

SPECTRAL ANALYSIS OF CYCLONE WAVES OFF DAMAN, INDIA

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ABSTRACT

A Datawell waverider buoy installed at 27 m water depth off Daman successfully recorded the waves during November 1982 cyclone. During 7 - 10th November 1982, 34 sets of wave data of each 20 minutes duration recorded at every 1½ hours were analysed to obtain spectra. For better understanding of the stages of growth and decay of the sea-state, wave spectra were computed for all the wave records. It was observed from the results of analysis that the peak frequencies of spectra at the wave decaying stage are in general higher than those corresponding to the wave growth stage for approximately the same significant wave height. This indicates that the wave energy is dominant in longer wave-lengths for growing stage of the cyclone waves. The observed spectra were also compared with various theoretical spectra. The Scott spectra generally yielded a better fit, whereas at the peak frequency region, however, the JONSWAP spectra fitted well.

INTRODUCTION

For planning, designing and constructing of an ocean structure it is very important to have an accurate evaluation of the wave climate at the site. Wave activity has been found to be severe along the west coast of India during the monsoon period (June to September). Worst wave conditions however, may occur during the occurrence of severe cyclones. Waves observed during cyclones are generally higher and steeper, thereby causing severe loading conditions on the structures in the region. Therefore, from the safety point of view, wave data measured during the cyclonic storm are of vital importance and are of very great value in the engineering designs of the nearshore as well as offshore structures.

Wave measurements were undertaken off Daman on the west coast of India by the Ocean Engineering Division of the National Institute of Oceanography, Goa under the sponsorship of the Oil and Natural Gas Commission, Bombay Offshore Project, Bombay. During the course of measurement, a severe cyclone occurred in the Arabian Sea in November 1982 moved towards the coast of Gujarat with the landfall point occurring near Veraval. High

waves generated due to cyclonic storm were recorded throughout cyclonic period at the wave rider station off Daman.

This paper presents the results of the spectral analysis on waves carried out on wave records pertaining to the cyclonic period. For better understanding of the waves generated due to cyclones, the variation of wave spectra during the stages of growth and decay of the cyclone has been studied. The measured spectral estimates were compared with the various theoretical spectral formulations.

WAVE OBSERVATION DURING THE CYCLONE

A cyclonic storm occurred in the Arabian Sea during 7 - 10th November, 1982 and hit the coast of Gujarat between Veraval and Diu with a wind speed varying from 170 to 180 km/hour on 8th November, 1982 as shown in Fig. 1. A Dutch Datawell waverider buoy was deployed off Daman at a

