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An analysis of the Wave Observations in the Arabian Sea

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1. Introduction

Till a few years ago, the observations of sea and swell recorded by the coastal observatories and the ships in the Indian seas were mainly qualitative in nature. The International Meteorological Organisation Conference of Directors held at Washington in 1947 decided to replace these by observations of the direction, period and height of waves, which are more quantitative and hence more reliable. Observations in the new form are available from ships in the Indian seas from January 1949 and from coastal observatories from January 1950. In order to get an idea of the heights and periods of waves prevailing in the Arabian Sea during the different months of the year, a preliminary analysis of these has been done for one year (1952), and the results are presented in this note. For the purpose of this analysis only the observations of the ships (and not those from the coastal observatories) were used as, firstly, these are more representative of the conditions in the open sea and secondly, the observations of the coastal stations are still not quite reliable due to various reasons such as non-availability of good observation spots, lack of suitable aids for measurement and lack of experience of the observing staff.

There were no storms in the Arabian Sea during the year under study. There was only one shallow depression in the south Arabian Sea for a period of five days from 1 to 5 December. The results obtained therefore represent the average conditions when weather is not seriously disturbed in the Arabian Sea.

2. Distribution of observations

The total number of wave observations from ships in the Arabian Sea during the year 1952 available for the present study was 5171. Their distribution in the various five degree squares (actual number of observations as also the percentage) is shown in Fig. 1. The maximum number of observations is along the main sea-route from Colombo to the Gulf of Aden. Although a sufficient number of observations are available from the other five-degree squares also, the results obtained should be taken as more representative of conditions in south Arabian Sea and the southern parts of west central Arabian Sea than the other parts. The analysis has been made monthwise for the Arabian Sea as a whole, as observations were not sufficient to analyse separately each five-degree square.

3. Analysis of data

As waves are generated by wind, analysis has been made of the heights and periods observed in relation to the winds blowing at that time. For each month the number of occurrences of waves of different heights and periods with each range of wind speed, as also their frequencies (expressed as percentage of the total number of observations under each wind speed range), was worked out. For illustrating the variation with wind-speed of the frequency distribution of height and period, the percentage frequencies for July are shown in Figs. 2 and 3. The average wave heights and periods associated with each wind speed range in different months are given in Table 1. Where the number of observations under a particular speed range is low (taken as 5 per cent of the total number of observations for the month), averages have not been worked out, since they could not be considered as significant.

In order to see how far the analysis would

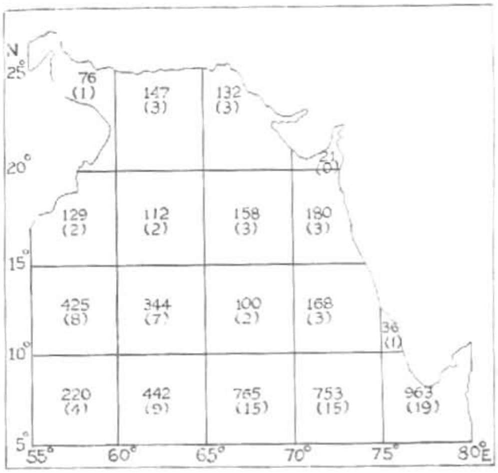

Fig. 1. Distribution of wave observations in the Arabian Sea (1952)

(Top figures are the actual number of observations, figures in brackets are the percentages of the total number)

be representative for other years, the data for July 1953 were also similarly analysed. The percentage frequencies of the wave heights and periods under each wind speed range for the month of July in the years 1952 and 1953 agreed with each other very well. The average heights and periods associated with each wind speed range in July 1953 included in Table 1 also correspond well with the figures for July 1952. This indicates that the results presented in this note can be taken to be generally true for a normal year.

4. Discussion

It will be seen from Table 1 that wave heights tend to increase with higher wind speeds. Winds of speed less than about 2 knots do not cause waves to build up nor help to maintain existing waves. The wave heights observed with such wind speeds should be attributed to swell, *i.e.*, waves generated elsewhere in regions of stronger winds which have advanced to the place of observation and are decreasing in height. With stronger winds, waves build up and finally attain a maximum height depending upon the strength of the wind.

