

Technical Report No. NIO/TR-4/93

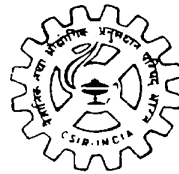
NATIONAL INSTITUTE OF OCEANOGRAPHY

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DEEP WATER WAVE CHARACTERISTICS OFF KARWAR WEST COAST OF INDIA

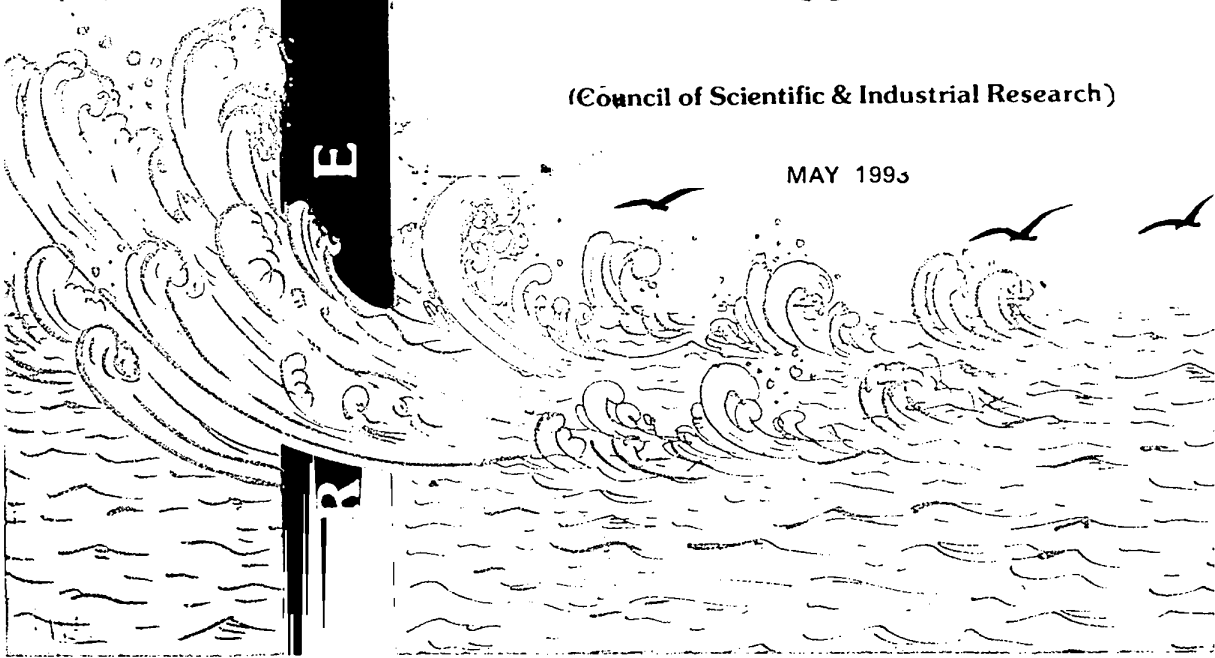
BY

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ANAND, B. U. NAYAK & P. PEDNEKAR**
OCEAN ENGINEERING DIVISION



(Council of Scientific & Industrial Research)

MAY 1993



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1. INTRODUCTION

Shallow water waves were measured off Karwar, west coast of India for four consecutive year by using a directional buoy "WAVEC" at a location with water depth of about 16m. The data analysis would lead to better assessment of the wave climate and evaluation of realistic design and operation parameters for the proposed Naval Base, "SEABIRD" at Karwar.

It would be of value if deep water wave measurement could also be carried out atleast for a shorter period particularly during the rough monsoon season. Such information would be highly beneficial for various offshore exercises of the Navy and also for various R&D activities like calibration of hind cast models etc.

During a combined cruise of RV Gaveshani it was decided to measure deep water monsoon waves off Karwar pertaining to peak monsoon period. An unidirectional waverider buoy was installed at 75m water depth off Karwar (Figure 1) and waves were measured using DIWAR placed on board RV Gaveshani stationed in the vicinity of the buoy location. Wave data were recorded from 25th June to 3rd July 1989 and were analyzed for evaluating various statistical parameters as discussed in this report. Spectral analysis shows that measured deep water waves generally formed single-peaked

spectra conforming to the sea generated by local wind which is predominant in the monsoon period.

2. METHOD OF STUDY

2.1. Wave characteristics

Waverider Buoy

Datawell waverider buoy consists of a spherical steel shell of 90 cm in diameter, designed to float on the sea surface (Fig. 2). Accelerometer housed inside the buoy measures the vertical acceleration of the buoy. The electronics, housed inside the top half of the buoy integrates the signals twice to obtain the amplitude and telemeters the same to a shore based DIWAR receiving/recording station, with the help of a 2 meter long antenna mounted on top of the buoy.

DIWAR

DIWAR is an instrument which receives and demodulates the FM signals from the waverider buoy and records the time series on wave height on a Personal computer. This equipment works on AC and DC power and has an inbuilt capacity to switch over from AC to DC at the time of power failure.

Mooring system

The buoy was moored at 75m water depth off Karwar as shown in Fig. 2. The mooring system consisted of a rubber cord of 15m long, a braided polypropylene rope of 150m long, a set of viny float of 40 kg buoyancy and a dead weight anchor of 1000 Kg.

Wave Analysis

The measured waves were recorded in Personal Computer (PC) in the digital form for 20 minutes duration in every 3 hours. Digital data was analyzed using spectral method for various statistical parameters, viz., significant wave height (H_S), zero-crossing wave period (T_Z), wave period corresponding to the maximum wave energy (T_p), maximum spectral energy (E_{max}), spectral width parameter (ϵ), peakedness parameter (Q_p) and wave steepness (s). The above statistical parameters were evaluated using the spectral moments as follows.

$$\text{Significant wave height } H_S = 4 \sqrt{m_0} \quad (1)$$

$$\text{Zero-crossing wave period, } T_Z = \sqrt{\frac{m_0}{m_2}} \quad (2)$$

$$\text{Spectral width parameter, } \epsilon = \sqrt{1 - \frac{m_2^2}{m_0 m_4}} \quad (3)$$

Wave steepness, S , based on significant wave height, H_s , and wave length, L , is defined as

$$\text{Wave steepness } S = \frac{H_s}{L} \quad (4)$$

For the calculation of wave length at 75m water depth, the corresponding deep water wave length, L_0 , is calculated from,

$$L_0 = 1.56 T_z^2 \quad (5)$$

Then for the required water depth, d (i.e. 75m), the ratio d/L_0 is computed. For this value of d/L_0 , corresponding value of d/L , is obtained from the gravity wave tables (Shore Protection Manual, Vol. III, U.S. Army Corps of Engineers, 1984). Once the d/L value is known, the wave length and wave steepness corresponding to the depth, d is calculated.

2.2. Wind characteristics:

The hourly variation of wind speed and direction were measured from ship's meteorological station on board RV Gaveshani.

3. RESULTS

3.1. Wave characteristics

The variation of significant wave height (H_s), zero crossing wave period (T_z), wave period corresponding to the maximum wave energy (T_p), maximum spectral energy (E_{max}), spectral width parameter (ϵ), peakedness parameter (Q_p) and wave steepness (S) during June 1989 to July 1989 is presented in Figures 3-9.

Variation of significant wave height: Three hourly variation of H_s is presented in Figure 3. The significant wave height, (H_s) varied from 2.05m to 3.9m during the study period.

Variation of zerocrossing wave period: Three hourly variation of zero crossing wave period is presented in Figure 4. The zero-crossing period, (T_z) varied between 5.07 - 7.68s during the study period.

Variation of wave period corresponding to maximum wave energy: Three hourly variations of wave period corresponding to maximum wave energy is presented in Figure 5. The wave period corresponding to maximum wave energy (T_p) varied from 8s to 13.3s during the study period.

Variation of maximum spectral energy: Three hourly variations of maximum spectral energy is presented in Figure 6. The maximum spectral energy varied between 3.69 - 20.9 m^2/Hz during the study period.

Variation of spectral width parameter ϵ : Three 3 hourly variations of spectral width parameter are presented in Figure 7. Spectral width parameter (ϵ) varied between 0.73 - 0.85.

Variation of peakedness parameter Q_p : Three 3 hourly variations of peakedness parameter are presented in Figure 8. The peakedness parameter varied between 1.4 to 3.

Variation of wave steepness S : Three 3 hourly variations of steepness is presented in Figure 9. Wave steepness varied from 0.02 to 0.07 during the study period.

Joint distribution of wave height and period: The joint distributions of the significant wave height and the zero-crossing wave period is shown in Figure 10.

Distribution of wave height and wave period: The percentage distribution and the cumulative distribution of the significant wave height and zero-crossing wave period during study period are shown in Figure 11.

The significant wave height predominantly persisted between 2.5m and 3.5m during the study period with the occurrence of 75%.

The zero-crossing wave period (T_z) predominantly persisted between 6s and 8s during the study period with the occurrence 75%.

Distribution of spectral width parameter and wave steepness- The percentage distribution and the cumulative distribution of the spectral width parameter and the wave steepness are shown in Figure 12.

Characteristics of wave spectra- The wave spectra derived from the recorded time series are presented from Figs. 13 to 28. The spectral analysis shows that measured waves generally form single peaked spectra. This indicates that waves are generated from wind.

3.2. Wind characteristics- The hourly variation of wind speed and direction are shown in Figures 29 and 30. The wind speed varied from 7.21m/s to 13.9m/s during the period. The wind direction varied from 210° - 315° .

4. CONCLUSION

Analysis of deep water waves measured off Karwar, west coast of India during monsoon period (June-July 1983) show that waves are in general seem to be oriented towards coast. Wave heights were relatively high during the study period. Mostly single peaked wave spectra are observed. This indicates that predominant waves are generated by wind having one main wave train approaching towards coast. The analysis of deep water waves will be useful for Naval Base operation off Karwar.

ACKNOWLEDGEMENTS

Authors express their deep sense of gratitude for the whole hearted support and encouragement extended by the Director, National Institute of Oceanography, Goa. Authors also thank Mr.S.S.Bhat, Mr.H.C.Mandal and Mr.Shantaram Mochemadkar of Ocean Engineering Division, NIO for their help in the data collection programme.