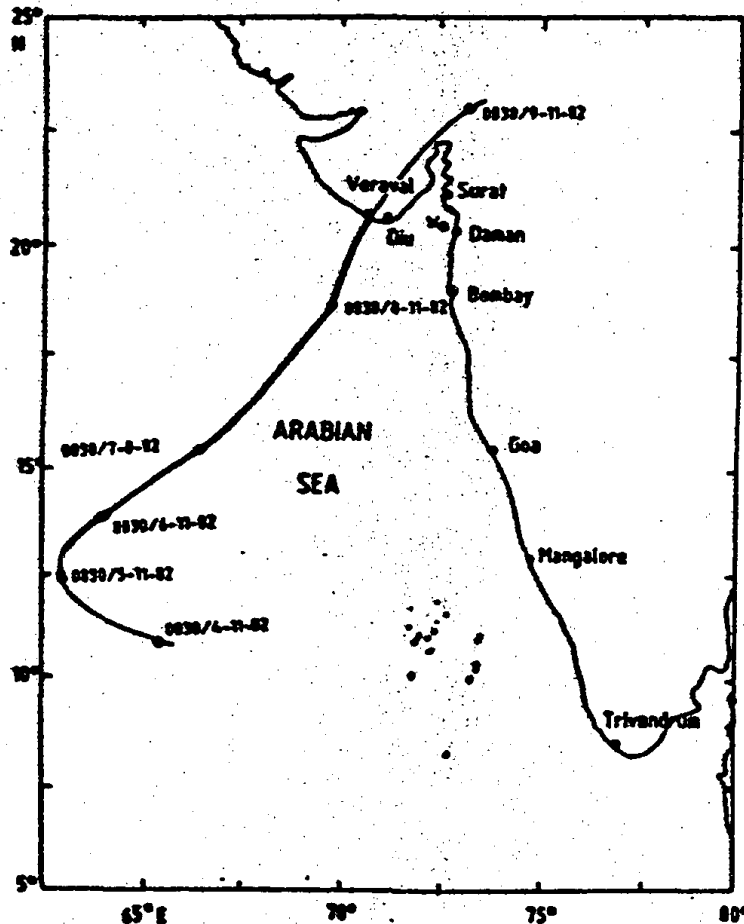


FIG 1 CYCLONE TRACK

water depth of 27 meters and the shortest distance of the buoy from the track of the cyclone was about 200 km. Time series data on waves were collected at 1½ hourly intervals for a duration of 20 minutes each. Data were telemetered to the shore station in Daman at a distance of 18 km from the buoy. The telemetered data were received by WAREP Mark II receiver/recorder system with a programmable strip chart recorder. A digital magnetic tape recorder (DIMA) was interfaced with the WAREP unit wherein the analog signal from the WAREP receiver was digitized at every 0.5 second interval and recorded on a digital cassette.

The highest maximum wave height H_{max} and the highest significant wave height H_s measured during the cyclone were 8.15 m and 5.41 m respectively. This occurred on 8 November 1982 evening at about 1601 hrs.

THEORETICAL SPECTRA

There are various mathematical formulations of theoretical wave spectra available. Most common spectra used here are:

(a) Pierson-Moskowitz spectrum

The one-parameter Pierson-Moskowitz spectrum (1964) is

$$E(f) = 0.0081g^2 (2\pi)^{-4} f^{-5} \text{Exp}(-1.25f_m^4/f^4)$$

where, E is the energy density in $M^2\text{-sec}$
 g is the gravitational acceleration ($9.81\pi/\text{sec}^2$)
 f is the frequency in H_z
 f_m is the peak frequency in H_z

(b) JONSWAP spectrum

The five-parameter JONSWAP (Hasselmann et al; 1973) spectrum is based on the measurement of wind generated waves during Joint North Sea Project, 1968-1969. It can be written as

$$E(f) = \alpha g^2 (2\pi)^{-4} f^{-5} \text{Exp}(-1.25f_m^4/f^4) \gamma \text{Exp}(-(f-f_m)^2 / (2\sigma^2 f_m^2))$$

where, α is the Phillip's constant
 γ is the ratio of spectral energy to the maximum of the corresponding Pierson-Moskowitz spectrum, called peak enhancement factor.
 σ is the width of the spectral peak
 $\sigma = \sigma_a$ for $f \leq f_m$
 $\sigma = \sigma_b$ for $f > f_m$

(c) Scott spectrum

The two-parameter Scott spectrum (1965) based on the extensive measurement of wave data using a ship borne wave recorder can be expressed as

$$E(f) = 0.428 \pi H_s^2 \text{Exp} \left[-\frac{\sqrt{4\pi^2(f-f_m)^2}}{0.065(2\pi(f-f_m)+0.26)} \right]$$

where, H_s is the significant wave height in meters.

(d) Bretschneider spectrum

The two-parameter Bretschneider spectrum (1959) is written as

$$E(f) = 5H_s^2 / (16f_m^6 / f^5 / \text{Exp}(-1.25f_m^4 / f^4))$$

RESULTS AND DISCUSSIONS

The variation of significant wave heights during different stages of the cyclone are compared with the radial distance of the eye of cyclone from the wave rider station as shown in fig. 2. It indicates that there