Fig. 2 also shows that the most frequent height of waves associated with each wind-speed range increases progressively as the wind speed increases. The highest significant waves produced by different wind-speeds with necessary fetch and duration taken from "Techniques for Forecasting Wind Waves and Swell" are marked in Fig. 2 on each curve. The average height of the highest one-third of all observed waves in a period of a half to one hour of observation is called the significant wave height. Wave heights estimated by observers approximate to this significant wave height. It is seen from Fig. 2 that with wind speeds 8-12 knots, most of the waves observed have heights greater than the highest significant waves that can be generated by that wind speed. With increasing wind speeds the percentage of observations of waves higher than the highest significant waves progressively decreases until it is an insignificant percentage for the wind speed range of 28-32 knots. The observed wave heights being greater than the highest significant waves in the smaller wind speed ranges may be due to swell or to waves generated in the same area earlier under higher wind speeds. Such possibility naturally decreases when the winds at the place of observation are strong, as this would require still higher wind speeds elsewhere or earlier in the same area.

With increasing wind speeds, the duration or fetch is insufficient for the maximum heights to be built up in increasing percentage of cases. This explains why in the higher speed ranges most of the observed wave heights are less than the maximum. In Fig. 2 the somewhat smaller percentage of waves in the height range $3\frac{1}{4}$-$3\frac{3}{4}$ metres under wind speeds 23-27 knots and 28-32 knots are not considered significant although this is observed in the data of July 1953 also.

Fig. 3 shows the percentage frequencies of different periods observed in association with different wind speeds. The periods that will be associated with the highest significant waves are marked in the histograms. Just as in the case of the wave height, the percentage of cases exceeding these limits decreases as the wind speed increases.

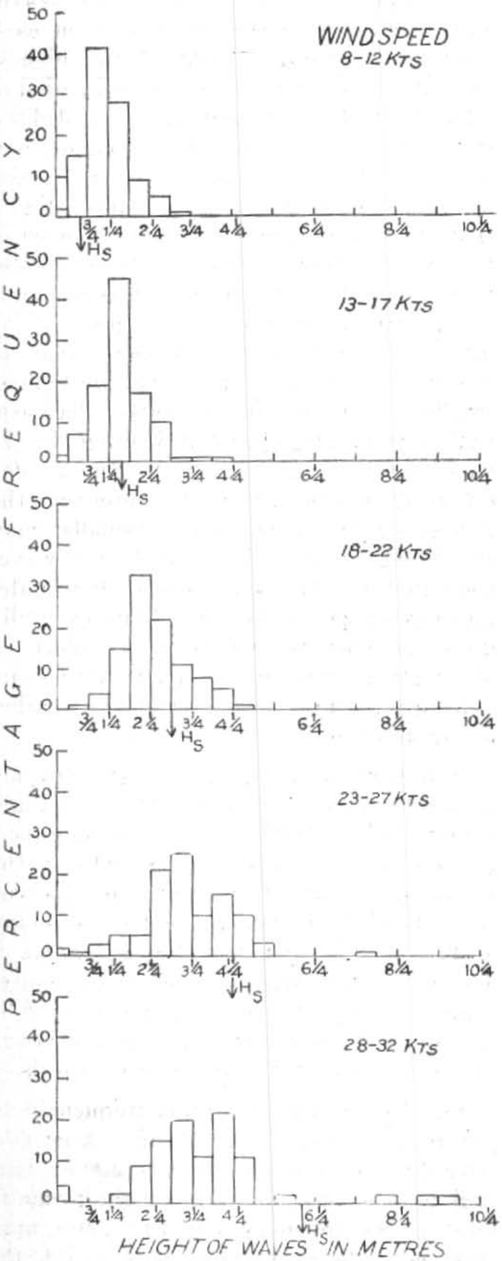

Fig. 2. Frequencies of wave-heights (July)

(H_S—Height of the highest significant wave)

