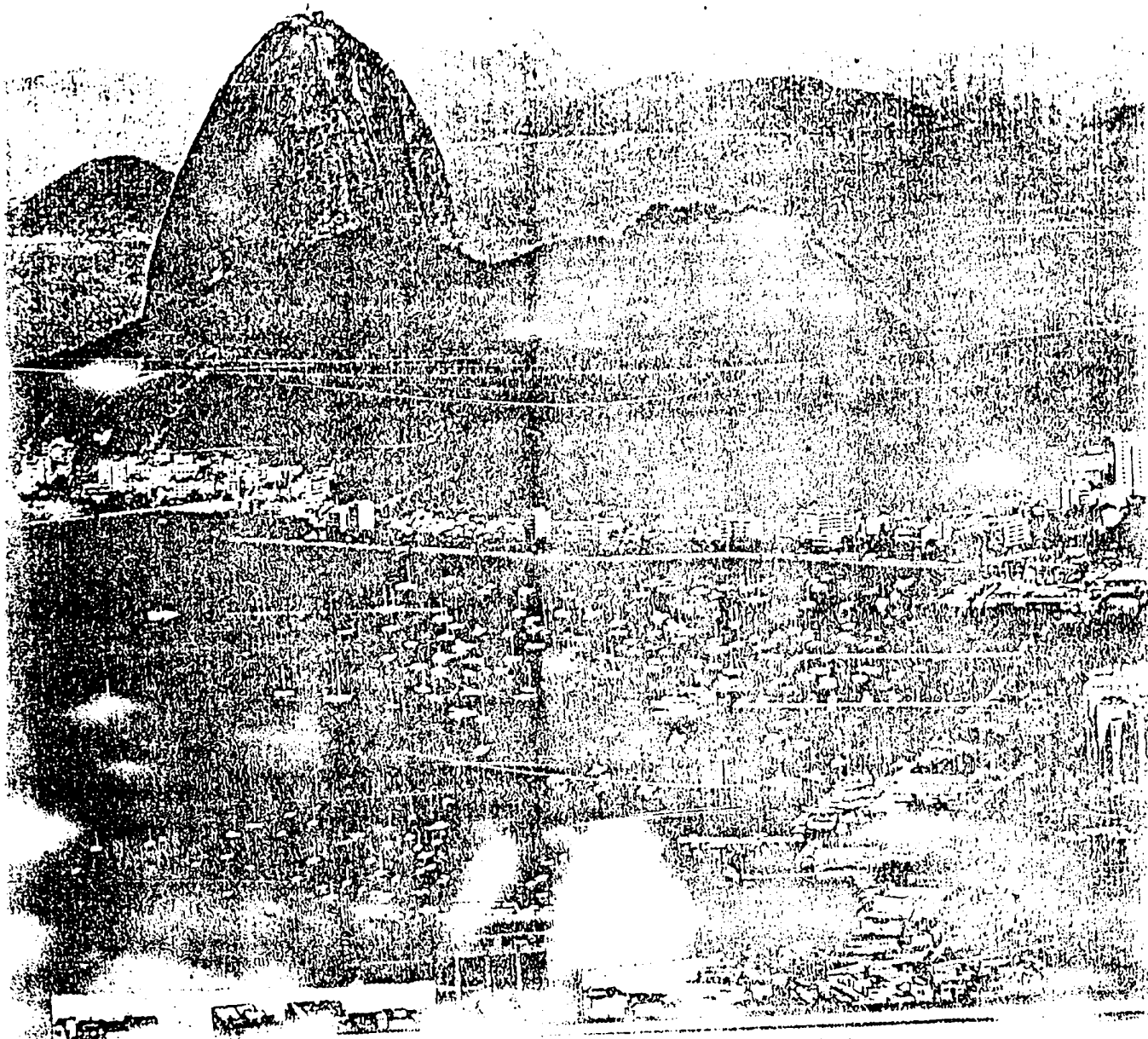


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**DIRECTIONAL WAVE MEASUREMENTS OFF NAVINAL, GULF OF KACHCHH,
INDIA**

By...