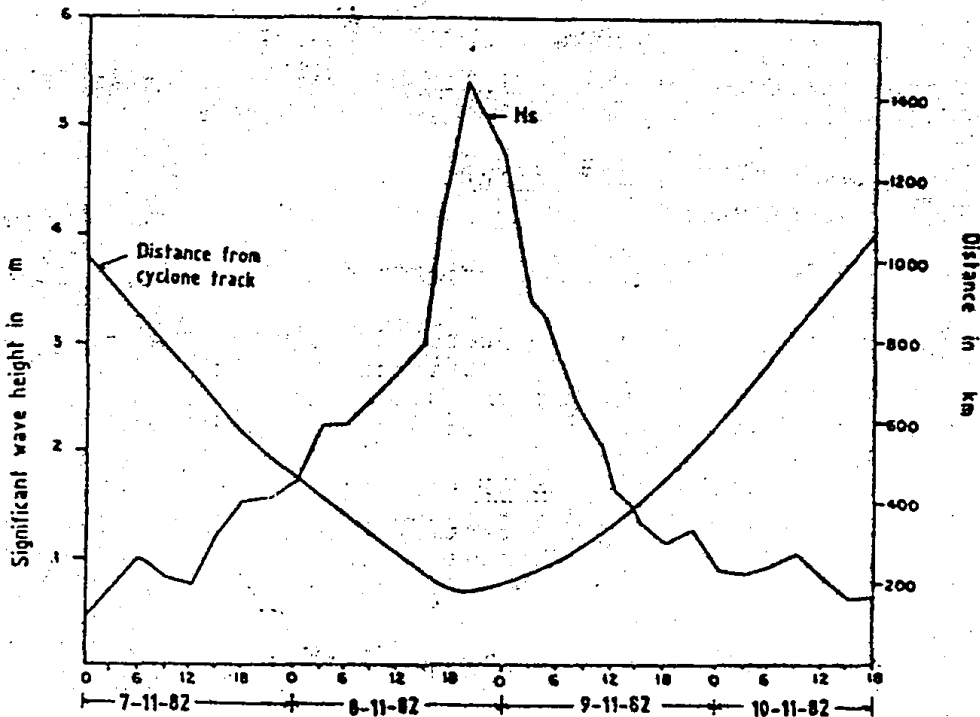


FIG. 2 VARIATION OF SIGNIFICANT WAVE HEIGHT AND RADIAL DISTANCE WITH TIME.

was a rapid decrease in the significant wave height during the wave decay stage whereas the increase in wave height during the growing stage, however, was relatively slower. In order to present the overall picture of the growth and decaying state of waves due to the cyclone, contour lines of spectral energy densities were drawn from 34 sets of wave records in the form of frequency-time plot of wave spectra as shown in fig. 3. Each contour in the figure represents spectral density of a certain level and inner portions of the enclosed contours correspond to higher spectral densities. The most severe sea state in which highest significant wave height obtained represents the innermost contour line. In general, the frequency-time plot of wave spectra would be useful in illustrating characteristics