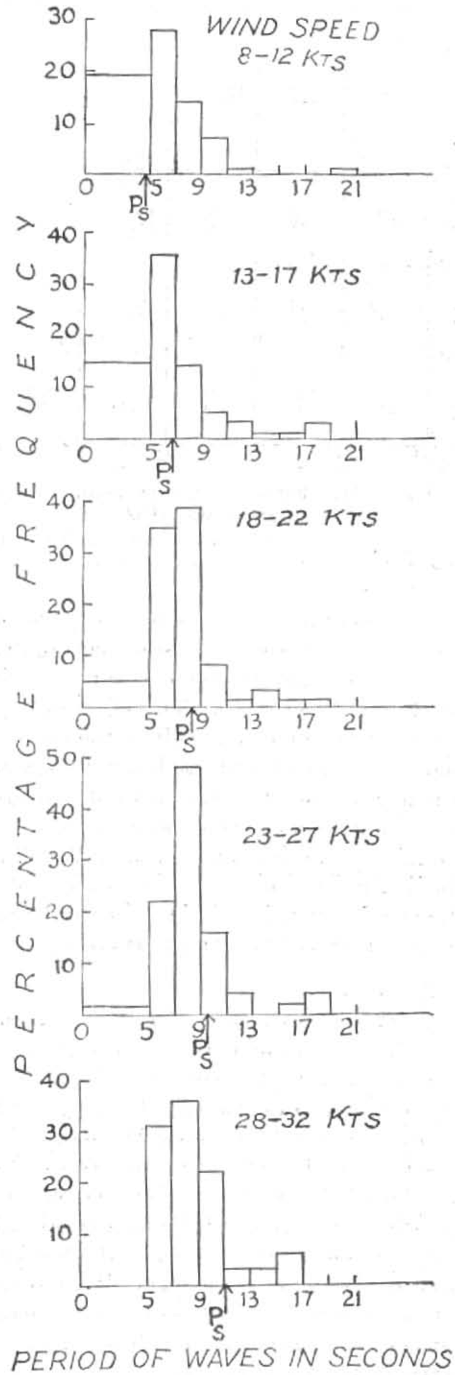

Fig. 3. Frequencies of wave-periods (July)

(P_S—Period of the highest significant wave)

TABLE 1

Average height of waves (in metres) and period (in seconds) associated with each wind-speed range in different months of 1952

Month	Wind speed (knots)						
	0—2	3—7	8—12	13—17	18—22	23—27	28—32
January		0·79 *4·1*	0·94 *3·7*	1·37 *4·7*	1·77 *6·0*		
February	0·76 *4·6*	0·67 *3·7*	0·85 *3·8*	1·31 *4·5*			
March	0·52 *3·4*	0·61 *3·5*	0·79 *3·4*	1·07 *4·4*			
April	0·52 *4·7*	0·55 *4·1*	0·73 *3·7*	1·13 *4·3*			
May	0·52 *3·6*	0·70 *3·7*	0·94 *4·7*	1·43 *5·0*	1·77 *5·7*		
June			1·34 *5·3*	1·95 *6·4*	2·41 *7·0*	3·11 *8·5*	3·41 *9·0*
July			1·22 *5·1*	1·55 *5·9*	2·29 *7·2*	3·08 *8·4*	3·60 *8·6*
July (1953)			(1·43) (*4·9*)	(1·71) (*5·8*)	(2·23) (*7·6*)	(2·93) (*8·2*)	(3·32) (*9·4*)
August		0·85 *4·0*	1·31 *5·3*	1·55 *5·5*	2·13 *6·9*	2·87 *7·4*	
September	0·85 *6·5*	0·70 *4·8*	1·10 *4·7*	1·43 *5·1*	1·59		
October	0·67 *4·6*	0·70 *3·6*	0·97 *3·7*	1·43 *5·0*	1·86 *5·1*		
November	0·82 *3·4*	0·64 *3·8*	0·82 *4·0*	1·16 *4·6*			
December	0·61	0·73 *3·5*	0·85 *3·8*	1·25 *4·4*	1·40 *5·8*		

NOTE— Figures in Roman indicate the height of waves, figures in italics indicate the period

It may be mentioned that the wave period increases continuously as the swell advances. Also in the case of a higher wind prevailing earlier and the wind decreasing later, the period increases although the wave height may decrease. The high periods observed must be due to these causes.

