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Waves in the Arabian Sea and the Bay of Bengal during the monsoon season

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सार — 1973 के इसमेक्स (भारत-रूस मानसून प्रयोग) और 1977 के मानसून प्रयोग की अवधि में रूसी अनुसंधान जलपोतों से हिन्द महासागर में लिए गए तरंगों के आंकड़ों का विश्लेषण किया गया । पता चला कि दी हुई पवन गति के लिए तरंगों की ऊँचाई आमतौर पर समान रहती है और उनमें विखराव बहुत कम होता है । ऐसा शायद इसलिए होता है क्योंकि मानसून ऋतु में पवन में काफी स्थिरता होती है और तरंग परास भी काफी बड़ा होता है । अत: पवन चाल और विशिष्ट तरंग ऊँचाई में एक आनुभविक संबंध स्थापित किया गया है ।

इस संबंध की जांच मॉनेक्स 1979 की अवधि में रूसी अनुसंधान जलपोतों से लिए गए आंकड़ों से की गई । पवन गति के आधार पर परिकलित तरंग ऊँचाइयां अपने वास्तविक प्रेक्षित मानों के पर्याप्त निकट पाई गई ।

ABSTRACT. The wave data recorded over the Indian seas by the Russian research vessels during the ISMEX (Indo-Soviet Monsoon Experiment) of 1973 and the Monsoon Experiment of 1977 are analysed. It is found that for given wind speeds, wave heights remain practically the same, the scattering being quite small. This is probably because during the monsoon season, the steadiness of the wind is quite high and the fetch is quite large. An empirical relationship is obtained between the wind-speed and characteristic wave height.

The relationship has been verified with the data of the Russian research vessels during Monex 1979. The wave heights computed from the reported windspeeds compare quite favourably with the observed values.

1. Introduction

Wave characteristics in the open sea like wave-height and wave period depend upon the strength of the wind, its fetch and duration. Curves connecting these parameters have been constructed by different workers and empirical relationships obtained on the basis of observational data.

There are, however, differences in the various sets of curves developed by different authorities, particularly regarding the fetch required for development of waves of maximum size. For example, Darbyshire (1952) considers that a fetch of about 100 miles is sufficient to develop waves to their maximum size. On the other hand, according to Bretschneider (1952), the fetch has to increase to 1000 miles for full development of waves when the wind speed is above 25 knots.

2. Difficulties over the Indian seas

A number of difficulties are encountered in evaluating relationships between these parameters over the Indian seas. The observers find it difficult to separate the "sea waves" from the "swell waves", particularly during the monsoon season, when both are coming from the same direction. This difficulty has been felt in other countries also and wave analysis is done, not on the basis of reported wave heights but on heights estimated from observed wind field, utilising the empirical relationships. The wind field has to be analysed to a high degree of accuracy, since a 10% error in the wind speed causes 20% error in the estimated wave height. Paucity of observations is a great handicap. In the middle and higher latitudes, geostrophic and gradient wind relationships are used to ensure that there is mutual consistency between the pressure and wind fields. However, these relationships break down at low latitudes.

3. Data studied

Special efforts were made during the Indo-Soviet Monsoon Experiment (ISMEX) of 1973 and the Monsoon Experiment of 1977 to obtain as many ships' reports as possible from the Indian seas. Four Russian research vessels took part in the observational programmes of each of the above periods. It was felt that the wind field could be analysed accurately over the Arabian Sea and the Bay of Bengal during these periods and the wave observations of the Russian research vessels could be used to derive empirical relationships between wave characteristics and wind speed, its fetch and duration.