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ABSTRACT

Results of directional wave measurements carried out off Navinal, Gulf of Kachchh representing pre-monsoon and southwest monsoon wave conditions are presented. Maximum wave height encountered during pre-monsoon and southwest monsoon are 1.36 and 1.54 m respectively. Though large wave heights of the order of 3 to 4m exist elsewhere along the west coast of India during these seasons, Navinal seems to be a less wave active zone because of its geographical location. Maximum wave energy is centred around 3 to 5 sec and shows that seas prevail over swells. Occurrence of a few long period waves, of the order of 20-25 sec, has been noticed during pre-monsoons but not during the southwest monsoon. spectral modification caused to the waves have been traced. An exercise was carried out to see if any relationship exists between these long period waves and various stages of tides, but no pattern could be noticed. As this study is meant for coastal developmental activities, occurrence of cyclone is also looked into, but not a single cyclone has hit Navinal directly in the last 87 years.

1. INTRODUCTION

Directional information on waves is very essential for undertaking any studies related to coastal erosion, wave-

structure interaction or sediment transport along a coastline where developmental activities are contemplated. Design of marine structures such as jetty, breakwater and groin depends mainly on the nearshore wave climate including high resolution directional wave spectra. As there is an increasing trend towards establishment of industries all along the Gulf of Kachchh, west coast of India, it has become a pre-requisite to obtain information on wave characteristics for the design of jetties, SBMs etc. and for laying pipelines for seawater intake and effluent discharge. In this context wave studies were carried out off Navinal, Gulf of Kachchh (Fig. 1) at a depth of 10 m (average tidal range is 6.0 m) using EHDECO/YSI wave track buoy (model No. 1156) during May-September 1993, covering pre-monsoon and southwest monsoon months.

2. WAVE TRACK BUOY

Wave track buoy is an orbital following buoy which responds to the orbital motions of the water particles. Orbital following buoy measures the vertical heave acceleration and the two orthogonal components of buoy-tilts (N-S and E-W) relative to magnetic north. The wave track buoy follows a cosine relationship with maximum tilt at the wave crest and trough and minimum tilt on the slope of the wave at mean sea level. The pendulum assembly of the buoy acts as a moment arm to tilt the buoy in response to incident wave field. Data specifications are given below (User's manual, 1991):

Wave height range: ± 15.24 m;
 Wave period range: 1-33.2 sec;
 Wave direction range: $0-360^\circ$;
 Wave height accuracy: $\pm 1\%$;
 Wave direction accuracy: $\pm 10^\circ$;
 Wave sampling rate: 1, 2, 4, 8 Hz;
 Number of samples for wave study: 256, 512, 1024, 2048.

3. WAVE DATA COLLECTION AND ANALYSIS

The base station computer through its 'buoy-watch' software communicates instructions to the buoy and the buoy accepts them and maintains a schedule of analyses to be performed. On request the buoy communicates the collected data from its memory bank to

the base station. It was planned to collect wave data for every 3 hour interval. Normally, for 2048 wave points with 2 Hz frequency, we get a raw data file size of approximately 6400 bytes. On several occasions the file size was found to be either 256 bytes or 4200 bytes. Due to these reasons data could not be collected with this (3 hour) interval. It was clarified that file size of 256 bytes is due to a bug in the buoy-watch software while the reason for receiving 4200 byte file size is not known.

The data collected were analyzed through digital band pass filtering technique. The FFT bandpass filtering technique minimizes the directional errors and provides an efficient computational method to achieve high resolution directional spectra. The data were corrected for amplitude and phase errors. Zero-crossing analysis was performed on the corrected heave data to obtain wave parameters such as significant wave height and period, maximum wave height and period and mean wave height and period.

Digital bandpass filtering method was employed for 50 discrete frequency bands: at frequency interval of 0.01 Hz for the first 38 bands (0.03 to 0.40 Hz), and at frequency interval of 0.05 Hz for the remaining 12 bands (0.41 to 1.00 Hz). At each wave crest, instantaneous direction, θ was computed as follows:

$$\theta = \tan^{-1} (TE-W / TN-S)$$

where, TE-W and TN-S are east-west and north south tilts, respectively. For each frequency band, spectral energy density, mean direction and standard deviation were obtained. Moreover, period and direction of maximum energy density were also obtained besides other wave statistics for each record.

The directional variance spectrum, which is a joint distribution of 0.01 Hz resolution frequency bands and 100 resolution direction bands, was computed and a sample plot is given in this paper (Fig.2).

Wind speeds and directions were measured using cup anemometer installed at the shorebased weather station.