It is interesting to note that in the wind speed ranges 18-22, 23-27 and 28-32 knots the maximum frequency is in the range of 7-9 secs. With increase in wind speed, the period increases much less rapidly than the height, which accounts for the maximum frequency being observed in about the same period.

For each wind speed range, the frequencies of association of different heights with different periods (for the month of July) have been worked out. The results are given in Figs. 4(**a**) to 4(d).

If we consider a steady wind blowing over an extensive fetch, the initial condition being calm, on account of the relationship between wave steepness and age (*vide* Fig. 1·7 on page 9 of "Techniques for Forecasting Wind Waves and Swell"), it should be expected that a certain wave height will be associated with a certain period. This relationship would change with different wind speeds. In Figs. 4(**a**) to 4(d) the curve showing this relationship has also been marked. In the range of wind speeds 13-17 kts, the maximum frequencies more or less lie along the curve. In the range 18-22 kts, the maximum frequencies still lie close to the curve, but with shift towards lower heights. This shift becomes more

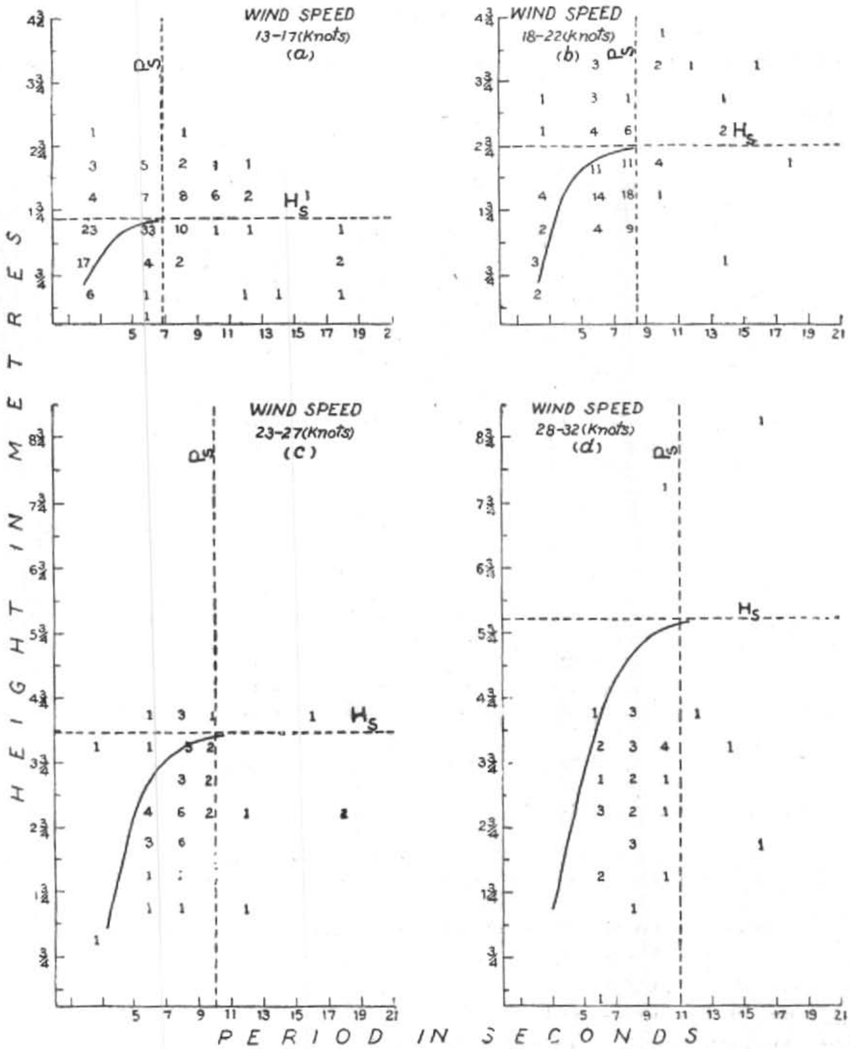

Fig. 4. Frequencies of wave-heights associated with different periods

noticeable in the ranges 23-27 ad 28-32 kts. In both these ranges, the heights deviate more from the curve than the periods. The percentage of cases of heights greater than the curve are more in lower speeds.

