

## ANALYSIS OF WAVES OFF UMBERGAON - WEST COAST OF INDIA

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### ABSTRACT

Waves measured off UMBERGAON on the west coast of India using the Datawell Waverider buoy are analysed and the results presented. The computed wave height parameters are found to follow the theoretical Rayleigh distribution relationship derived by Longuet-Higgins (1952). The scatter diagram of significant wave height versus zero-crossing wave period shows that the highest waves are not associated with the longest periods. The steeper and higher waves are found to occur mostly in the monsoon period in the absence of severe cyclones which may occur in October-November. The percentage occurrence of wave height, period, spectral width and steepness have been presented in the paper and discussed.

### INTRODUCTION

National Institute of Oceanography, Goa undertook wave measurement programme off UMBERGAON on the west coast of India using Datawell Waverider buoy. This programme was sponsored by the Oil and Natural Gas Commission, Bombay Offshore Project, Bombay for its project on subsea gas pipeline from South Bassein to Umbhrat on the Gujarat coast. In November 1982, a cyclonic storm passed from south to north in the Arabian sea; the shortest distance of the cyclone track from the wave rider buoy location was about 350 km. The effect of the cyclone on waves could be clearly observed from the wave records obtained by means of wave rider buoy deployed off UMBERGAON. The results of the analysed wave data are presented in this paper.

### WAVE MEASUREMENT PROGRAMME

A 70 cm diameter Datawell waverider buoy was installed off UMBERGAON at a distance of 25 km from the shore. The waverider location is shown in Fig. 1. The vertical movements of the buoy were telemetered to the receiving and recording equipment installed in the light house at UMBERGAON. The Datawell waverider receiver (WAREP) recorded analog wave data of twenty minutes duration each on chart paper rolls at every three hour interval. Digital magnetic tape recorder (DIMA) interfaced to WAREP

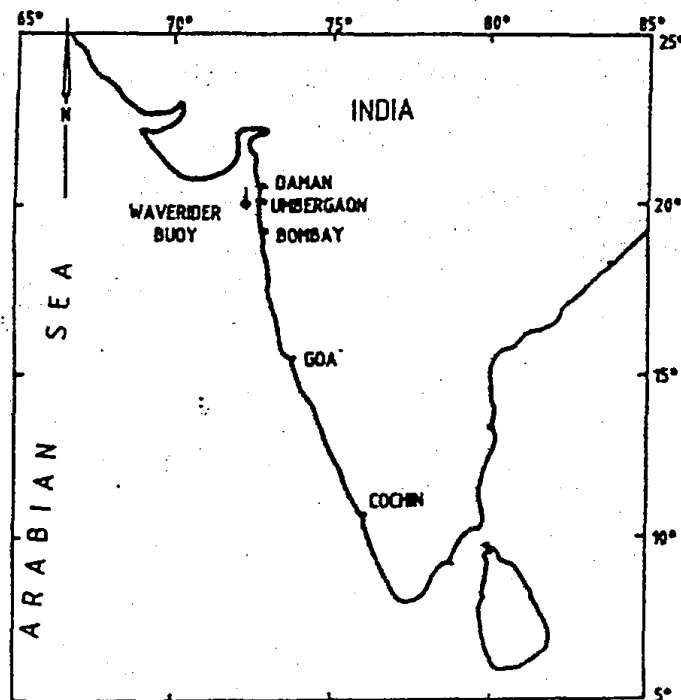


FIG. 1 LOCATION OF WAVERIDER BUOY

receiver in program mode recorded digitised data on cassettes for every 0.5 second interval. The quality of digital data was, however, not satisfactory due to serious interference of the radio and wireless signals coming from other sources. Analysis of the time series wave data contained on DIMA cassettes using the special software package called NEPTUN revealed that the digital data recorded were not satisfactory due to the above reasons.

Higher waves were found to occur as expected during the monsoon period (June to September) with highest waves occurring in July when the monsoon was very intense. Cyclones in the Arabian Sea generally occur in October or November and the Gujarat coast is more vulnerable to the attack of cyclones on the west coast. The sea state is generally calm during the non-monsoon period except for the short cyclonic periods. The wind blows from the west or the south-west during the monsoon and from the north-west during the non-monsoon period except during the cyclonic period when wind field may become very complex.