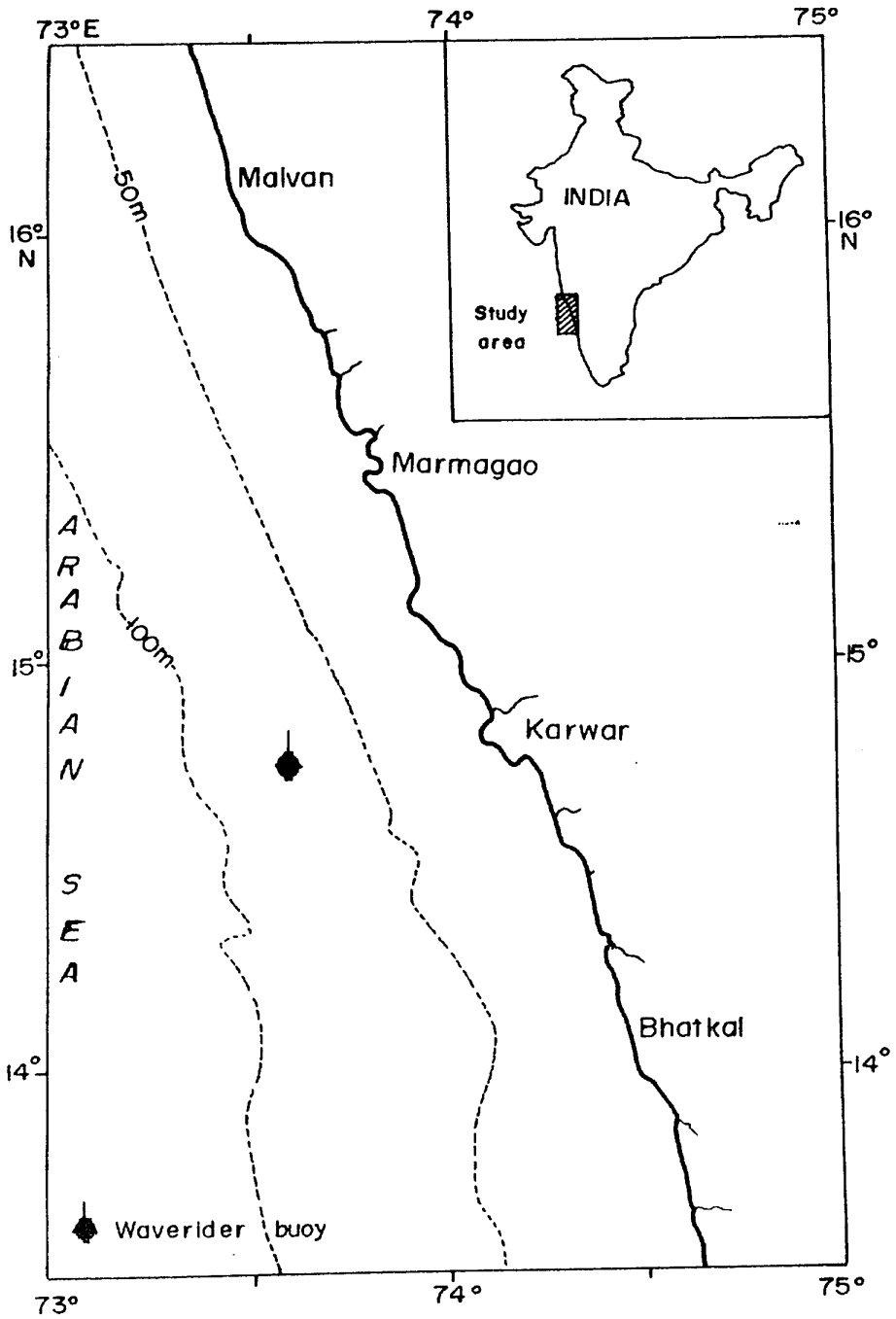


FIG. 1 LOCATION MAP

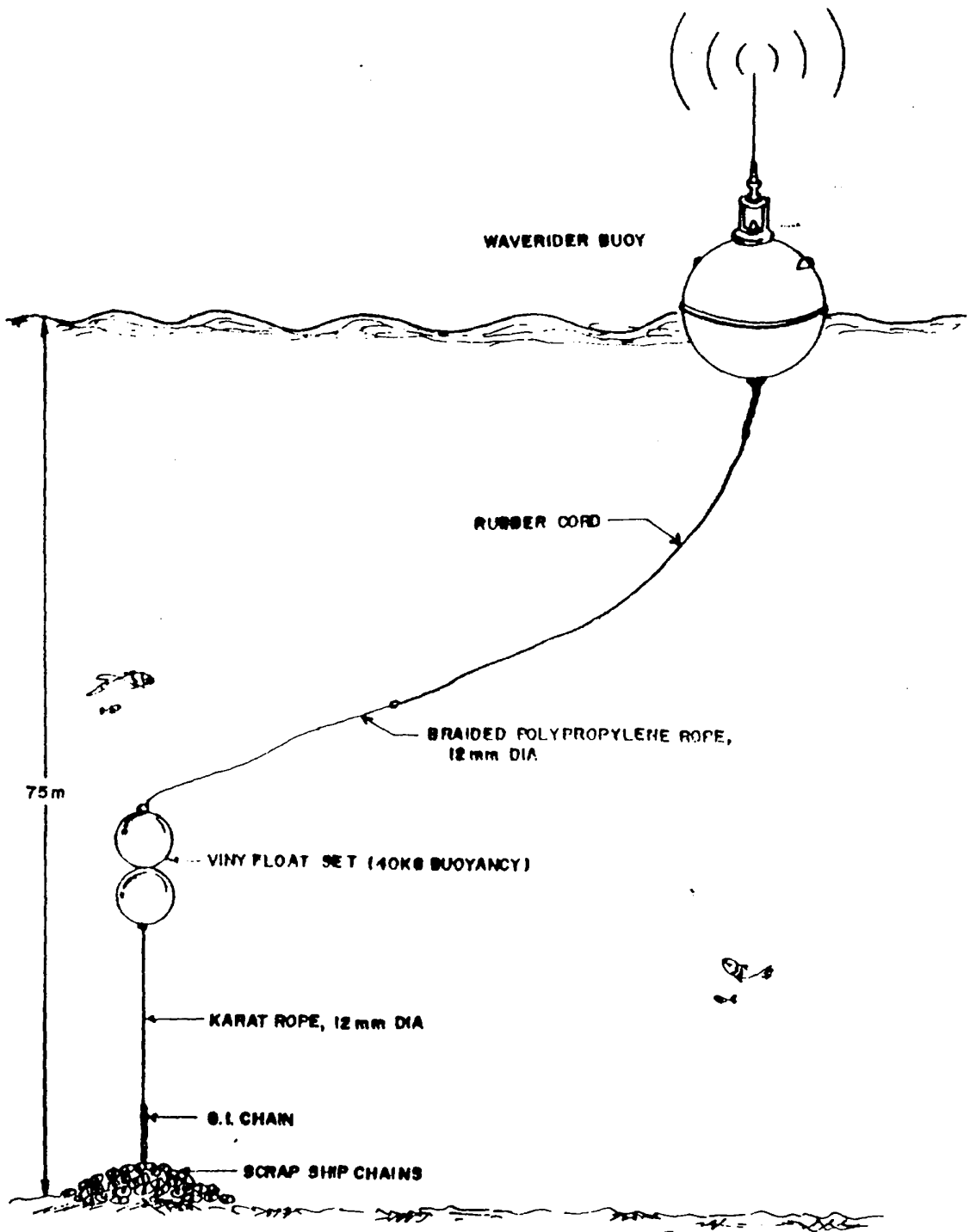


FIG. 2 WAVERIDER BUOY MOORING SYSTEM

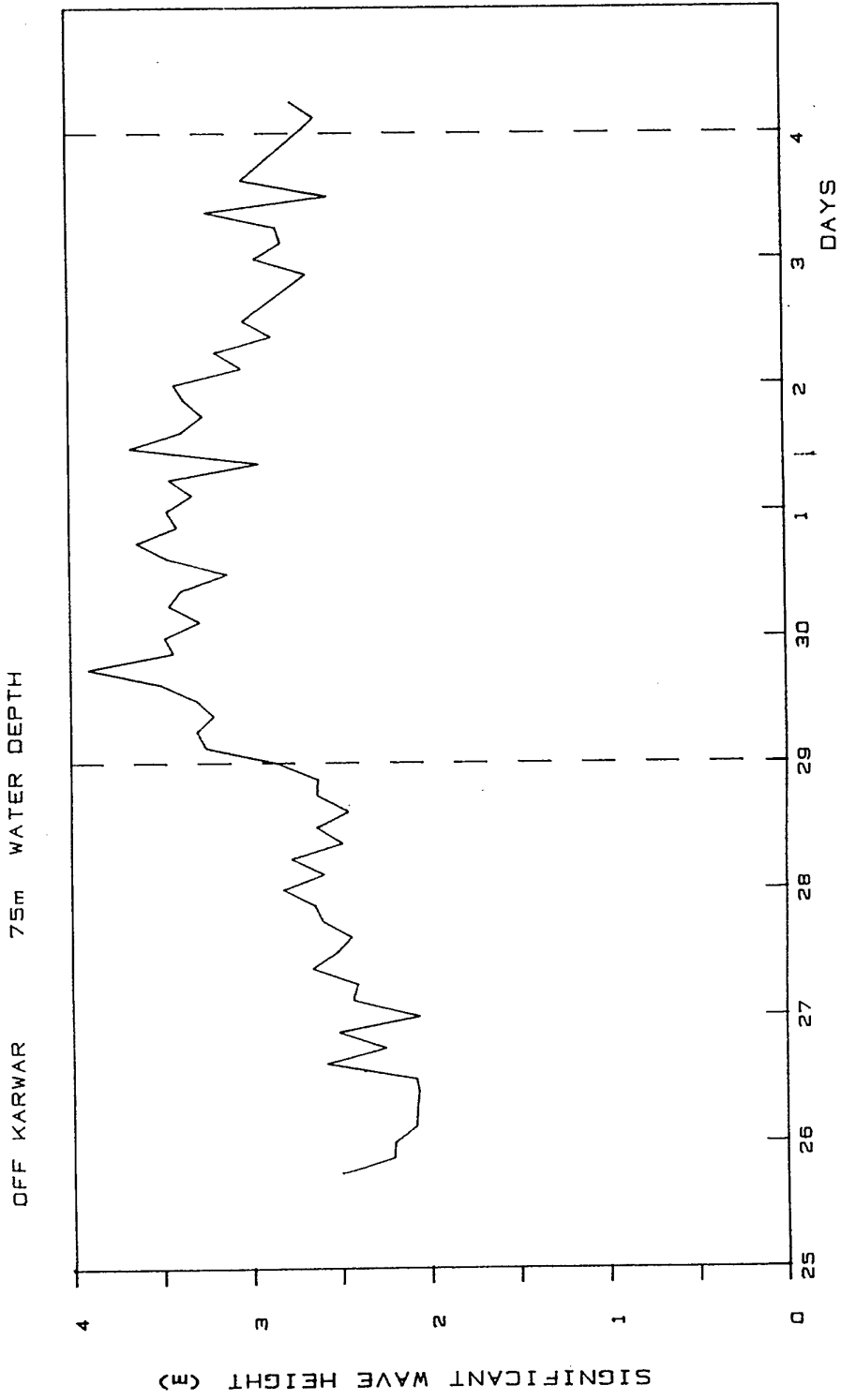


FIG. 3 VARIATION OF SIGNIFICANT WAVE HEIGHT

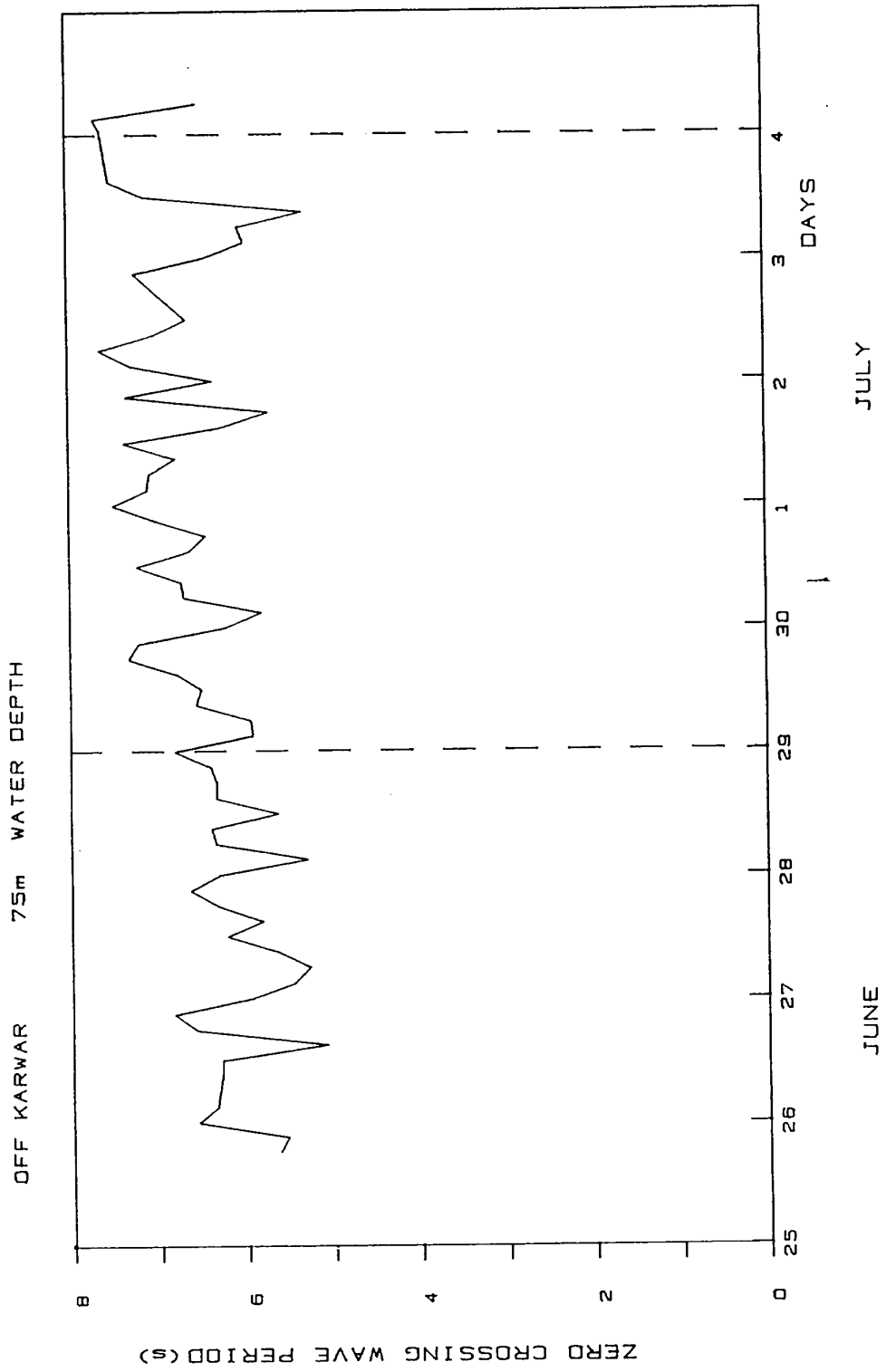


FIG. 4 VARIATION OF ZERO CROSSING WAVE PERIOD

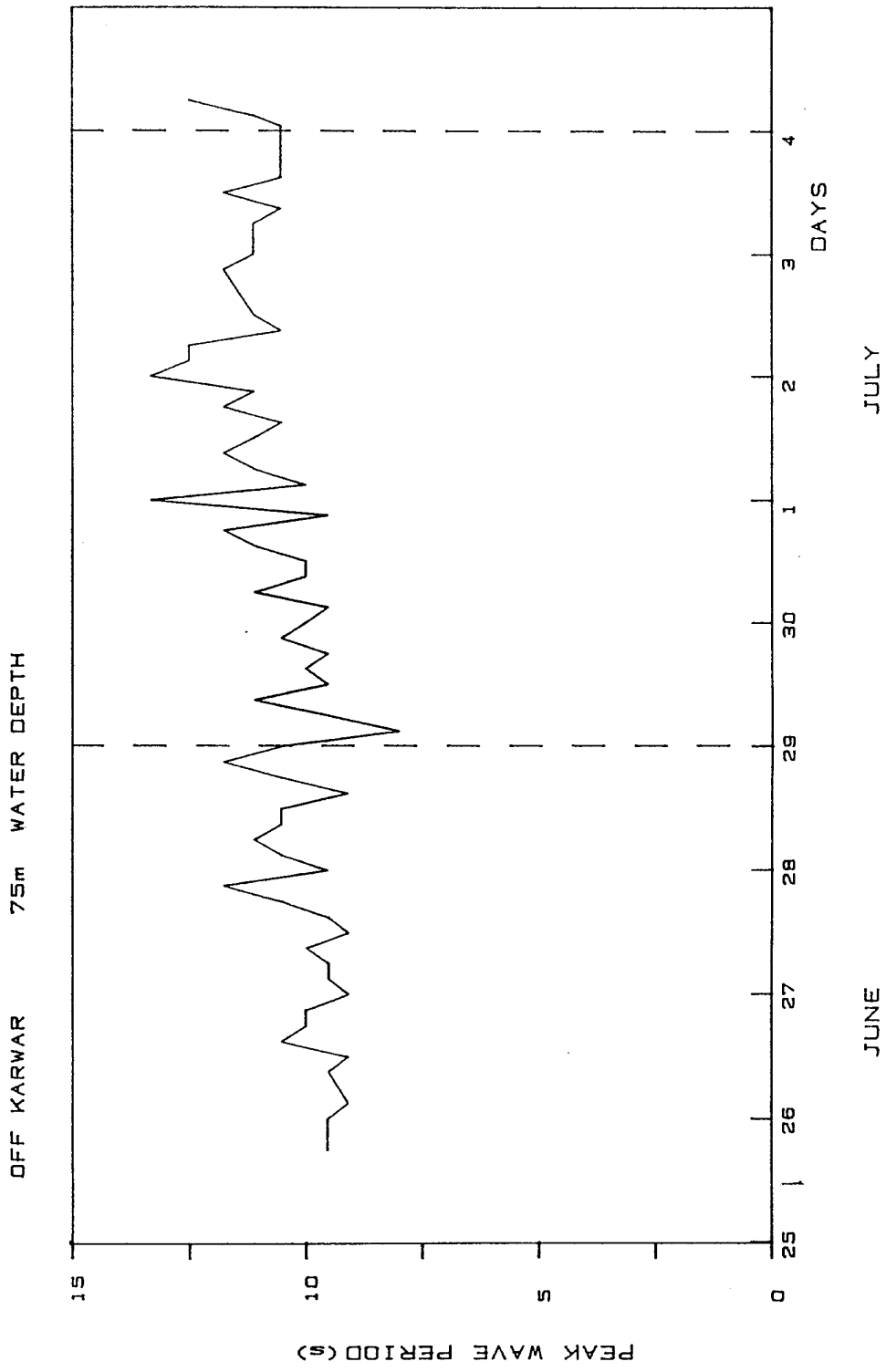
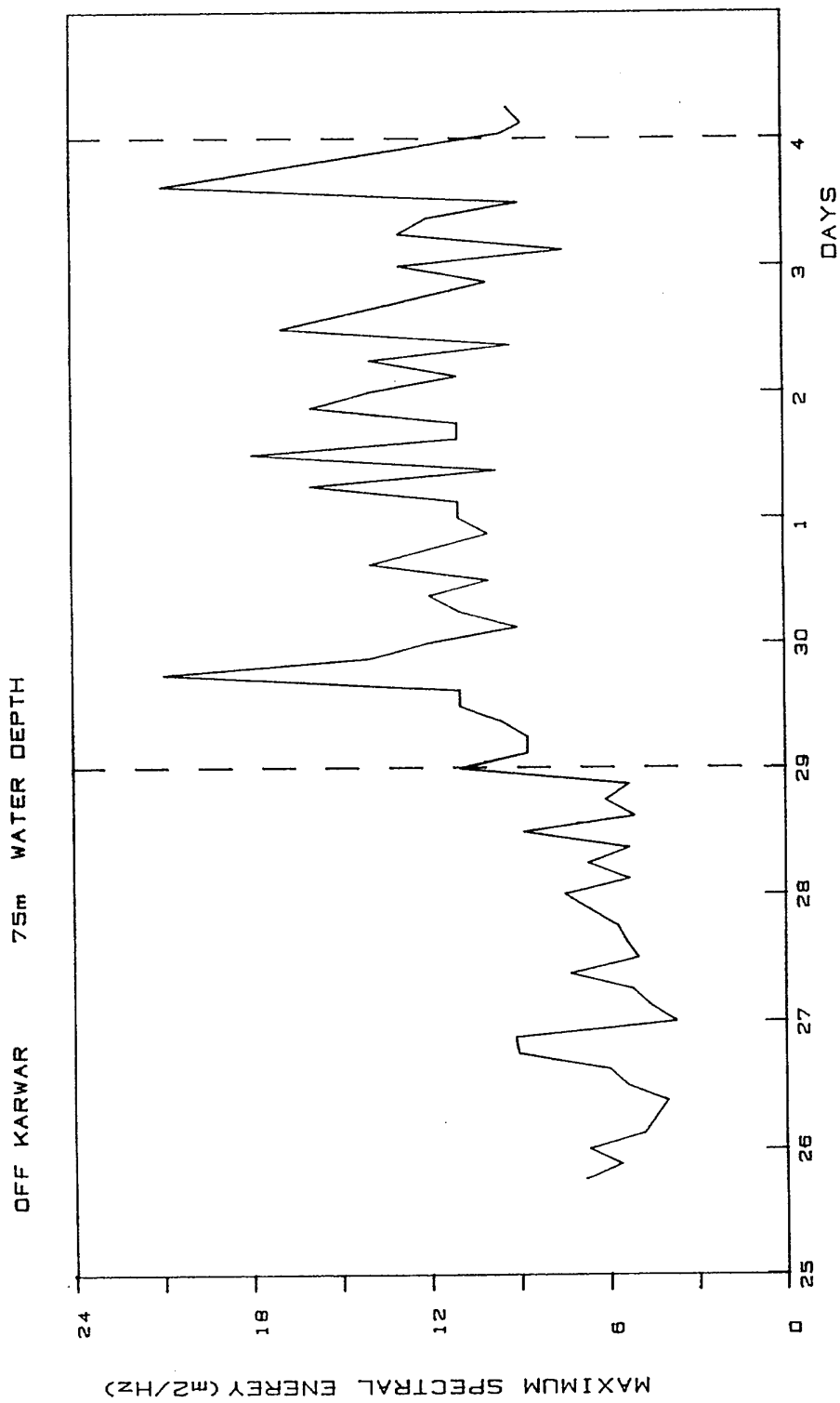
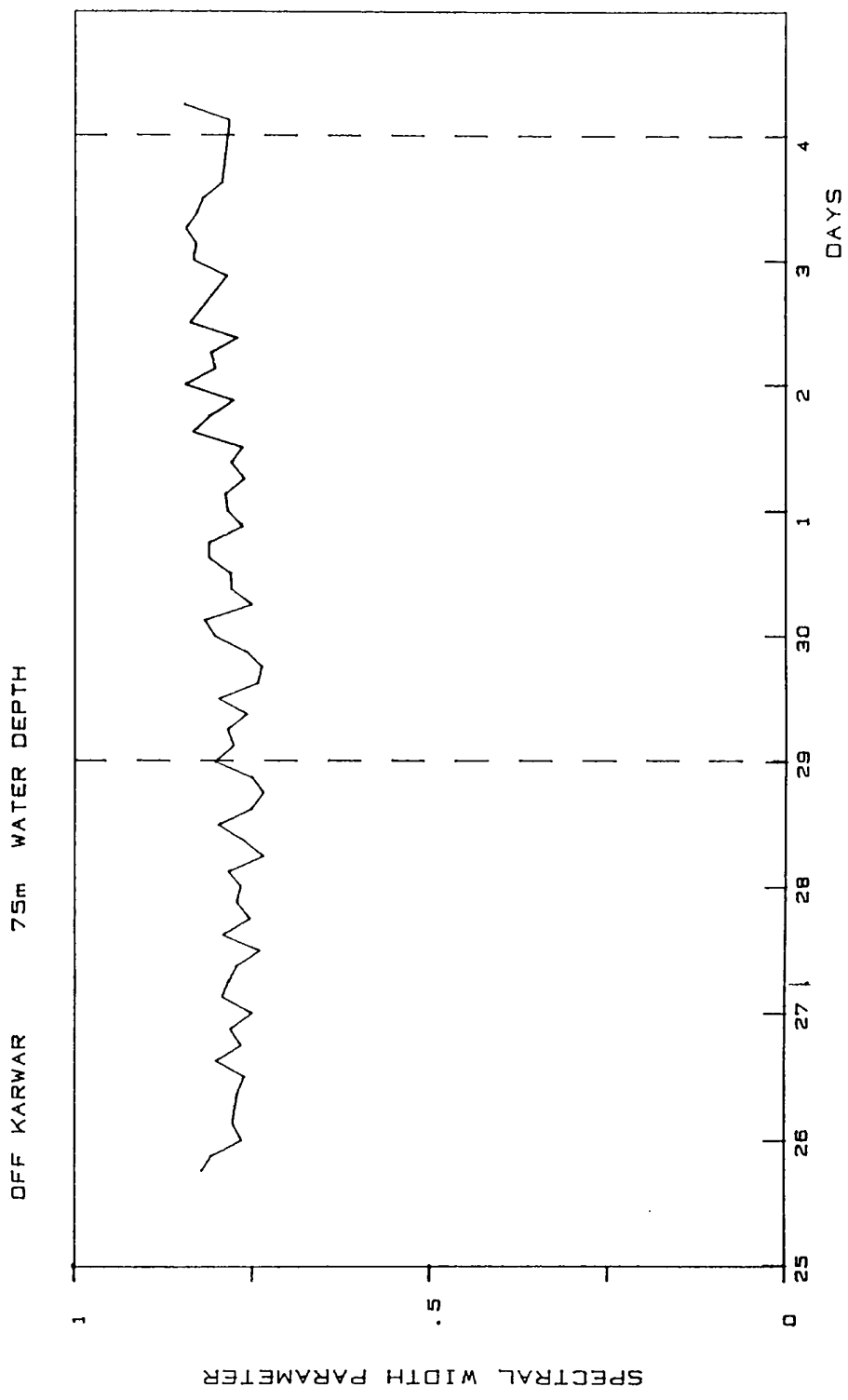