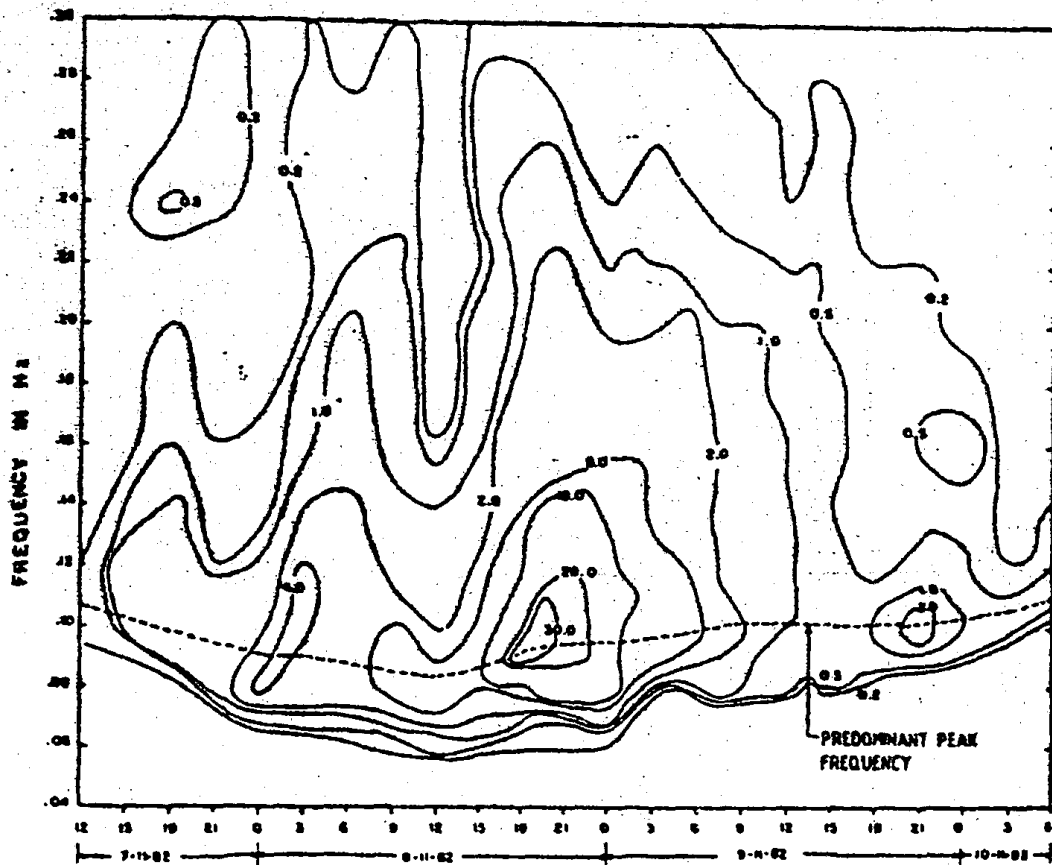


FIG. 3 CONTOURS OF SPECTRAL DENSITY

of swell and locally generated waves (the sea) it was not possible to use figure 3 to identify the swell and the sea characteristics probably because the cyclone track was quite far away from the wave rider station and waves at this station were quite complex due to interference of different wave trains coming from different directions. The maximum energy density measured was $33.72 \text{ m}^2\text{-sec}$ at peak frequency of 0.0898 Hz .

The temporal variation of spectral width, zeroth spectral moment etc. due to the effect of cyclone have been presented in table I.

The spectra obtained during the growth and the decay of the cyclone for the sea state of approximately same significant wave height were compared. It is observed that the peak frequency during the wave decaying stage is larger than that observed for the wave growing stage for a given significant wave height. As an example, figure 4 shows a comparison of wave spectra for the sea state with significant wave height of 1.60 m . This indicates that the wave energy is distributed in larger wave-lengths for the wave growth stage when compared to that occurring in the wave decaying stage.

TABLE-I: VARIATION OF WAVE SPECTRAL PARAMETERS DURING CYCLONE

Record No	Date	Time (IST)	Period of spectral peak T_p (Sec)	Spectral energy density at T_p ($m^2\text{-sec}$)	Spectral peakedness parameter Q_p	Spectral width parameter ϵ	Zereth spectral moment m_0 (m^2)
1	7-11-82	0009	3.66	0.08	1.77	0.87	0.011
5	"	1202	9.48	0.98	4.22	0.83	0.029
9	8-11-82	0009	12.34	4.15	1.87	0.84	0.157
11	"	0612	10.56	2.69	1.43	0.81	0.271
14	"	1456	11.01	9.78	2.53	0.80	0.488
15	"	1636	11.51	15.13	1.85	0.83	0.910
16	"	1801	11.13	33.72	1.92	0.82	1.150
17	"	1928	9.06	33.25	1.98	0.80	1.551
18	9-11-82	0007	10.78	17.48	1.81	0.77	1.155
22	"	0734	8.61	4.14	1.88	0.77	0.319
24	"	1206	5.75	1.78	1.65	0.77	0.159
27	"	1756	8.00	1.00	1.91	0.63	0.074
29	10-11-82	0307	8.46	0.53	1.22	0.52	0.042
32	"	1224	6.67	0.52	1.51	0.45	0.040