#### RESULTS AND INTERPRETATION OF WAVE DATA

Statistical wave parameters namely significant wave height ( $H_s$ ), root-mean-square wave height ( $H_{rms}$ ), average wave height ( $H_{mean}$ ), zero-crossing period ( $T_z$ ), spectral width ( $\sigma$ ) and steepness are computed using

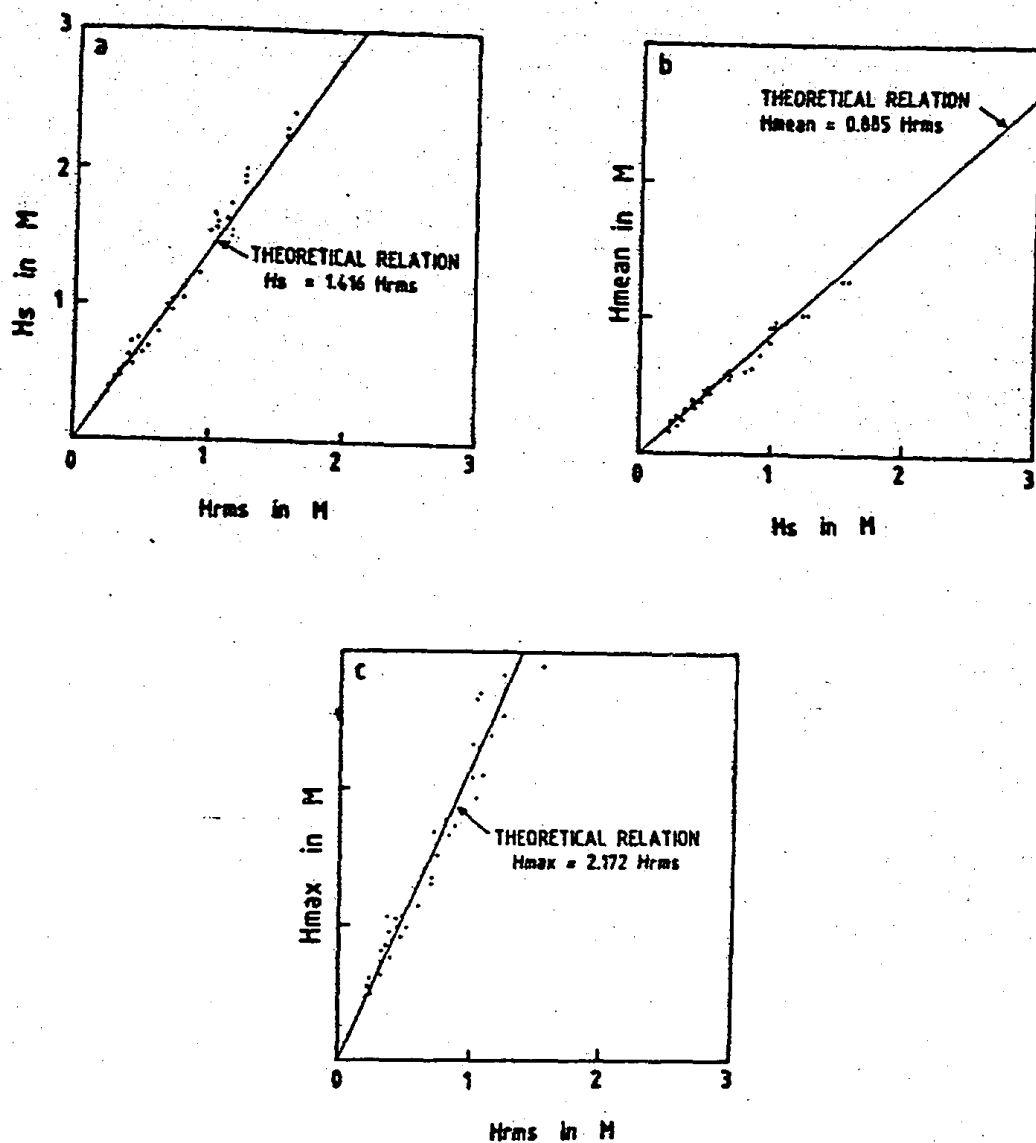


FIG.2 . WAVE HEIGHT RELATIONSHIPS

the Tucker's method (1963) and zero up-crossing method (Torsethaugen & Krogstad, 1979) for each three hourly wave record of 20 minute length.