4. RESULTS AND DISCUSSION

Significant wave period, mean wave period, period of maximum energy density, significant wave height, mean wave height and direction of maximum energy density for pre-monsoon and southwest monsoon are shown in Figures 3 and 4 respectively. Significant wave height obtained through spectral analysis varies from 0.15 to 0.80m and this closely agrees with that of zero-crossing method (0.16 to 0.79 m). Maximum wave height observed during pre-monsoon is 1.36 m. Though one may expect large wave heights in Arabian Sea during the pre-monsoon month of May as well as southwest monsoon, wave activity is not so in the Navinal region since it is protected geographically from the open ocean and less influenced by premonsoon winds. Mean wave period varies from 2.1 to 6.2 sec and significant wave period from 2.7 to 9.6 sec. Fig.3a shows the rare occurrence of a few long period waves, having periods of the order of 20-25 sec. As tidal range at Navinal is of the order of 6.0 m, an exercise was carried out to see whether any relation exists between the occurrence of long period waves and the stages of tide elevation, but no pattern emerged. Barring these higher values, we find that the predominant wave period is around 4 to 5 sec and in all the spectra, maximum spectral energy is centered around 4 to 5 sec. This shows that seas prevail over swells. Usually swells and seas coexist more or less in equal proportion during the pre-monsoon and southwest monsoon seasons in the Arabian Sea and the absence or less dominance of swells may be due to the orientation of the gulf which obstructs the passage of swells, and thus the waves within the gulf are mostly locally generated seas.

Directional wave spectra show that predominant wave direction is between SW and WSW and maximum energy is concentrated between 220 and 250° TN (Figs. 3b and 4b). Wind and wave directions are nearly the same. Winds are relatively weak in the mornings, of the order of 15 km/hr and strong in the evenings, of the order of 30 km/hr. Correspondingly, wave heights are also higher during evenings. The diurnal repetition of wave conditions at regular interval of time is noteworthy. For example, directional variance spectra of 10th and 11th May 1993 (NIO, 1993, Figures are not presented here): at 0000 and 1200 hrs, corresponding spectra are doubly peaked and well separated; at 0900 and 1800 hrs, distribution of energy is narrow banded both frequency-wise and directionally. This trend is almost repeated in all the wave data and this is in accordance with the diurnal variation of winds.

This further confirms that waves off Navinal during premonsoon are locally generated waves.

It was generally expected that southwest monsoon (June-September) waves may exceed 2.5 m. But the limited wave data (NIO, 1993b) during July-September 1993 show that the maximum wave height is only 1.54 m which is slightly higher than the premonsoon waves. Significant wave period and height are 5.2 sec and 0.62 m respectively (Figs. 4a and 4b). Maximum energy is concentrated around 3 to 5 sec (Fig. 4a), by the wave coming from SSW-WSW direction (Fig. 4b). Thus it is found that there is not much difference between the premonsoon and south-west monsoon wave conditions off Navinal.

The buoy results were compared with the ships of opportunity results, (Chandramohan, et al, 1989 and NIO 1982). The basic source for these two documents are visually observed data of the Indian Daily Weather Reports. It is reported in the Wave Table that the predominant wave height is below 3.0 m and period between 5 and 7 sec for the entire Gujarat region during southwest monsoon. In Wave Atlas also larger heights are reported. The larger wave heights reported in the Wave Table and Wave Atlas are due to the very nature of visual observations and the vast open sea considered for the 50 square grids. But visually observed and measured directions agree closely.

Though wave group analysis is usually meant for higher waves, prevalence of wave groups is common during monsoon season and hence a portion of the data was subjected to wave group analysis. Results show that in the 17 minutes wave record, one wave (in each group) has exceeded the mean wave height 45 times and two consecutive waves 13 times and so on. Average run length computed, based on significant wave height will be less than that based on mean wave height. Thus we find that wave group formation is not remarkable.

Wave information presented in this paper is for the non-stormy period. Cyclonic storms may generate higher waves and affect the offshore/coastal structures. An analysis of cyclonic storms for the period 1891-1960 shows that 130 storms occurred in the Arabian Sea and only 5 have attacked the Gujarat coast. An unpublished information shows that only 4 cyclones hit the Gujarat coast-directly or indirectly during 1977-1994. However, not a single storm has hit the Navinal area. Occurrence of

storms in Arabian Sea is much less compared to Bay of Bengal.