TABLE 1

Wind speed (mps)	No. of obsns. (n)	Mean reported wave height (m)	Standard deviation (m)	Computed wave height (m)
1	40	0	0	
2	97	0.02	0	
3	112	0.1	0.23	0.3
4	186	0.4	0.22	0.4
5	202	0.6	0.20	0.6
6	217	0.7	0.25	0.7
7	316	1.0	0.13	0.9
8	321	1.2	0.25	1.1
9	325	1.4	0.25	1.4
10	357	1.6	0.29	1.7
11	286	2.0	0.26	2.0
12	253	2.2	0.30	2.3
13	169	2.7	0.35	2.7
14	184	3.1	0.39	3.1
15	175	3.5	0.47	3.5
16	121	3.9	0.61	3.9
17	90	4.5	0.80	4.4
18	123	4.9	0.91	4.9
19	62	5.5	0.93	5.5
20	13	6.0	0.55	6.0
21	4	6.1	0.65	
25				9.2
30				13.2
35				17.8
40				23.2
45				29.3
50				36.0

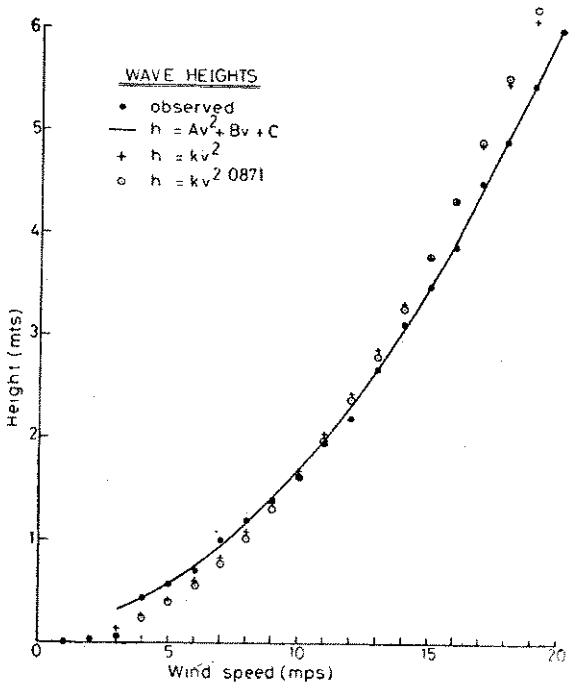

Fig. 1

An examination of the observations of the wind speeds and the corresponding wave heights showed that for given wind speeds, the observed wave heights were nearly the same, scattering being small. The relationship between them is studied in this paper. The effect of fetch and duration will be dealt with later.

4. Results

The Russian vessels reported wind speed correct to one metre per sec and wave height correct to half a metre. Table 1 gives the mean wave height and standard deviation for different speeds along with the number of observations.

It will be seen that the mean wave height increases with wind speed, slowly initially and more rapidly later. The standard deviation is quite small, about 0.2 to 0.3 m upto about 12 mps, about 0.5 m from 13 to 16 mps, and about 0.8 m from 17 to 20 mps.

As a first approximation, it is possible to specify a unique value of the characteristic height of the wave correct to 0.5m, from a knowledge of the wind speed alone, over the Arabian Sea and the Bay of Bengal during the monsoon season, for wind speeds less than 13 mps. Even for higher speeds normally available, (upto 20 mps) most of the observed heights lie within a metre. This is probably because during the monsoon season, the steadiness of the wind is quite high.

A reference to the graphs presented in the World Meteorological Organisation Publication No. 446 (1976), "*Handbook on Wave Analysis and Forecasting*" shows that the wave heights given by the study are such that the limiting value of the wind duration increases from 6 to 11 hours and that of the fetch increases from 50 to 200 km as the wind speed increases from 7.5 to 20 mps. According to Bretschneider, the corresponding values are 8 to 14 hours and 45 to 180 nautical miles.

The mean observed values of the wave heights have been plotted against corresponding speeds (Fig. 1). It may be seen that a smooth curve can be drawn through all points except those corresponding to wave heights less than 0.5 metre. The laws governing the generation of waves at low wind speeds may be different from those governing the generation at moderate and high speeds. Different authors have proposed critical wind speeds from 20 cm per sec to 790 cm per sec. Keeping this in view and also the fact that the number of observations for wind speed of 20 mps and above are few, a second degree curve has been fitted utilising only the wave heights corresponding to wind speeds from 3 to 19 mps. The relationship is found to be $H = 0.17 + 0.87 \times 10^{-2} \times V + 1.4167 \times 10^{-2} V^2$ where H is the characteristic wave height in metres and V the wind speed in metres per second.