#### Wave height distribution:

For best representation of wave height distribution, theoretical relationship for Rayleigh distribution, which is valid for narrow frequency band (Longuet-Higgins, 1952) can be compared with the observed data. This has been discussed by Colonell and Ferry (1968) and also by Dattatri (1973). Figure 2 shows the comparison of the computed wave height parameters with theoretical Rayleigh distribution relationship. Here the observed data are found to follow the theoretical relationship quite well.

Figure 3a shows the cumulative distribution of significant wave height ( $H_s$ ) and highest wave height ( $H_{max}$ ).  $H_s$  was found to exceed 1 m for 42% of the time and 2 m for only 7% of the time. Similarly  $H_{max}$  exceeded 1 m and 2 m for 62% and 32% of the time respectively.

Seasonal variations of wave heights are shown in figure 3b, where histograms showing percentage occurrence of  $H_s$  during monsoon (June-Sept) and non-monsoon periods are presented. Wave height,  $H_s$  varied between 1.0 and 2.5 m for most of the time in the monsoon period with highest significant wave height occurred being 3.5 m. In the non-monsoon period, the significant wave height  $H_s$  was found to be within 1 m except for the short cyclonic period in November during which  $H_s$  upto 4.75 m occurred. The effect of the cyclone at the wave rider station was apparently not that severe since the distance of the cyclone track was more than 350 km from the buoy station.

#### Period distribution:

Zero-crossing wave period distributions for both seasons are shown in figure 4. The predominant wave period was 6 to 7 sec during the monsoon period (43.5% of monsoon time). In the non-monsoon period,  $T_z$  was widely varying from 3 to 12 sec.

#### Spectral width parameter:

Spectral width parameters are defined by Tucker's ( $e_T$ ) and by spectral methods ( $e_s$ ) as follows:

$$e_T = \sqrt{1 - \frac{T_c^2}{T_z^2}} \quad \dots \quad 1$$

$$e_s = \sqrt{1 - \frac{m_2^2}{m_0 m_4}} \quad \dots \quad 2$$

where  $T_c$ ,  $T_z$  - wave crest period and zero-crossing wave period respectively.

$m_0$ ,  $m_2$ ,  $m_4$  - zeroth, second and fourth spectral moments respectively computed from spectral analysis.

