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Evaluation of the Computation of Wave Direction with Three-Gage Arrays

by

Dinorah C. Esteva

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A description of the collection and analyses of data obtained with an array of five pressure sensors near Pt. Mugu, California, is presented. The 10 three-gage arrays possible with five gages are used to compare redundant values of the direction of wave propagation. The dependence of directional determination on array orientation relative to incident wave direction and wavelength at the array site is shown by calculations based on simulated narrow-banded wave trains. Directional results from the field study indicate

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) the maximum accuracy of wave direction determinations with a three-gage array is on the order of ±20°. This level of accuracy may be expected only for narrow-banded wave trains with periods longer than a lower limit determined at each location by array dimensions and water depth. The field study also indicates narrow-banded wave trains are frequent at this coastal location.

PREFACE

This report is published to provide guidance to coastal engineers in planning wave data collection in coastal waters for climatology purposes, including wave direction. The popularity of three-gage arrays for proposed wave direction measuring systems makes it necessary to evaluate the capabilities and the limitations of these arrays. The availability of the CERC five-gage array at Pt. Mugu, California, provided a unique opportunity for evaluating the performance of wave recording systems and the directional capabilities of three-gage arrays. The work was carried out under the wave measurement and analyses program of the U.S. Army Coastal Engineering Research Center (CERC).

This report was prepared by Dr. Dinorah C. Esteva under the supervision of Dr. D. Lee Harris, Chief, Coastal Oceanography Branch, Research Division. The author acknowledges the valuable insight and comments provided by Dr. D. Lee Harris and Mr. R. P. Savage, Chief, Research Division, CERC.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

JOHN H. COUSINS
Colonel, Corps of Engineers
Commander and Director

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.39	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.8532	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.1745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1]To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: C = (5/9) (F -32).

To obtain Kelvin (K) readings, use formula: K = (5/9) (F -32) + 273.15.

EVALUATION OF THE COMPUTATION OF WAVE DIRECTION WITH THREE-GAGE ARRAYS

by
Dinorah C. Esteva

I. INTRODUCTION

Wave direction is an important parameter in the solution of many coastal engineering problems. A knowledge of wave direction is essential for (a) estimating the direction and magnitude of sediment transport by waves, (b) using refraction calculations to infer wave conditions at one site from measurements made elsewhere, and (c) verifying theories of wave generation.

Visual observations of wave directions have been collected by shipboard observers for over a century. About 20 years ago the Beach Erosion Board (BEB), predecessor to the Coastal Engineering Research Center (CERC), engaged the assistance of U.S. Coast Guard installations in the collection of visual observations of breaker direction from shore. However, objective determinations of wave direction are desirable without being restricted to location, time of day, or visibility condition. The capability to do so involves the use of wave measuring instruments. Panicker (1971, 1974) presents extensive reviews of reports dealing with the determination of wave direction from instrument records with particular emphasis on those involving sea-surface elevation or pressure records.

In March 1970, CERC installed an array of wave gages at Pt. Mugu, California. Records from the array were to be used to compare redundant values of wave direction and to estimate the level of accuracy of the computations. The available procedures for determining wave direction from an array involved assumptions that had not been thoroughly established. Thus, the records from the array would also be used in a systematic examination of these assumptions, and of the reliability of wave gages.

This study discusses the array performance and the information gained about wave direction. Redundant values of directions were obtained from the 10 three-gage arrays possible with five gages. The mathematical model used assumes that the sea surface is the result of the superposition of a small number of narrow-banded wave trains consisting of long-crested waves traveling in well-defined directions. It was also assumed that only one wave train is present with a particular period. The first assumption is supported by the energy spectra computed at CERC (Thompson, 1974), by aerial photos of the sea surface (Fig. 1), and by radar images of the wave field (Fig. 2). Many published reports include photos similar to that in Figure 1; e.g., McClenan and Harris (1975). Fujinawa (1974, 1975) conjectured that narrow directional spread might be responsible for the incomplete recovery of the true directional spectrum from field records in his computations using high directional resolution.

Average values of wave direction for bands of constant frequency width were computed from cross-spectra between gage pairs. Direction

Figure 1. Aerial photo of wave field at Pt. Saint George, California.

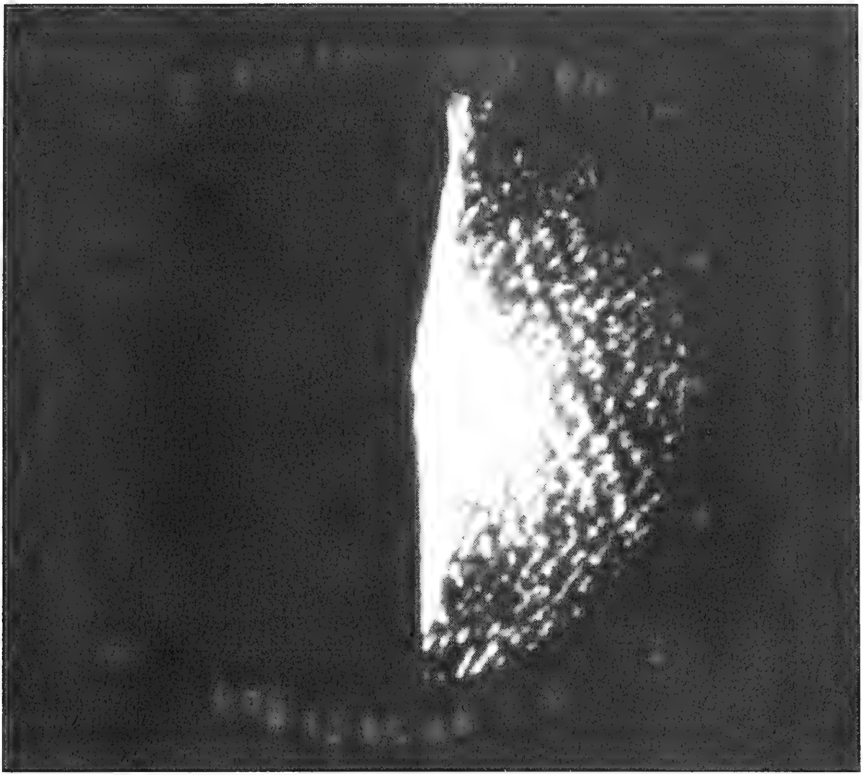

Figure 2. Radar scan of wave field at Nauset, Massachusetts.

estimates for all bands 0.01 hertz wide between approximately 30 and 3 seconds were obtained for the 10 arrays. The results displayed discrepancies of the order of 20° for those bands with central periods above 10 seconds and of 180° for those with shorter central periods. It had been expected that the array would yield direction to better than 20° and for periods between 25 and 7 seconds.

To isolate problems associated with the calculations, the propagation of narrow-banded wave trains across the array was simulated in a computer. The computational model was applied to the simulated observations using the maximum frequency resolution available from spectral computations based on 20-minute records. It was found that the directional results obtained with this model are highly dependent on the spectral width, both in frequency and direction, of the wave train involved and on the relationship between wavelength at the site and gage separations. The assigned directions were recovered within 1° for 16-second waves when the frequencies of the spectral components in the wave train differed by 0.003 hertz or more, and the directions were spread within a 5° arc. This frequency separation results in a minimum difference in periods of 0.7 second for waves with periods near 16 seconds.

Application of the same analyses to field wave pressure records with standard deviations above 0.61 meter (2 feet) resulted in an average discrepancy of 20° among computed directions for narrow-banded wave trains with periods longer than 10 seconds. Larger discrepancies resulted for shorter periods. Thus, accuracies no better than 20° can be expected for wave directions resulting from three-gage arrays.

1. The System.

A minimum of three gages is required for a unique determination of wave direction by most proposed models. Since these models make a few assumptions about the nature of ocean waves which have not been established, some redundance was thought to be necessary which would require a minimum of four gages. However, it was agreed that a five-gage array would increase the probability of redundance in the ocean environment. An array was designed at CERC by Leon E. Borgman, statistician-engineer, while on sabbatical leave from the University of California, Berkeley, when the experiment was being planned. He investigated the directional resolving power of several array geometries and concluded that the pattern shown in Figure 3 would be the most suitable for the conditions to be expected at Pt. Mugu (Borgman and Panicker, 1970).

The array was installed off Pt. Mugu, approximately 80.47 kilometers (50 miles) northwest of Los Angeles (Fig. 4), in about 9.14 meters (30 feet) of water, 0.76 meter (2.5 feet) from the bottom. The gages in the array are pressure transducers developed mostly at CERC (Williams, 1969). The heart of the system is a Fairchild pressure transducer which is potted inside a 2-inch Plexiglas tube (Fig. 5) (Peacock, 1974). A plastic tube filled with silicone oil transmits the pressure from the seawater to the pressure transducer. The silicone oil is separated from seawater by

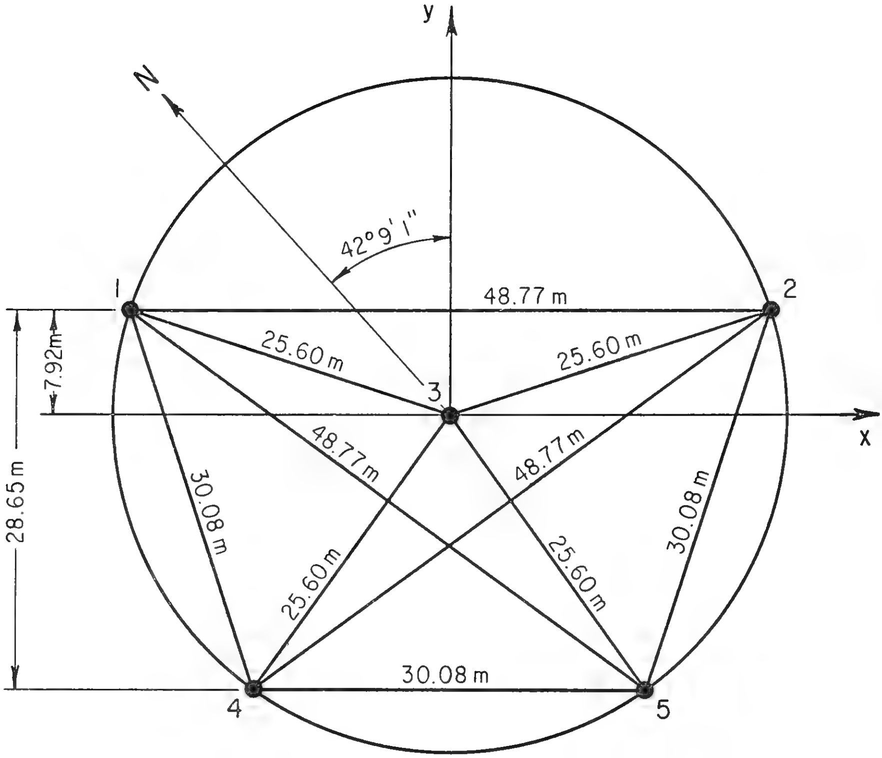

Figure 3. Five-gage array dimensions and geometry.

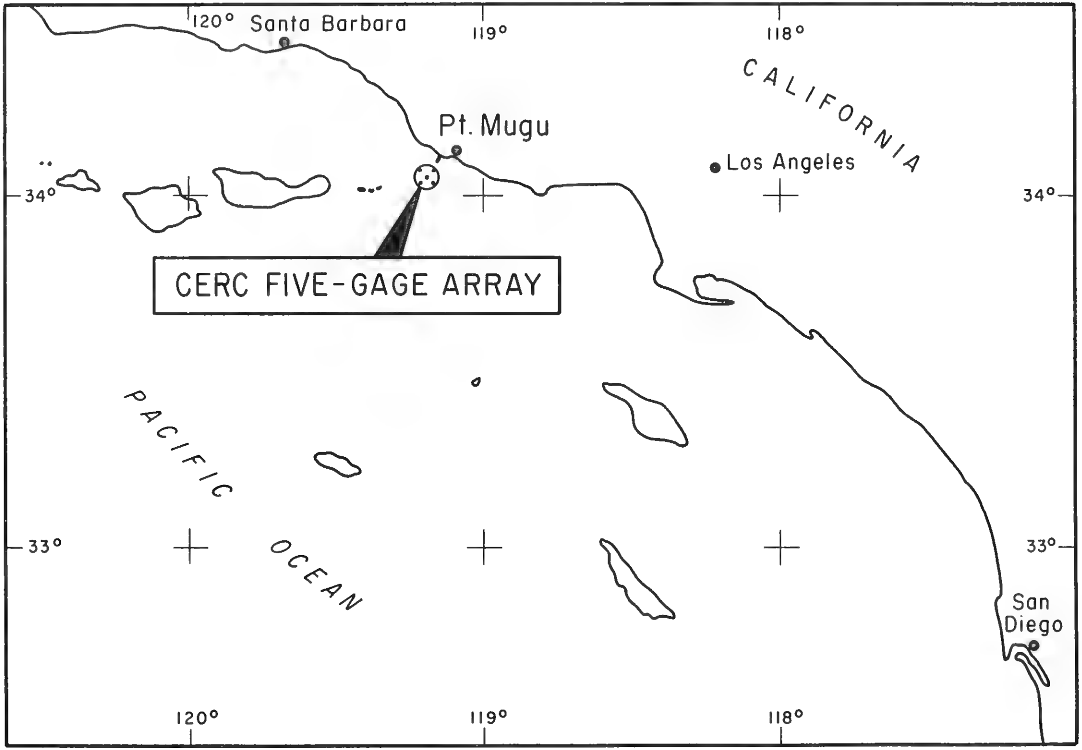

Figure 4. Location of the five-gage array (from Panicker, 1971).

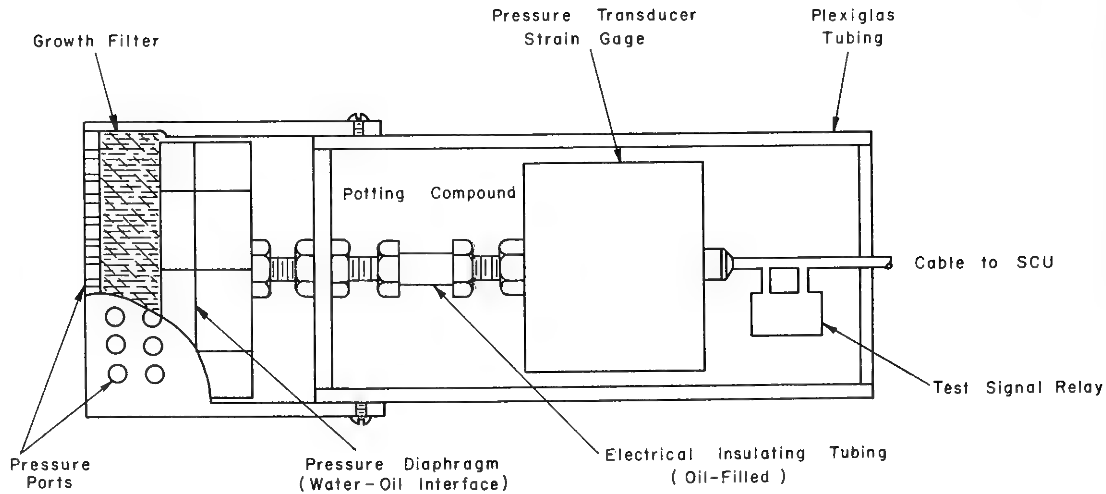

Figure 5. Schematics of transducer assembly (Peacock, 1974).

rubber diaphragms. A Teflon scouring pad dipped in antifouling paint separates the rubber diaphragm from the end of the package which admits the seawater pressure. The instrument is mounted vertically on a tripod (Fig. 6). The signals from the pressure transducers are brought by cables to a recording and transmitting station onshore.

2. Data Collection.

The array went into operation on 27 March 1970. The water pressure at the five gages was registered continuously at a rate of four times a second on digital magnetic tape. Difficulties experienced during the first year with individual sensors were mostly of short duration and were presumed to be due to biological activity. However, major difficulties were experienced with the recording system, and on 16 March 1971 the recorder was disconnected at Pt. Mugu and transferred to the CERC laboratory, then located in Washington, D.C. Recording from all five gages was reinitiated at CERC on 9 April 1971. Records were obtained continuously until 3 January 1972 when the recorder failed. During this period much of the data were useless because of an unacceptable level of high-frequency noise. The source of the noise was difficult to locate and was not eliminated from the signal until shortly before the failure of the recorder in January. Since 2 February 1972, records from three of the five gages at Pt. Mugu have been included in the time-shared recording of waves from east and gulf coast wave stations (Peacock, 1974). In 1972, data were recorded for 20 minutes out of each hour; since February 1973, data have been recorded for 20 minutes out of each 2-hour interval.

II. FIELD DATA ANALYSIS

The five gages in the array provided uninterrupted data for most of the first year of operation. Eight daily observations, each consisting of simultaneous 20-minute records from the five gages, were processed from these data. The observations had starting times within 1.5 hours of the weather synoptic times (0100, 0400, 0700, 1000, 1300, 1600, and 1900 hours P.s.t.). The potential energy in the wave field is proportional to the variance of the time history of sea-surface elevation at a fixed location (Kinsman, 1965). For most conditions, the standard deviation of the surface displacement is one-fourth of the significant wave height. The standard deviation of the pressure at a fixed depth is roughly proportional to the wave height and may also serve as a measure of the wave height.