FIG.5 VARIATION OF PEAK PERIOD



JUNE JULY

FIG. 6 VARIATION OF MAXIMUM SPECTRAL ENERGY



JUNE JUNE JULY JULY

FIG. 7 VARIATION OF SPECTRAL WIDTH PARAMETER

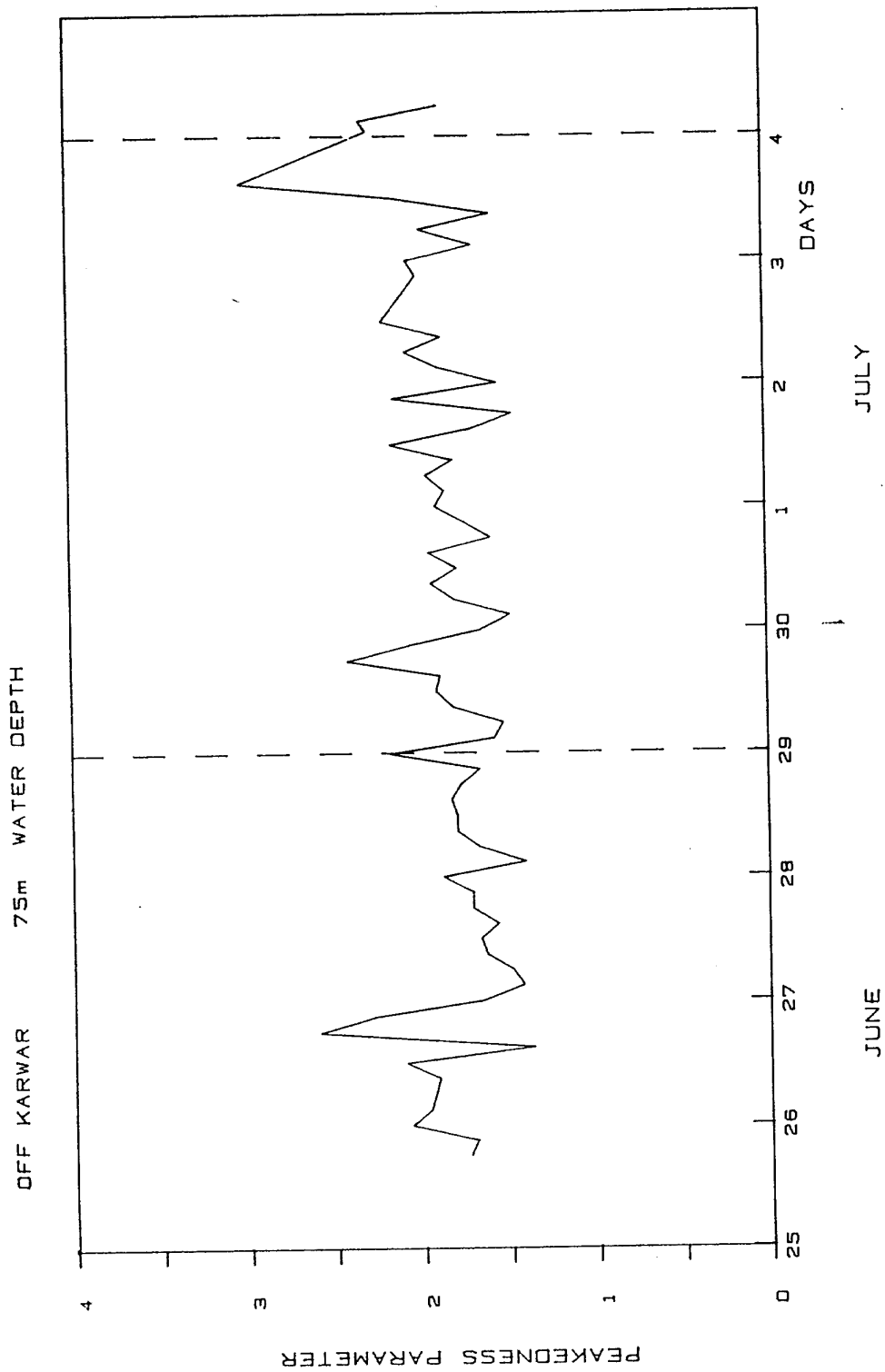
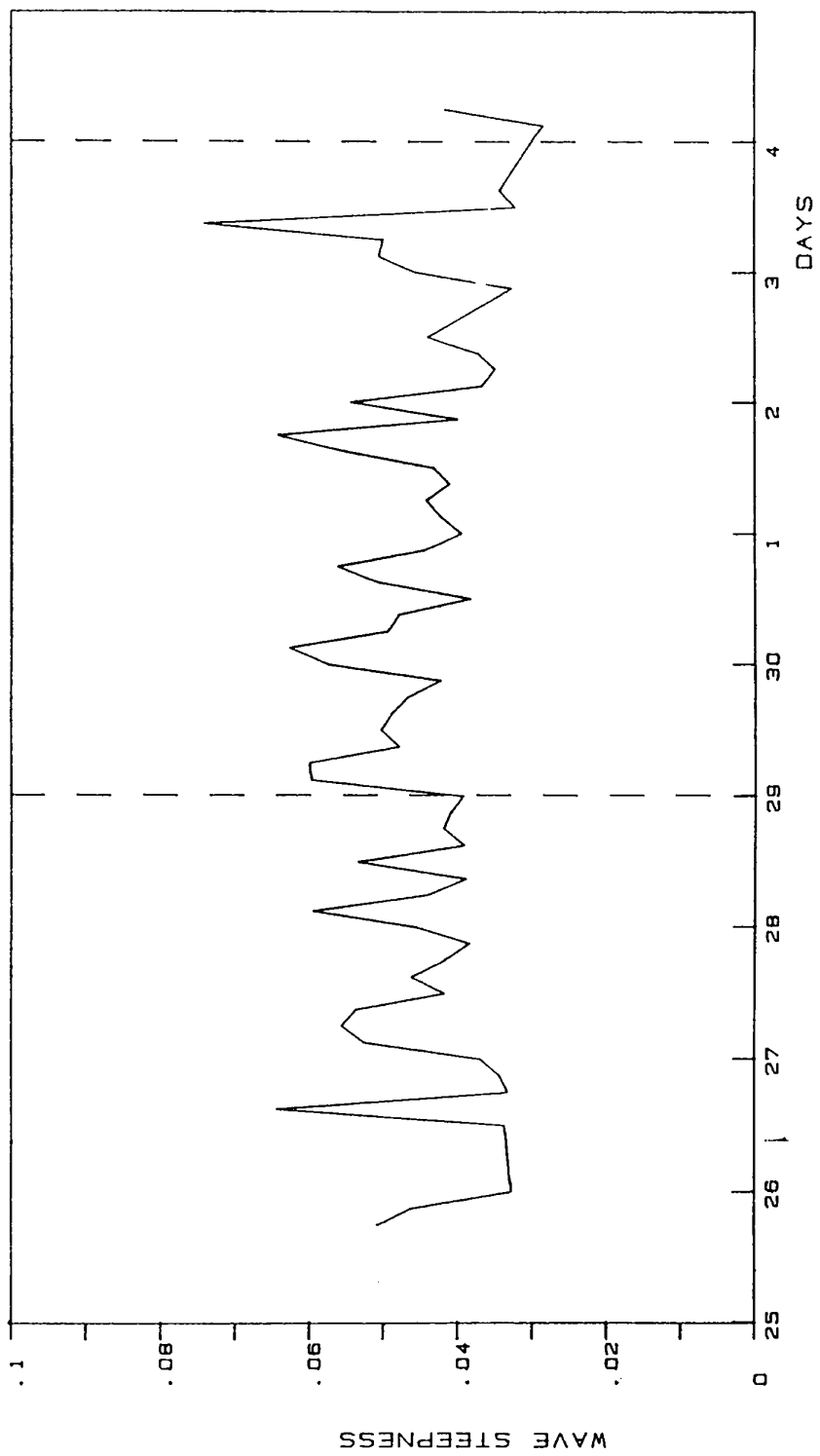


FIG. 8 VARIATION OF SPECTRAL PEAKEDNESS PARAMETER

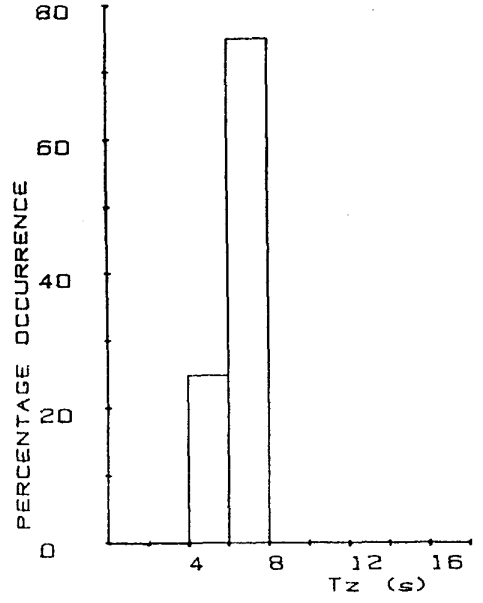
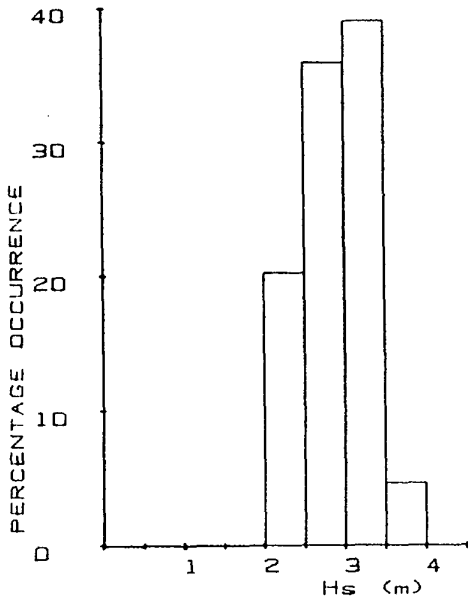
OFF KARWAR 75m WATER DEPTH



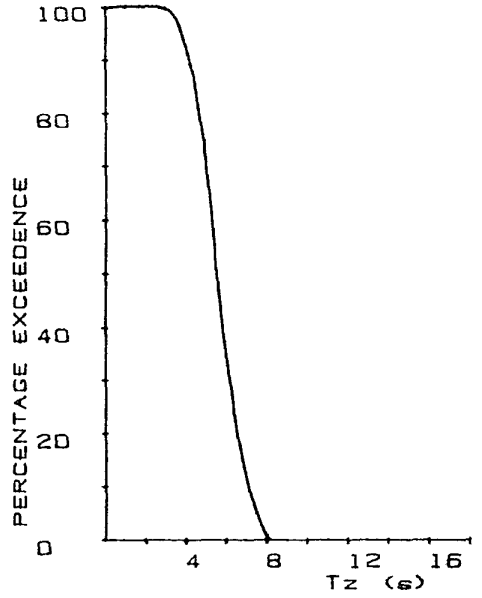
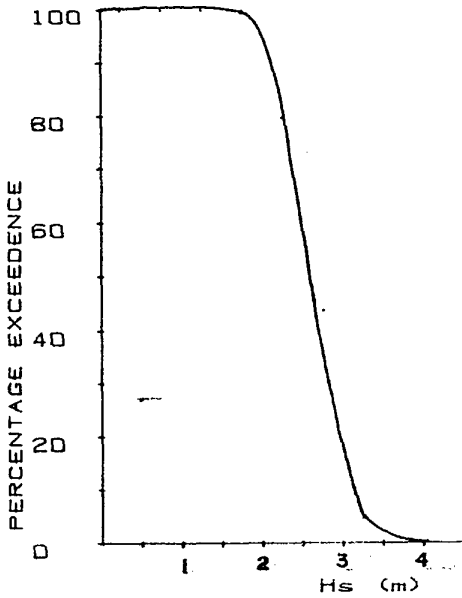
JULY

JUNE

FIG. 9 VARIATION OF WAVE STEEPNESS

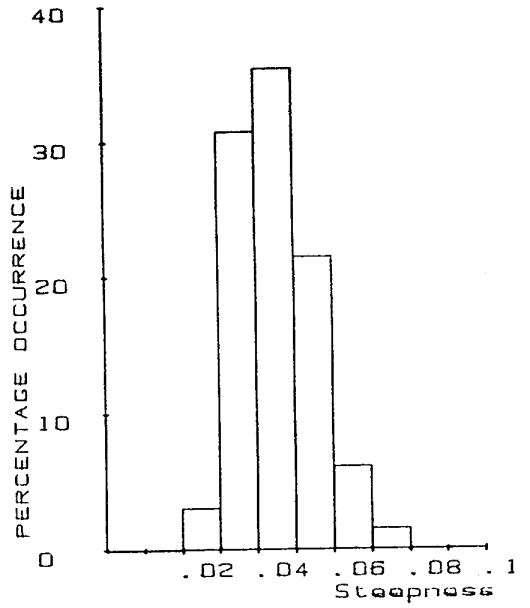
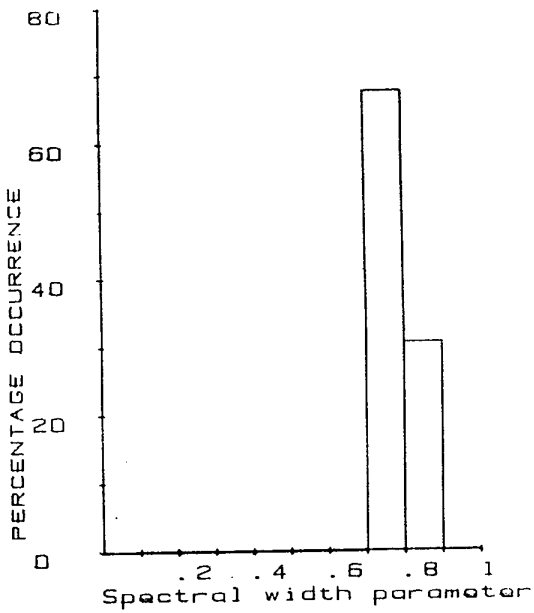