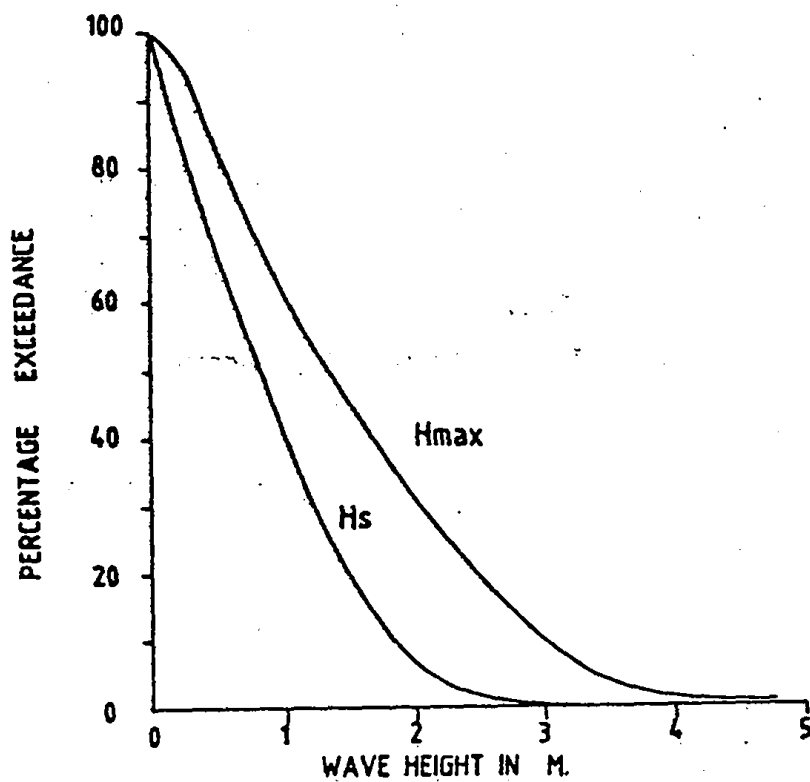


FIG. 3a CUMULATIVE DISTRIBUTION OF  $H_s$  AND  $H_{max}$

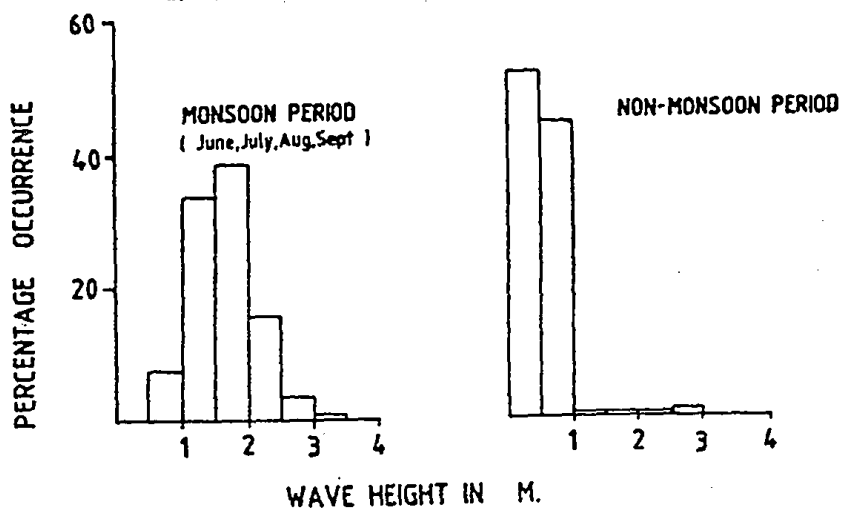


FIG. 3b FREQUENCY DISTRIBUTION OF  $H_s$

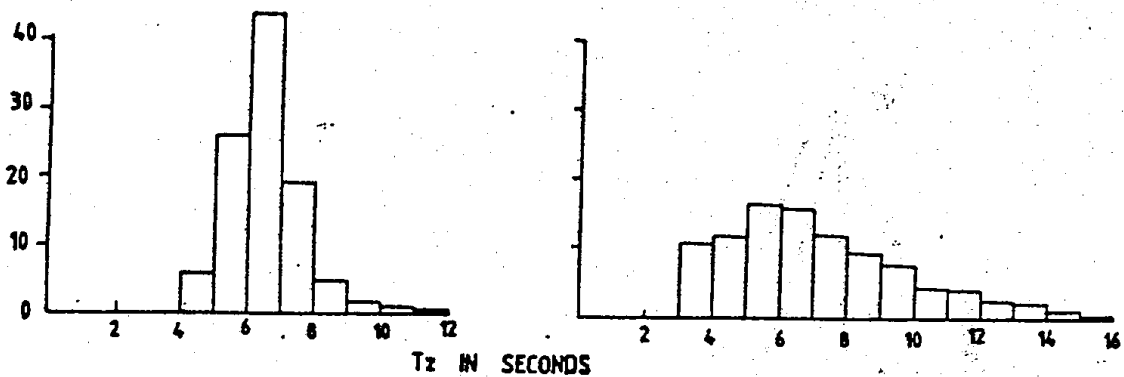


FIG. 4 DISTRIBUTION OF ZERO-CROSSING PERIOD

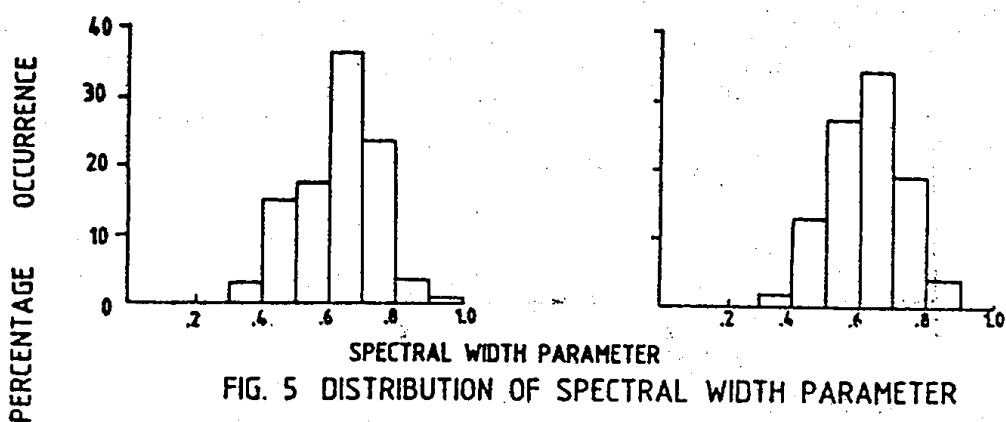


FIG. 5 DISTRIBUTION OF SPECTRAL WIDTH PARAMETER

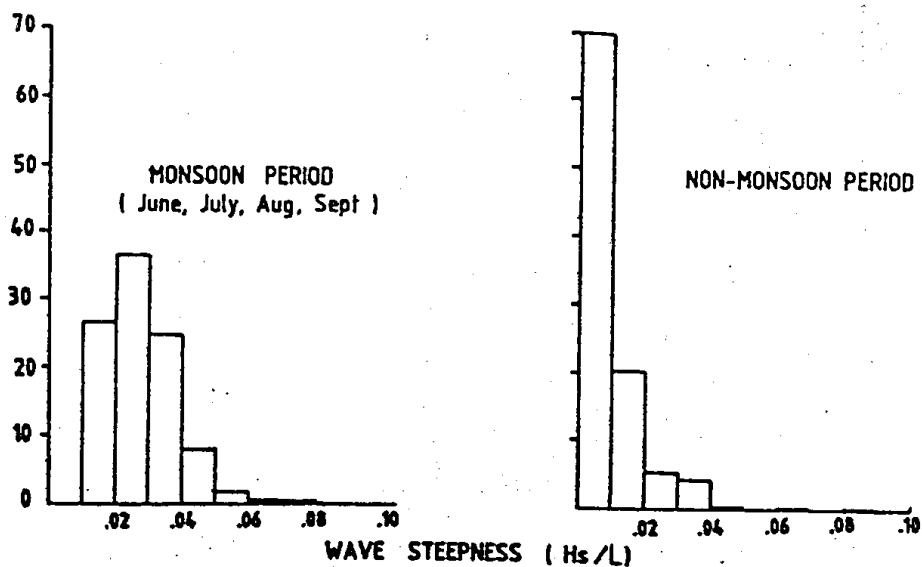


FIG. 6 STEEPNESS DISTRIBUTION

Table - I shows some computed values of  $\epsilon_T$  and  $\epsilon_S$ .  $T_C$  and  $T_2$  were obtained from Tucker's method and  $\epsilon_S$  was calculated by spectral method.

TABLE I: SOME COMPUTED VALUES OF  $\epsilon_T$  AND  $\epsilon_S$

Date	Time (hrs)	$\epsilon_T$	$\epsilon_S$
31- 8-82	1155	0.56	0.77
15- 9-82	0854	0.67	0.85
15- 9-82	2041	0.75	0.83
12-10-82	1557	0.73	0.88
12-10-82	1557	0.73	0.88
13-10-82	2350	0.60	0.85
14-10-86	0901	0.70	0.83

The distribution of the spectral width parameters is shown in figure 5. Here it is ranging widely from 0.40 to 0.90 indicating that the waves fall in a wide band rather than a narrow band. But the theoretical relationship of Rayleigh distribution is valid for the narrow frequency band. Eventhough, the spectral width is very high in the present case, the observed values still follow approximately the Rayleigh distribution relationship.

#### Steepness distribution:

The steepness of wave is expressed as

$$\text{Wave steepness} = H_s/L \quad \dots \quad 3$$

where,

$$L = \frac{gT^2}{2\pi} \tanh \frac{2\pi d}{L} \quad \dots \quad 4$$

$L$  = wave length for water depth  $d$ .

The wave steepness distribution is shown in figure 6. It is clearly shown that the higher waves have high steepnesses during the monsoon period, whereas non-monsoon waves have low steepnesses (less than 1/100).