The standard deviation of the recorded pressure was computed from the records of each of the five gages for eight records each day. The standard deviation of the record from each gage was compared with the average of the five gages. If the standard deviation from any gage differed from the average by more than 20 percent, the record from that gage was deleted and the average recomputed from the remaining gages. A comparison of the individual standard deviations from the mean for that time period is shown in Table 1.

Figure 6. Tripod mounting for pressure sensors.

Table 1. Percent of observations where the largest departure of the standard deviations from the mean in the observations was as indicated (871 observations in 1970).

Deviation from mean (pct)	Percent of Observations
≤ 2	41
3 to 10	52
11 to 20	1
≥ 20	6

This comparison indicates the system operated consistently. The field wave records used for wave direction computation (discussed later) were chosen from the observations in Table 1, for which the standard deviations from all gages differed by 3 percent or less from their mean and for which the average significant wave height (uncompensated for attenuation with depth) was above 0.61 meter.

Fourier analysis provides a reliable procedure for obtaining the periods of the most important waves. A Fourier analysis of sea-surface elevation (or pressure) with time results in the distribution of energy with frequency, usually referred to as the *energy spectrum*. The energy spectrum for the record from gage 5 in each of the eight daily observations was computed using the Fast Fourier Transform algorithm developed by Cooley and Tukey (1967). The first 1,024 seconds of the 20-minute record was used in this computation. Gage 5 was chosen because of a good history of performance.

Fast Fourier Transform computations yield the contribution to the variance at each of a set of frequencies which are harmonics of a fundamental given by the inverse of the record duration, T. In this study, the frequencies of these harmonics are referred to as *spectral frequencies*, and the corresponding periods, given by their inverse, as *spectral periods*. The energy content between 32 seconds and 3 seconds was used to normalize the spectrum. The lower limit on period was estimated from the thickness of the water column above the pressure sensors. A summarized spectrum (Fig. 7) was formed by combining the energy content in 11 adjacent spectral periods. The band width in the summarized spectrum was slightly larger than 10^{-2} hertz (0.0107 hertz). The energy appearing at each spectral period in the pressure spectrum was compensated for attenuation with depth by using the classical hydrodynamic pressure correction:

$$F(k,h) = \frac{\cosh kh}{\cosh k\Delta z} , \qquad (1)$$

where k is the wave number, h the water depth, and Δz the vertical distance of sensor from bottom. This resulted in a surface or compensated

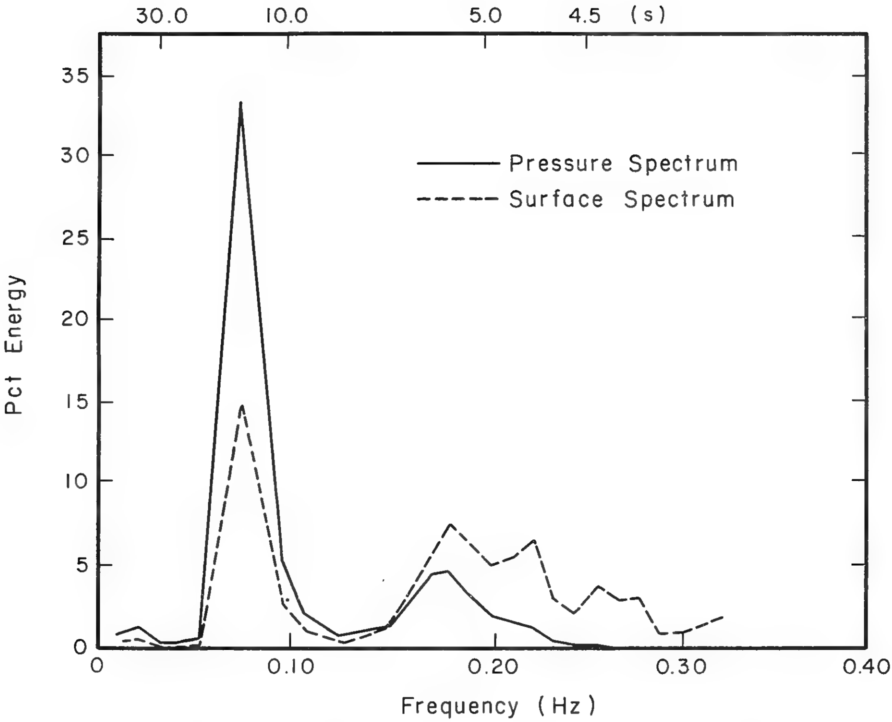

Figure 7. Summarized pressure and surface spectra.

spectrum. Surface root-mean-square (rms) values were obtained from the compensated energy at each spectral period.

Since 1972, four simultaneous 20-minute records from each of the three gages included in the time-shared recording sequence are processed daily. More records are processed during special studies. The records processed from gages 1, 2, and 3 of the Pt. Mugu array start about 0100, 0700, 1300, and 1900 hours (P.s.t.). The significant wave height, the distribution function, the first five moments of the distribution, and the pressure spectra are computed for these records in a study of wave record variability. These records are not analyzed for wave direction.

1. <u>Computation of Wave Direction.</u>

For a long-crested sinusoidal wave with frequency $\sigma_{\hat{m}}$, propagating in direction $\alpha_{\hat{m}}$ (Fig. 8), the phase difference between locations 1 and 2 with coordinates (x_1,y_1) and (x_2,y_2) respectively, is given by:

$$\Phi_{12} = k_{\hat{m}}[(x_1 - x_2) \cos \alpha_{\hat{m}} + (y_1 - y_2) \sin \alpha_{\hat{m}}] \ , \tag{2}$$

where $k_{\hat{m}} = 2\pi/L_{\hat{m}}$ is the wave number associated with frequency $\sigma_{\hat{m}}$, and $L_{\hat{m}}$ is the wavelength. The subscript is used to indicate the possible presence of different wave trains with different frequencies and directions.

The addition of the wave profile, η_3, at a third noncolinear location allows solving for the sine and cosine of $\alpha_{\hat{m}}$. Thus, a unique solution for the wave direction is obtained from the following equation when the signs of numerator and denominator are considered. (see App. A.):

$$\alpha_{\hat{m}} = \tan^{-1}\left[\frac{[(x_1 - x_3)\ \Phi_{12} - (x_1 - x_2)\ \Phi_{13}]/D}{[(y_1 - y_2)\ \Phi_{13} - (y_1 - y_3)\ \Phi_{12}]/D}\right] , \tag{3}$$

where Φ_{13} is the phase difference between the third and first locations, and D is a function of gage separation.

Phase differences between locations for each different wave period are the only unknowns in the right-hand side of equation (3). Estimates of a representative phase difference between gage pairs for bands of constant frequency width are easily computed from cross-spectra of the wave (pressure) records. These spectra give, for each band, average values of the covariance of the wave records along two perpendicular directions.

Substitution of these representative values of phase difference into equation (3) affords an expedient and economic means of obtaining estimates of a "representative" wave direction for each of the spectral bands, provided the results are of engineering use. The agreement among

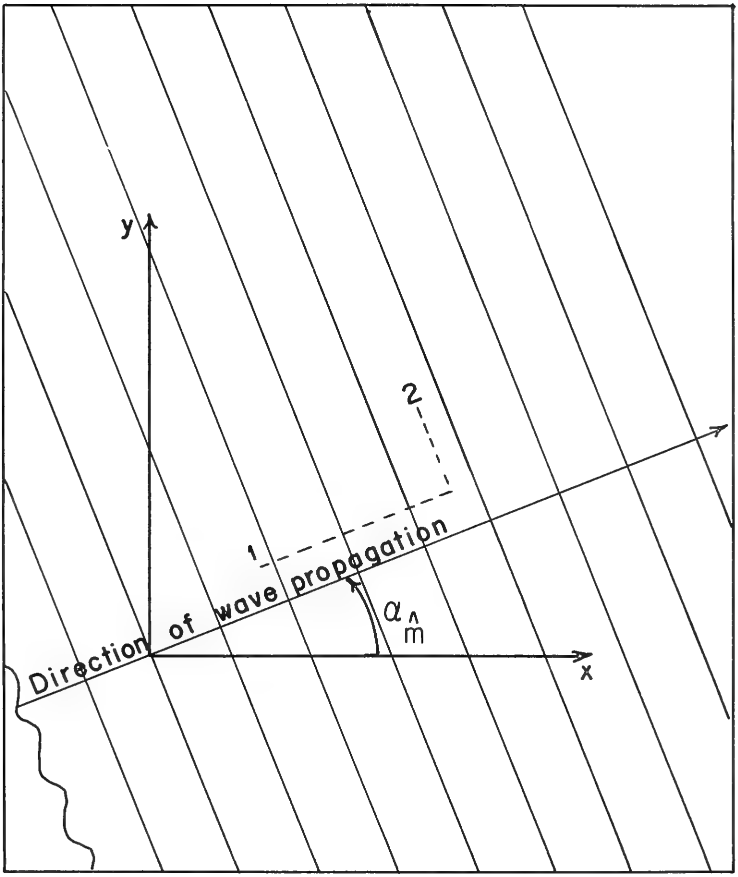

Figure 8. Long-crested wave propagating in direction $\alpha_{\hat{m}}$.

redundant computations of direction from the 10 three-gage arrays is an indication of the degree of confidence that can be placed on the resulting directions.

Directions were computed for a few observations (using the equation below) for the representative phase difference in each spectral band, where again, the sign of numerator and denominator must be considered.

$$\phi_{12_\Delta} = \tan^{-1}\left[\frac{\text{Quad}_\Delta}{\text{Co}_\Delta}\right]. \tag{4}$$

The subscript Δ in equation (4) indicates the value is for a given spectral band. The cospectrum, Co, and quadrature spectrum, Quad, are defined as:

$$\text{Co}_\Delta = \sum_\Delta x_1 x_2 \cos \phi_{12}$$

$$\text{Quad}_\Delta = \sum_\Delta x_1 x_2 \sin \phi_{12} , \tag{5}$$

where x_1 and x_2 are the spectral amplitudes from wave records 1 and 2, and $\sum_\Delta$ indicates summation over the adjacent spectral periods combined to make up a band. Jenkins and Watts (1968) showed that the definitions in equation (5) are equivalent to the more standard definitions based on correlation functions.

A computer output for runs using this approach is presented in Appendix B. Summaries of the results of the observations at 0700 hours, 25 June, and 2010 hours, 28 June, are given in Table 2. The first column in the table gives the period at the center of the band; the second column gives the average percent energy in each band for the five gages. The last 10 columns give the computed "representative" direction of each band for the three-gage array. Directions are measured from the seaward normal with positive values counterclockwise and negative values clockwise. The table shows that in these two observations disagreements in direction of the order of 20° are obtained for the longer period peaks and of 160° for the shorter period peaks. Examination of the computer output in Appendix B indicates the results are typical.

The array had been expected to yield directions to better than 20° for periods between 25 and 7 seconds. Understanding of the problems involved was sought by simulating the propagation through the array of narrow-banded wave trains traveling in a specified direction (discussed in next subsection).

2. Simulated Data Analysis.

In simulating the wave records for use, special consideration was given to wave period and to the difficulties arising in spectral analysis.

Table 2. Directional results with 0.01 hertz resolution for two observations.

Period at center of band (s)	Avg. pct energy	Three-gage arrays									
		1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
25 June 1970 at 0700 hr											
5.99	2.32	173	44	156	–50	–42	–46	–145	–131	–147	–39
6.40	0.46	173	32	157	–44	–44	–44	–147	–135	–153	–30
6.87	0.56	–64	–23	–45	–33	–43	–39	–149	–136	–166	–18
7.42	1.08	167	56	150	–35	–50	–42	–150	–24	46	–20
8.06	0.75	133	33	162	3	155	–49	8	5	–5	0
8.83	1.51	–20	–12	–9	–19	–18	0	5	2	–1	0
9.75	2.01	2	3	2	5	1	13	10	12	16	18
10.89	4.04	5	4	4	4	–2	16	–1	2	8	11
12.34	9.13	21	19	16	16	7	27	14	14	20	21
14.22	27.19	33	30	26	29	16	40	31	28	32	34
16.79	42.92	29	25	22	21	10	33	26	25	27	28
20.48	1.23	–1	–1	0	0	–8	31	26	25	27	28
26.26	0.24	74	119	121	117	131	120	178	144	109	135
28 June 1970 at 2010 hr											
5.99	7.44	169	52	136	–38	–31	–28	–148	–136	–155	–23
6.40	10.85	–47	–38	–33	–40	–34	–33	–148	–138	–157	–25
6.87	16.56	–40	–34	–29	–36	–30	–27	–151	–22	46	–21
7.42	9.75	–40	–33	–29	–35	–30	–27	–152	–20	48	–20
8.06	19.61	–40	–33	–29	–36	–30	–27	–152	–22	49	–21
8.83	7.65	–37	–29	–24	–32	–27	–20	–18	–15	–14	–14
9.75	0.96	–16	–15	–12	–16	–16	–2	–3	–3	–4	0
10.89	1.10	0	0	0	1	–7	25	–3	8	21	24
12.34	2.34	23	13	11	5	–4	26	14	14	14	14
14.22	4.46	12	12	10	12	4	24	8	10	16	18
16.79	1.61	19	14	12	9	0	28	15	15	21	21
20.48	1.00	108	46	40	25	2	52	40	49	43	34
26.26	0.70	–91	–89	–75	–89	–67	–95	–92	–66	–56	–72

Assume a sinusoid with frequency given as:

$$\sigma = \frac{2\pi(\hat{m} + \delta)}{N\Delta t} , \tag{6}$$

where Δt is the interval of time between samples, $|\delta|$ is less than or equal to $1/2$, and $N\Delta t = T$, the record duration.

Equation (6) provides for assigning frequencies which differ from the spectral frequencies. The contribution to the variance at the spectral frequencies of the sampled record is given by S_m^2 as:

$$S_m^2 = a_m^2 + b_m^2 , \tag{7}$$

where a_m and b_m are the Fourier coefficients.

Harris (1974) showed that for values of m near $\hat{m}$ (i.e., for spectral frequencies near the frequency of the sinusoid), and for $\hat{m}$ far removed from one and $N/2$, the approximations below are good estimates to the coefficients.

$$a_m \doteq \frac{A \sin \pi\delta \cos(\phi - \pi\delta)}{\pi(\hat{m} - m + \delta)} ,$$

$$b_m \doteq \frac{A \sin \pi\delta \sin(\phi - \pi\delta)}{\pi(\hat{m} - m + \delta)} . \tag{8}$$

Slow convergence of the energy toward the spectral period closest to the assigned period is clearly indicated. Thus, the energy is spread over adjacent spectral periods. This spreading, due to the finiteness of the record, is usually referred to as *spillover*.

The technique routinely used at CERC to decrease spillover is to apply the cosine bell data window as defined by:

$$\hat{y}_i = \frac{1}{2}\left[1 - \cos\frac{2\pi t_i}{T}\right] y_i , \quad i = 1, . . . N , \tag{9}$$

where y_i are the values in the original record. The Fourier coefficient for the resulting function $\hat{y}_i$, is given by:

$$\tilde{a}_m \doteq \frac{A \sin \pi\delta \cos(\phi - \pi\delta)}{2\pi(\hat{m} - m + \delta)[(\hat{m} - m + \delta)^2 - 1]} ,$$

$$\tilde{b}_m \doteq \frac{A \sin \pi\delta \sin(\phi - \pi\delta)}{2\pi(\hat{m} - m + \delta)[(\hat{m} - m + \delta)^2 - 1]} .$$

Thus, convergence is greatly increased and spillover is effectively reduced to three adjacent spectral periods.

The cosine bell data window was applied to the simulated records; therefore, it was sufficient to consider wave trains consisting of three sinusoids with nearby periods spread over at most six adjacent spectral periods. In general, the periods of waves in the ocean will differ from the spectral periods. Thus, the sinusoids in each simulated observation were specifically assigned periods differing slightly from the spectral periods by use of equation (6). Central periods of about 8 and 16 seconds were chosen to simulate 8- and 16-second swells. Swells with periods in this range are observed on the west coast.

Each simulated wave record consisted of values of the wave profile at the five gage locations computed at 0.25-second intervals for 17.07 minutes (1,024 seconds), to simulate the sampling rate and record duration customarily used at CERC for field data.

The three sinusoids were assigned specific directions and zero initial phase at the origin of coordinates, and were propagated across the array assuming a constant depth of 9.14 meters. Appendix C shows that the Finite Fourier Transform gives the correct phases for three sinusoids thus combined, provided the sinusoids are assigned the same direction, nearly the same amplitudes, and the frequency difference of each component to the nearest spectral frequency is the same. A frequency difference of $0.134/1{,}024 \doteqdot 0.000120$ hertz was chosen.