A comparison of the observed wave heights with those computed from the above equation (Table 1)

TABLE 2

Wind speed (mps)	Wave height computed (m)	Total no. of obsns.	Frequencies of wave height (m)* 0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	Mean wave height(m) observed
3	0.3	36	17 (47)	19 (53)							0.3
4	0.4	49		46 (94)	3 (6)						0.5
5	0.6	61		46 (75)	15 (25)						0.6
6	0.7	42		8 (19)	30 (71)	4 (10)					1.0
7	0.9	49		1 (2)	37 (76)	11 (22)					1.1
8	1.1	54			17 (32)	31 (57)	6 (11)				1.4
9	1.4	52			1 (2)	42 (81)	9 (17)				1.6
10	1.7	37				11 (30)	19 (51)	7 (19)			1.9
11	2.0	28					23 (82)	5 (18)			2.1
12	2.3	20					3 (15)	11 (55)	6 (30)		2.5
13	2.7	18					1 (6)	8 (44)	6 (33)	3 (17)	2.8

*Figure in brackets % frequencies

TABLE 3

Wind speed (mps)	Computed wave height (m)	Total No. of obsns.	Frequencies of wave height (m)* 1	2	3	4	5	6	Observed mean wave height (m)
10	1.7	321	85 (26)	231 (72)	5 (2)				1.8
11	2.0	240	5 (2)	222 (93)	13 (5)				2.0
12	2.3	167		131 (78)	36 (22)				2.2
13	2.7	92		18 (20)	70 (76)	4 (4)			2.8
14	3.1	58		9 (15)	38 (66)	11 (19)			3.0
15	3.5	31			6 (19)	25 (81)			3.8
16	3.9	38			12 (32)	26 (68)			3.7
17	4.4	18			6 (33)	5 (28)	4 (22)	3 (17)	4.2

*Figure in brackets % frequencies

reveals that the parabolic relation fitted to the observed data is a very good representation of the data set.

Approximate formulae have been given for heights of waves in terms of wind speeds by various workers in the form $H = K \times V^a$ where K and a are constants. 'a' has been taken to be 2 to 2.5. Bretschneider (1957) has examined the various formulae and has favoured the square formula. Data of the Russian ships over the Indian seas during the monsoon season (during the ISMEX' 73 and Monsoon' 77 experiments), give the value 2.0877 to the power 'a' for best fit. This formula gives a root mean square deviaton of about 0.35 m from the observed values as against the root mean square deviation slightly less than 0.1 m for the quadratic expression with all the terms. The latter appears to be applicable for wind speeds greater than 3 mps. This is probably because the waves generated for wind speeds of 3 mps and below are of different type from those for higher wind speeds, the restoring force being surface tension for low wind speeds and gravity for higher speeds.

5. Verification with Monex 1979 data

The validity of the formula derived in 4 above has been tested with the observations made by the Russian research vessels during Monex 1979. Unfortunately, in the print-outs supplied by the International Monex Management Centre (IMMC), New Delhi, wave-heights are given correct to a metre only. Hence, verification for wind speeds equal to or less than 13 mps has been done from the observations available in the *Indian Daily Weather Report* of the India Meteorological Department where wave heights in the coded messages are correct to 0.5 m. Results of the verification are given in Table 2. The table shows, for each wind speed, the total number of observations, actual and percentage frequencies of waves of different heights and the mean wave heights for each wind speed on the basis of the 1979 Monex sample data as well as those computed on the basis of the empirical formula derived from the ISMEX - 1973 and Monsoon-1977 data. The mean wave heights of the sample generally lie within ± 0.2 m of the values given by the formula and nearly 90% of the observed values lie within 0.5 m of the computed values.

Table 3 gives results of verification for wind speeds, 10 mps or more, taking all available observations from the computer read-out, provided by the IMMC. It will be seen from the table that the mean wave height for different wave speeds agree within ± 0.2 m of the computed values. It is also noticed that the individual values are within ± 0.5 m of computed value on 70 to 80% of the occasions and rarely exceed 1 m.

It may therefore be concluded that the empirical relationship developed in this paper can be used for wave forecasting in Indian seas during the southwest monsoon period.

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