5. CONCLUSIONS

Important wave conditions off Navinal, Gulf of Kachchh during premonsoon and southwest monsoon of 1993 are presented in this article, in the context of coastal developmental activities contemplated there. Partial data loss during the observational sequence is due to communication failure between the buoy and the base station as well as a bug in the software. Wave spectra clearly show that 'seas' prevail over 'swells'. Relatively strong winds, of the order of 30 km/hr could not generate larger waves due to geographical location of Navinal and fetch limitation. There is not much difference between premonsoon and southwest monsoon wave conditions. Cyclone data for the past 87 years show that not a single weather disturbance has hit the Navinal region directly. Though larger wave heights exist elsewhere in the Arabian Sea outside the gulf during premonsoon/southwest monsoon, Navinal seems to be a less wave active zone. Hence, Navinal is a suitable site (with reference to wave activity) for the construction of coastal structures.

6. ACKNOWLEDGEMENTS

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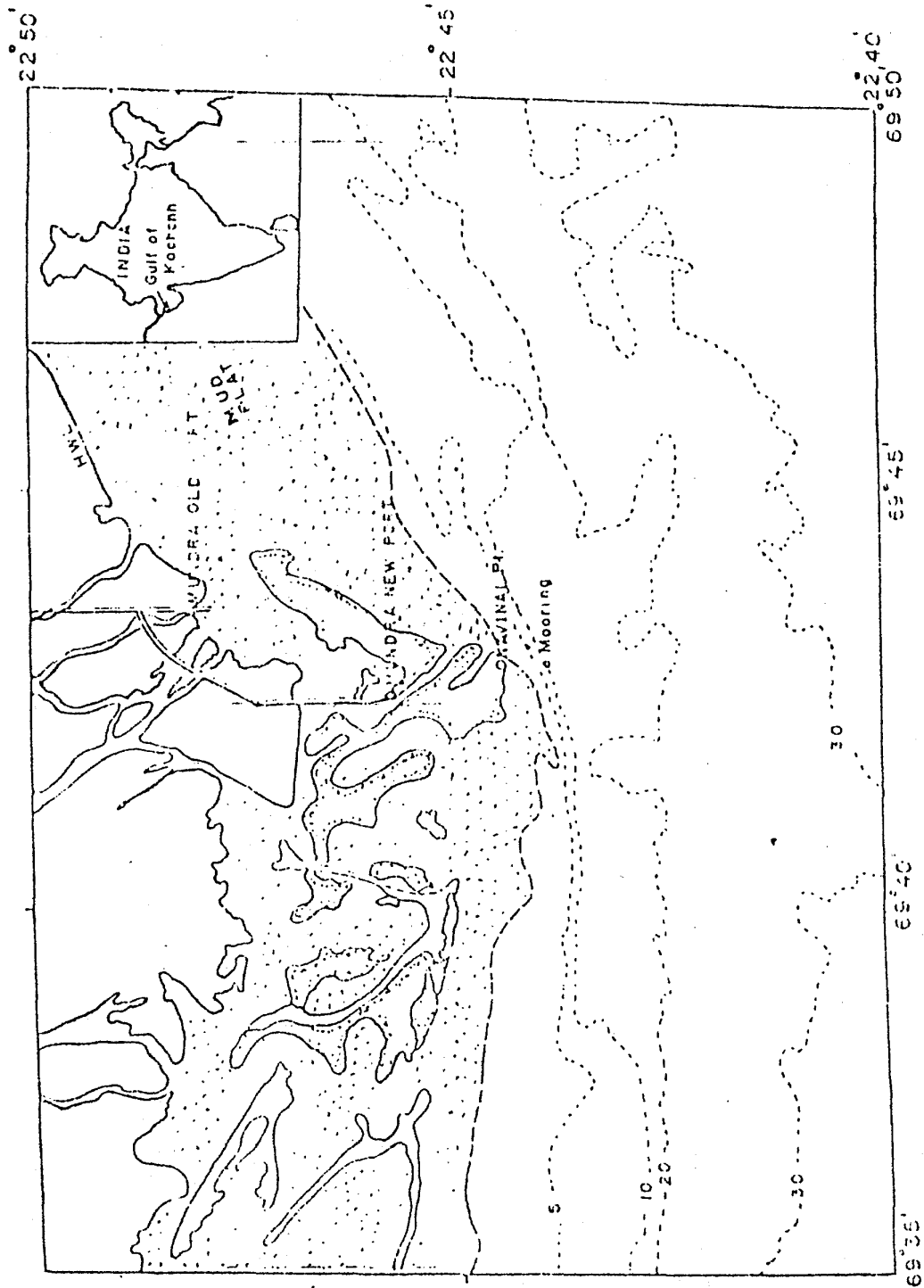