PERCENTAGE DISTRIBUTION

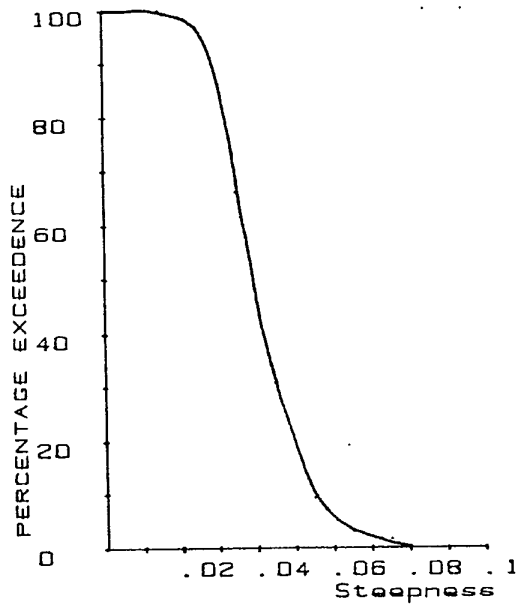
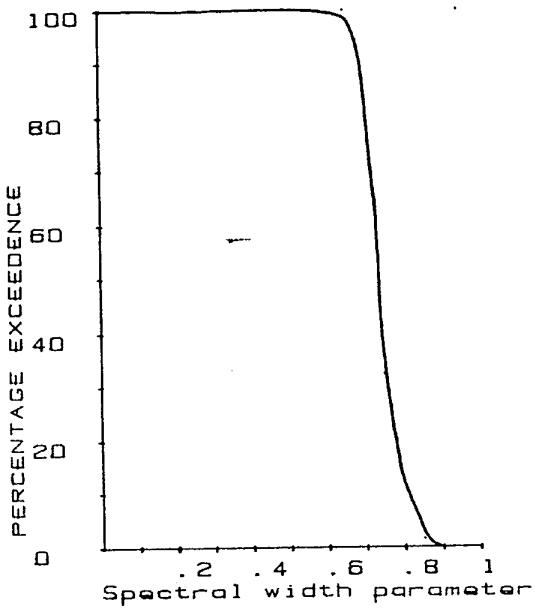


CUMULATIVE DISTRIBUTION

FIG. II DISTRIBUTION OF SIGNIFICANT WAVE HEIGHT AND ZERO CROSSING WAVE PERIOD



PERCENTAGE DISTRIBUTION



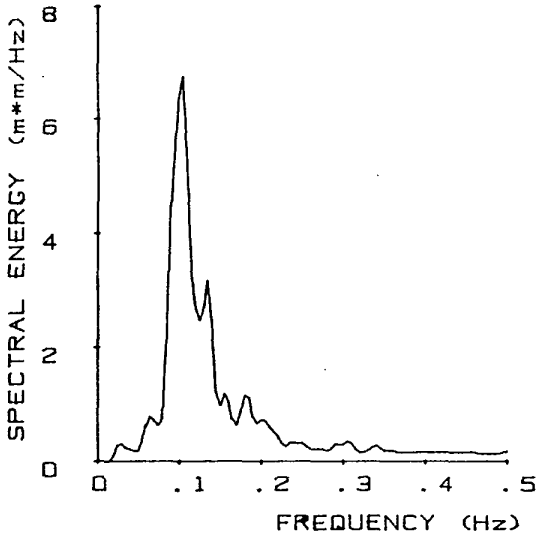
CUMULATIVE DISTRIBUTION

FIG. 12 DISTRIBUTION OF SPECTRAL WIDTH PARAMETER AND WAVE STEEPNESS

WAVERIDER 1989-6-25 1820 Hrs

Hs = 2.49m Tz = 5.6s

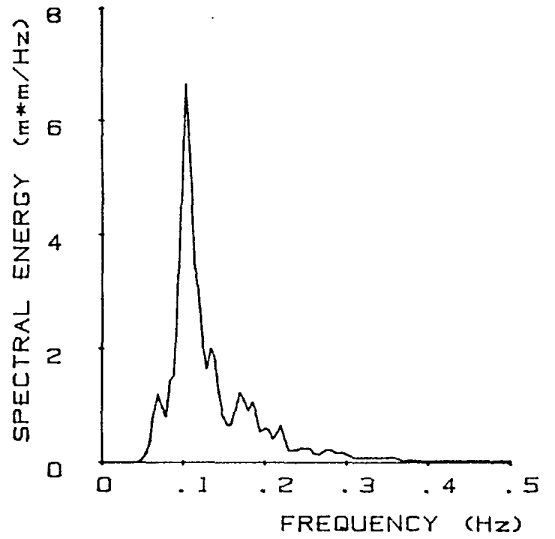
Emax = 6.77344 m*m/hz



WAVERIDER 1989-6-26 20 Hrs

Hs = 2.19m Tz = 6.5s

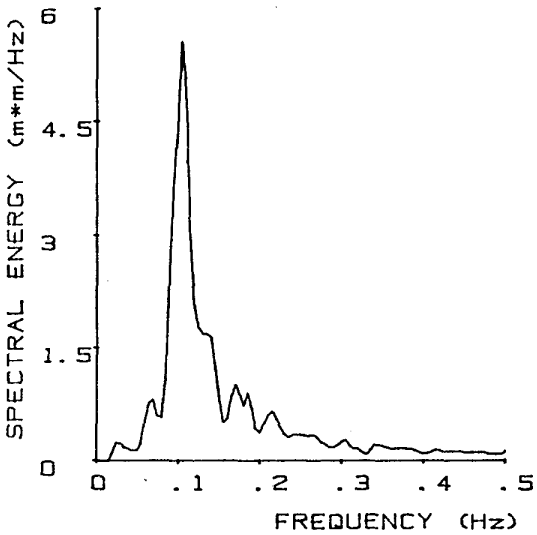
Emax = 6.67383 m*m/hz



WAVERIDER 1989-6-25 2120 Hrs

Hs = 2.19m Tz = 5.5s

Emax = 5.57813 m*m/hz



WAVERIDER 1989-6-26 320 Hrs

Hs = 2.07m Tz = 6.3s

Emax = 4.78125 m*m/hz

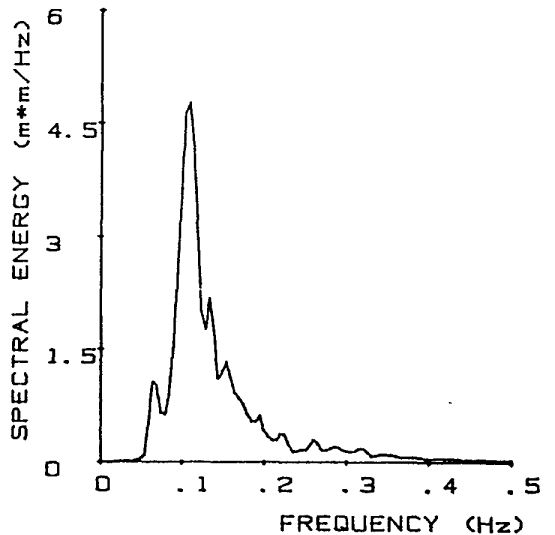
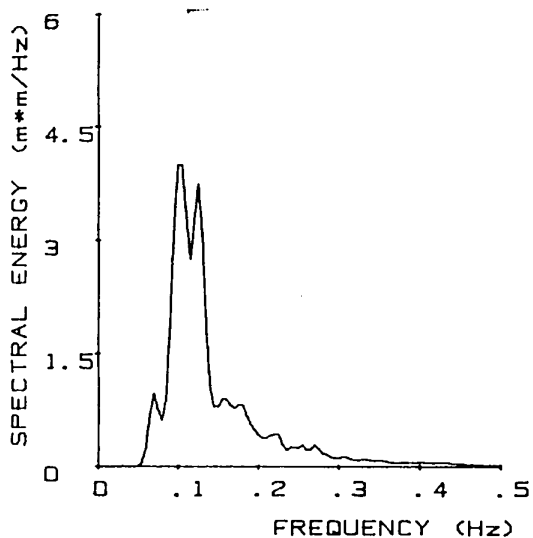


FIG.13 WAVE SPECTRA

WAVERIDER 1989-6-26 920 Hrs

Hs = 2.06m Tz = 6.2s

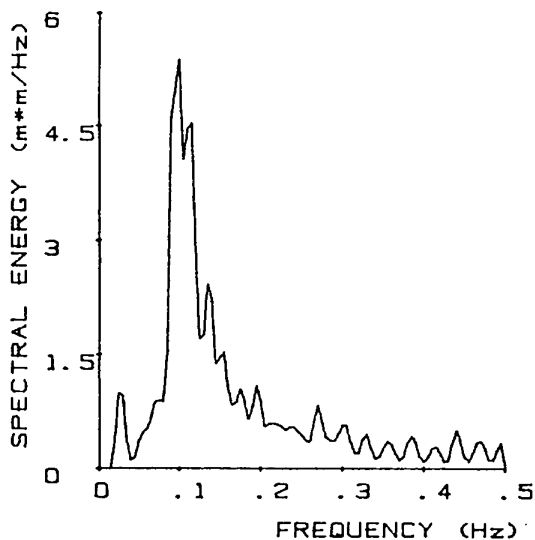
E_{max} = 4.00398 m*m/hz



WAVERIDER 1989-6-26 1520 Hrs

Hs = 2.58m Tz = 5.0s

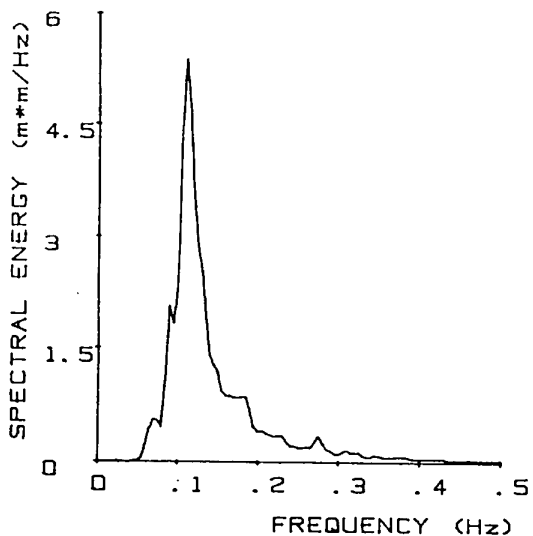
E_{max} = 5.97656 m*m/hz



WAVERIDER 1989-6-26 1220 Hrs

Hs = 2.07m Tz = 6.2s

E_{max} = 5.37891 m*m/hz



WAVERIDER 1989-6-26 1820 Hrs

Hs = 2.24m Tz = 6.5s

E_{max} = 9.06445 m*m/hz

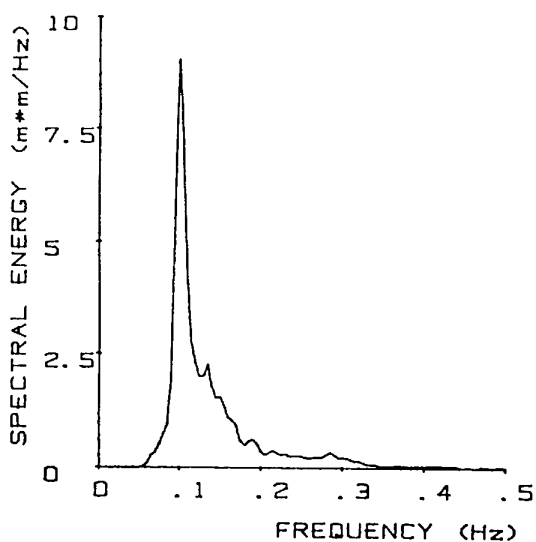
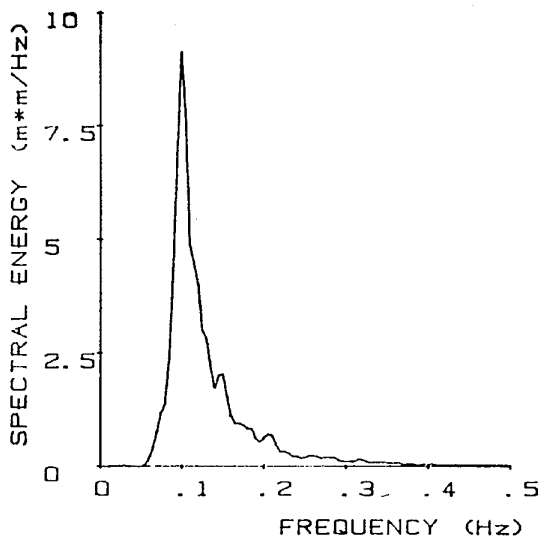


FIG.14 WAVE SPECTRA

WAVERIDER 1989-6-26 2120 Hrs

Hs = 2.51m Tz = 6.8s

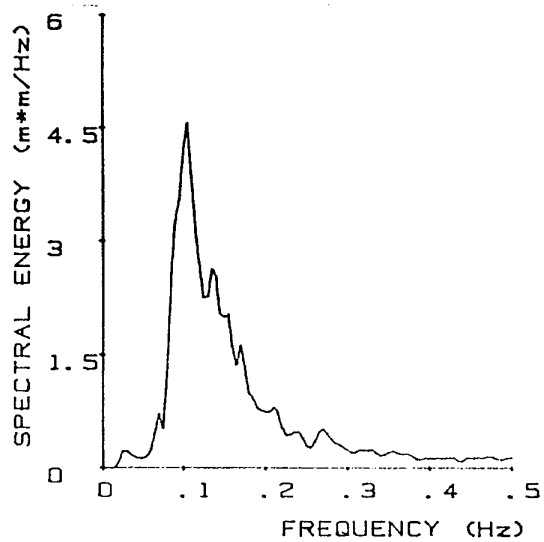
Emax = 9.164061 m*m/hz



WAVERIDER 1989-6-27 320 Hrs

Hs = 2.42m Tz = 5.4s

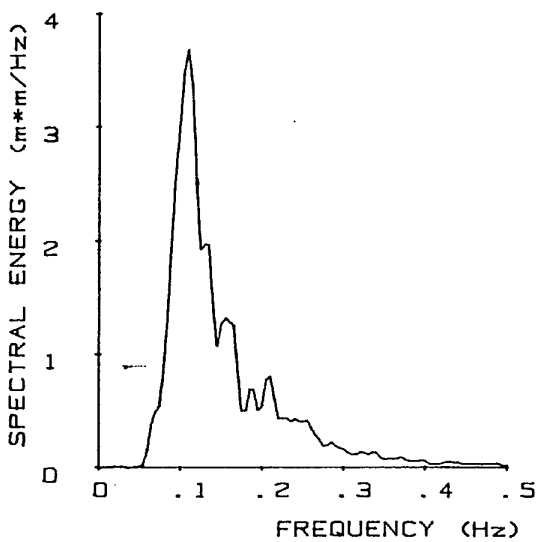
Emax = 4.582031 m*m/hz



WAVERIDER 1989-6-27 20 Hrs

Hs = 2.05m Tz = 5.9s

Emax = 3.68555 m*m/hz



WAVERIDER 1989-6-27 620 Hrs

Hs = 2.40m Tz = 5.2s

Emax = 5.17969 m*m/hz

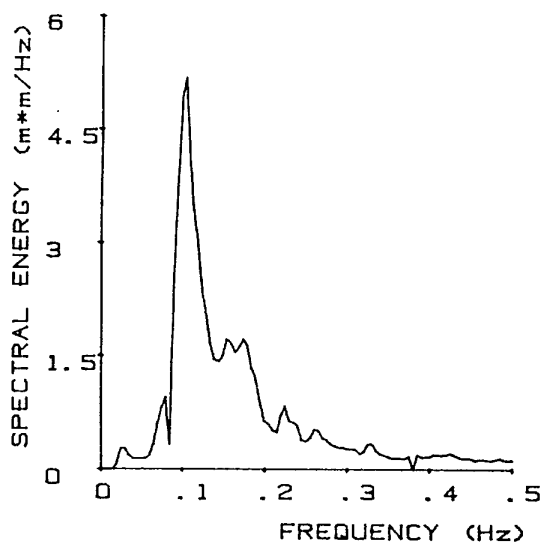
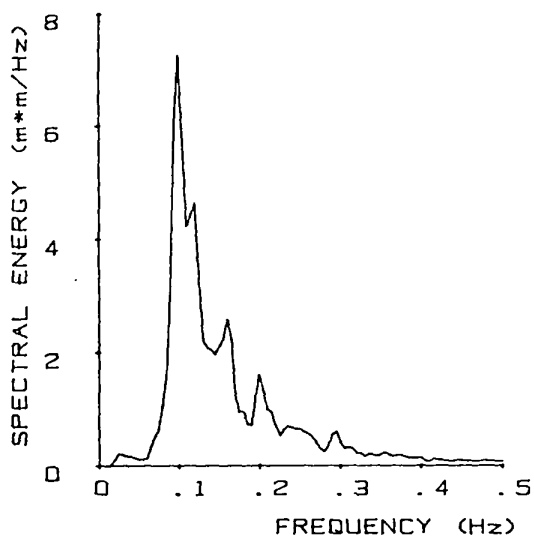