The greater heights may be the effect of stronger winds earlier. The heights lower than the curve may be due to winds having strengthened recently, the duration of the stronger wind not being sufficient to build up the wave to the maximum height appropriate to it.

The above observations are generally true for the other months as well, except that in the non-southwest monsoon months, there are very few cases in the higher wind speed ranges. Also, in association with any wind speed, the average height and period are greater during the southwest monsoon months. This will be seen from Table 1 and

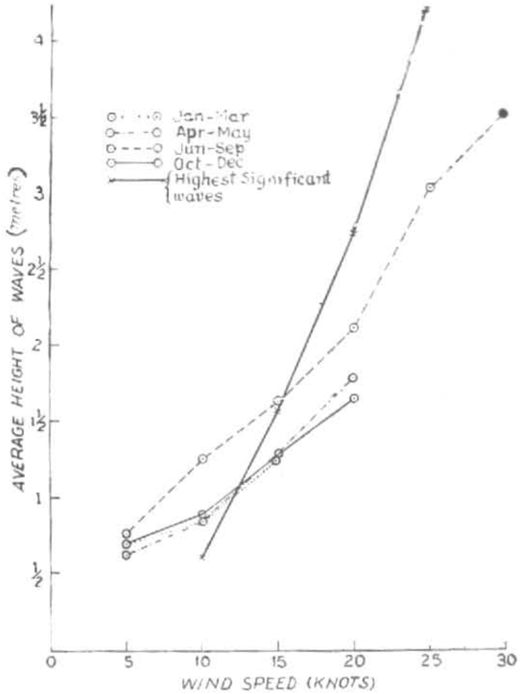

Fig. 5. Variation of wave-height with wind speed in different seasons

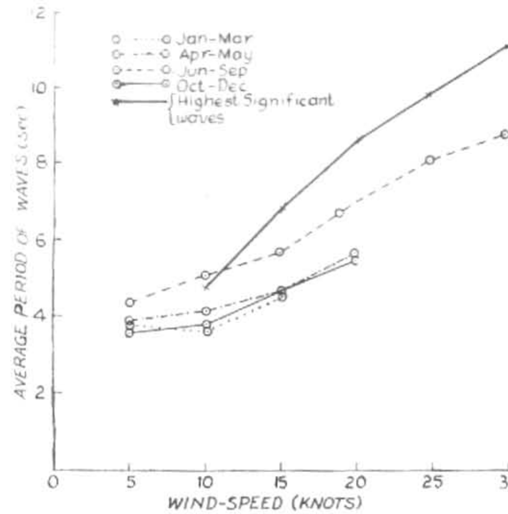

Fig. 6. Variation of wave-period with wind speed in different seasons

Figs. 5 and 6. In these figures, the average heights and periods for the four seasons of the year are shown. It will be seen that during June to September the heights and periods are distinctly higher than during the other seasons when they differ very little from one to another.

Winds are generally stronger and steadier during southwest monsoon period. For the waves to build up to greater heights and periods, the wind should blow for a sufficient time over a sufficient area (fetch). These conditions prevail more during the southwest monsoon. The contribution of earlier stronger winds would be also more frequent in this season.

It is interesting to note that in Fig. 5, the average height of waves observed with a wind speed of 10 kts is greater in all the seasons of the year than the highest significant waves, and the difference becomes more in the southwest monsoon period. For wind speed of 15 kts, the average height during monsoon equals the highest significant waves, but in other seasons, the average is less. For still higher wind speeds, the average height is always less than the highest significant waves. While the higher average height of waves with winds of 10 kts may be due in part to the effect of swell, it is doubtful whether this can explain fully the observed difference in the non-monsoon months, particularly since observers are likely to underestimate the height of low waves.

5. Acknowledgement

I would like to thank Dr. B. N. Desai for his guidance in the course of this work. I am also extremely grateful to Mr. Y. P. Rao for valuable discussions.

REFERENCE

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