Characteristics of the first eight simulated observations are given in Table 3. Rough considerations of refraction using linear theory (McClenan, 1975) yield 22° from the normal to the coastline as the maximum possible direction that waves with a 16-second period may have at the depth of the array. Directions within 21° N. and 21° S. from the normal were chosen for the first four simulated wave trains. Since waves with an 8-second period may approach the coastline at the array site from a much wider arc, directions up to 60° N. and 60° S. were used for the directions of the fifth to eighth simulated trains.

The computed spectra for these eight simulated observations are shown in Appendix D (Figs. D-1 to D-8). In these figures the variance of the record, proportional to the energy, at each spectral period is plotted versus a linear frequency scale. No grouping of the variance at adjacent spectral periods has been made. These ungrouped spectra are referred to as *high-resolution spectra*. For spectra computed from 1,024-second records, this high resolution is approximately 0.001 hertz.

The program used to compute these spectra is the same program used at CERC for the analysis of field data. Many spectra of field data computed with this program and summarized by grouping 11 adjacent spectral periods are given by Thompson (1974).

The effect of spillover in the spectrum is shown in the figures of Appendix D. Each spectrum resulted from combining only three sinusoids; however, energy contributions appear at from five to nine adjacent spectral periods.

Table 3. Characteristics of simulated wave trains.

Wave train	Period[1] (s)	Amplitude (cm)	Direction (°)
1	16.75	11.43	21 S.
	15.97	15.24	21 S.
	15.25	11.43	21 S.
2	16.75	11.43	21 S.
	15.97	15.24	15 S.
	15.25	11.43	21 N.
3	16.48	11.43	21 S.
	15.97	15.24	21 S.
	15.72	11.43	21 S.
4	16.48	11.43	21 S.
	15.97	15.24	15 S.
	15.72	11.43	21 N.
5	8.18	11.43	60 N.
	7.99	15.24	60 N.
	7.80	11.43	60 N.
6	8.18	11.43	60 N.
	7.99	15.24	40 N.
	7.80	11.43	60 S.
7	8.11	11.43	60 N.
	7.99	15.24	60 N.
	7.93	11.43	60 N.
8	8.11	11.43	60 N.
	7.99	15.24	40 N.
	7.93	11.43	60 S.

[1]Approximate value.

The periods assigned to the sinusoids giving rise to simulated observations 1, 2, 5, and 6, differed by exactly three spectral periods (see Table 3). The spectra for these four observations (Figs. D-1, D-2, D-5, and D-6) exhibit three maxima separated by two minima. The energy at these two minima may be interpreted as due to spillover since no sinusoids were combined with the corresponding periods.

The high-resolution spectra from field wave observations are discussed later; however, the use of the minima in these spectra to estimate spillover and noise is discussed here. The average energy at the minima between 25 and 7 seconds in the high-resolution spectra of the field observations was used as a measure of spillover and noise. Only spectral periods displaying an energy content at least twice this "background" energy were interpreted as possibly arising from physical wave components in the wave field.

The average directions resulting from the 10 three-gage arrays are given in Table 4 (last column). Only results of computations at the spectral periods closest to the assigned periods are shown. The table shows that for wave trains 1, 2, and 3 the computed directions for the 10 arrays agree with the input directions to within 1°.

The directional results for wave train 4 are correct only for spectral period 62. The main difference between this train and wave train 2 is the narrower spectral width. Wave train 2 gave the correct directions for all spectral periods; wave train 4 did not.

For simulated wave trains 5 to 8, the average directions seem meaningless. To determine whether these poor results were due to a programing deficiency, another eight sets of simulated records were generated, interchanging periods and directions. The computer output for the simulated observations is in Appendix D. This appendix and Table 5 should be referenced in the following discussion of additional simulated wave trains.

The directional results for the sinusoids with periods clustered around 16 seconds were of the same quality regardless of the assigned direction. However, the directional results for the 8-second sinusoids indicate that the capability to sense the correct direction for these shorter waves depends on the orientation of the three-gage array relative to the direction of propagation of the incoming wave. The resulting directions, which differed by less than 87° from the assigned directions, are given in Table 5. The top of each column in the table shows the shape and orientation of the array. These results are not surprising since the effective gage separation for the different gage pairs varies with orientation relative to direction of wave propagation. Table 5 also shows that the more nearly equilateral arrays have wider direction discernability. The design considerations for the array indicated an effectiveness for wave periods between 25 and 7 seconds (Borgman and Panicker, 1970).

Table 4. Computational results at closest spectral frequencies for simulated wave trains.

Wave train	Closest spectral frequency (1/1024 hz)	Spectral period (s)	Amplitude (cm)	Direction (°)
1	61	16.79	5.62	20 S.
	64	16.00	7.55	20 S.
	67	15.28	5.70	20 S.
2	61	16.79	5.62	21 S.
	64	16.00	7.55	15 S.
	67	15.28	5.70	20 N.
3	62	16.52	5.52	20 S.
	64	16.00	5.35	20 S.
	65	15.75	1.19	20 S.
4	62	16.52	5.52	21 S.
	64	16.00	5.35	25 S.
	65	15.75	1.19	36 N.
5	125	8.19	5.62	142 N.
	128	8.00	7.55	142 N.
	131	7.82	5.70	142 N.
6	125	8.19	5.62	142 N.
	128	8.00	7.55	78 N.
	131	7.82	5.70	162 S.
7	126	8.13	5.52	142 N.
	128	8.00	5.35	142 N.
	129	7.94	1.19	142 N.
8	126	8.13	5.52	142 N.
	128	8.00	7.14	76 N.
	129	7.94	5.83	172 S.

Table 5. Directional results of high-resolution spectral computations for 8-second wave.

Assigned direction[1] (°)	Three-gage arrays									
	1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
60 N.				59 N.	60 N.	59 N.		60 N.		60 N.
40 N.	40 N.	40 N.	40 N.	40 N.	40 N.	40 N.		40 N.		39 N.
21 N.	21 N.	20 N.	21 N.	21 N.	20 N.	20 N.		21 N.		20 N.
15 N.	14 N.	14 N.	14 N.	14 N.	14 N.	14 N.		14 N.		15 N.
15 S.	14 S.	14 S.		14 S.			14 S.	14 S.	14 S.	15 S.
21 S.	21 S.	20 S.		20 S.			20 S.	20 S.	20 S.	20 S.
40 S.	40 S.	39 S.		39 S.			39 S.	40 S.	39 S.	39 S.
60 S.				60 S.			60 S.	59 S.	59 S.	60 S.

[1] Results differing by 87° or more from the assigned directions have been omitted.

The consistent and exact recovery of assigned directions achieved for the simulated 16-record wave trains is in part due to the use of the high computational resolution available in a large computer. Use of less exact data as available from recording instruments is expected to result in a less consistent and accurate recovery of the true direction. Simulated observations 1 to 4 were rerun truncating the computed profile values to three digits as is commonly available from recording systems. The effect of this truncation is estimated to have introduced an error of the order of ±0.127 centimeter (0.05 inch) in the instantaneous values of the profiles. No appreciable differences in computed directions resulted by this truncation.

3. Identification of Wave Trains from the High-Resolution Spectrum.

A wave train in the real ocean is conceivably made up of several wave components with nearby periods propagating in approximately the same direction. Simplistic idealizations of such wave trains are exemplified by simulated observations 1, 3, 5, and 7. For wave trains 1 and 3, the long-crested wave model gave the correct direction of wave propagation for all 10 combinations (within 5°), not only at those spectral periods closest to the periods of the sinusoids combined, but at several adjacent ones on either side of these periods (see App. D, Figs. D-1 and D-3). At some of these adjacent spectral periods, the contribution to the energy was several times the background level and nearly the same at the five gage locations. Thus, it can be assumed that a wave train in the ocean will give rise to a number of adjacent spectral periods in the high-resolution energy spectrum with energy content several times the background level. This background level can be estimated by inspection of the minima in the energy spectrum, as discussed previously. A criterion for what energy level will be considered "high-energy content" can be set, and groups of adjacent spectral periods in the spectrum with high-energy content identified. These groups may each be assumed to arise from the presence of a wave train in the field with a mean wave period within the range of spectral periods in the group (a wave packet). The number of adjacent spectral periods in each group will be used as a measure of the width of the energy peak in the spectrum and indicates the spread in periods of the wave train. The spread in computed directions at adjacent spectral periods in a group is an indication of the degree of directional organization in the wave train. Large spread in directional results may indicate the possibility that crossing wave trains with nearly the same period are present. As results for simulated wave train 4 indicate, the long-crested model based on the assumption of a single wave train at each frequency is not suitable for a determination of wave direction in such cases. Multiple wave trains at a single frequency may result from refraction around a shoal or island or from reflection by a vertical wall.

4. Spectra and Direction of Wave Propagation for Field Data.

The energy and direction of wave propagation at each spectral period were computed for 44 field observations where the average uncompensated significant wave height was over 2 feet and the discrepancy of individual standard deviations from their mean was 3 percent or less. Plots of the high-resolution spectra for these observations are in Appendix E. The vertical lines represent the energy contribution at each spectral period. The background level for each observation was estimated from the minima between 25 and 7 seconds in the spectra. Spectral periods in this range with energy content above twice the estimated background energy were identified. Contributions to the energy satisfying this criterion at adjacent spectral periods were considered as arising from the same wave train. The number of adjacent periods in each train was used as a measure of the *spectral width* of the train. The energy had to be above the chosen level at all five gages for the spectral period to be included in the group. The spectral period among these showing maximum energy was taken as the "period" of the wave train.

Directions were computed at all the spectral periods in each train for the 10 arrays. The total spread among these directions was found, and an average total spread was computed for the trains having the same spectral width. The same was done for the computed directional spread at the period of the train.

Twenty-five percent of the identified wave trains had total directional (computed) spreads above 100° and were not considered further. For 89 percent of the discarded trains, the period of the train was under 9.4 seconds. Thus, all trains with periods under 9.4 seconds were discarded.

Results for the different spectral widths for the trains retained (280) are shown in Table 6. The second column in the table gives the average total directional spread for the corresponding spectral width; the third column gives the average directional spread at the period of the wave train. The last column gives the number of wave trains having the spectral width in the first column.

These results indicate that the total directional spread increased with frequency width. Narrow peaks consisting of from one to three spectral periods are most frequent, and the spread in the direction at the period of the train remains relatively constant. Since the average spread for narrow-banded trains (width ≤ 0.003 hertz) is 21.8°, it is expected that three-gage arrays cannot yield directional results to any better accuracy. The mathematical exercise in Appendix C shows that array dimension is a limiting factor as to the shortest period for which some directional discrimination may be expected. An important factor in the validity of the directional result is the spectral structure of the wave train involved. Only in very special circumstances will the quantities involved in equation C-10 (App. C) combine to give better results.

There are various possible explanations for the large spreads observed in the directional results from field records. For the long-crested wave model to be strictly applicable, it is important that:

Table 6. Average spread in computed directions for 280 wave trains identified in the high-resolution spectra of 44 field wave observations.

Spectral width (hz)	Avg. total spread in direction for all periods (°)	Avg. spread in direction for period of train (°)	Cases (No.)
0.001	21.8	21.8	96
0.002	30.9	22.9	58
0.003	33.6	20.2	41
0.004	41.5	20.4	22
0.005	38.7	19.8	21
0.006	43.8	19.8	16
0.007	48.2	17.0	5
0.008	84.5	17.6	8
0.009	53.0	15.3	6
0.010	49.3	13.7	3
0.011	38.0	18.0	1
0.012	81.0	15.0	1
0.013	48.5	15.2	2

(a) The phase differences be known accurately or that the probable error in their computed values be known.

(b) The wave crests over the array site be long and straight; thus, the waves must not have undergone appreciable refraction.

(c) The sea surface be stationary in time for the duration of the record and in space over the span of the array.

The mathematical exercise in Appendix D indicates that the analysis yields accurate phase differences only for strictly monochromatic conditions. When this is not the case, no accurate estimate of the error involved in the computation of direction can be given. This inability is inherent to the computational procedure and cannot be resolved.

Waves with periods over 8 seconds have been and are undergoing refraction at the site of the array. Therefore, the wave crests are not exactly straight. For the longer waves, with wavelengths at the array site several times the gage separations, the curvature will not introduce much error. This will not be the case for the shorter waves and orientation of the array becomes important.

Because of refraction, the curvature of a wave train changes, perhaps only slightly, while propagating over the array. This change will introduce differences in the direction at each gage and differences in the direction sensed by different gage pairs, causing undetermined additional errors in the computation of direction. To determine the magnitude of these errors, two additional sets of simulated wave records were generated. The periods of the sinusoids combined were those for simulated observation 3; the directions assigned were spread within a 10° arc for the first set and 20° for the second. The last two computer outputs in Appendix D show that spreads of the order of 16° and 32°, respectively, resulted in computed directions.

A stationary condition in time is usually assumed when developing wave directional models. Indications are that this is not strictly applicable at all times.

The three factors discussed above are sufficient to account for the inaccuracies encountered in the computations.

5. Conclusions.

The results of directional computations, for both simulated and field wave data records, indicate three-gage arrays have some capabilities to determine wave direction under certain conditions. These capabilities depend on:

(a) The dimension of the array and the water depth at the site which place a lower limit on the wave period for which possibly accurate directions may be computed.

(b) The orientation of the array for the shorter periods.

(c) The nature of the wave field; directional results for wave trains with a narrow frequency distribution or where the computed directions differ little at the adjacent spectral periods might be meaningful.

For wave trains with narrow frequency and directional width, and period above 10 seconds, the three-gage arrays at Pt. Mugu yield directions to an estimated accuracy of 20°.

At the Pt. Mugu site, 16-second waves may approach the coastline at angles of 22° or less from the normal. The directional information provided by the array adds little to this and seems hardly cost effective.

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APPENDIX A

DERIVATION OF THE EXPRESSION FOR WAVE DIRECTION

Let the coordinates of nearby gage sites be (x_i, y_i), i = 1, N; with N = number of gages. The water surface displacement at each site due to the passage of a sinusoidal wave of frequency σ, and amplitude A, traveling in direction α ($\alpha_{\hat{m}}$ in Fig. 8), is given by:

$$\eta_i = A \cos\{k[x_i \cos\alpha + y_i \sin\alpha] - 2\pi\sigma t - \phi\} , \tag{A-1}$$

where $k = 2\pi/L$ is the wave number, L the wavelength, and ϕ the initial phase at the origin.

The phase difference, Φ_{ij}, between locations i and j for the sinusoid considered is:

$$\Phi_{ij} = k[(x_i - x_j) \cos\alpha + (y_i - y_j) \sin\alpha] . \tag{A-2}$$

Thus, for three noncolinear locations,

$$\Phi_{12} = k[(x_1 - x_2) \cos\alpha + (y_1 - y_2) \sin\alpha] ,$$

$$\Phi_{13} = k[(x_1 - x_3) \cos\alpha + (y_1 - y_3) \sin\alpha] , \tag{A-3}$$

suffice for a unique solution of the direction α. Eliminating first the $\sin\alpha$ terms and then the $\cos\alpha$ terms, to obtain:

$$\sin\alpha = \frac{(x_1 - x_3)\,\Phi_{12} - (x_1 - x_2)\,\Phi_{13}}{k[(x_1 - x_3)(y_1 - y_2) - (x_1 - x_2)(y_1 - y_3)]} ,$$

$$\cos\alpha = \frac{(y_1 - y_2)\,\phi_{13} - (y_1 - y_3)\,\Phi_{12}}{k[(x_1 - x_3)(y_1 - y_2) - (x_1 - x_2)(y_1 - y_3)]} . \tag{A-4}$$

Since k is always positive, consideration need only be given to the other terms. Letting D stand for the quantity in square brackets, the direction, α, for $D \neq 0$ is given by:

$$\alpha = \tan^{-1}\left\{\frac{[(x_1 - x_3)\,\Phi_{12} - (x_1 - x_2)\,\Phi_{13}]/D}{[(y_1 - y_2)\,\Phi_{13} - (y_1 - y_3)\,\Phi_{12}]/D}\right\} . \tag{A-5}$$

A unique value for direction can be obtained by considering the signs of both numerator and denominator. The quantity D differs from zero for all nonlinear arrays as shown below.

Let $x_1 = y_1 = 0$, D will equal zero for $y_2/x_2 = y_3/x_3$; thus, x_2, y_2 and x_3, y_3 will be on a straight line with slope given by this ratio.

APPENDIX B

COMPUTER OUTPUT FOR CROSS-SPECTRA COMPUTATIONS

Table. Guide to computer output.

Line (from top)	Column (from left)	Explanation
1		Title, plus date and time of the observation (day, month, year, hour, and minutes).
2 to 4		Headings for columns. The numbers separated by dashes in the fourth line give the numbers of the gages in the array (see Fig. 3).
	1	Sequential number of bands 0.0107 hertz wide.
	2	Period at center of band (seconds).
	3 to 7	Percent of energy in each band for gages 1 to 5. Normalized to the energy content from approximately 30 to 3 seconds.
	8 to 17	Resulting "representative" direction of wave propagation for the 10 arrays for the corresponding band (degrees).