FIG.15 WAVE SPECTRA

WAVERIDER 1989-6-27 920 Hrs

Hs = 2.65m Tz = 5.6s

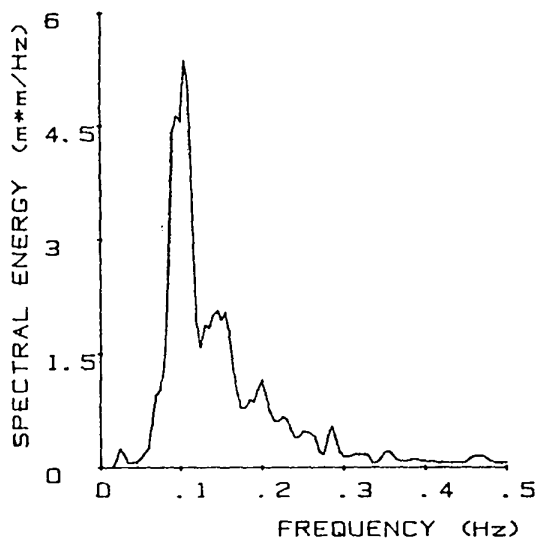
Emax = 7.27148 m*m/hz



WAVERIDER 1989-6-27 1520 Hrs

Hs = 2.43m Tz = 5.8s

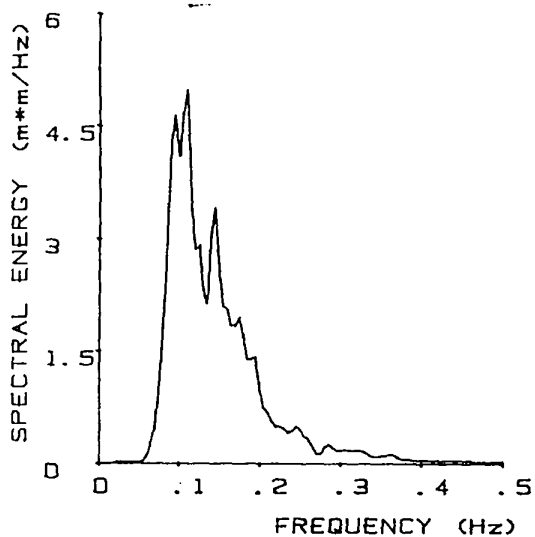
Emax = 5.37891 m*m/hz



WAVERIDER 1989-6-27 1220 Hrs

Hs = 2.51m Tz = 6.2s

Emax = 4.98047 m*m/hz



WAVERIDER 1989-6-27 1820 Hrs

Hs = 2.59m Tz = 6.3s

Emax = 5.67773 m*m/hz

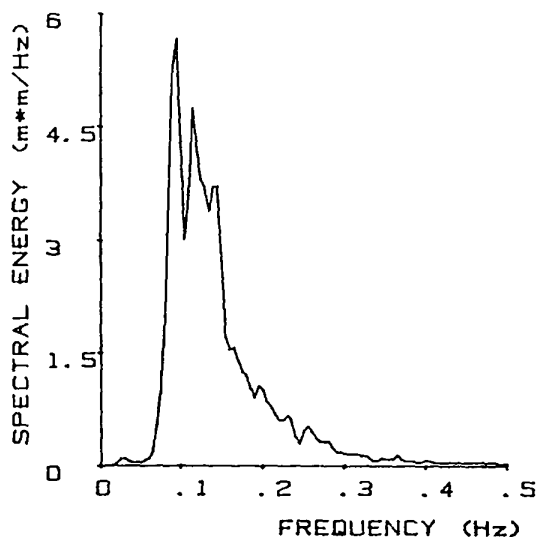
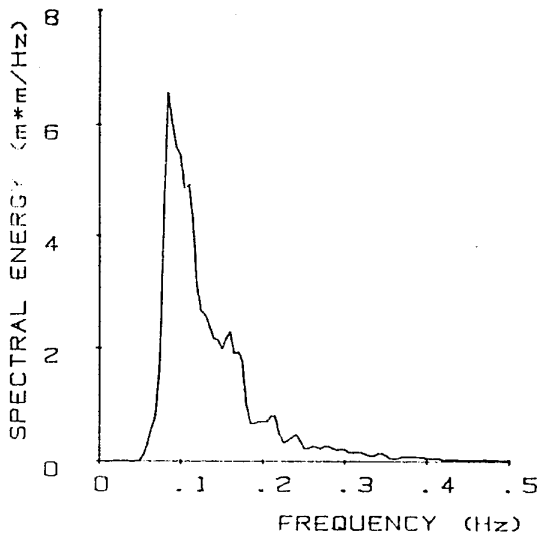


FIG.16 WAVE SPECTRA

WAVERIDER 1989-6-27 2120 Hrs

Hs = 2.64m Tz = 6.6s

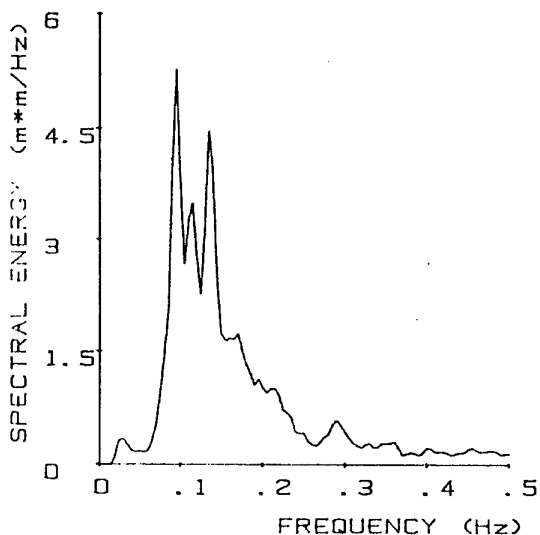
E_{max} = 6.57422 m*m/hz



WAVERIDER 1989-6-28 320 Hrs

Hs = 2.58m Tz = 5.2s

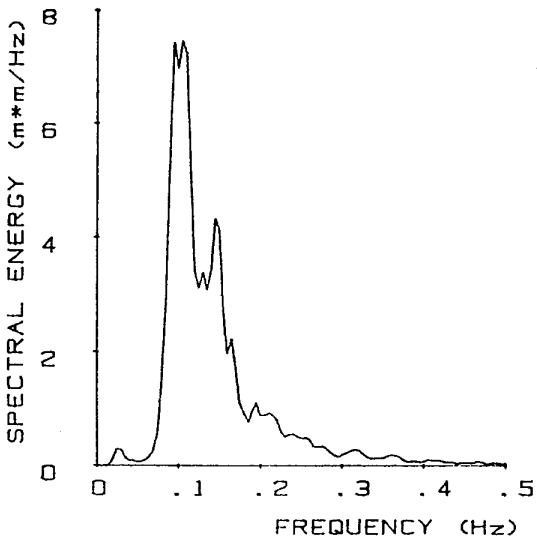
E_{max} = 5.2793 m*m/hz



WAVERIDER 1989-6-28 20 Hrs

Hs = 2.81m Tz = 6.2s

E_{max} = 7.4707 m*m/hz



WAVERIDER 1989-6-28 620 Hrs

Hs = 2.77m Tz = 6.3s

E_{max} = 6.67383 m*m/hz

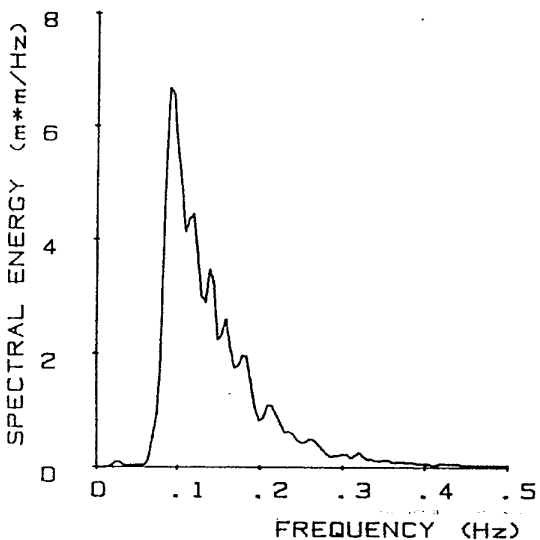
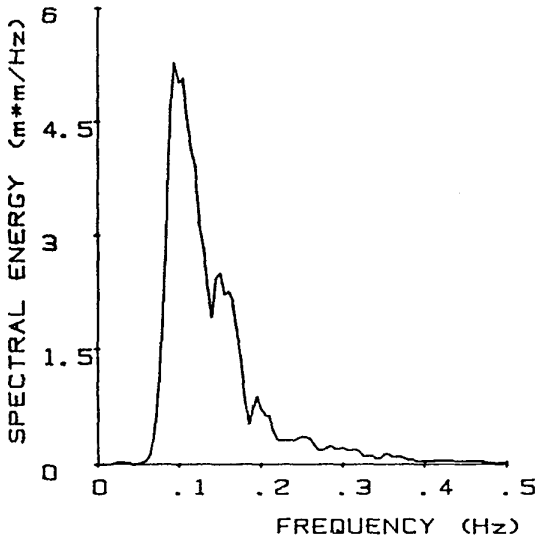


FIG.17 WAVE SPECTRA

WAVERIDER 1989-6-28 920 Hrs

Hs = 2.48m Tz = 6.3s

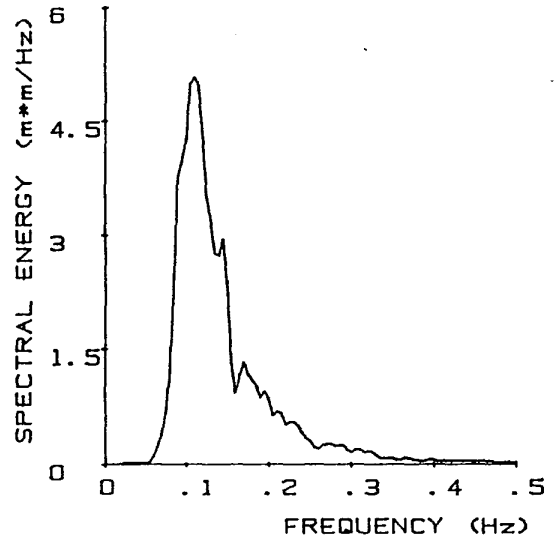
Emax = 5.2793 m*m/hz



WAVERIDER 1989-6-28 1520 Hrs

Hs = 2.45m Tz = 6.3s

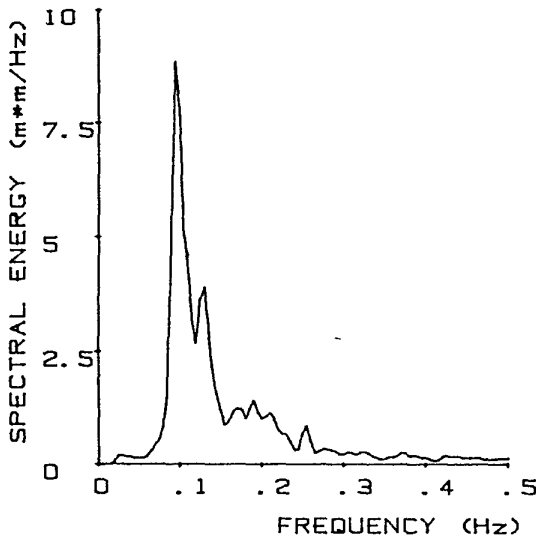
Emax = 5.08008 m*m/hz



WAVERIDER 1989-6-28 1220 Hrs

Hs = 2.62m Tz = 5.6s

Emax = 8.865229 m*m/hz



WAVERIDER 1989-6-28 1820 Hrs

Hs = 2.62m Tz = 6.3s

Emax = 6.07617 m*m/hz

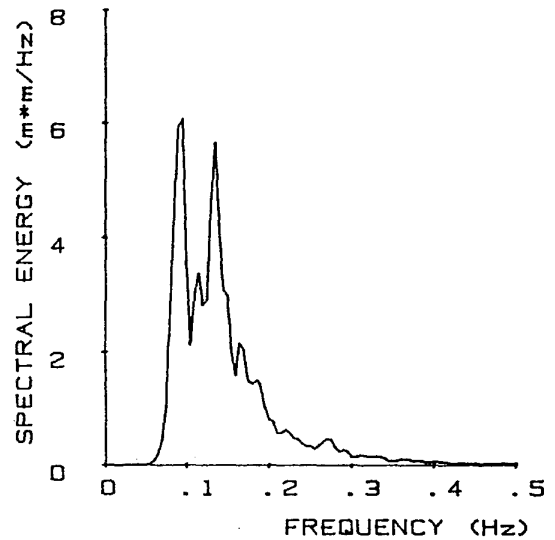
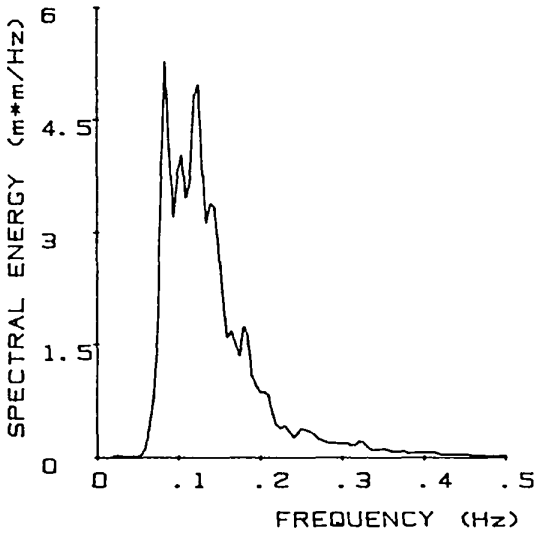


FIG.18 WAVE SPECTRA

WAVERIDER 1989-6-28 2120 Hrs

Hs = 2.62m Tz = 6.4s

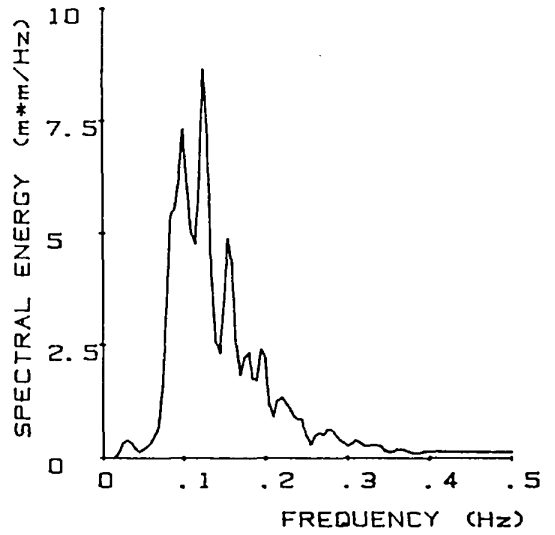
E_{max} = 5.2793 m*m/hz



WAVERIDER 1989-6-29 320 Hrs

Hs = 3.24m Tz = 5.9s

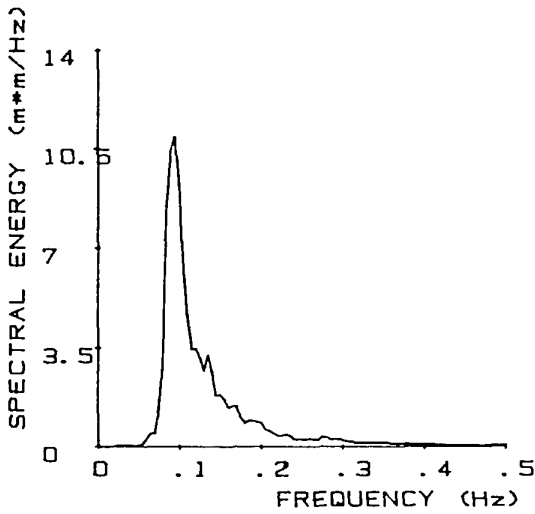
E_{max} = 8.666021 m*m/hz



WAVERIDER 1989-6-29 20 Hrs

Hs = 2.84m Tz = 6.8s

E_{max} = 10.95703 m*m/hz



WAVERIDER 1989-6-29 620 Hrs

Hs = 3.29m Tz = 5.9s

E_{max} = 8.666021 m*m/hz

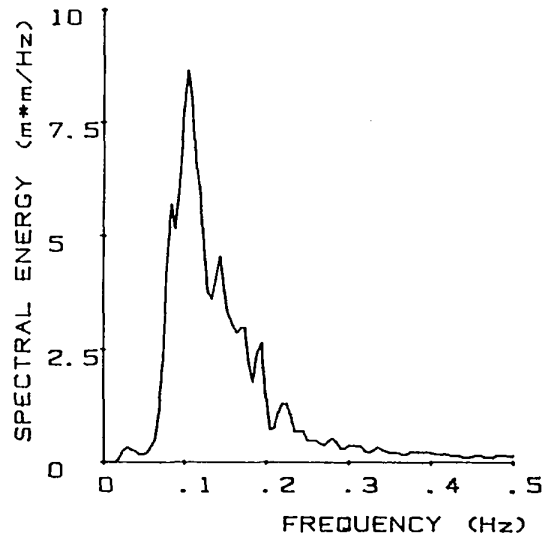
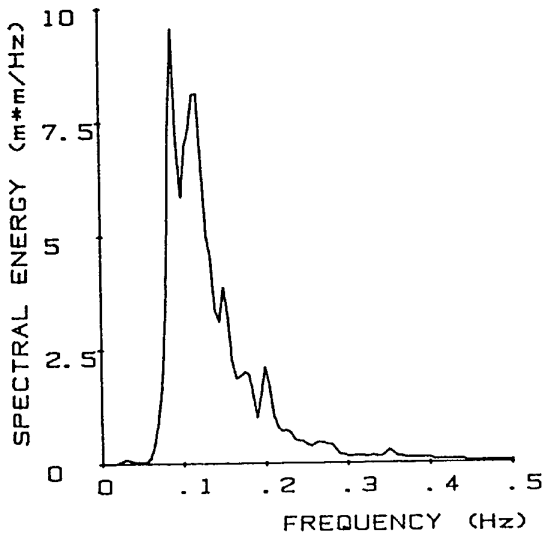