Fig 1 Location map showing wave rock buoy mooring

ENTRIES ARE SCALED LINEARLY FROM 0 TO 50
 PEAK VALUE CORRESPONDS TO SPECTRAL DENSITY OF .00345 (M-SQ/HZ X DEG)
 DOT INDICATES ZERO VALUE

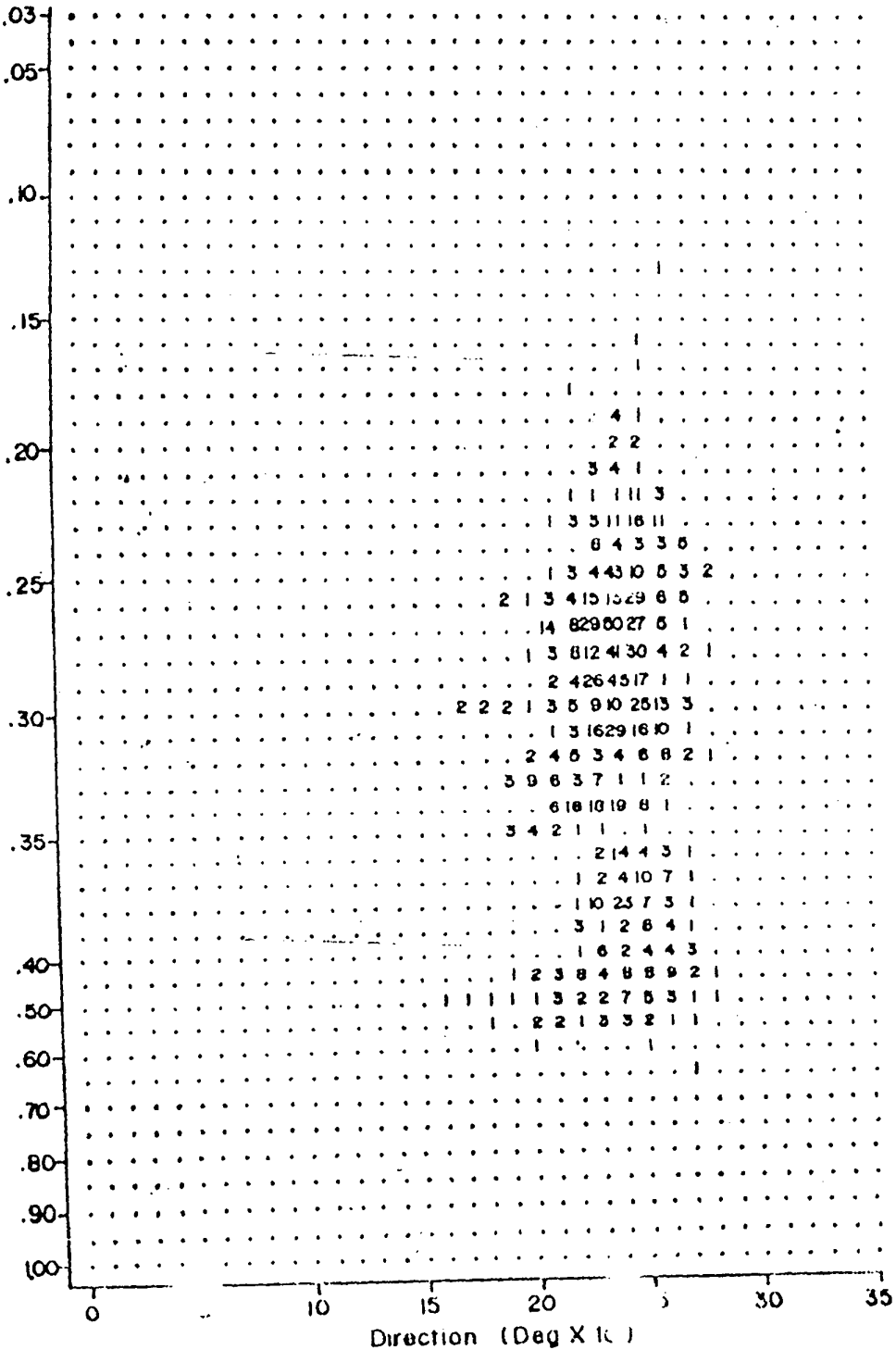


Fig 1 Frequency-Direction spectrum : 0900Hrs of 0-5-1993

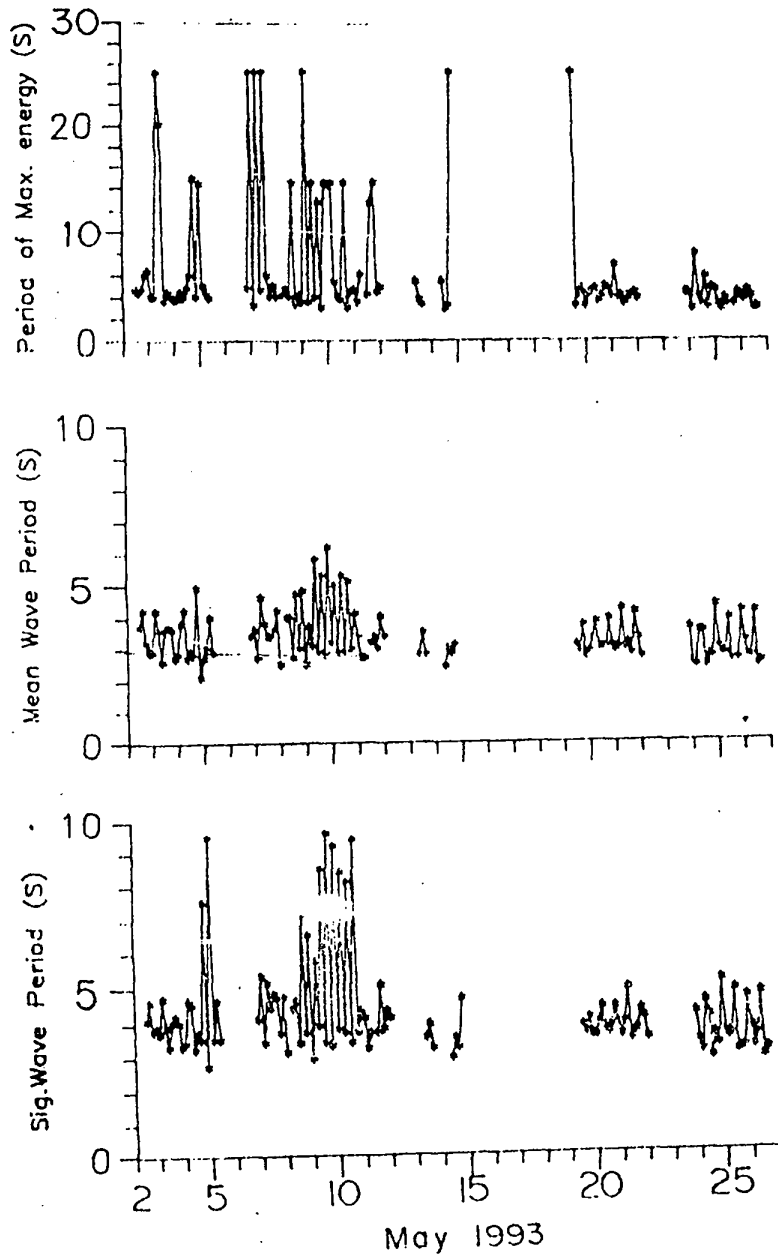