PT MUGU FIVE GAGE ARRAY 24 6 1970 906

BAND	PERIOD AT CENTER	PRESSURE SPECTRA					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE 1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
1	170.67	1.61	1.94	1.69	1.56	1.55	10	18	14	34	31	35	-27	3	20	34
2	60.24	.52	.64	.60	.50	.57	45	67	49	74	56	79	119	60	63	68
3	36.57	.31	.17	.20	.24	.16	72	40	35	28	8	48	46	50	48	38
4	26.26	.11	.12	.08	.13	.10	133	92	88	83	27	92	92	72	72	71
5	20.48	2.23	1.93	2.16	2.39	2.42	18	20	17	22	16	28	18	18	23	26
6	16.79	35.51	33.15	32.81	33.63	32.57	26	23	20	21	11	31	24	23	25	27
7	14.22	24.00	25.70	23.85	24.56	24.85	12	11	9	9	2	21	13	14	16	17
8	12.34	26.44	22.19	26.85	27.07	24.81	13	12	10	11	3	22	12	13	17	18
9	10.89	1.86	5.57	3.91	2.36	4.67	2	2	2	2	-3	15	6	8	12	14
10	9.75	1.13	3.10	2.13	1.37	2.92	-7	-6	-6	-4	-8	7	4	5	6	9
11	8.83	3.00	1.54	2.60	2.95	1.74	3	2	2	-2	-6	9	7	7	7	8
12	8.06	1.16	2.10	1.13	.81	1.85	127	46	157	18	152	-47	1	1	1	10
13	7.42	1.33	1.14	1.06	1.16	1.11	-25	-28	-24	-26	-24	-20	-152	-14	47	-10
14	6.87	.77	.30	.60	.91	.43	132	29	161	0	154	-47	-150	-142	-162	0
15	6.46	.28	.30	.23	.27	.20	133	26	155	-1	151	-42	-146	-141	-148	-1
16	5.99	.12	.32	.21	.15	.29	1	1	54	5	142	-34	-152	-143	-167	-8
17	5.63	.23	.16	.23	.16	.19	173	22	145	-39	-36	-36	-140	-132	-138	-8
18	5.31	.22	.22	.09	.11	.28	176	15	152	-44	-37	-36	-138	-135	-137	87
19	5.02	.20	.38	.45	.46	.24	177	10	159	-46	-38	-40	31	99	-128	105
20	4.76	.22	.24	.35	.35	.25	179	1	178	-53	-40	-44	31	94	-128	101
21	4.53	.23	.33	.24	.26	.24	-178	-5	-117	-48	-37	-39	29	86	-119	95
22	4.32	.26	.43	.44	.47	.36	-4	-28	-122	82	148	-52	131	78	76	97
23	4.13	.25	.18	.18	.15	.09	-5	-26	-110	70	149	-50	83	72	72	78
24	3.95	.13	.14	.10	.10	.15	-4	-17	-27	50	142	-31	73	49	54	64
25	3.79	.11	.15	.13	.09	.05	-6	-25	-90	54	149	-47	44	46	45	45
26	3.64	.06	.10	.06	.04	.07	-6	-148	-54	135	147	152	39	36	38	40
27	3.51	.04	.02	.03	.02	.06	-3	-124	-51	118	145	159	-81	-4	19	10
28	3.38	.03	.02	.03	.02	.02	-4	-6	-7	2	32	-13	-154	-144	178	-1
29	3.26	.03	.01	.01	.02	.02	-2	-175	-176	147	155	-165	-151	-24	48	-52
30	3.15	.02	.01	.01	.00	.01	-2	-176	-177	147	155	-165	-146	-131	-153	-13
31	3.05	.01	.01	.01	.00	.00	-5	-111	-154	119	152	-87	36	84	-150	92
32	2.95	.01	.00	.00	.00	.00	168	136	61	-147	-23	121	-141	-131	-138	100
33	2.86	.00	.00	.00	.00	.00	170	126	12	-96	-21	111	-133	-130	-132	-141
34	2.76	.00	.00	.00	.00	.00	-174	-13	-3	-47	-23	90	23	-167	-137	-151

PT MUGU FIVE GAGE ARRAY 24 6 1970 1206

BAND	PERIOD AT CENTER	PRESSURE SPECTRA					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE									
							1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
1	170.67	2.62	3.90	3.38	2.42	2.58	154	114	98	122	-6	112	64	85	89	75
2	60.24	1.90	3.79	3.06	2.31	2.88	117	80	63	71	17	86	61	62	62	71
3	36.57	.48	.53	.56	.59	.59	-22	-60	-50	-43	-175	-57	-76	-74	-73	-82
4	26.26	.76	.62	.84	.59	.59	66	116	143	114	143	139	177	52	63	137
5	20.48	1.08	1.59	1.35	.95	1.26	29	31	18	32	4	60	35	27	35	43
6	16.79	51.21	48.30	51.60	54.75	59.25	13	14	12	14	6	24	14	15	18	20
7	14.22	19.65	20.15	21.69	20.12	17.35	13	11	9	9	0	24	15	15	17	20
8	12.34	9.13	10.92	8.33	7.36	7.49	38	24	23	16	6	28	24	23	25	22
9	10.89	5.42	8.34	5.24	6.05	5.05	-1	0	0	-2	-8	13	11	9	0	7
10	9.75	2.47	1.51	1.25	2.16	1.27	88	48	163	35	154	-54	73	29	42	39
11	8.83	3.81	1.21	1.58	2.82	.96	142	51	162	12	155	-53	69	34	44	22
12	8.06	.81	.74	1.75	.76	1.35	0	1	1	15	15	14	-4	4	15	14
13	7.42	.93	.60	1.34	.69	.53	117	39	162	14	154	-50	23	24	20	11
14	6.87	.54	1.17	.68	.47	1.02	166	42	146	-26	-42	-38	-147	-137	-152	-20
15	6.40	.22	.29	.46	.23	.41	172	42	148	-45	-38	-39	-145	-135	-148	-14
16	5.99	.59	1.01	.56	.41	.70	173	41	150	-49	-38	-40	-145	-133	-147	101
17	5.63	.18	.22	.22	.21	.09	172	37	151	-45	-39	-41	35	116	-142	113
18	5.31	.18	.13	.20	.21	.14	165	15	162	-21	168	-43	29	159	-134	-71
19	5.02	.22	.44	.34	.31	.38	179	1	2	-40	-28	-3	32	92	-128	89
20	4.76	.18	.16	.19	.13	.17	175	20	117	-47	-33	-29	-127	-119	-121	-152
21	4.53	.32	.41	.61	.54	.24	-166	-22	-15	-46	-29	5	29	83	-117	87
22	4.32	.83	.42	.35	.16	.42	-171	-23	-15	-51	-30	9	81	68	69	-145
23	4.13	.57	.59	.50	.41	.60	174	146	67	-98	-30	126	82	64	65	55
24	3.95	.46	.68	.49	.39	.44	-5	-23	-71	48	148	-44	49	50	49	47
25	3.79	.26	.23	.21	.15	.14	8	10	176	17	157	-56	32	31	32	39
26	3.64	.10	.07	.12	.05	.06	-166	-13	-166	-38	-167	-53	-19	9	27	-114
27	3.51	.04	.08	.05	.03	.05	-166	-70	-38	-71	-36	-61	-12	-147	-130	6
28	3.38	.03	.05	.02	.01	.02	-13	-22	-20	-10	-7	-17	-150	-137	-169	-27
29	3.26	.00	.02	.01	.01	.01	171	88	135	-60	-33	1	-152	-144	-168	-70
30	3.15	.01	.01	.01	.01	.01	-174	-11	-32	-44	-35	-34	-145	-109	83	67
31	3.05	.01	.01	.01	.00	.00	-149	-40	-88	-53	-54	-53	-155	-52	59	131
32	2.95	.00	.00	.00	.00	.00	-9	-32	-22	35	122	-10	-100	-23	7	177
33	2.86	.00	.00	.00	.00	.00	-20	-75	-27	-100	-23	114	136	25	41	81
34	2.78	.00	.00	.00	.00	.00	3	161	4	122	22	115	41	-173	-145	-132

PT MUGU FIVE GAGE ARRAY 24 6 1970 1506

BAND	PERIOD AT CENTER	PRESSURE SPECTRA					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE									
							1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
1	170.67	1.09	.79	.62	.59	.56	76	143	141	134	142	141	-171	-179	153	153
2	60.24	1.06	1.23	1.09	1.02	1.26	84	59	54	52	27	64	50	55	54	49
3	36.57	.33	.41	.35	.40	.42	117	121	140	121	141	134	167	161	154	157
4	26.26	1.12	.80	.93	.80	.75	155	162	163	157	158	164	-164	-170	122	167
5	20.48	2.50	2.43	3.08	3.31	3.49	32	36	35	38	42	36	37	36	37	39
6	16.79	42.11	35.17	35.57	33.74	31.54	27	18	14	10	-1	33	21	21	23	23
7	14.22	37.61	42.90	41.35	41.32	40.66	26	23	21	21	12	29	24	24	25	26
8	12.34	4.18	6.04	4.89	6.12	7.93	16	18	17	21	20	22	12	14	20	23
9	10.89	1.55	2.41	2.00	1.72	2.38	-6	-6	-5	-6	-10	8	7	4	-3	7
10	9.75	.97	1.28	1.39	1.90	2.07	7	7	5	5	-2	20	2	5	11	13
11	8.83	2.04	.92	1.25	1.87	.96	-15	-24	-16	-14	-15	4	-8	-4	1	8
12	8.06	1.48	.90	1.64	1.48	1.14	97	28	31	7	0	21	23	23	25	13
13	7.42	.31	.55	1.02	.38	.58	154	31	166	-9	159	-52	15	14	7	7
14	6.87	.20	.35	.42	.36	.37	163	46	153	-20	166	-44	-149	-20	43	-11
15	6.40	.28	.33	.37	.16	.26	172	59	150	-52	-39	-43	-148	-137	-156	-21
16	5.99	.24	.15	.14	.32	.21	168	29	150	-29	-47	-39	-65	-150	-136	-94
17	5.63	.50	.15	.21	.25	.32	165	29	51	-22	-20	3	-144	-131	-144	0
18	5.31	.47	.39	.38	.43	.39	177	12	171	-52	-48	-50	33	111	-136	111
19	5.02	.63	.31	.40	.28	.73	173	33	95	-45	-30	-14	32	93	-130	90
20	4.76	1.06	.65	1.32	1.54	.94	-177	-13	-6	-56	-29	49	30	111	-128	125
21	4.53	.90	1.57	1.20	1.43	2.80	-2	-15	-55	75	145	-40	28	99	-122	100
22	4.32	.61	1.62	1.34	1.58	1.50	-4	-31	-141	84	150	-55	27	89	-116	94
23	4.13	.41	.51	.52	.49	.45	51	79	124	85	135	21	124	72	72	98
24	3.95	.46	.27	.22	.25	.19	25	147	146	130	144	146	162	71	71	91
25	3.79	.07	.08	.12	.12	.10	-165	-156	-12	-149	-27	130	152	23	40	66
26	3.64	.17	.09	.09	.07	.10	-3	-4	-6	1	54	-18	-36	-1	16	-19
27	3.51	.06	.08	.09	.05	.06	-76	-64	-16	-64	-25	103	-50	5	25	42
28	3.38	.03	.03	.02	.02	.03	166	154	67	172	-23	132	-68	-139	-130	11
29	3.26	.01	.03	.03	.02	.02	0	179	179	111	153	-74	-151	-121	100	-112
30	3.15	.01	.01	.01	.01	.01	179	177	1	-100	-30	125	-149	-123	145	-5
31	3.05	.01	.00	.01	.00	.01	179	173	89	-79	-35	140	38	86	-170	91
32	2.95	.00	.01	.00	.00	.00	-9	-74	-43	110	146	-63	34	57	24	-169
33	2.86	.00	.00	.00	.00	.00	-145	-60	-39	-65	-37	-46	21	25	-26	0
34	2.78	.00	.00	.00	.00	.00	85	14	166	-4	155	-46	1	-149	-130	-133

PT MUGU FIVE GAGE ARRAY 24 6 1970 1807

BAND	PERIOD AT CENTER	PRESSURE SPECTRA					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE 1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
1	170.67	1.44	2.63	1.94	1.62	1.15	-175	-170	-81	-148	-39	148	134	143	148	158
2	60.24	1.22	1.17	1.04	1.22	1.38	14	20	24	30	66	11	14	14	15	16
3	36.57	.29	.40	.29	.25	.26	49	58	44	62	37	71	49	30	40	57
4	26.26	.32	.23	.29	.25	.20	1	2	1	26	3	52	-43	0	18	37
5	20.48	1.50	1.52	1.37	1.24	1.12	45	26	18	15	-2	47	22	23	20	23
6	16.79	25.81	34.03	28.25	24.68	27.16	24	21	18	16	8	29	22	21	23	24
7	14.22	28.06	23.70	25.52	28.86	27.29	20	18	16	15	6	27	19	19	21	22
8	12.34	10.03	12.21	11.79	10.58	12.25	19	15	13	11	1	26	16	17	18	19
9	10.89	4.87	3.43	3.47	4.25	3.37	39	27	24	19	8	32	27	26	27	26
10	9.75	3.10	1.25	2.72	4.37	1.77	6	6	5	6	-1	20	11	11	9	14
11	8.83	1.62	1.02	1.47	1.67	1.25	33	19	15	9	-2	35	21	21	21	21
12	8.06	.93	.77	1.21	1.09	1.11	-16	-24	-17	-15	-16	-3	12	8	-13	-1
13	7.42	.63	1.25	2.75	1.50	2.00	-5	-3	-2	-10	-13	3	8	6	0	0
14	6.87	.40	.62	.56	.44	.64	167	54	140	-33	-32	-32	-151	-141	-164	-9
15	6.40	.50	.60	.81	.55	.69	170	56	145	-44	-36	-37	-149	-137	-158	-18
16	5.99	1.86	2.80	2.14	1.71	2.98	173	50	150	-50	-39	-42	-146	-133	-151	-27
17	5.63	4.72	2.48	3.26	3.52	2.99	174	35	159	-49	-44	-47	-144	-131	-144	112
18	5.31	4.73	5.17	4.67	5.06	5.58	174	29	152	-45	-38	-40	-142	-127	-140	103
19	5.02	4.40	3.29	3.34	3.43	3.08	176	20	158	-46	-40	-42	-141	-124	-135	99
20	4.76	3.89	2.37	3.72	3.67	2.02	178	9	170	-49	-44	-46	31	103	-131	105
21	4.53	1.17	1.45	.84	1.37	2.58	-178	-5	-168	-51	-42	-46	29	95	-123	96
22	4.32	.24	.46	.55	.79	.68	-164	-46	-18	-60	-30	70	27	91	-118	127
23	4.13	.41	.59	.51	.41	.49	-174	-13	-10	-46	-29	2	94	73	73	82
24	3.95	.36	.28	.22	.15	.35	-167	-25	-86	-49	-44	-47	77	59	61	73
25	3.79	.22	.11	.20	.12	.09	-6	-25	-35	49	143	-35	57	42	47	-124
26	3.64	.05	.18	.17	.16	.09	-179	-177	-1	-119	-29	127	46	43	44	-119
27	3.51	.05	.09	.07	.05	.15	14	16	171	19	155	-53	23	21	29	32
28	3.38	.04	.04	.05	.04	.05	49	150	85	136	110	130	28	178	-137	-82
29	3.26	.03	.02	.02	.02	.01	-166	-130	-150	-102	-66	-107	22	-174	-129	-87
30	3.15	.01	.01	.01	.01	.01	174	47	92	-52	-31	3	-154	-120	62	-54
31	3.05	.01	.02	.01	.01	.00	12	143	90	123	134	127	-150	-82	55	-73
32	2.95	.00	.01	.00	.00	.00	0	178	1	127	129	127	37	60	42	-85
33	2.86	.01	.00	.00	.00	.00	0	8	2	104	141	77	-145	-66	44	149
34	2.78	.00	.00	.00	.00	.00	-176	-3	-175	-33	-167	-50	-137	-56	20	147