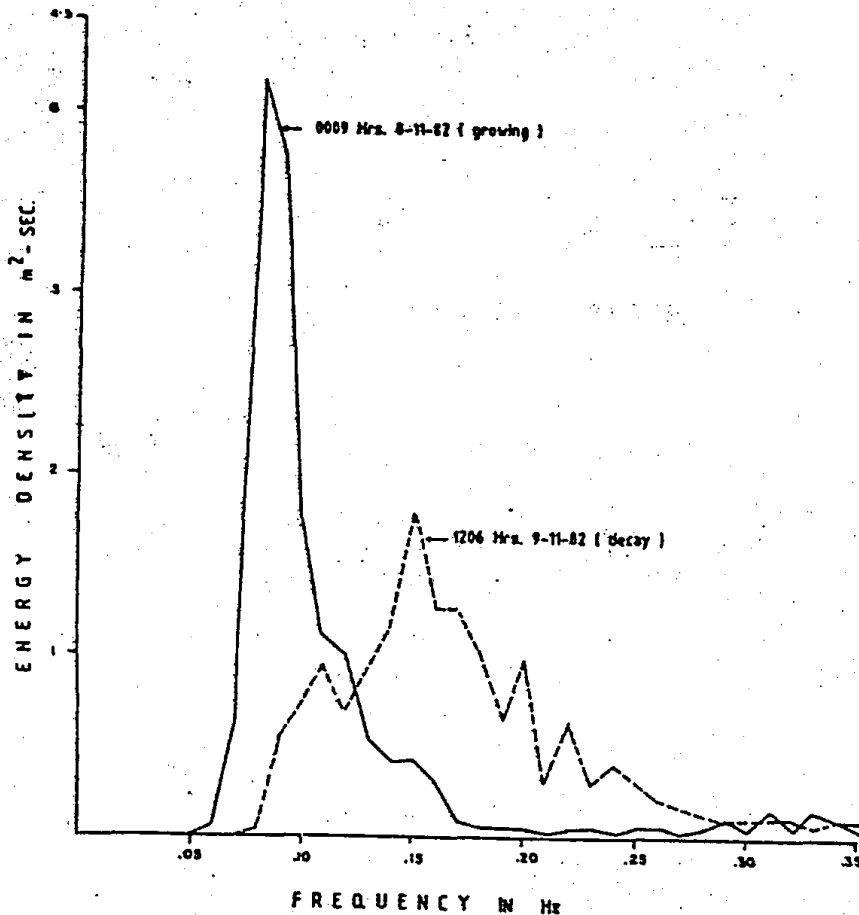


FIG. 4 WAVE SPECTRA OBTAINED IN THE GROWING AND DECAYING STAGES OF THE CYCLONE FOR $H_s = 1.60m$.

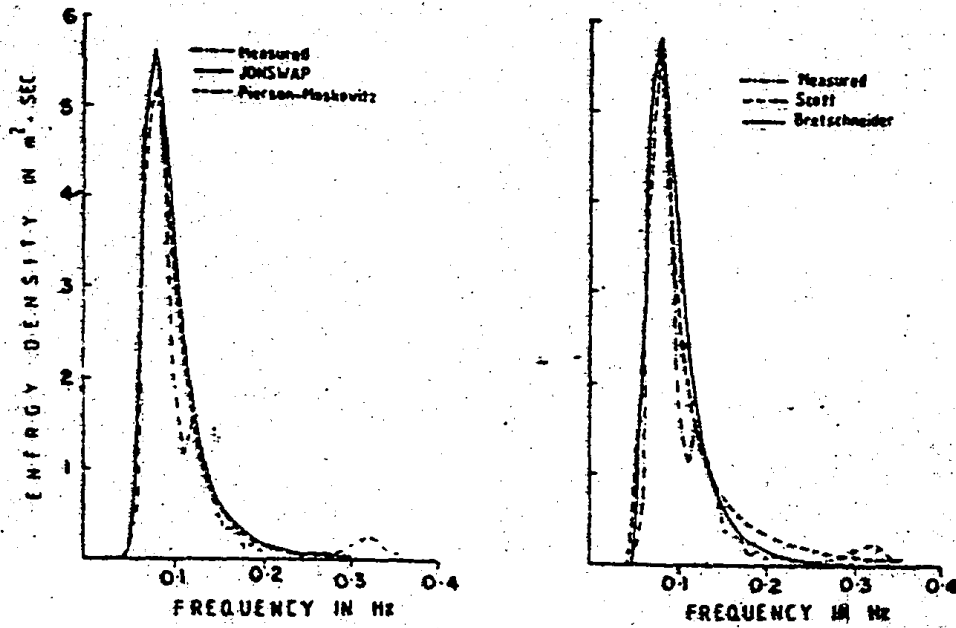


FIG. 5a COMPARISON BETWEEN MEASURED AND THEORETICAL SPECTRA ($H_s=2.23m$)