#### Scatter diagram $H_s$ versus $T_2$ :

The scatter diagram presenting the joint distribution of  $H_s$  and  $T_2$  is shown in figure 7 for wave data covered over 7 months period. It is clearly seen that the monsoon waves are higher. The contours give the concentration of waves for the period of observation. Inner-most contour gives highest occurrence of waves with wave height 1.0 to 2.0 m and corresponding period 6-7 sec. From this diagram, it is observed that the highest waves are not associated with longest period confirming the result reported earlier by Battjes (1970). Based on the theoretical investigation on wave generations, the wave height increases with period at the initial stage and thereafter, at a certain stage, the wave height decreases eventhough period increases. As long as wave height increases it is

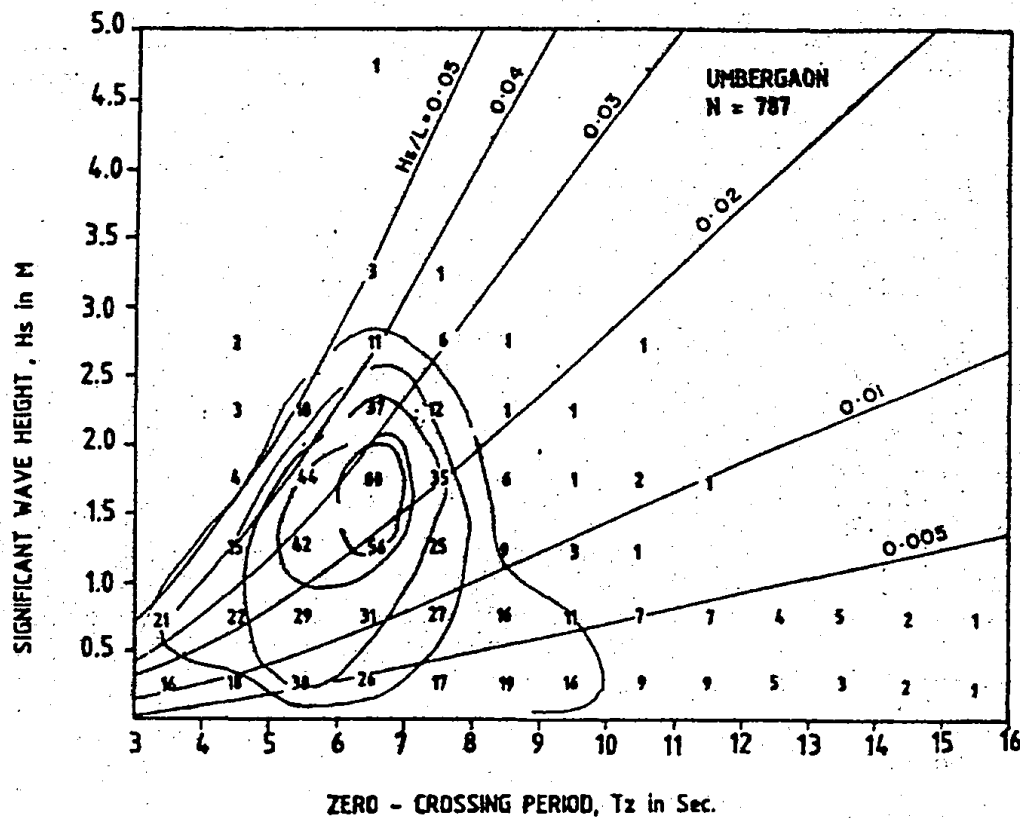


Fig.7 SCATTER DIAGRAM

growing wind-sea state. When the wave height starts decreasing, it is fully developed state and then a part of wind wave energy is being converted into swell energy. The non-monsoon wave periods are widely scattered ranging from 3 - 12 sec. It is however, difficult to highlight the predominant wave height and the associated period for the non-monsoon period. From the observations on the monsoon waves, predominant waves appear to have  $H_s = 1.75$  m and  $T_z = 6.5$  sec.

#### Wave spectra:

The study of the shape of the wave spectra is of great value in the analysis of offshore structures. Using the FFT techniques, the energy spectra are obtained by a moving average of 8 raw spectral estimates. A few typical wave spectra are shown in fig. 8 which indicates occurrence of multi peaked spectra during the measurement period. Similar observations have also been made by Harish and Baba (1986) for the Kerala coast. The highest peak frequency varies from 0.06 to 0.15  $H_z$ .

#### CONCLUSIONS

From the wave observation and interpretation of the results, the following points may be concluded.