Fig. 3a Wave parameters during pre monsoon

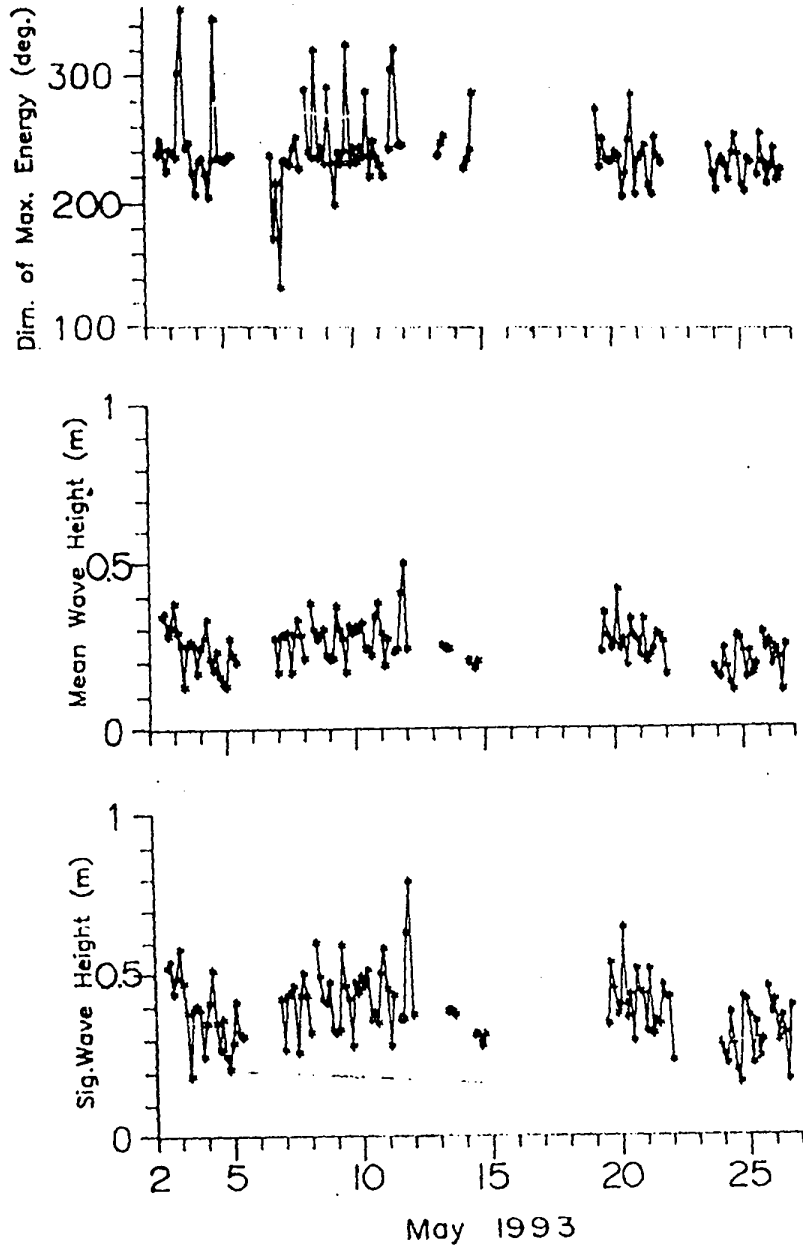


Fig.3b Wave parameters during pre monsoon