FIG.19 WAVE SPECTRA

WAVERIDER 1989-6-29 920 Hrs

$H_s = 3.20\text{m}$ $T_z = 6.5\text{s}$

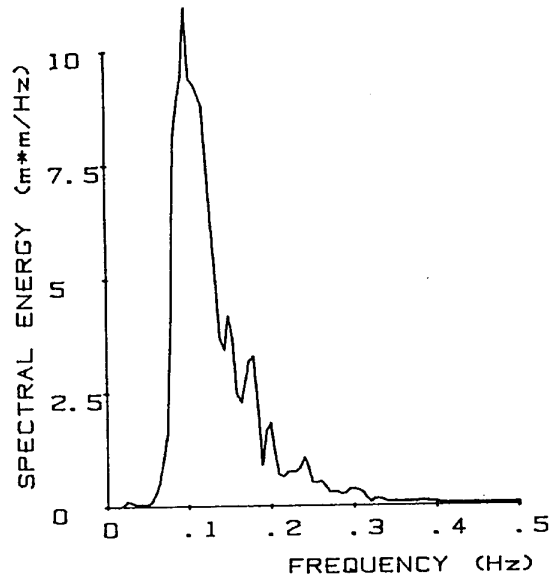
$E_{\text{max}} = 9.5625 \text{ m}^2/\text{hz}$



WAVERIDER 1989-6-29 1520 Hrs

$H_s = 3.49\text{m}$ $T_z = 6.7\text{s}$

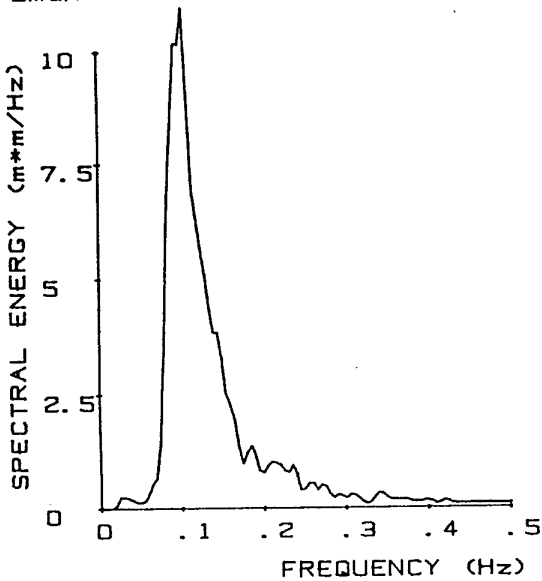
$E_{\text{max}} = 10.95703 \text{ m}^2/\text{hz}$



WAVERIDER 1989-6-29 1220 Hrs

$H_s = 3.30\text{m}$ $T_z = 6.4\text{s}$

$E_{\text{max}} = 10.95703 \text{ m}^2/\text{hz}$



WAVERIDER 1989-6-29 1820 Hrs

$H_s = 3.90\text{m}$ $T_z = 7.3\text{s}$

$E_{\text{max}} = 20.91797 \text{ m}^2/\text{hz}$

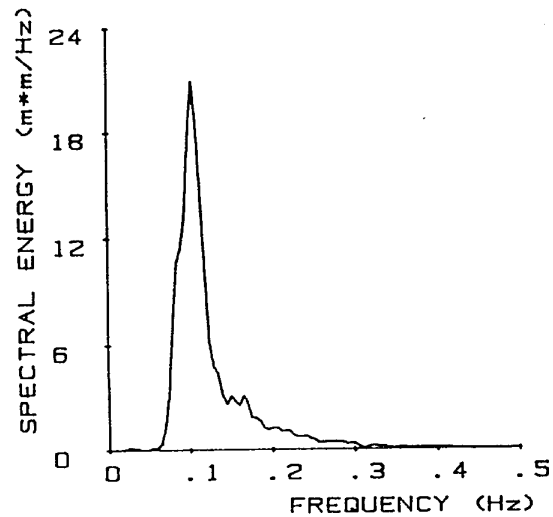
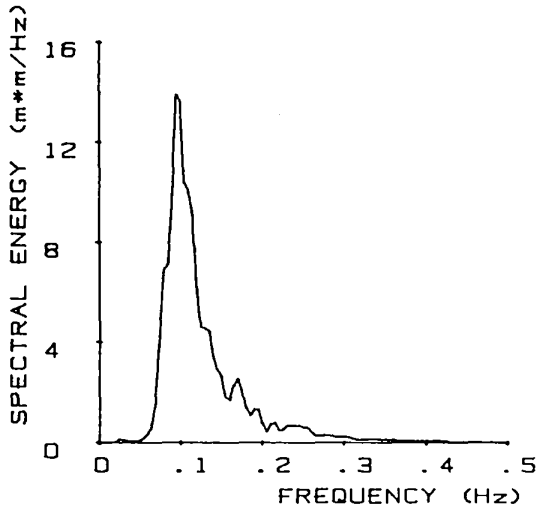


FIG.20 WAVE SPECTRA

WAVERIDER 1989-6-29 2120 Hrs

Hs = 3.42m Tz = 7.2s

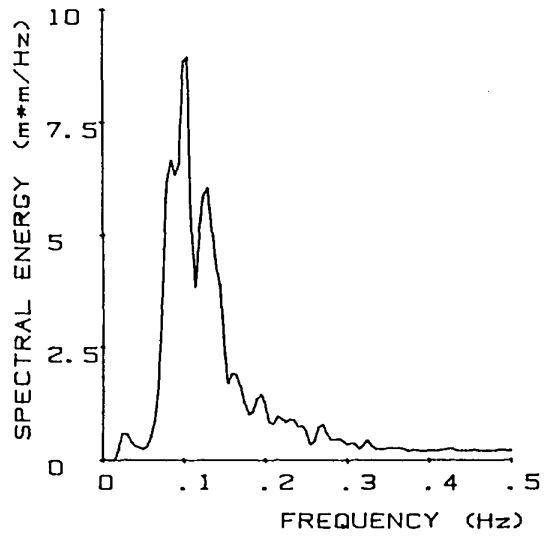
E_{max} = 13.94531 m*m/hz



WAVERIDER 1989-6-30 320 Hrs

Hs = 3.27m Tz = 5.7s

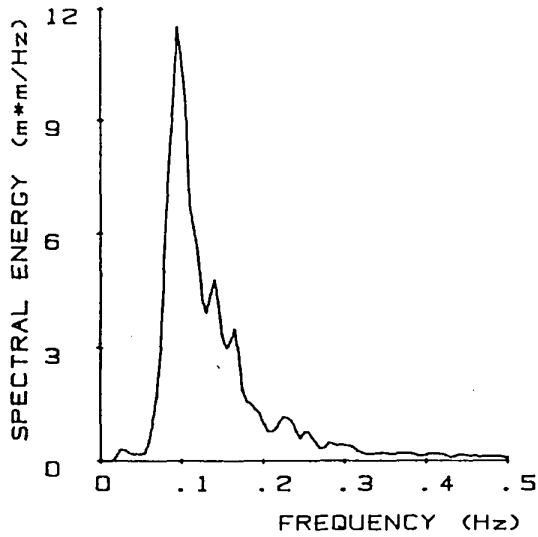
E_{max} = 8.96484 m*m/hz



WAVERIDER 1989-6-30 20 Hrs

Hs = 3.47m Tz = 6.2s

E_{max} = 11.95313 m*m/hz



WAVERIDER 1989-6-30 620 Hrs

Hs = 3.44m Tz = 6.6s

E_{max} = 10.95703 m*m/hz

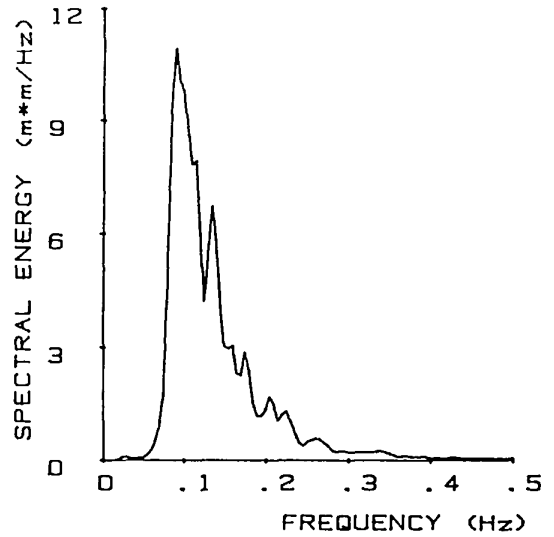
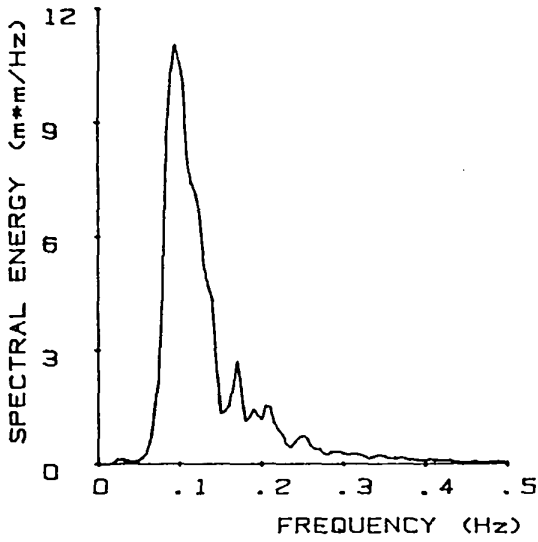


FIG.21 WAVE SPECTRA

WAVERIDER 1989-6-30 920 Hrs

Hs = 3.37m Tz = 6.7s

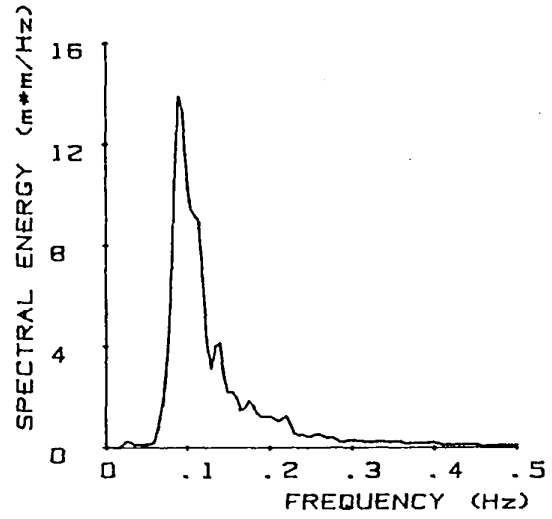
E_{max} = 11.95313 m*m/hz



WAVERIDER 1989-6-30 1520 Hrs

Hs = 3.45m Tz = 6.6s

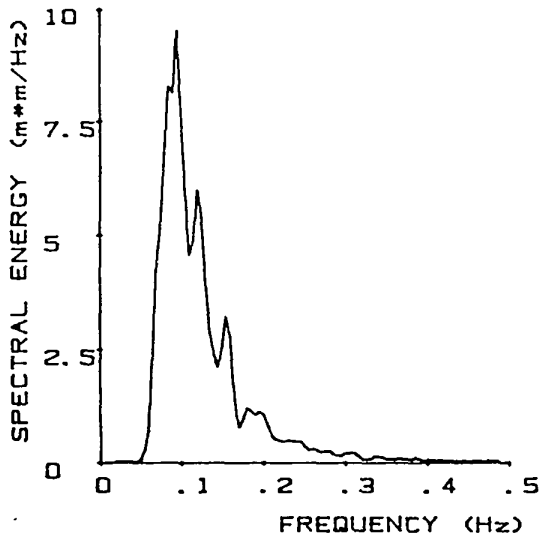
E_{max} = 13.94531 m*m/hz



WAVERIDER 1989-6-30 1220 Hrs

Hs = 3.11m Tz = 7.2s

E_{max} = 9.96099 m*m/hz



WAVERIDER 1989-6-30 1820 Hrs

Hs = 3.62m Tz = 6.4s

E_{max} = 11.95313 m*m/hz

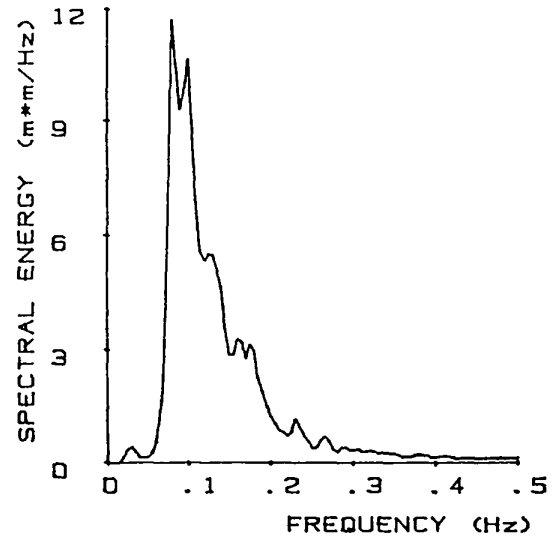
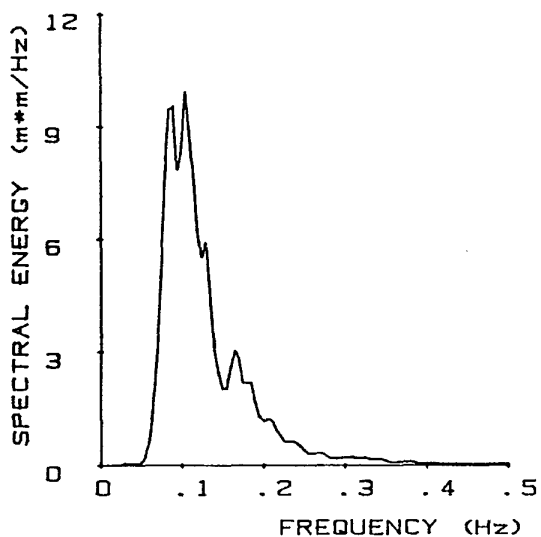