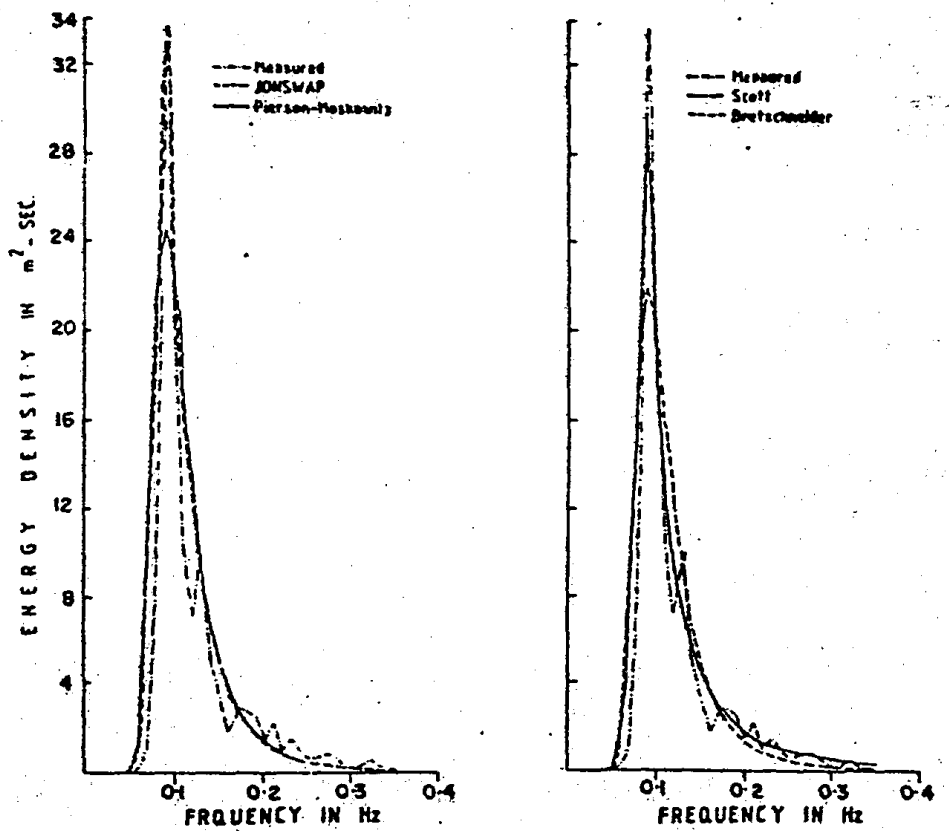


FIG. 5b COMPARISON BETWEEN MEASURED AND THEORETICAL SPECTRA ($H_s=4.67m$)

The measured spectra were compared with various theoretical spectra to see how best storm generated wave spectra can be described by various theoretical spectral formulations. The theoretical spectra used are one-parameter Pierson-Moskowitz (1964), two-parameter Scott (1965) and Bretschneider (1959), and five-parameter JONSWAP (1973). Theoretical spectra were obtained by fitting the measured spectra by the method of least squares as shown in figures 5a and 5b.

The results show that JONSWAP spectra represent the measured spectra very well at the peak frequency region whereas the Scott spectra is found to give the best fit based on the method of least squares.

CONCLUSIONS

The paper presents the results of the wave spectral analysis carried out on wave records measured off Daman on the west coast of India during the occurrence of a severe cyclonic storm in the Arabian Sea on 7-10 November, 1982. A comparatively rapid decrease in the significant wave height was observed for the wave decay stage whereas there was a relatively slow increase in the wave height for the wave growth stage.

It is also found that the peak frequencies for the wave growth stage is relatively lower than the peak frequencies occurring for the wave decay stage for a given significant wave height. This indicates that the wave energy is predominantly distributed in longer wave lengths for the wave growth stage when compared to the wave energy distribution for the wave decaying stage during the occurrence of a cyclone.

The shape of the measured spectra can be well represented by a two-parameter Scott spectra. The JONSWAP spectra, however, is found to yield a better fit for the peak frequency regions of the observed spectra.

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