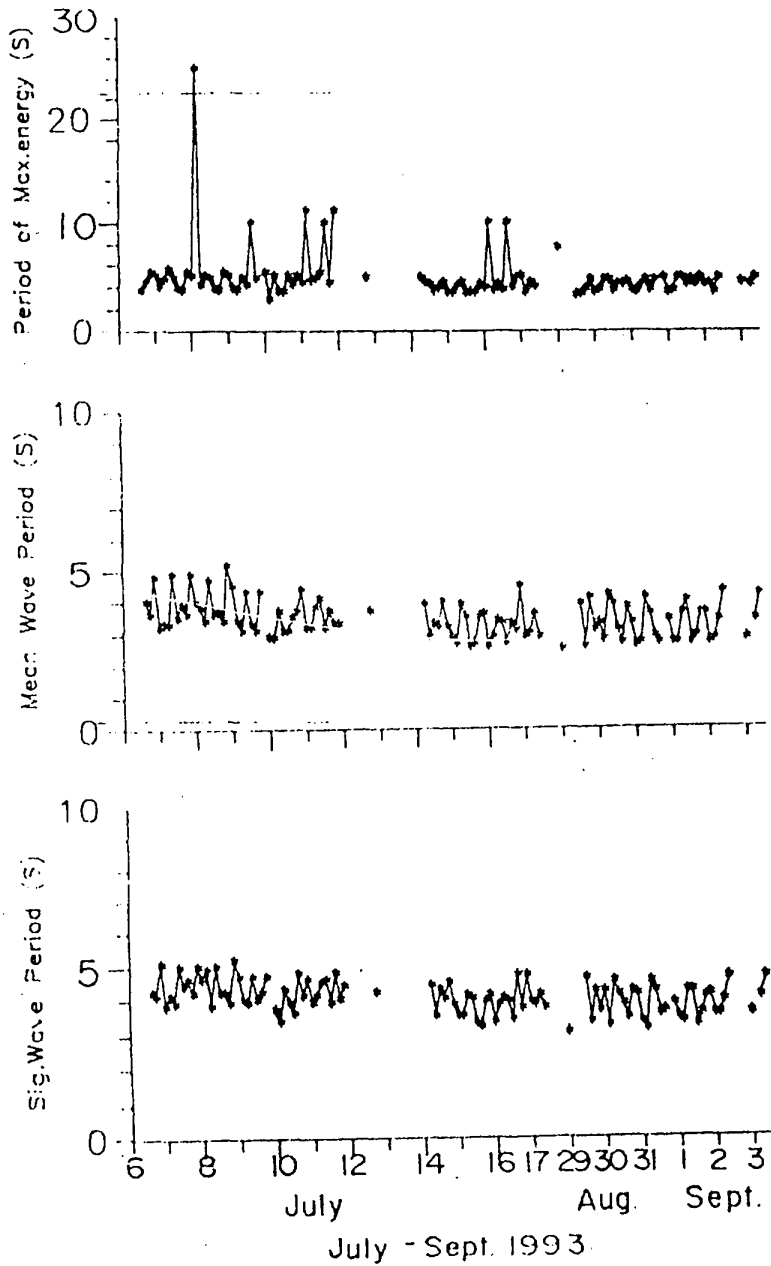


Fig. 4a Wave parameters during southwest monsoon

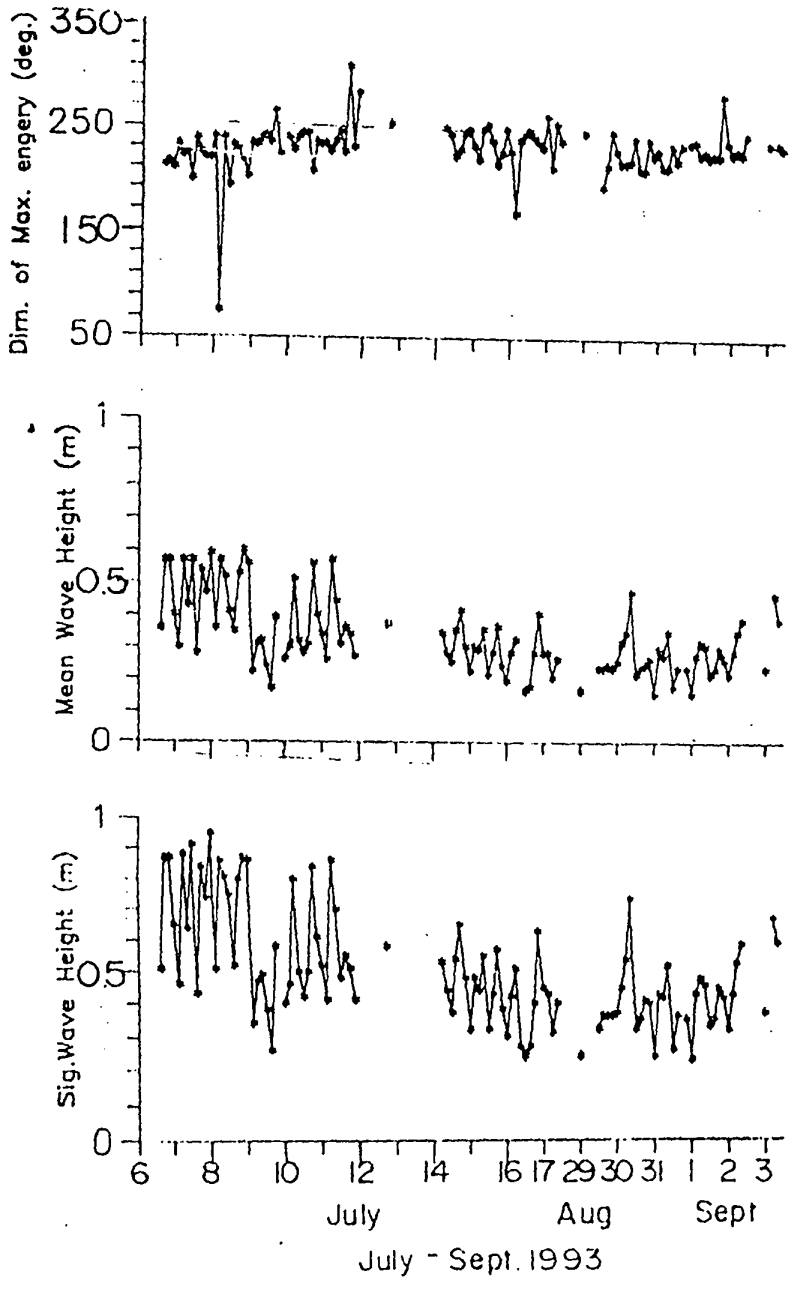


Fig 4b Wave parameters during southwest monsoon