PT MUGU FIVE GAGE ARRAY 25 6 1970 7

DIRECTION (DEGREES FROM SEAWARD NORMAL)
POSITIVE VALUES ARE COUNTERCLOCKWISE

BAND	PERIOD AT CENTER	PRESSURE SPECTRA					1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
1	170.67	.80	.94	.87	.64	.54	-178	-175	-1	-124	-24	119	88	38	48	76
2	60.24	.79	.78	.75	.72	.78	159	110	110	121	-12	110	43	84	121	41
3	36.57	.57	.24	.38	.62	.40	150	123	142	131	141	139	118	129	135	156
4	26.26	.17	.34	.18	.17	.34	74	119	121	117	131	120	178	144	109	135
5	20.48	1.24	.87	.97	1.54	1.52	-1	-1	0	0	-8	31	0	4	11	16
6	16.79	42.85	43.41	46.87	40.89	40.58	29	25	22	21	10	33	26	25	27	28
7	14.22	29.75	25.95	25.29	27.94	27.03	33	30	26	29	16	40	31	28	32	34
8	12.34	8.81	9.10	8.50	9.66	9.55	21	19	16	16	7	27	14	14	20	21
9	10.89	3.26	4.28	3.65	4.03	4.96	5	4	4	4	-2	16	-1	2	8	11
10	9.75	1.68	1.58	2.56	2.35	1.87	2	3	2	5	1	13	10	12	16	18
11	8.83	.63	2.18	1.47	1.13	2.15	-20	-12	-9	-19	-18	0	5	2	-1	0
12	8.06	1.08	.77	.74	.52	.65	133	33	162	3	155	-49	8	5	-5	0
13	7.42	1.54	1.48	.43	1.04	.90	167	56	150	-35	-50	-42	-150	-24	46	-20
14	6.87	1.05	.38	.33	.70	.33	-64	-23	-45	-33	-43	-39	-149	-136	-166	-18
15	6.40	.56	.53	.41	.37	.45	173	32	157	-44	-44	-44	-147	-135	-153	-30
16	5.99	1.04	2.31	2.65	3.10	2.48	173	44	156	-50	-42	-46	-145	-131	-147	-39
17	5.63	1.70	2.45	1.98	2.24	2.55	174	35	156	-48	-41	-44	-144	-128	-144	111
18	5.31	1.27	1.03	1.00	.99	.97	178	11	174	-54	-54	-54	34	113	-141	117
19	5.02	1.48	1.39	.93	1.00	1.45	178	5	171	-49	-41	-44	32	96	-132	96
20	4.76	.61	.45	.60	.70	.71	178	5	172	-44	-45	-45	30	111	-128	115
21	4.53	.57	.47	.55	.57	.43	-179	0	-179	-48	-37	-39	29	88	-121	89
22	4.32	.27	.30	.40	.41	.46	-177	-8	-158	-49	-43	-46	84	87	88	96
23	4.13	.18	.27	.20	.29	.25	-4	-19	-75	63	147	-43	114	78	77	87
24	3.95	.11	.19	.13	.13	.16	-175	-167	-46	-132	-37	146	62	57	58	62
25	3.79	.07	.16	.10	.11	.10	16	149	8	128	-5	115	68	43	49	90
26	3.64	.03	.07	.03	.04	.07	175	167	175	-157	174	-109	44	28	38	-116
27	3.51	.02	.02	.03	.04	.02	16	147	160	127	149	-171	10	5	-11	-9
28	3.38	.01	.01	.01	.01	.01	-108	-74	-44	-74	-40	-81	2	4	8	-72
29	3.26	.01	.01	.00	.01	.01	172	109	144	-72	-36	-158	-149	-136	-159	-14
30	3.15	.00	.00	.00	.00	.00	170	63	148	-46	-39	-41	43	56	50	-7
31	3.05	.00	.00	.00	.00	.00	0	-41	-5	107	142	102	31	173	-139	154
32	2.95	.00	.00	.00	.00	.00	155	135	167	147	159	-87	42	45	43	-137
33	2.86	.00	.00	.00	.00	.00	136	60	158	28	153	-51	28	19	35	87
34	2.78	.00	.00	.00	.00	.00	20	21	4	22	-13	93	-152	13	38	41

PT MUGU FIVE GAGE ARRAY 25 6 1970 307

BAND	PERIOD AT CENTER	PRESSURE SPECTRA					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE 1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
1	170.67	1.03	.70	.92	1.25	1.48	-174	-166	-155	-138	-53	169	-171	-177	159	63
2	60.24	1.10	.74	.97	.97	.79	34	44	125	50	137	-22	46	176	-149	-108
3	36.57	.22	.21	.21	.26	.24	-10	-27	-1	10	-17	104	27	-173	-138	26
4	26.26	.26	.26	.23	.26	.31	55	44	39	39	22	51	42	37	40	40
5	20.48	.84	.69	.87	1.04	.87	13	10	7	4	-4	27	159	38	52	32
6	16.79	40.90	36.98	40.02	38.34	38.07	23	20	17	17	7	29	21	21	23	24
7	14.22	34.15	41.76	37.63	39.08	42.24	18	16	15	15	8	24	18	18	19	21
8	12.34	8.31	6.00	6.64	6.86	5.54	31	25	21	20	8	33	24	24	26	27
9	10.89	2.74	2.46	2.80	3.21	2.52	4	4	3	2	-4	18	7	8	10	12
10	9.75	1.40	2.00	1.65	1.29	2.24	11	11	10	11	5	19	12	12	15	16
11	8.83	1.28	.45	.85	1.16	.65	8	6	4	0	-7	25	9	8	6	10
12	8.06	.50	.56	.56	.81	.61	21	16	170	11	154	-51	21	22	14	14
13	7.42	.95	1.19	1.30	.75	1.10	48	18	169	4	156	-51	18	18	17	9
14	6.87	.60	.64	.71	.76	.70	44	27	163	18	152	-48	18	18	28	15
15	6.40	.17	.38	.14	.09	.30	9	28	161	61	148	-46	-147	-143	-148	-7
16	5.99	.49	.25	.34	.39	.24	170	37	146	-36	-37	-37	-145	-130	-147	-32
17	5.63	1.61	1.20	1.22	1.33	.83	173	36	147	-44	-37	-38	-144	-129	-144	102
18	5.31	1.27	1.06	1.26	1.15	.94	174	26	150	-45	-38	-39	-142	-125	-138	103
19	5.02	2.37	1.64	1.65	1.73	1.33	174	20	145	-41	-36	-36	33	95	-132	97
20	4.76	.74	.56	.65	.57	.41	-178	-4	-170	-48	-43	-46	29	91	-122	96
21	4.53	.47	.59	.59	.53	.62	179	1	161	-44	-36	-36	29	80	-115	80
22	4.32	.43	.25	.43	.31	.24	-176	-11	-135	-50	-40	-44	82	80	60	82
23	4.13	.27	.11	.14	.15	.07	-174	-14	-77	-46	-39	-41	67	64	64	69
24	3.95	.13	.11	.06	.06	.10	2	171	42	133	139	137	48	48	48	-121
25	3.79	.04	.03	.02	.02	.03	-179	-177	-1	-104	-28	123	47	38	43	-114
26	3.64	.05	.03	.01	.02	.02	-177	-151	-172	-87	-76	-89	19	18	30	34
27	3.51	.02	.02	.01	.01	.02	25	148	156	131	148	164	12	14	23	28
28	3.36	.01	.01	.01	.01	.01	170	114	86	-79	-26	112	-155	-143	143	-109
29	3.26	.01	.00	.01	.00	.00	171	94	149	-62	-40	-52	-148	-94	56	-81
30	3.15	.00	.00	.00	.00	.00	177	113	157	-72	-38	-77	-152	-136	165	-39
31	3.05	.00	.00	.00	.00	.00	-3	-16	-21	66	139	-23	-141	-134	-140	122
32	2.95	.00	.00	.00	.00	.00	20	161	133	140	141	141	34	34	34	170
33	2.86	.00	.00	.00	.00	.00	-1	-4	-2	56	105	29	-144	-154	-144	89
34	2.78	.00	.00	.00	.00	.00	-14	-106	-13	146	-14	117	22	22	23	68

PT MUGU FIVE GAGE ARRAY 25 6 1970 1808

BAND	PERIOD AT CENTER	PRESSURE SPECTRA					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE									
							1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
1	170.67	1.73	1.95	.81	.93	1.28	-176	-5	-19	-40	-33	-32	161	32	48	-160
2	60.24	1.28	1.00	.99	1.07	1.16	49	39	40	34	29	38	45	61	56	40
3	36.57	1.02	1.12	1.01	.99	1.01	-171	-161	-160	-139	-69	-164	156	173	-174	-167
4	26.26	.28	.36	.29	.45	.29	138	102	117	99	91	99	165	126	106	104
5	20.48	.82	.76	.66	.67	.66	37	19	11	8	-8	53	19	19	16	25
6	16.79	30.08	21.95	26.39	29.42	24.84	26	24	21	22	13	30	26	26	26	26
7	14.22	15.58	19.79	15.58	12.75	15.62	33	31	28	29	21	35	29	28	29	30
8	12.34	14.04	8.70	11.45	14.66	10.51	31	26	21	22	8	37	26	25	28	29
9	10.89	4.33	3.15	3.75	3.88	2.67	7	5	4	0	-6	17	12	12	9	12
10	9.75	1.59	1.45	1.89	2.09	1.66	-1	-1	-1	0	-3	11	-5	-1	3	6
11	8.83	.99	.44	.64	.83	.63	150	41	162	-2	157	-51	12	14	22	14
12	8.06	.84	.70	1.13	1.17	.95	-5	-5	-5	-3	-4	-2	1	0	-4	1
13	7.42	.69	.91	1.04	.95	.79	-13	-19	-14	-10	-12	-2	-154	-7	49	-1
14	6.87	.86	1.49	1.71	.87	1.66	169	56	145	-41	-36	-37	-151	-143	-161	-17
15	6.40	3.20	3.06	2.98	2.65	3.28	172	52	155	-50	-43	-47	-147	-135	-152	-36
16	5.99	5.82	6.54	5.03	4.96	6.36	174	44	156	-52	-43	-48	-146	-133	-150	-34
17	5.63	4.42	8.38	6.27	5.81	9.51	174	39	150	-50	-37	-40	-145	-131	-147	105
18	5.31	3.69	10.89	7.70	7.12	9.19	173	33	143	-46	-35	-35	-143	-126	-142	97
19	5.02	4.73	4.18	4.95	4.37	4.39	176	18	160	-48	-40	-43	-140	-125	-135	100
20	4.76	3.40	3.57	4.56	4.02	2.70	179	0	179	-52	-46	-50	31	103	-130	109
21	4.53	1.52	1.04	1.13	.97	1.61	-5	-65	-16	105	124	104	31	83	-121	-173
22	4.32	1.25	.74	.92	.95	1.06	-173	-23	-14	-54	-30	18	107	114	117	137
23	4.13	.78	.56	.38	.37	.43	-5	-36	-124	81	150	-56	114	79	77	103
24	3.95	.49	.79	.43	.40	.66	-7	-37	-93	69	150	-53	78	65	64	70
25	3.79	.31	.25	.33	.40	.17	-5	-143	-41	130	145	147	84	53	57	65
26	3.64	.13	.14	.08	.09	.16	-171	-127	-22	-92	-33	131	81	24	39	-139
27	3.51	.07	.04	.08	.06	.05	0	178	179	143	156	-121	-138	-80	10	-105
28	3.38	.02	.05	.05	.05	.03	173	144	145	-108	-36	145	-47	-4	15	8
29	3.26	.02	.02	.03	.03	.02	165	17	25	-21	-20	1	11	-155	-131	-99
30	3.15	.01	.03	.02	.01	.01	0	-176	-166	120	145	154	-151	-119	42	-98
31	3.05	.02	.02	.02	.01	.01	177	10	162	-46	-39	-41	-143	-121	-140	73
32	2.95	.01	.01	.00	.01	.00	-2	-21	-124	91	146	-49	35	63	31	-160
33	2.86	.01	.01	.00	.00	.00	-2	-22	-16	93	140	0	34	60	25	149
34	2.78	.00	.00	.00	.00	.00	-5	-30	-17	77	131	19	34	81	-129	157

PT MUGU FIVE GAGE ARRAY 25 6 1970 2108

BAND	PERIOD AT CENTER	PRESSURE SPECTRA					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE									
							1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
1	170.67	.77	1.04	.97	1.15	.99	174	171	172	-176	-173	179	172	-171	-157	171
2	60.24	.46	.87	.65	.54	.69	172	165	148	-171	-37	145	43	40	42	41
3	30.57	.29	.40	.35	.34	.38	74	40	66	27	58	11	33	50	24	6
4	20.26	.07	.13	.09	.07	.13	-147	-124	-53	-113	-42	163	-30	-19	-12	-22
5	20.48	.43	.56	.45	.37	.46	24	25	19	26	11	40	20	19	24	27
6	16.79	10.57	9.29	9.48	10.32	8.72	31	27	24	25	14	35	27	26	28	29
7	14.22	39.72	35.24	37.56	40.44	40.06	24	22	19	19	10	29	23	23	24	25
8	12.34	9.27	12.45	10.70	9.06	10.58	25	21	19	17	8	26	22	22	23	23
9	10.89	2.53	3.71	3.41	2.51	3.47	26	22	19	19	9	31	22	21	24	25
10	9.75	.76	1.14	.89	.80	.74	60	27	24	14	0	36	28	26	30	25
11	8.83	.81	.73	.75	.74	.57	96	25	21	4	-6	34	26	25	27	16
12	8.06	.50	.69	.63	.49	.80	27	16	170	8	155	-52	15	15	18	15
13	7.42	1.46	1.90	2.00	1.71	2.03	-45	-38	-35	-40	-35	-35	-151	-21	47	-20
14	6.87	3.75	3.49	3.58	3.97	3.10	167	56	142	-35	-34	-34	-149	-28	44	-19
15	6.40	5.97	7.88	6.92	5.99	8.12	171	54	147	-46	-38	-39	-147	-136	-153	-28
16	5.99	8.57	8.21	9.63	9.77	7.13	171	48	146	-44	-37	-37	-146	-133	-150	-29
17	5.63	4.69	3.72	4.06	3.71	2.53	172	40	146	-45	-37	-37	-145	-131	-147	103
18	5.31	2.26	4.09	3.47	3.59	4.75	174	26	155	-47	-39	-42	-142	-126	-139	104
19	5.02	3.93	2.25	2.31	2.34	2.06	175	17	155	-44	-39	-40	33	100	-133	102
20	4.76	1.44	1.68	1.47	1.61	2.06	178	7	170	-48	-41	-44	30	96	-126	102
21	4.53	1.14	1.33	.65	.76	1.24	-175	-21	-156	-56	-50	-54	29	90	-121	89
22	4.32	1.00	.87	1.32	1.16	.56	-177	-10	-13	-50	-32	-21	28	81	-115	76
23	4.13	.39	.11	.15	.17	.16	-169	-157	-20	-135	-32	136	69	75	75	-145
24	3.95	.46	.19	.24	.10	.25	-6	-33	-83	67	149	-50	54	54	54	-144
25	3.79	.15	.15	.05	.06	.23	167	149	159	-176	-172	178	52	49	50	52
26	3.64	.05	.09	.07	.10	.09	-174	-157	-29	-110	-34	141	33	28	34	44
27	3.51	.02	.05	.08	.07	.05	36	28	152	22	147	-40	23	31	-22	-91
28	3.38	.04	.04	.02	.03	.05	12	156	143	131	143	143	-123	-58	-9	-83
29	3.26	.02	.02	.01	.01	.01	172	134	155	-101	-45	-169	-10	-8	-6	-15
30	3.15	.01	.01	.02	.01	.01	174	137	103	-88	-32	126	-155	-131	96	-85
31	3.05	.01	.01	.00	.01	.00	176	152	52	-93	-31	127	44	87	129	-87
32	2.95	.00	.00	.00	.00	.00	-177	-176	-173	-156	-62	164	53	115	168	-144
33	2.56	.00	.00	.00	.00	.00	-3	-152	-9	123	123	123	33	52	25	125
34	2.78	.00	.00	.00	.00	.00	-6	-135	-71	131	148	168	33	58	4	-2