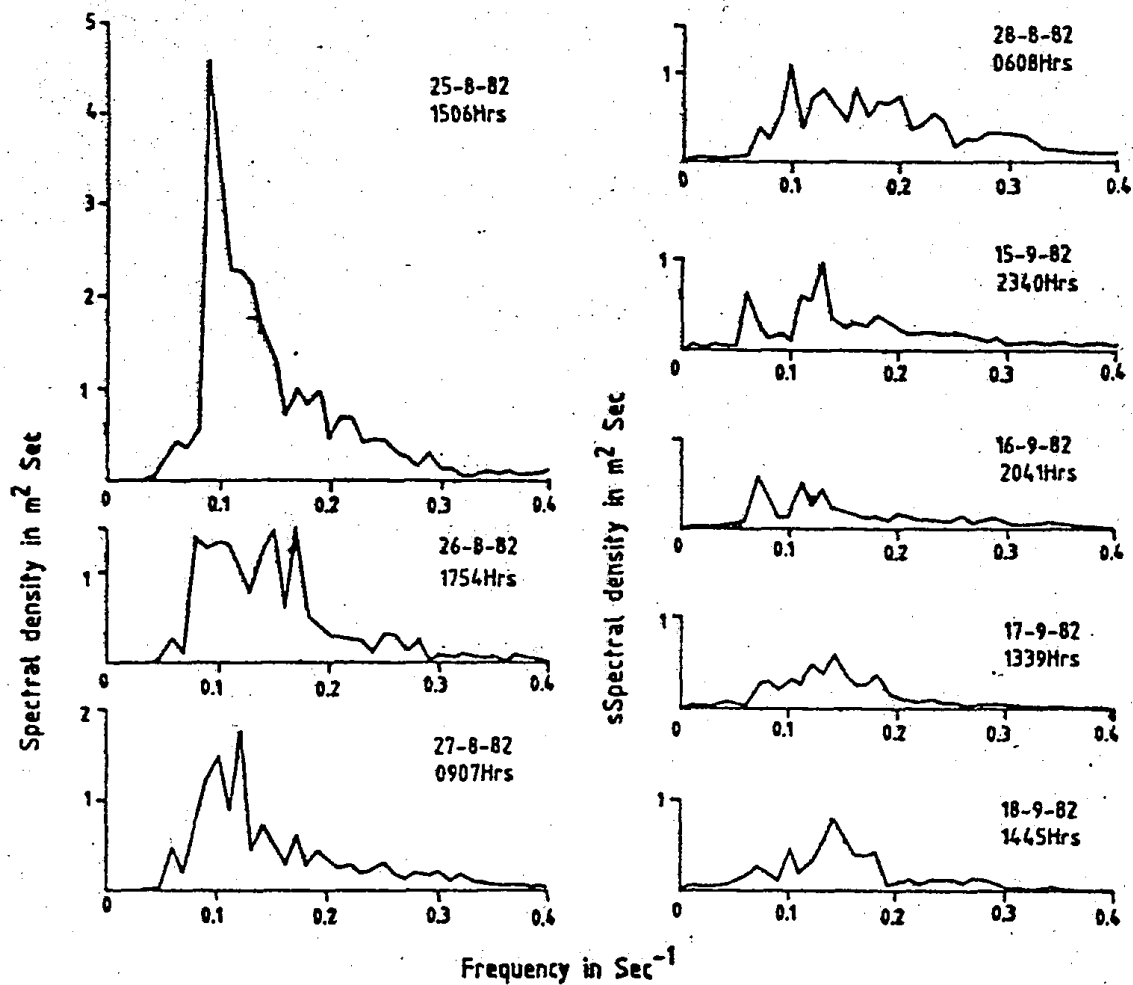


Fig. 8 OBSERVED WAVE SPECTRA OFF UMBERGAON

1. The observed wave height distributions closely follow a Rayleigh distribution relationship derived by Longuet-Higgins (1952).
2. The higher and steeper waves occur mostly in the monsoon period. Higher and steeper waves can also be observed during the occurrence of a severe cyclone as that occurred in November '82 off Gujarat coast. In general, in the absence of cyclones, the non-monsoon period is dominated by a relatively calm sea-state.
3. The highest observed waves are not associated with longest periods which confirms the similar observations made by Battjes (1970).
4. The spectral width parameters are widely varying (0.40 to 0.90), that is, the waves observed do not fall into a narrow frequency band.
5. The steepest observed waves during the monsoon period had the steepness of about 1 : 11.

#### ACKNOWLEDGEMENT

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