FIG.22 WAVE SPECTRA

WAVERIDER 1989-6-30 2120 Hrs

Hs = 3.40m Tz = 7.0s

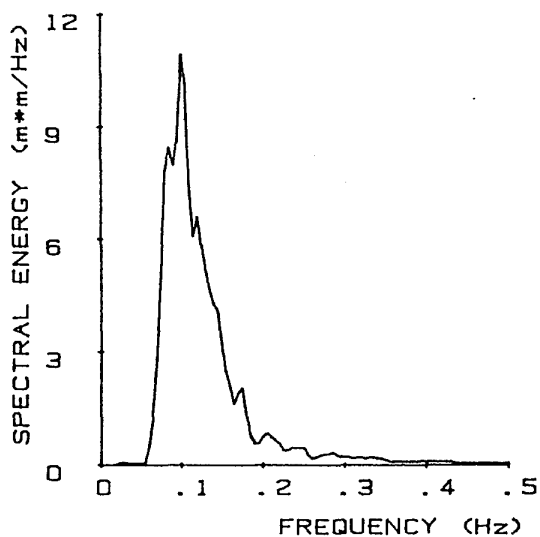
E_{max} = 9.960939 m**m/hz



WAVERIDER 1989-7-1 320 Hrs

Hs = 3.31m Tz = 7.0s

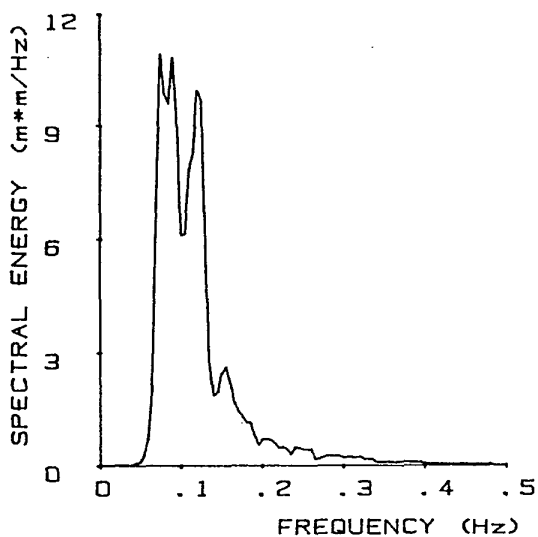
E_{max} = 10.95703 m**m/hz



WAVERIDER 1989-7-1 20 Hrs

Hs = 3.45m Tz = 7.4s

E_{max} = 10.95703 m**m/hz



WAVERIDER 1989-7-1 620 Hrs

Hs = 3.44m Tz = 7.0s

E_{max} = 15.9375 m**m/hz

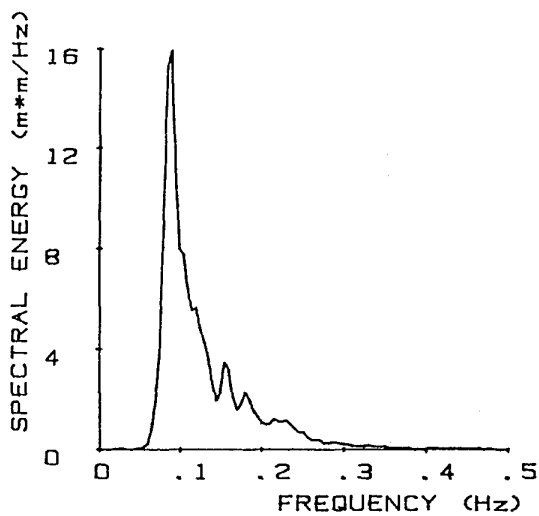
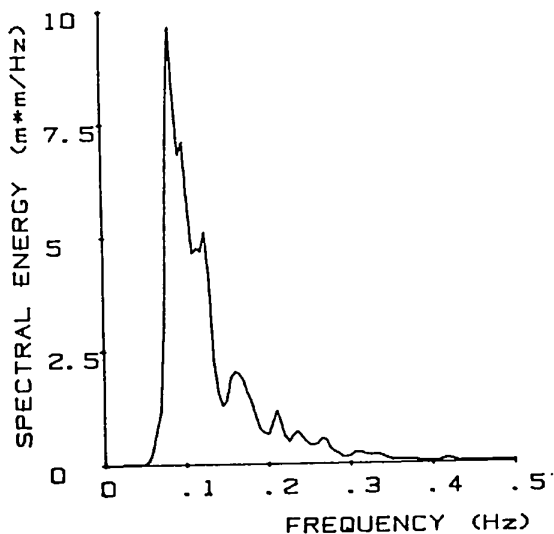
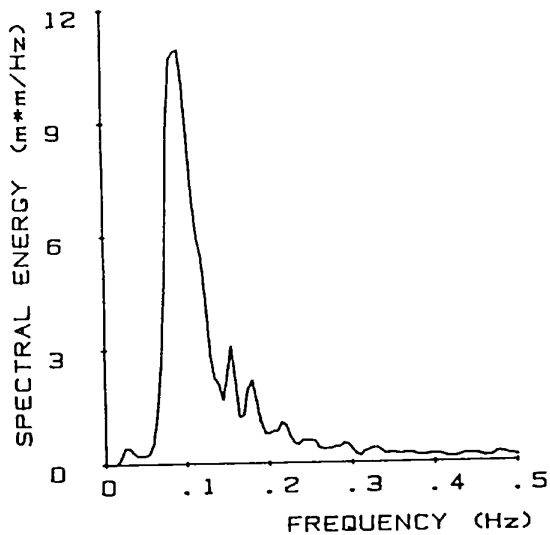


FIG.23 WAVE SPECTRA

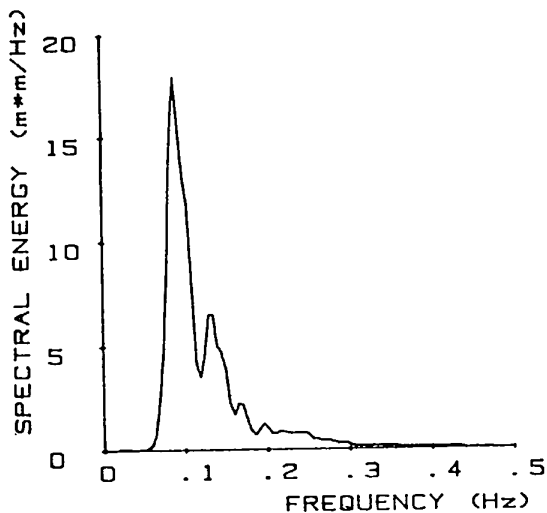
WAVERIDER 1989-7-1 920 Hrs
Hs = 2.93m Tz = 6.7s
Emax = 9.662111 m**m/hz



WAVERIDER 1989-7-1 1520 Hrs
Hs = 3.36m Tz = 6.2s
Emax = 10.95703 m**m/hz



WAVERIDER 1989-7-1 1220 Hrs
Hs = 3.65m Tz = 7.3s
Emax = 17.92969 m**m/hz



WAVERIDER 1989-7-1 1820 Hrs
Hs = 3.24m Tz = 5.6s
Emax = 10.95703 m**m/hz

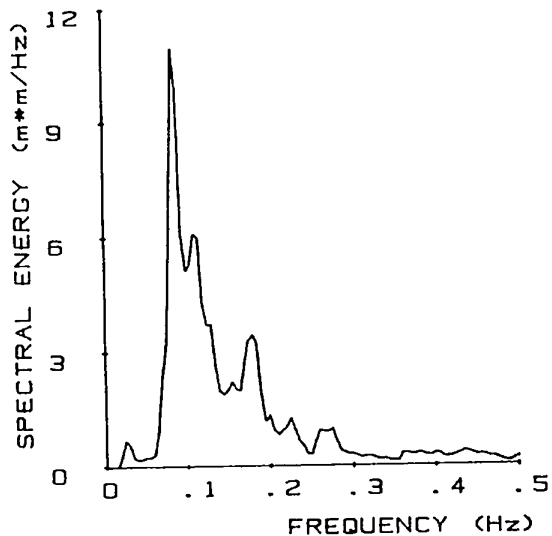
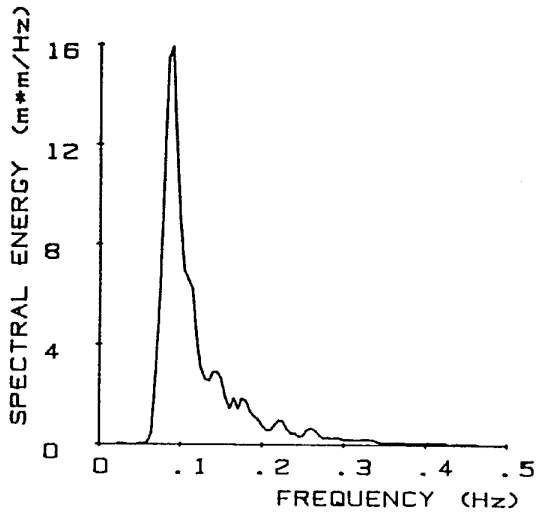


FIG.24 WAVE SPECTRA

WAVERIDER 1989-7-1 2120 Hrs

Hs = 3.35m Tz = 7.3s

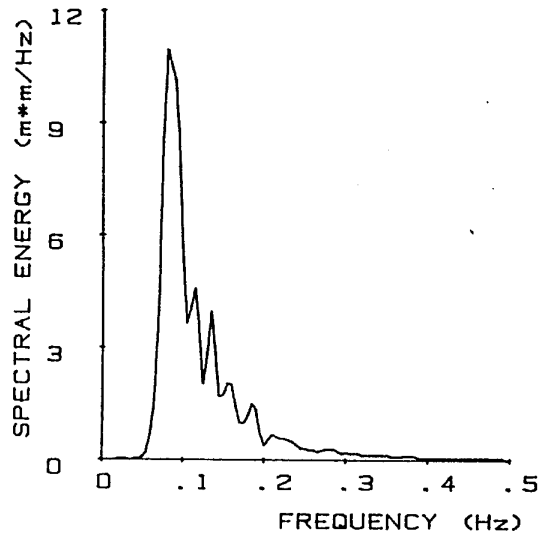
E_{max} = 15.9375 m*m/hz



WAVERIDER 1989-7-2 320 Hrs

Hs = 3.03m Tz = 7.2s

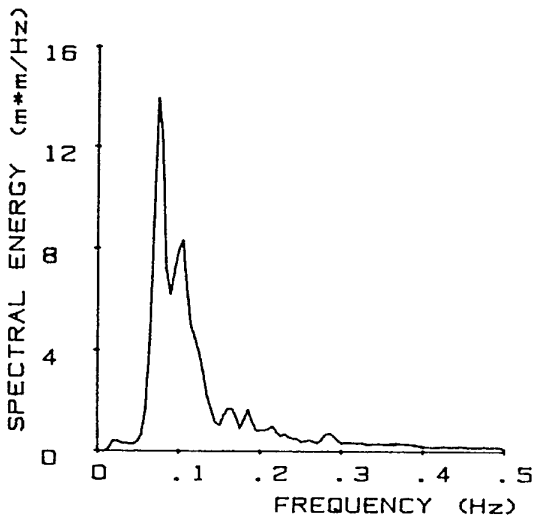
E_{max} = 10.95703 m*m/hz



WAVERIDER 1989-7-2 20 Hrs

Hs = 3.41m Tz = 6.3s

E_{max} = 13.94531 m*m/hz



WAVERIDER 1989-7-2 620 Hrs

Hs = 3.17m Tz = 7.6s

E_{max} = 13.94531 m*m/hz

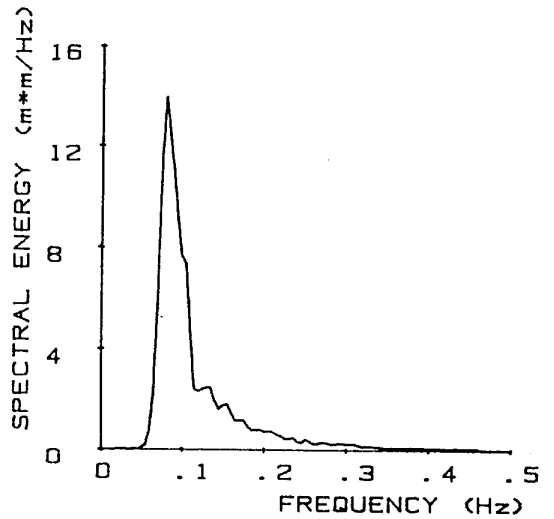
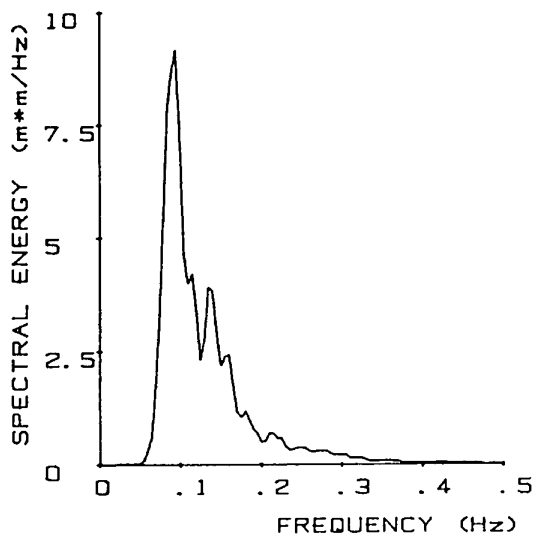


FIG.25 WAVE SPECTRA

WAVERIDER 1989-7-2 920 Hrs

Hs = 2.86m Tz = 7.0s

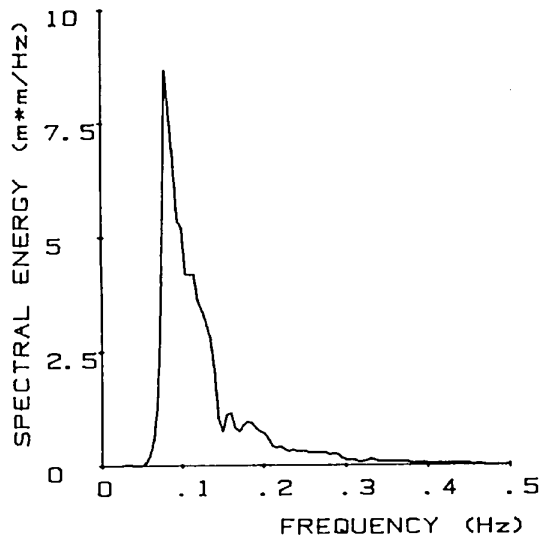
E_{max} = 9.164061 m*m/hz



WAVERIDER 1989-7-2 2120 Hrs

Hs = 2.66m Tz = 7.2s

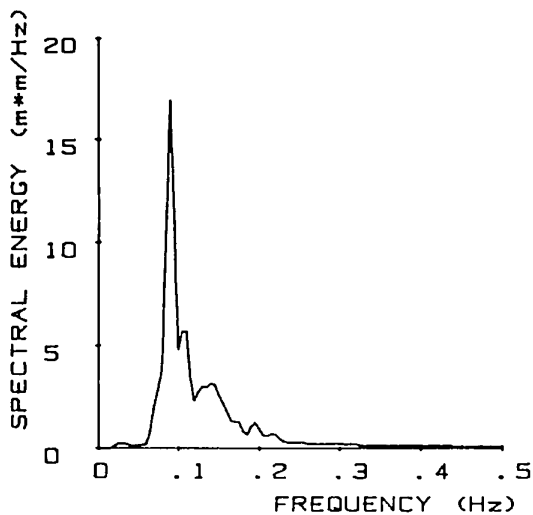
E_{max} = 9.960939 m*m/hz



WAVERIDER 1989-7-2 1220 Hrs

Hs = 3.02m Tz = 6.6s

E_{max} = 16.93359 m*m/hz



WAVERIDER 1989-7-3 20 Hrs

Hs = 2.94m Tz = 6.4s

E_{max} = 12.94922 m*m/hz

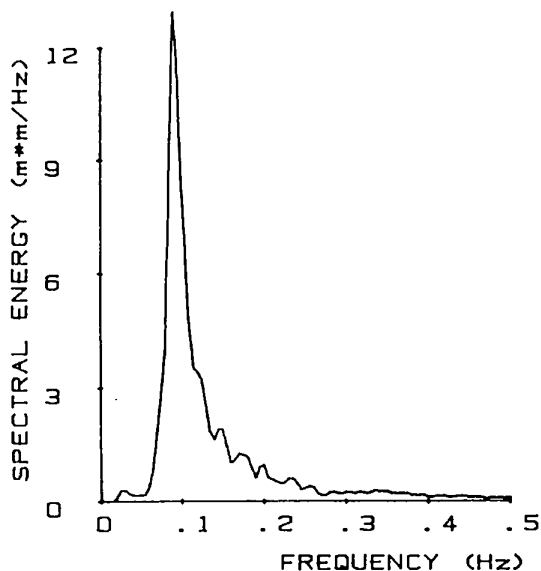
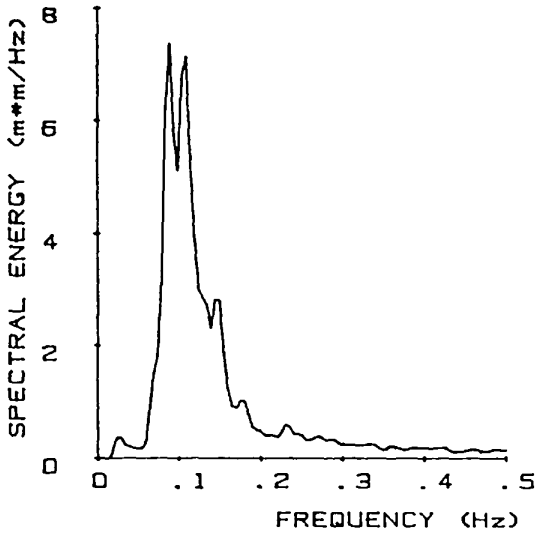


FIG.26 WAVE SPECTRA

WAVERIDER 1989-7-3 320 Hrs

$H_s = 2.80m$ $T_z = 5.9s$

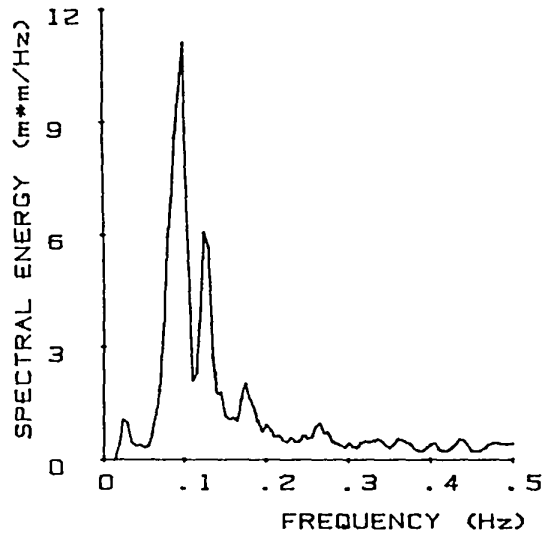
$E_{max} = 7.37109 \text{ m}^2/\text{Hz}$



