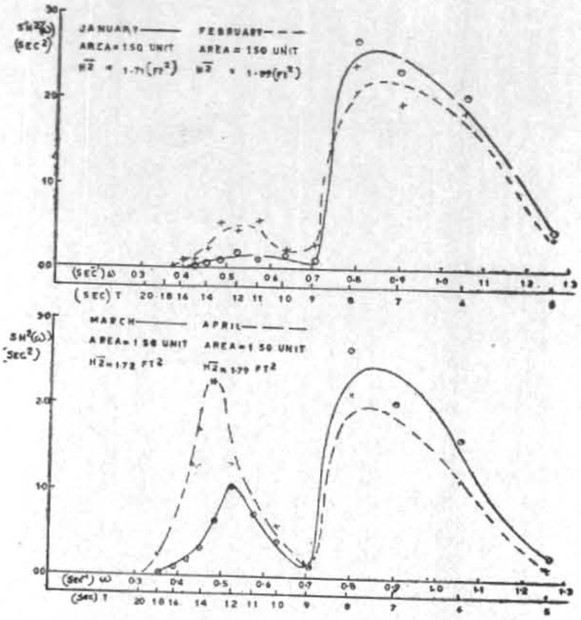

Fig. 6

Energy Spectra (January—April)

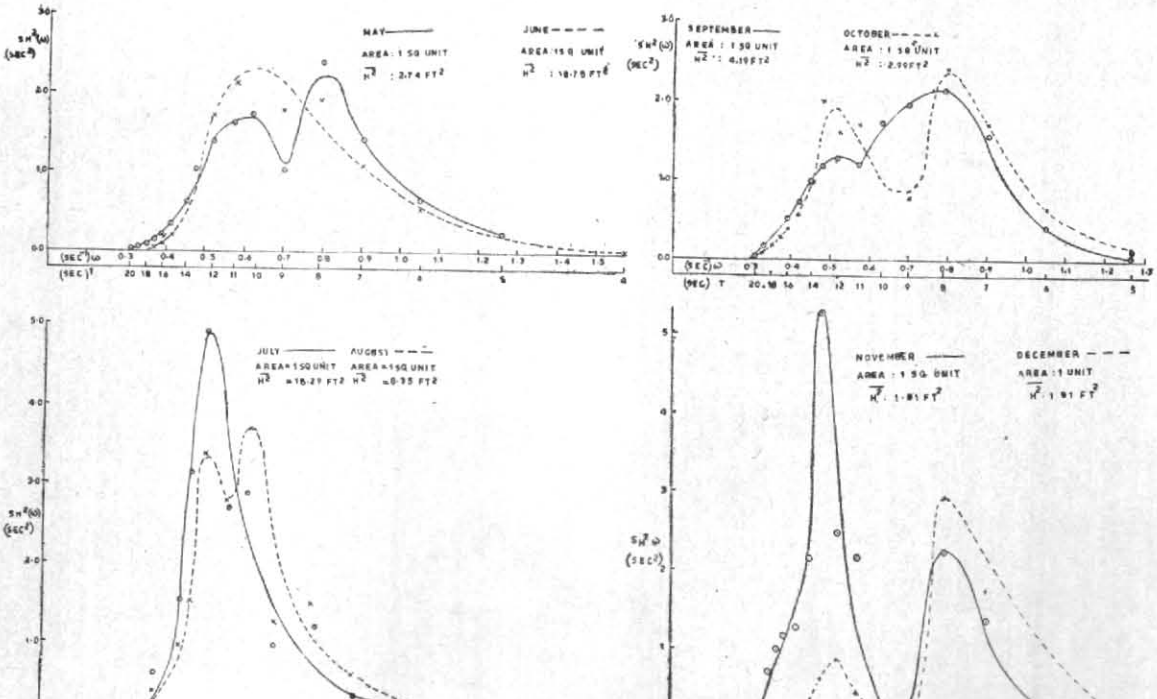

Fig. 7

Energy Spectra (May-December)

3.8. *Energy* — The wave energy for frequency (ω) is represented by $S_H^2(\omega)=H^2(T)/N\overline{H}^2(T^2/2\pi)$, where $H^2(T)$ is the sum of the squares of wave height corresponding to a particular period (T). $\overline{H}^2$ is mean square height for all periods for the whole month and N is the total number of observations for the whole month.

3.9. The variation of $S_H^2(w)$ with frequency (w) during the twelve months is shown in Figs. 6 and 7. The energy curves during December February have two peaks, out of which one is prominent around 7 seconds period, while the other peak, not so prominent as the former, is around 12 seconds. An increase in the energy of high period waves (13 seconds) was observed during March-April with equally high energy around 7 seconds. The increase in the energy of long period waves may be due to winds in the summer months and the presence of swells in that area. But, the significant point is that the total energy was much reduced, making the peaks more prominent. By May, the boundary between the two peaks has been reduced and the curve has become more uniform in June. The shape of the curves remain almost the same from May to August. By October, the curve again starts changing into a double peak. Both the peaks become prominent during October, showing that the energy was equally distributed in the long and short period waves. The peak associated with long period waves is more intense during November. During December-February, the energy due to long period waves is small. This may be due to the absence of swells in the area. Swells are absent because of low winds of short duration and fetch. The mean square height for the whole month ($\overline{H}^2$) is maximum during June and minimum in December.

4. Summary

The maximum of the frequency of occurrence of waves during all months except in July and August is around 8 seconds period. The relative frequency of occurrence of long period waves increases from April to November. The most predominent height during November-April is around 1.5 ft. A very narrow band was observed in the height distribution from November to April. The observed height distribution follows Rayleigh distribution, while the average height varies from 1.3 to 1.6 ft throughout the year except during the southwest monsoon season. During the southwest monsoon season, the average height rises to 3.8 ft, with a large standard deviation showing the variability of waves during this season. The maximum wave height of 17 ft occurred on 13 June 1968 and the daily average significant wave height during southwest monsoon season was more than 4 ft. The energy distribution has two peaks corresponding to waves and swells during March-April and October-December.

Acknowledgements

The authors are thankful to Shri M. S. Narayanan, Director NPOL for allowing us to prepare this paper. Thanks are due to Mangalore Harbour Project authorities who have supplied the wave records for analysis. Thanks are also due to Dr.C.B. Murty, Assistant Director (Oceanography) for going through the manuscript and offering suggestions.

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