PT MUGU FIVE GAGE ARRAY 26 6 1970 1758

BAND	PERIOD AT CENTER	PRESSURE SPECTRA					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE 1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
1	170.67	.66	2.18	1.93	1.65	.95	-167	-155	-14	-136	-28	129	161	20	38	174
2	60.24	.51	.76	.74	.61	.55	176	175	175	-179	-167	170	137	164	179	142
3	36.57	.67	.46	.47	.38	.28	2	0	0	-15	-17	58	17	16	-15	16
4	26.26	.49	.23	.41	.54	.56	-152	-152	-164	-151	179	-116	-12	-18	-24	-81
5	20.48	.97	1.00	.97	.79	.76	7	6	4	2	-8	34	10	10	10	13
6	16.79	3.70	3.04	3.45	2.87	3.23	41	21	15	9	-4	39	25	25	25	25
7	14.22	11.61	12.20	13.00	13.58	15.06	26	24	23	21	17	25	23	23	22	22
8	12.34	6.07	4.48	3.40	3.96	3.98	17	13	11	7	0	19	18	18	16	16
9	10.89	6.67	5.27	6.25	6.06	4.25	29	19	16	11	0	30	23	23	23	22
10	9.75	.99	1.63	2.34	1.55	1.45	29	20	20	14	7	21	20	20	22	20
11	8.83	1.20	1.94	1.73	1.08	1.21	-16	-20	-17	-16	-16	-9	3	-2	-14	4
12	8.06	.85	1.01	1.18	1.30	.91	-16	-25	-23	-15	-14	-20	7	2	-12	-2
13	7.42	3.43	.99	1.51	1.54	1.21	-48	-41	-45	-43	-44	-44	-150	-32	46	-38
14	6.87	7.32	7.83	7.30	7.61	7.16	-37	-34	-30	-35	-31	-29	-150	-140	-160	-23
15	6.40	23.83	28.82	28.19	28.63	26.71	170	58	147	-45	-38	-39	-147	-136	-154	-32
16	5.99	16.08	11.97	14.87	14.73	10.62	170	51	144	-41	-36	-36	-147	-134	-152	-31
17	5.63	4.38	9.72	6.29	6.67	12.07	172	42	148	-45	-37	-39	-145	-132	-148	106
18	5.31	5.25	3.24	4.36	4.34	3.08	173	33	148	-45	-37	-38	-143	-126	-142	102
19	5.02	1.32	1.42	1.00	1.19	2.32	174	23	134	-42	-34	-32	-141	-123	-135	98
20	4.76	1.78	2.36	1.44	1.17	3.37	179	1	179	-49	-65	-53	32	101	-132	107
21	4.53	1.82	.66	.40	.38	.49	-177	-7	-167	-46	-47	-47	29	110	-127	112
22	4.32	1.26	.67	.56	.58	.43	-177	-6	-161	-46	-42	-44	28	97	-121	96
23	4.13	.46	.69	.77	.73	.35	-5	-36	-20	83	135	17	102	87	85	94
24	3.95	.09	.11	.12	.09	.28	159	138	62	155	-15	122	73	69	69	-144
25	3.79	.10	.30	.14	.30	.28	179	178	177	-168	-61	157	135	117	110	154
26	3.64	.20	.23	.16	.16	.11	1	175	174	135	149	164	49	24	38	-122
27	3.51	.03	.10	.05	.07	.04	-161	-139	-90	-121	-49	175	25	19	34	-116
28	3.38	.03	.03	.03	.03	.02	-1	-2	-137	17	145	-36	10	-158	-136	-81
29	3.26	.03	.03	.03	.02	.01	171	137	107	-109	-29	127	-79	-140	-130	12
30	3.15	.02	.01	.01	.01	.00	-76	-37	-23	-43	-29	-4	-154	-143	170	3
31	3.05	.00	.01	.01	.01	.01	-12	-31	-21	2	6	-2	-148	-129	-166	-11
32	2.95	.00	.01	.00	.00	.01	154	74	105	14	-2	45	41	80	116	-101
33	2.86	.00	.00	.01	.00	.00	3	81	162	104	146	-61	-146	-73	45	-23
34	2.78	.00	.01	.00	.00	.00	158	153	156	157	158	160	-144	-57	36	118

PT MUGU FIVE GAGE ARRAY 28 6 1970 2010

PRESSURE SPECTRA / DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE

Band	Period at center	Spectrum 1	Spectrum 2	Spectrum 3	Spectrum 4	Spectrum 5	1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
1	170.67	.97	.98	.68	.60	.81	-90	-142	-36	-159	-36	144	-143	-10	35	86
2	60.24	.46	.54	.48	.49	.48	-65	-111	-104	-125	-146	-116	-112	-94	-91	-121
3	36.57	.78	1.12	.85	.60	.66	-116	-79	-74	-77	-58	-79	-35	-70	-60	-61
4	26.26	.74	.61	.68	.81	.64	-91	-89	-75	-89	-67	-95	-92	-66	-56	-72
5	20.48	1.40	.88	.80	.87	1.03	103	46	40	25	2	52	40	49	43	34
6	16.79	1.69	1.57	1.75	1.66	1.38	19	14	12	9	0	28	15	15	21	21
7	14.22	3.65	4.21	4.70	5.07	4.67	12	12	10	12	4	24	8	10	16	18
8	12.34	2.60	1.91	2.03	2.51	2.65	23	13	11	5	-4	26	14	14	14	14
9	10.89	1.11	1.29	1.10	.88	1.11	0	0	0	1	-7	25	-3	8	21	24
10	9.75	1.10	.86	1.03	1.09	.71	-16	-15	-12	-16	-16	-2	-3	-3	-4	0
11	8.83	7.60	7.88	8.47	7.72	6.58	-37	-29	-24	-32	-27	-20	-18	-15	-14	-14
12	8.06	18.02	19.68	19.80	20.27	20.27	-40	-33	-29	-36	-30	-27	-152	-22	49	-21
13	7.42	10.78	9.77	9.20	9.34	9.67	-40	-33	-29	-35	-30	-27	-152	-20	48	-20
14	6.87	14.31	17.51	16.45	16.77	17.77	-40	-34	-29	-36	-30	-27	-151	-22	46	-21
15	6.40	12.96	10.16	10.39	11.02	9.70	-47	-38	-33	-40	-34	-33	-148	-138	-157	-25
16	5.99	9.71	6.45	7.39	7.52	6.14	169	52	136	-38	-31	-28	-148	-136	-155	-23
17	5.63	1.95	6.24	4.39	4.33	6.70	170	43	129	-37	-30	-25	-145	-130	-148	104
18	5.31	4.37	1.94	2.61	2.24	2.06	172	33	128	-40	-32	-28	-142	-126	-140	96
19	5.02	2.53	4.60	3.57	3.10	4.18	175	23	159	-49	-40	-43	-142	-124	-138	99
20	4.76	2.94	1.14	2.03	1.47	1.90	176	14	20	-46	-29	-1	32	84	-125	-172
21	4.53	.98	1.83	1.58	1.59	1.51	175	13	142	-38	-35	-35	32	83	-125	84
22	4.32	.82	.42	.50	.44	.27	-151	-151	-14	-151	-27	129	32	78	-119	86
23	4.13	.29	.55	1.02	.81	.56	179	3	3	-45	-29	-1	28	69	-105	143
24	3.95	.16	.13	.13	.21	.23	147	145	131	146	120	136	128	70	71	120
25	3.79	.09	.19	.16	.09	.07	159	118	53	141	-15	113	62	58	59	63
26	3.64	.12	.00	.13	.09	.08	11	150	162	127	149	-164	136	34	48	68
27	3.51	.04	.04	.03	.03	.06	174	156	156	-128	-42	156	43	132	-158	-135
28	3.38	.02	.02	.03	.02	.02	164	67	169	-25	163	-64	140	155	164	-107
29	3.26	.01	.01	.01	.01	.01	-12	-37	-21	10	8	11	-97	-32	-2	-89
30	3.15	.01	.01	.01	.01	.01	172	28	142	-38	-35	-35	2	-71	-95	-46
31	3.05	.01	.01	.01	.01	.01	174	52	146	-54	-36	-38	-150	-29	47	102
32	2.95	.00	.00	.00	.00	.00	174	83	122	-64	-33	40	-148	-38	44	113
33	2.86	.00	.00	.00	.00	.00	-23	-28	-26	-24	-25	-25	42	45	43	-3
34	2.78	.00	.00	.00	.00	.00	-15	-73	-38	117	150	-95	32	48	18	161

PT MUGU FIVE GAGE ARRAY 26 6 1970 2058

BAND	PERIOD AT CENTER	PRESSURE SPECTRA					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE 1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
1	170.67	.20	.39	.27	.36	.37	12	42	156	73	147	-46	-164	-163	-154	-141
2	60.24	.42	.53	.40	.62	.64	173	150	154	-127	-42	157	-18	-152	-135	28
3	36.57	.22	.37	.30	.20	.25	-3	-44	-7	99	68	101	-93	-39	-12	-11
4	26.26	.16	.11	.15	.12	.12	-7	-2	-4	-14	-13	-18	9	2	-22	-21
5	20.48	.34	.46	.37	.33	.40	18	12	[illegible]	5	-6	36	-7	0	7	8
6	16.79	1.91	1.61	1.60	1.89	1.60	32	24	21	18	7	32	25	25	25	24
7	14.22	12.29	13.90	12.86	12.52	13.00	16	14	12	12	3	24	16	16	19	20
8	12.34	8.25	6.76	7.34	8.40	7.42	16	14	13	12	5	22	16	16	18	19
9	10.89	2.11	3.10	2.69	2.46	2.75	19	19	17	18	12	25	18	18	21	22
10	9.75	2.00	1.39	1.87	2.22	1.36	1	0	0	-5	-9	12	6	7	9	8
11	8.83	.99	.56	.65	.84	.49	-14	-11	-8	-15	-16	9	4	3	0	4
12	8.06	1.99	1.04	1.23	1.54	.65	-24	-28	-27	-25	-26	-26	-151	-27	48	-24
13	7.42	3.11	2.19	2.46	2.91	1.68	-35	-31	-30	-32	-31	-30	-151	-21	47	-20
14	6.87	19.44	19.31	22.94	22.28	18.49	-41	-37	-32	-38	-32	-30	-149	-138	-159	-24
15	6.40	15.66	15.40	15.47	14.96	15.44	169	57	141	-40	-34	-32	-148	-136	-156	-25
16	5.99	6.56	10.76	9.56	9.44	11.87	172	50	150	-48	-39	-42	-146	-135	-151	-31
17	5.63	10.88	11.51	9.15	9.41	12.84	174	38	156	-49	-42	-45	-144	-131	-145	109
18	5.31	6.36	4.15	5.41	4.71	3.95	175	21	163	-48	-45	-46	-142	-128	-140	107
19	5.02	2.04	1.86	1.93	2.15	2.33	172	27	122	-39	-51	-27	-141	-123	-136	94
20	4.76	1.35	1.84	1.00	.86	2.07	-80	-151	-17	-172	-26	132	-142	-124	-138	86
21	4.53	.90	1.60	1.23	.86	1.11	-3	-34	-159	96	149	-61	31	91	-126	94
22	4.32	.63	1.04	.91	.94	1.07	-4	-30	-141	85	149	-55	27	88	-117	95
23	4.13	.26	.41	.56	.47	.43	-167	-160	-67	-148	-41	151	100	95	93	112
24	3.95	.18	.22	.22	.22	.43	19	108	60	108	128	108	113	65	67	170
25	3.79	.10	.13	.06	.11	.16	-172	-161	-69	-133	-39	151	56	65	64	50
26	3.64	.14	.18	.12	.13	.16	12	22	32	38	106	3	58	38	45	17
27	3.51	.07	.12	.11	.10	.06	0	-173	-179	123	155	-80	30	-166	-142	-110
28	3.38	.04	.07	.04	.04	.04	-5	-3	-171	-9	155	-44	31	-175	-141	-104
29	3.26	.03	.02	.03	.04	.03	-175	-164	-149	-123	-46	166	-113	-115	-115	-62
30	3.15	.02	.01	.01	.01	.01	-117	-121	-107	-122	-98	-134	-3	-97	-103	-81
31	3.05	.01	.01	.01	.01	.01	-169	-160	-25	-145	-53	139	-148	-99	60	-70
32	2.95	.01	.00	.01	.00	.01	11	160	162	134	149	166	-147	-92	51	151
33	2.86	.00	.00	.01	.00	.00	0	-179	0	152	-9	129	35	58	32	102
34	2.78	.00	.00	.00	.00	.00	167	161	156	170	-150	152	30	86	-121	111

APPENDIX C

FOURIER COEFFICIENTS FOR A MIXTURE OF THREE SINUSOIDS

The Fourier Transform of the function:

$$f(t) = A \cos(\sigma t - \phi) \tag{C-1}$$

with

$$\sigma = \frac{2\pi(\hat{m} + \delta)}{N\Delta t}, \quad |\delta| \le \frac{1}{2}, \tag{C-2}$$

where $1 << \hat{m} << N$, computed from N values of $f(t)$ evaluated at equal increments of t; Δt is given by the set of coefficients (Harris, 1974):

$$a_m = \frac{2A \sin \pi\delta \cos(\pi\delta - \phi)}{N}\left[\frac{1}{\tan[\pi(\hat{m} - m + \delta)/N]} + \frac{1}{\tan[\pi(\hat{m} + m + \delta)/N]}\right],$$

$$b_m = \frac{2A \sin \pi\delta \sin(\pi\delta - \phi)}{N}\left[\frac{1}{\tan[\pi(\hat{m} - m + \delta)/N]} - \frac{1}{\tan[\pi(\hat{m} + m + \delta)/N]}\right],$$

$$m = 1, 2, \ldots \frac{N}{2}. \tag{C-3}$$

Harris shows that for values of m near $\hat{m}$, and for $\hat{m}$ far removed from 1 and $N/2$,

$$a_m \doteq \frac{A \sin \pi\delta \cos(\phi - \pi\delta)}{\pi(\hat{m} - m + \delta)},$$

$$b_m \doteq \frac{A \sin \pi\delta \sin(\phi - \pi\delta)}{\pi(\hat{m} - m + \delta)}, \qquad m = 1, 2, \ldots \frac{N}{2} \tag{C-4}$$

are good approximations to the coefficients in equation (C-3). Equation (C-4) shows that convergence is slow.

For the special case $\delta = 0$, substitution into equations (C-3) or (C-4) gives:

$$a_m = b_m = 0, \qquad m \neq \hat{m},$$

and

$$a_m = b_m = \text{indeterminate for } m = \hat{m}.$$

Use of L' Hospital Rule in equation (C-3) when $\delta \to 0$, shows that:

$$a_m = A \cos \phi \;, \quad b_m = A \sin \phi \;, \quad m = \hat{m} \;. \tag{C-5}$$

Application of the cosine bell data window,

$$\tilde{f}(n\Delta t) = \frac{1}{2} \left\{ \left[1 - \cos \frac{2\pi n}{N} \right] \right\} f(n\Delta t) \;, \quad n = 1, \ldots N \;, \tag{C-6}$$

is equivalent to replacing the original sinusoid $f(n\Delta t)$ with the sum of three sinusoids (Harris, 1974), where

$$\tilde{f}(n\Delta t) = \frac{A}{2} \left[2 \cos \left[\frac{2\pi(\hat{m} + \delta)n}{N} - \phi \right] - \cos \left[\frac{2\pi(\hat{m} - 1 + \delta)n}{N} - \phi \right] - \cos \left[\frac{2\pi(\hat{m} + 1 + \delta)}{N} - \phi \right] \right] . \tag{C-7}$$

For $\delta = 0$, and in view of equation (C-5), the Fourier Transform of this modified function will be given by:

$$a_{\hat{m}-1} = a_{\hat{m}+1} = -\frac{A}{4} \cos \phi \;, \quad b_{\hat{m}-1} = b_{\hat{m}+1} = -\frac{A}{4} \sin \phi$$

and

$$a_{\hat{m}} = \frac{A}{2} \cos \phi \;, \quad b_{\hat{m}} = \frac{A}{2} \sin \phi$$

with $a_m = b_m = 0$ for all other values of m. Thus, energy appears at three adjacent m values.

Harris (1974) shows that after application of the cosine bell data window, the approximate values of the coefficients are given by:

$$a_m \doteq \frac{A \sin \pi\delta \cos(\phi - \pi\delta)}{2\pi(\hat{m} - m + \delta)[(\hat{m} - m + \delta)^2 - 1]} \;,$$

$$b_m \doteq \frac{A \sin \pi\delta \sin(\phi - \pi\delta)}{2\pi(\hat{m} - m + \delta)[(\hat{m} - m + \delta)^2 - 1]} \;, \quad m = 1, \ldots \frac{N}{2} . \tag{C-8}$$

Thus, convergence increases rapidly, and values of the coefficients for $(\hat{m} - m) \geq 3$ may be disregarded.

Equations (C-3), (C-4), and (C-8) imply that

$$\tan(\phi - \pi\delta) = \frac{a_m}{b_m} \tag{C-9}$$

Since δ may be as large as 1/2, phase values computed from the Finite Fourier Transform may be in error by as much as 90°.