WAVERIDER 1989-7-3 920 Hrs

$H_s = 3.22m$ $T_z = 5.2s$

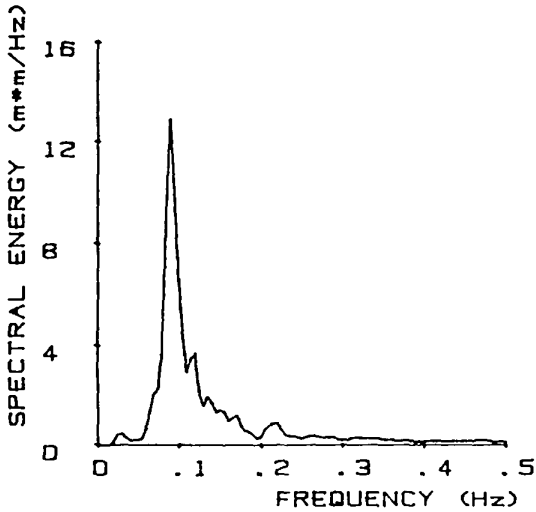
$E_{max} = 11.95313 \text{ m}^2/\text{Hz}$



WAVERIDER 1989-7-3 620 Hrs

$H_s = 2.83m$ $T_z = 6.0s$

$E_{max} = 12.94922 \text{ m}^2/\text{Hz}$



WAVERIDER 1989-7-3 1220 Hrs

$H_s = 2.53m$ $T_z = 7.1s$

$E_{max} = 8.865229 \text{ m}^2/\text{Hz}$

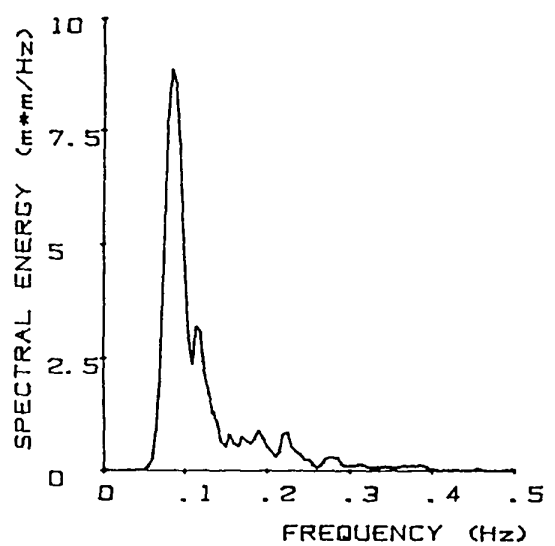
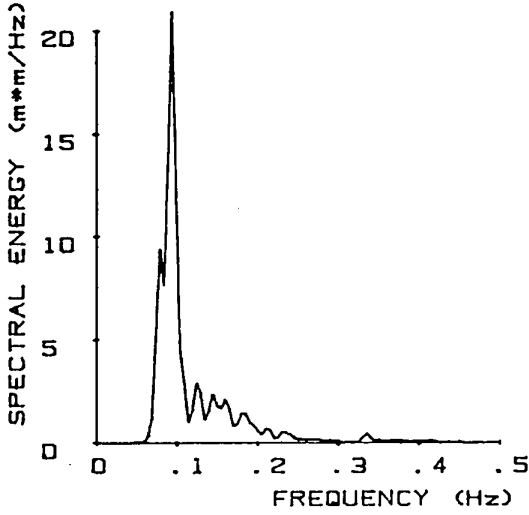


FIG.27 WAVE SPECTRA

WAVERIDER 1989-7-3 1520 Hrs

Hs = 3.02m Tz = 7.5s

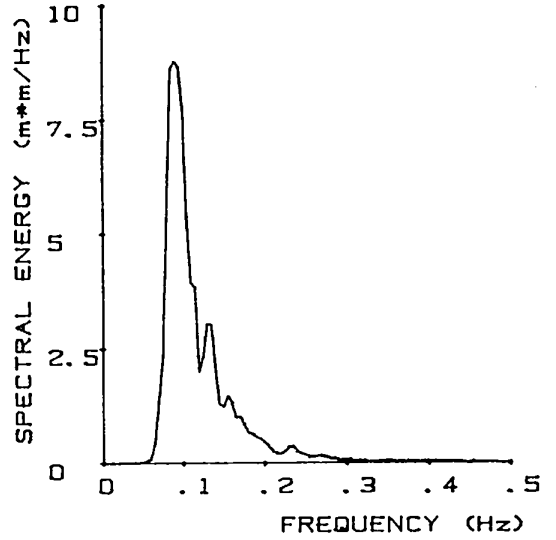
Emax = 20.91797 m**m/hz



WAVERIDER 1989-7-4 320 Hrs

Hs = 2.60m Tz = 7.6s

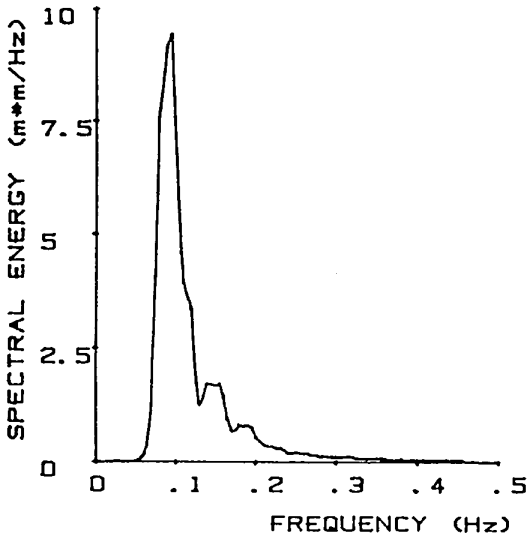
Emax = 8.76563 m**m/hz



WAVERIDER 1989-7-4 120 Hrs

Hs = 2.66m Tz = 7.6s

Emax = 9.462889 m**m/hz



WAVERIDER 1989-7-4 620 Hrs

Hs = 2.73m Tz = 6.4s

Emax = 9.26367 m**m/hz

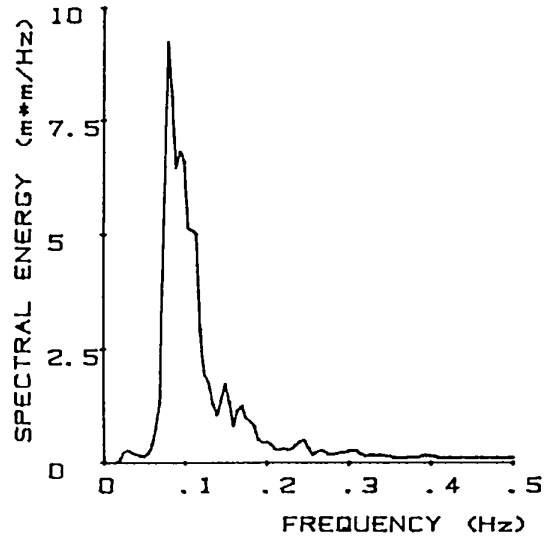


FIG.28 WAVE SPECTRA

OFF KARWAR 75m WATER DEPTH

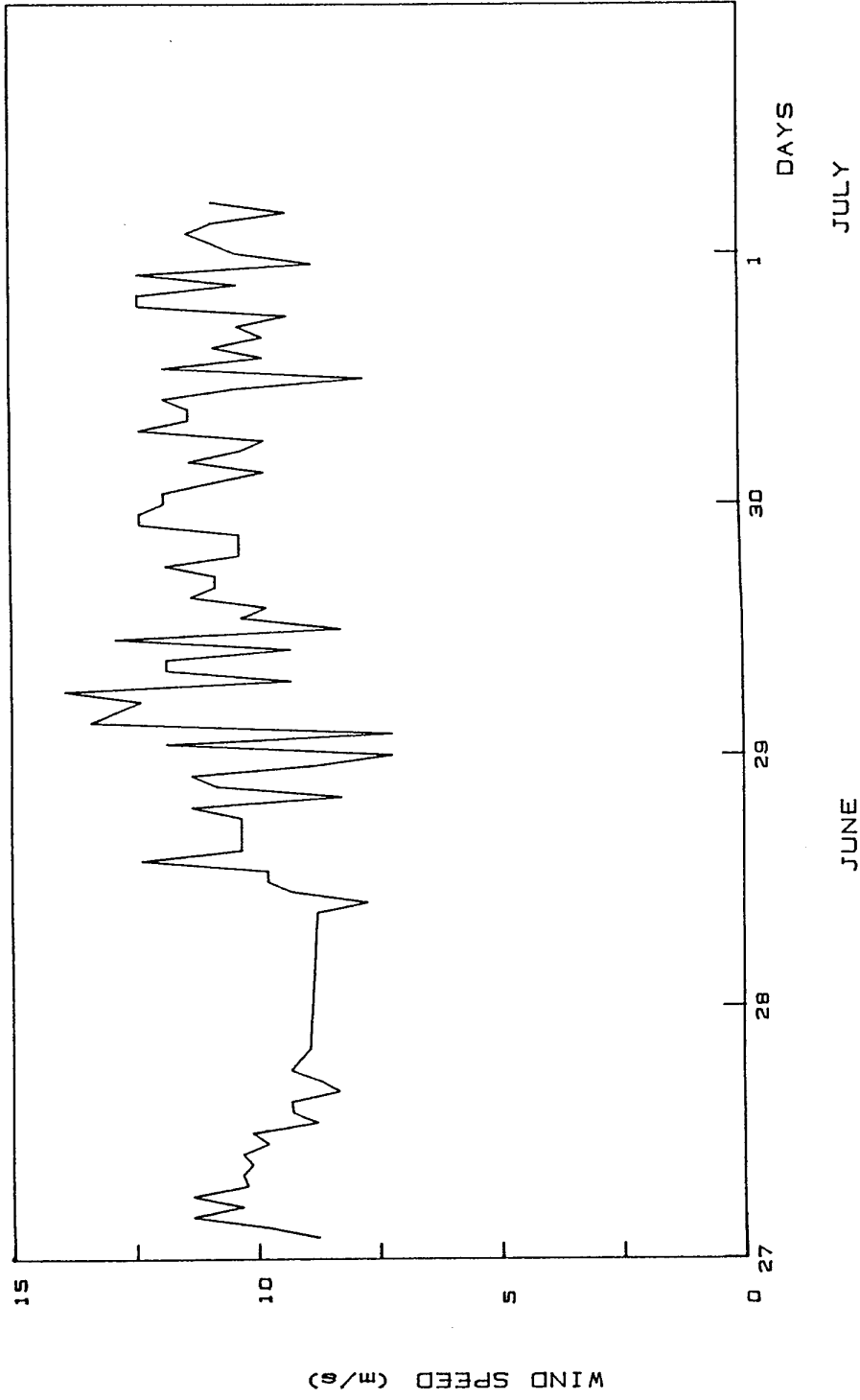


FIG. 29 VARIATION OF WIND SPEED

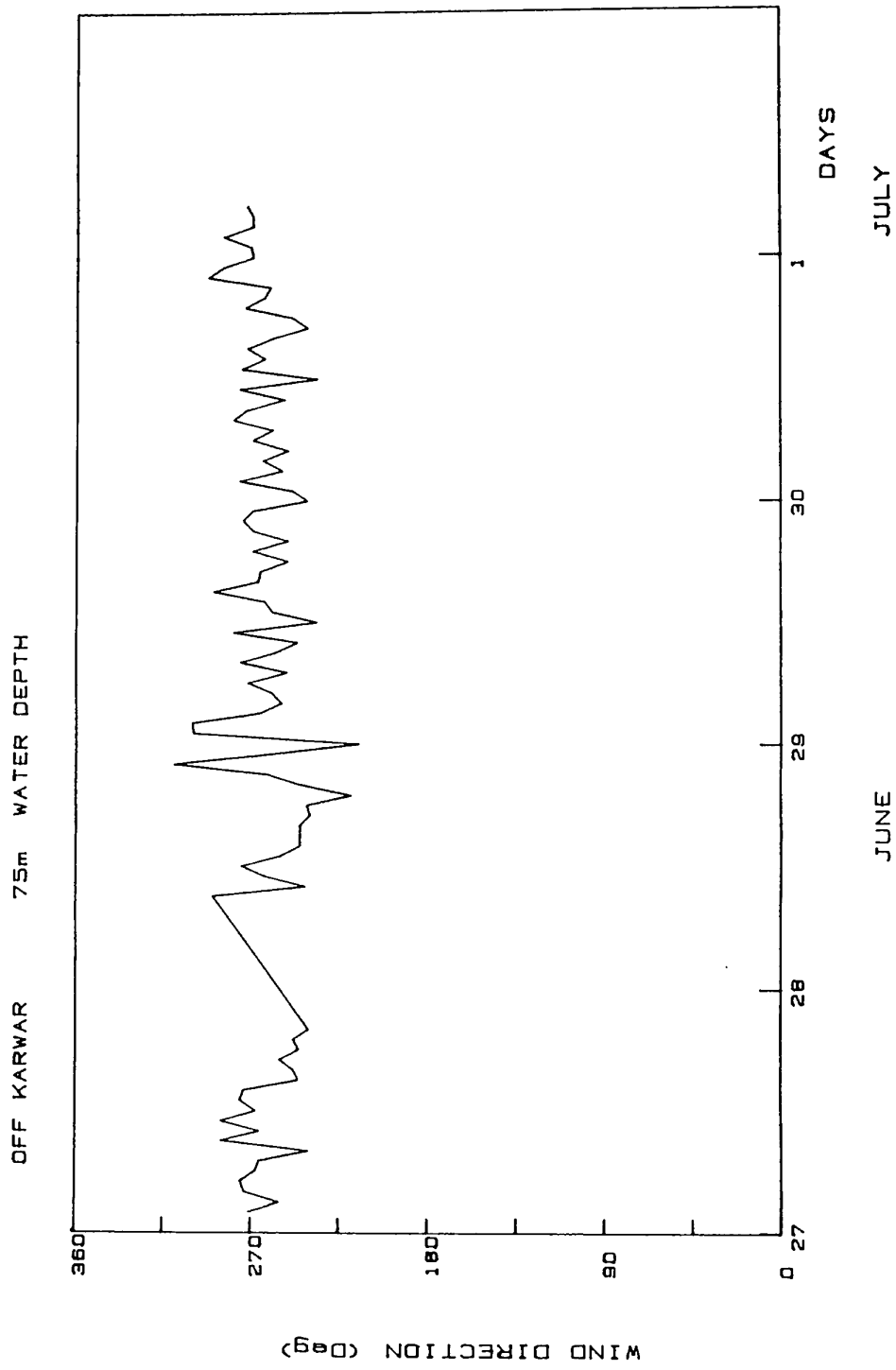
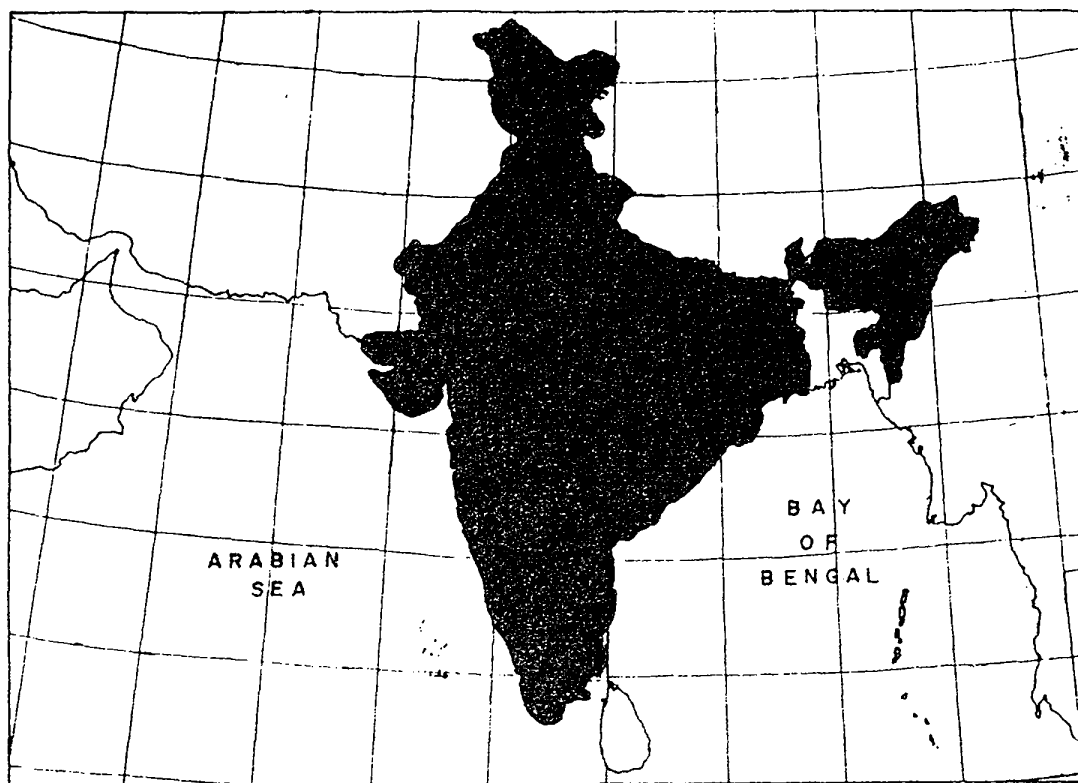


FIG. 30 VARIATION OF WIND DIRECTION



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