For a simplistic simulation of a wave train, it is sufficient to combine three sinusoids with nearby periods propagating in the same direction. Letting A_i equal the amplitudes and k_i, i - 1,2,3, the wave numbers, the Fourier Transform of the combination is given by:

$$a_m = \sum_{i=1}^{3} \frac{A_i \sin \pi\delta_i \cos(\Phi_i - \pi\delta_i)}{2\pi(\hat{m}_i - m + \delta_i)[(\hat{m}_i - m + \delta_i)^2 - 1]} ,$$

$$b_m = \sum_{i=1}^{3} \frac{A_i \sin \pi\delta_i \sin(\Phi_i - \pi\delta_i)}{2\pi(\hat{m}_i - m + \delta_i)[(\hat{m}_i - m + \delta_i)^2 - 1]} . \qquad \text{(C-10)}$$

Nearby periods are attained by setting

$$\Delta_i = (\hat{m}_i - m) \leq 3 . \qquad \text{(C-11)}$$

Let the coordinates of three nearby locations be (x_j, y_j); j = 1,2,3. The only difference among the Fourier Transforms (eq. C-10) arising from wave records at each location is the values of the Φ_i's. At each location j, the Φ_i values are:

$$\Phi_{ij} = k_i(x_j \cos\alpha + y_j \sin\alpha) - \phi_i , \qquad i = 1,2,3 , \qquad \text{(C-12)}$$

or

$$\Phi_{ij} = k_i\Omega_j - \phi_i ,$$

where

$$\Omega_j = x_j \cos\alpha + y_j \sin\alpha , \qquad j = 1,2,3 . \qquad \text{(C-13)}$$

Since the three sinusoids are assumed to have nearby periods, let

$$k_1 \doteq k_2 \doteq k_3 = k .$$

Thus,

$$\Phi_{ij} = k\Omega_j - \phi_i .$$

Then, for the wave record at location j :

$$a_{mj} \doteq \sum_{i=1}^{3} \frac{A_i \sin \pi\delta_i \cos(k\Omega_j - \pi\delta_i - \phi_i)}{2\pi(\Delta_i + \delta_i)[(\Delta_i + \delta_i)^2 - 1]} ,$$

$$b_{mj} \doteq \sum_{i=1}^{3} \frac{A_i \sin \pi\delta_i \sin(k\Omega_j - \pi\delta_i - \phi_i)}{2\pi(\Delta_i + \delta_i)[(\Delta_i + \delta_i)^2 - 1]} . \qquad \text{(C-14)}$$

Let:

$$[i] = 2\pi(\Delta_i + \delta_i)[(\Delta_i + \delta_i)^2 - 1] , \quad i = 1,2,3 . \qquad \text{(C-15)}$$

The expanded expression for a_{mj}, after collecting terms in $\cos k\Omega_j$ and $\sin k\Omega_j$, is:

$$a_{mj} \doteq \cos k\Omega_j \left\{ \frac{A_1 \sin \pi\delta_1 \cos(\phi_1 + \pi\delta_1)}{[1]} + \frac{A_2 \sin \pi\delta_2 \cos(\phi_2 + \pi\delta_2)}{[2]} + \frac{A_3 \sin \pi\delta_3 \cos(\phi_3 + \pi\delta_3)}{[3]} \right\}$$

$$+ \sin k\Omega_j \left\{ \frac{A_1 \sin \pi\delta_1 \sin(\phi_1 + \pi\delta_1)}{[1]} + \frac{A_2 \sin \pi\delta_2 \sin(\phi_2 + \pi\delta_2)}{[2]} + \frac{A_3 \sin \pi\delta_3 \sin(\phi_3 + \pi\delta_3)}{[3]} \right\} ;$$

and similarly for b_{mj} :

$$b_{mj} \doteq \sin k\Omega_j \left\{ \frac{A_1 \sin \pi\delta_1 \cos(\phi_1 + \pi\delta_1)}{[1]} + \frac{A_2 \sin \pi\delta_2 \cos(\phi_2 + \pi\delta_2)}{[2]} + \frac{A_3 \sin \pi\delta_3 \cos(\phi_3 + \pi\delta_3)}{[3]} \right\}$$

$$- \cos k\Omega_j \left\{ \frac{A_1 \sin \pi\delta_1 \sin(\phi_1 + \pi\delta_1)}{[1]} + \frac{A_2 \sin \pi\delta_2 \sin(\phi_2 + \pi\delta_2)}{[2]} + \frac{A_3 \sin \pi\delta_3 \sin(\phi_3 + \pi\delta_3)}{[3]} \right\} .$$

For every narrow-banded wave train, $|\Delta_i| < 3$ in equation (C-15), unpredictable terms are introduced in the expressions for the coefficients which make the ratio b_m/a_m a poor estimator of the value of the phase of the sinusoid.

The numerators of the terms inside the braces in the above equations for a_{mj} and b_{mj} are at most of order A_i, i = 1,2,3.

Randomness in the values of δ_i, i = 1,2,3 and in the phase relationships of the three sinusoids at the origin of coordinates might produce partial cancellations among the terms inside the braces to reduce the resulting error.

Assume for example: $\phi_i = 0$, i = 1,2,3. The coefficients reduce to:

$$a_{mj} \doteq \frac{1}{2}\cos k\Omega_j \left\{\frac{A_1 \sin 2\pi\delta_1}{[1]} + \frac{A_2 \sin 2\pi\delta_2}{[2]} + \frac{A_3 \sin 2\pi\delta_3}{[3]}\right\}$$

$$+ \sin k\Omega_j \left\{\frac{A_1 \sin^2 \pi\delta_1}{[1]} + \frac{A_2 \sin^2 \pi\delta_2}{[2]} + \frac{A_3 \sin^2 \pi\delta_3}{[3]}\right\} ;$$

similarly, for b_{mj} :

$$b_{mj} \doteq \frac{1}{2}\sin k\Omega_j \left\{\frac{A_1 \sin 2\pi\delta_1}{[1]} + \frac{A_2 \sin 2\pi\delta_2}{[2]} \div \frac{A_3 \sin 2\pi\delta_3}{[3]}\right\}$$

$$- \cos k\Omega_j \left\{\frac{A_1 \sin^2 \pi\delta_1}{[1]} + \frac{A_2 \sin^2 \pi\delta_2}{[2]} + \frac{A_3 \sin^2 \pi\delta_3}{[3]}\right\} . \qquad \text{(C-16)}$$

Letting:

$$L_1 = A_1 \sin 2\pi\delta_1 , \qquad L_2 = A_1 \sin^2 \pi\delta_1 ,$$

$$M_1 = A_2 \sin 2\pi\delta_2 , \qquad M_2 = A_2 \sin^2 \pi\delta_2 ,$$

$$N_1 = A_3 \sin 2\pi\delta_3 , \qquad N_2 = A_3 \sin^2 \pi\delta_3 ; \qquad \text{(C-17)}$$

then:

$$a_{mj} \doteq \frac{1}{2}\cos k\Omega_j \left[\frac{L_1}{[1]} + \frac{M_1}{[2]} + \frac{N_1}{[3]}\right] + \sin k\Omega_j \left[\frac{L_2}{[1]} + \frac{M_2}{[2]} + \frac{N_2}{[3]}\right] ,$$

and

$$b_{my} \doteq \frac{1}{2}\sin k\Omega_j \left[\frac{L_1}{[1]} + \frac{M_1}{[2]} + \frac{N_1}{[3]}\right] - \cos k\Omega_j \left[\frac{L_2}{[1]} + \frac{M_2}{[2]} + \frac{N_2}{[3]}\right] . \qquad \text{(C-18)}$$

Assume further: $A_1 \sim A_2 \sim A_3$ and $|\hat{m}_i - m| = 0$ for i = 2 and equal for i = 1 and 3. Since $|\delta| < 1$, the terms [1] and [3] are of approximately the same magnitude but of opposite signs. Thus, terms involving the products [1] [2] and [2] [3] tend to cancel. Letting $\delta_1 = \delta_2 = \delta_3 = \delta$:

$$\frac{b_{mj}}{a_{mj}} \doteq \frac{\sin k\Omega_j \sin 2\pi\delta - 2 \cos k\Omega_j \sin^2 \pi\delta}{\cos k\Omega_j \sin 2\pi\delta + 2 \sin k\Omega_j \sin^2 \pi\delta} .$$

Using the trigonometric identities for the double arc, this expression reduces to:

$$\frac{b_{mj}}{a_{mj}} \doteq \tan (k\Omega_j - \pi\delta) . \qquad \text{(C-19)}$$

Phase differences between locations will be approximately correct.

APPENDIX D

SPECTRA PLOTS AND COMPUTER OUTPUT FOR SIMULATED OBSERVATIONS

Figures D-1 to D-8 show high-resolution spectra pressure gages 1 to 5 at Pt. Mugu, California.

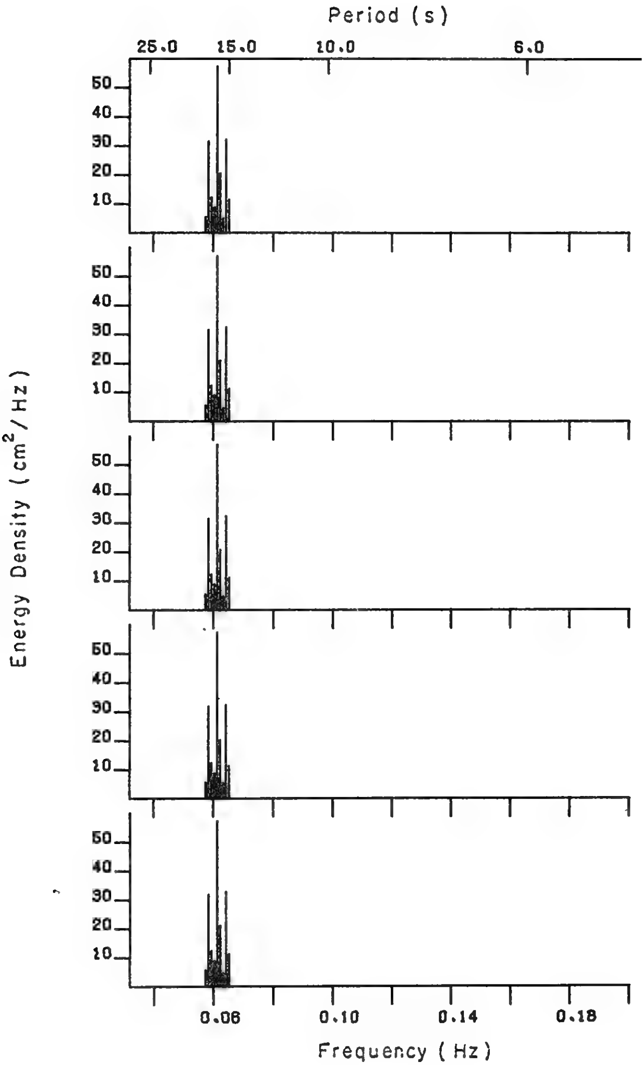

Period (s)
25.0
15.0
10.0
6.0
50
40
30
20
10
Energy Density (cm²/Hz)
0.06
0.10
0.14
0.18
Frequency (Hz)

Figure D-1.

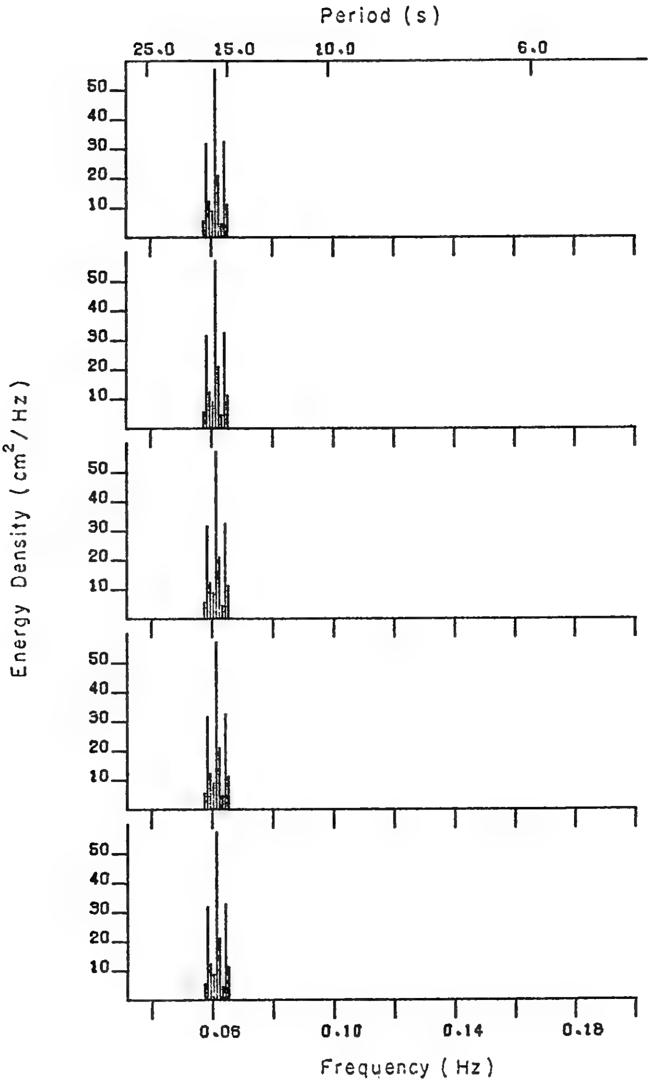

Period (s)
25.0
15.0
10.0
6.0
50
40
30
20
10
Energy Density (cm²/Hz)
0.06
0.10
0.14
0.18
Frequency (Hz)

Figure D-2.

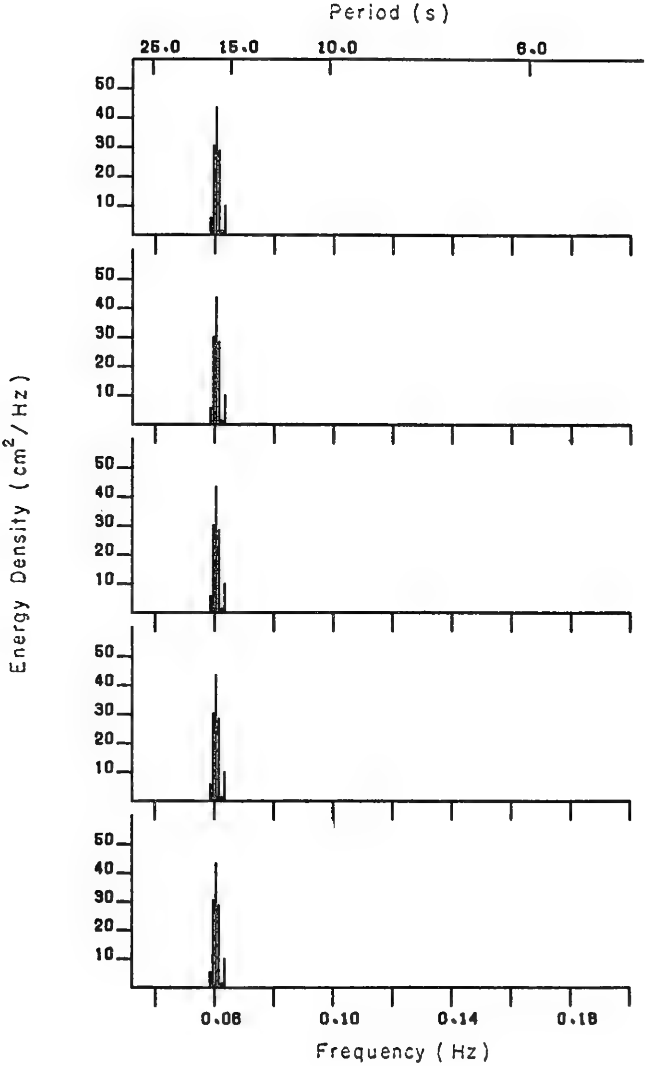

Period (s)
25.0
15.0
10.0
6.0
50
40
30
20
10
Energy Density (cm^2 / Hz)
0.06
0.10
0.14
0.18
Frequency (Hz)

Figure D-3.

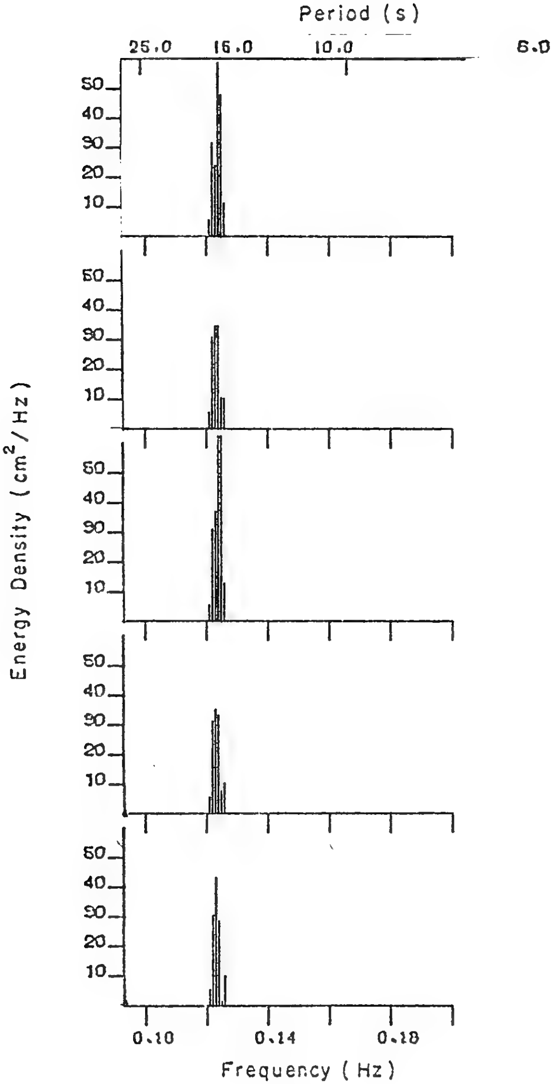
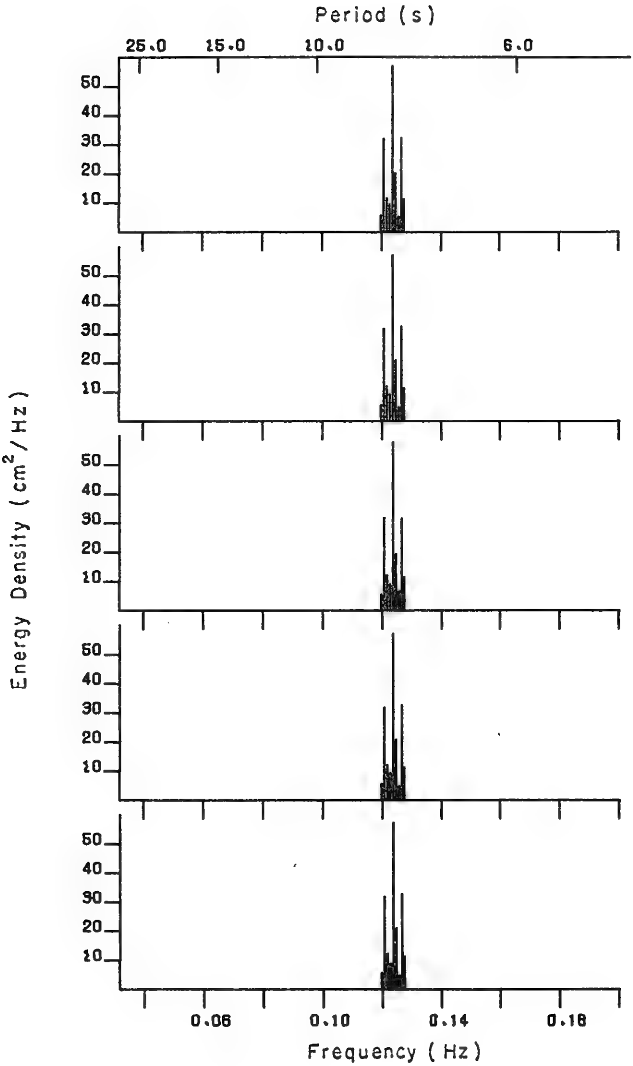

Period (s)
25.0
16.0
10.0
6.0
50
40
30
20
10
Energy Density (cm2/Hz)
0.10
0.14
0.18
Frequency (Hz)

Figure D-4.



Period (s)
25.0
15.0
10.0
6.0
50
40
30
20
10
Energy Density (cm²/Hz)
0.06
0.10
0.14
0.18
Frequency (Hz)

Figure D-5.

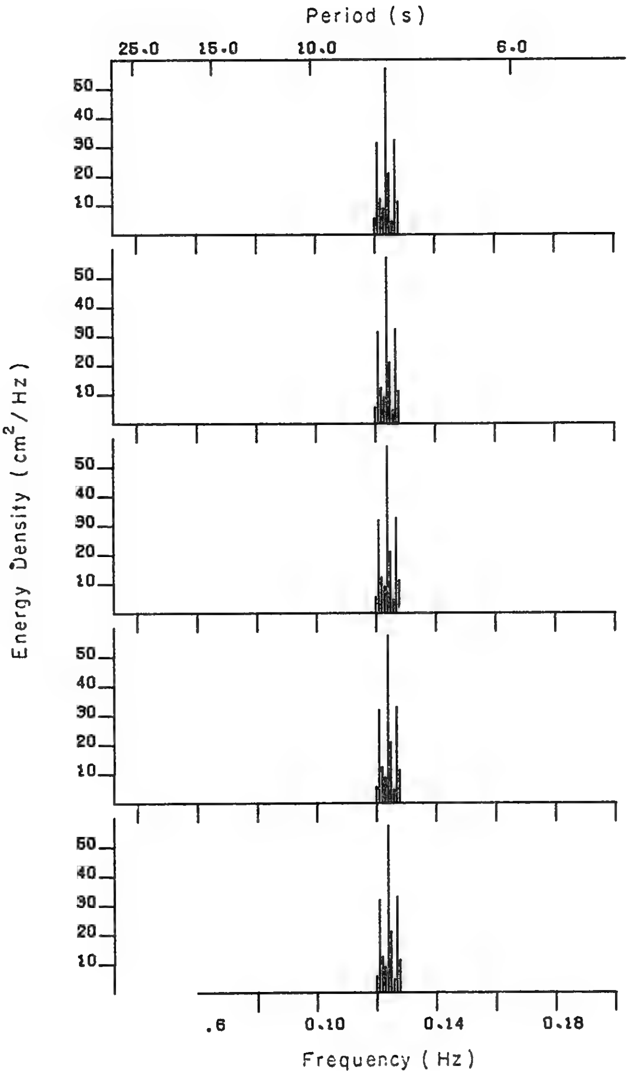
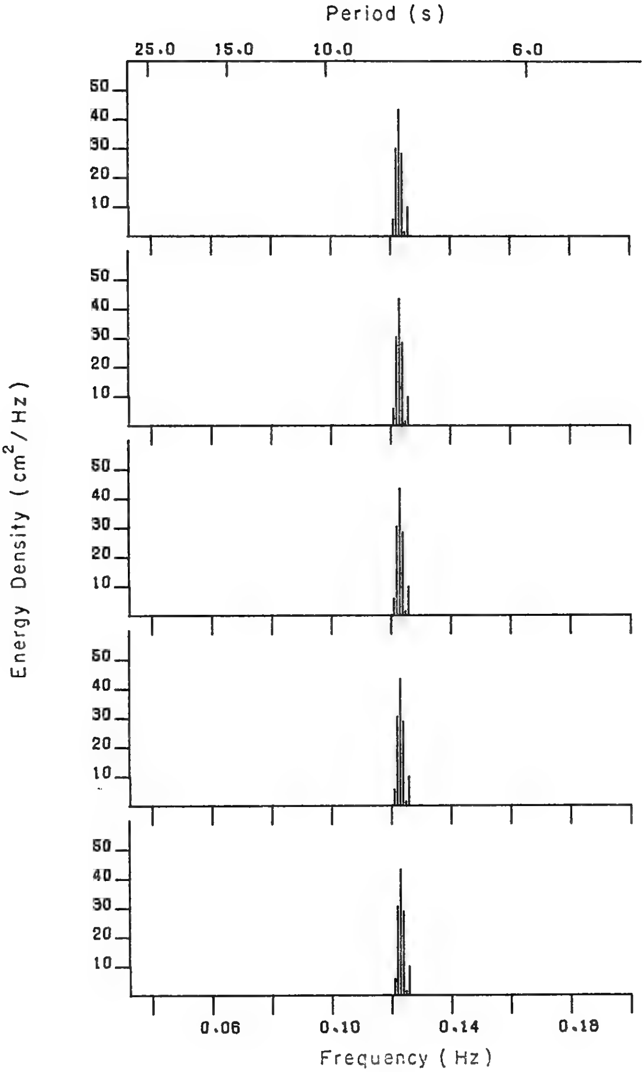

Period (s)
25.0
15.0
10.0
6.0
50
40
30
20
10
Energy Density (cm2/Hz)
.6
0.10
0.14
0.18
Frequency (Hz)

Figure D-6.



Period (s)
25.0
15.0
10.0
6.0
50
40
30
20
10
Energy Density (cm²/Hz)
0.06
0.10
0.14
0.18
Frequency (Hz)

Figure D-7.

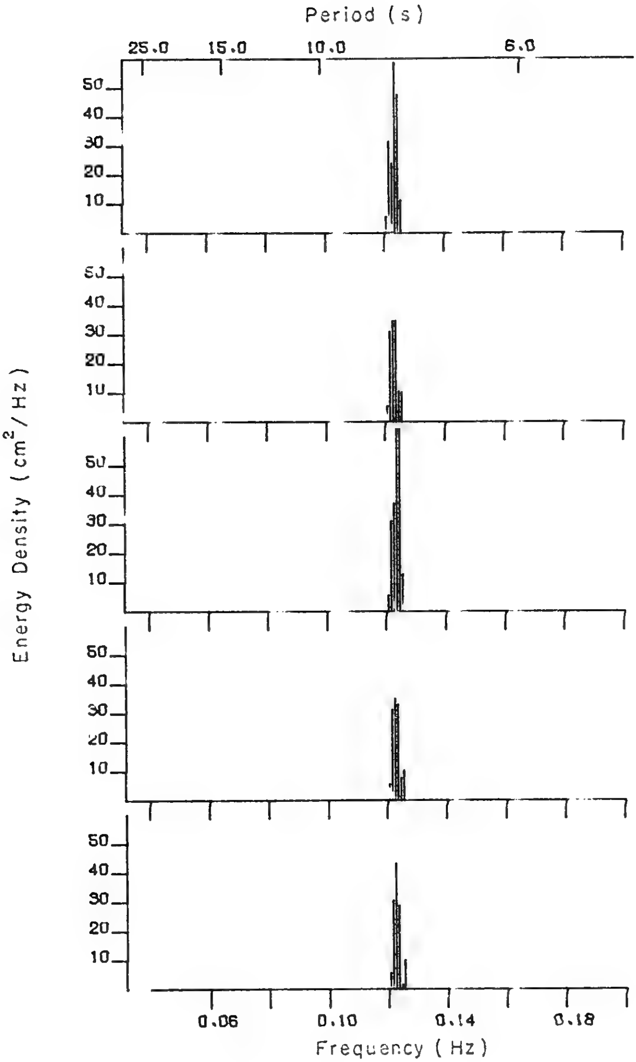

Period (s)
25.0
15.0
10.0
6.0
Energy Density (cm²/Hz)
50
40
30
20
10
0.06
0.10
0.14
0.18
Frequency (Hz)

Figure D-8.

SIMULATED MIXED SEA

PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
16.75	21.	11.43
15.97	21.	15.24
15.26	21.	11.43

LINE	PERIOD (SEC)	PRESSURE SPECTRA (SQ CM)					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE									
							1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
41	24.98	.00	.00	.00	.00	.00	-77	-178	-178	163	162	-179	-161	-160	-179	-179
42	24.38	.00	.00	.00	.00	.00	-75	-177	-177	163	162	-179	-160	-160	-179	-179
43	23.81	.00	.00	.00	.00	.00	-76	-177	-177	163	163	-179	-160	-159	-179	-179
44	23.27	.00	.00	.00	.00	.00	-74	-177	-177	164	163	-179	-160	-159	-179	-179
45	22.76	.00	.00	.00	.00	.00	-74	-176	-176	164	163	-179	-160	-159	-179	-179
46	22.26	.00	.00	.00	.00	.00	-74	-175	-175	165	163	-179	-159	-158	-179	-179
47	21.79	.00	.00	.00	.00	.00	-74	-175	-174	165	164	-179	-159	-157	-179	-179
48	21.33	.00	.00	.00	.00	.00	-75	-173	-172	166	165	-179	-158	-156	-179	-179
49	20.90	.00	.00	.00	.00	.00	-77	-172	-171	167	166	-179	-158	-154	-179	-179
50	20.48	.00	.00	.00	.00	.00	-86	-169	-167	170	168	-179	-156	-152	-178	-179
51	20.08	.00	.00	.00	.00	.00	-96	-167	-164	173	170	-178	-156	-150	-178	-178
52	19.69	.00	.00	.00	.00	.00	-118	-164	-159	178	176	-178	-155	-148	-177	-178
53	19.32	.00	.00	.00	.00	.00	-137	-161	-155	-175	-173	-177	-155	-148	-176	-177
54	18.96	.00	.00	.00	.00	.00	-150	-158	-149	-165	-147	-176	-155	-150	-173	-176
55	18.62	.00	.00	.00	.00	.00	-156	-156	-144	-155	-115	-175	-156	-152	-170	-173
56	18.29	.00	.00	.00	.00	.00	-159	-152	-139	-145	-87	-173	-157	-155	-165	-167
57	17.96	.00	.00	.00	.00	.00	-160	-150	-135	-139	-76	-172	-158	-157	-160	-162
58	17.66	.00	.00	.00	.00	.00	19	25	29	31	58	17	21	21	22	22
59	17.36	.01	.01	.01	.01	.01	20	22	22	23	28	20	21	20	21	21
60	17.07	5.48	5.54	5.54	5.54	5.51	20	21	21	21	21	21	21	21	21	21
61	16.79	31.70	31.57	31.57	31.56	31.64	21	20	20	20	20	20	21	21	20	20
62	16.52	12.23	12.32	12.31	12.32	12.27	20	21	21	21	21	21	21	21	21	21
63	16.25	8.85	8.92	8.91	8.92	8.88	20	21	21	21	21	21	21	21	21	21
64	16.00	57.15	56.97	56.98	56.98	57.09	21	20	20	20	20	20	21	21	20	20
65	15.75	20.92	21.02	21.02	21.02	20.96	20	21	21	21	21	21	21	21	21	21
66	15.52	4.54	4.59	4.59	4.59	4.56	20	21	21	21	21	21	21	20	21	21
67	15.28	32.65	32.51	32.52	32.52	32.61	21	20	20	20	20	20	21	21	20	20
68	15.06	11.22	11.30	11.30	11.29	11.24	20	21	21	21	21	21	21	20	21	21
69	14.84	.03	.02	.02	.02	.03	21	20	20	19	18	20	20	21	20	20
70	14.63	.00	.00	.00	.00	.00	21	18	18	15	12	18	20	21	18	17
71	14.42	.00	.00	.00	.00	.00	23	16	16	9	5	14	20	21	15	13
72	14.22	.00	.00	.00	.00	.00	25	14	15	4	0	9	20	22	10	8
73	14.03	.00	.00	.00	.00	.00	29	12	13	0	-3	6	21	22	7	5
74	13.84	.00	.00	.00	.00	.00	33	10	12	-3	-6	4	21	23	5	3
75	13.65	.00	.00	.00	.00	.00	39	9	10	-6	-9	2	21	23	3	2
76	13.47	.00	.00	.00	.00	.00	47	8	9	-8	-11	2	21	23	2	1
77	13.30	.00	.00	.00	.00	.00	54	7	8	-10	-12	1	20	23	1	1
78	13.13	.00	.00	.00	.00	.00	62	6	6	-12	-13	1	20	22	1	0
79	12.96	.00	.00	.00	.00	.00	67	5	5	-12	-14	0	20	22	1	0
80	12.80	.00	.00	.00	.00	.00	75	4	4	-13	-15	0	20	21	0	0
81	12.64	.00	.00	.00	.00	.00	77	4	4	-14	-15	0	19	21	0	0
82	12.49	.00	.00	.00	.00	.00	82	3	3	-15	-16	0	19	20	0	0
83	12.34	.00	.00	.00	.00	.00	85	2	3	-15	-16	0	19	20	0	0
84	12.19	.00	.00	.00	.00	.00	87	2	2	-15	-16	0	19	20	0	0
85	12.05	.00	.00	.00	.00	.00	89	2	2	-16	-16	0	19	19	0	0
86	11.91	.00	.00	.00	.00	.00	90	1	2	-16	-17	0	18	19	0	0
87	11.77	.00	.00	.00	.00	.00	91	1	1	-16	-17	0	18	19	0	0
88	11.64	.00	.00	.00	.00	.00	92	1	1	-16	-17	0	18	19	0	0
89	11.51	.00	.00	.00	.00	.00	93	1	1	-16	-17	0	18	19	0	0

SIMULATED MIXED SEA

PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
16.75	21.	11.43
15.97	15.	15.24
15.26	-21.	11.43

LINE	PERIOD (SEC)	PRESSURE SPECTRA (SQ CM)					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE									
							1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
41	24.98	.00	.00	.00	.00	.00	-172	-179	-179	162	162	-179	-162	-162	-179	-179
42	24.38	.00	.00	.00	.00	.00	-173	-179	-179	162	162	-179	-162	-162	-179	-179
43	23.81	.00	.00	.00	.00	.00	-172	-179	-179	162	162	-179	-162	-162	-179	-179
44	23.27	.00	.00	.00	.00	.00	-172	-179	-179	162	162	-179	-162	-162	-179	-179
45	22.76	.00	.00	.00	.00	.00	-172	-179	-179	162	162	-179	-162	-162	-179	-179
46	22.26	.00	.00	.00	.00	.00	-172	-179	-179	162	162	-179	-162	-162	-179	-179
47	21.79	.00	.00	.00	.00	.00	-172	-179	-179	162	162	-179	-162	-162	-179	-179
48	21.33	.00	.00	.00	.00	.00	-172	-179	-179	162	162	-179	-162	-162	-179	-179
49	20.90	.00	.00	.00	.00	.00	-171	-179	-179	163	162	-179	-162	-162	-179	-179
50	20.48	.00	.00	.00	.00	.00	-171	-179	-179	163	163	-179	-162	-162	-179	-179
51	20.08	.00	.00	.00	.00	.00	-171	-179	-179	164	163	-179	-162	-162	-179	-179
52	19.69	.00	.00	.00	.00	.00	-171	-178	-178	165	164	-179	-162	-163	-179	-179
53	19.32	.00	.00	.00	.00	.00	-171	-178	-178	166	165	-179	-163	-163	-178	-179
54	18.96	.00	.00	.00	.00	.00	-171	-176	-176	170	167	-178	-163	-164	-178	-179
55	18.62	.00	.00	.00	.00	.00	-170	-174	-174	176	174	-179	-165	-167	-179	-179
56	18.29	.00	.00	.00	.00	.00	-169	-169	-167	-170	-153	178	-169	-172	177	178
57	17.96	.00	.00	.00	.00	.00	-176	-175	-172	-171	-104	164	177	165	146	154
58	17.66	.00	.00	.00	.00	.00	24	32	35	40	[illegible]	29	31	28	32	36
59	17.36	.01	.01	.01	.01	.01	21	23	23	25	29	22	21	21	22	23
60	17.07	5.48	5.52	5.52	5.54	5.52	20	21	21	21	21	21	21	21	21	21
61	16.79	31.70	31.64	31.61	31.56	31.62	21	21	20	20	20	21	21	21	21	21
62	16.52	12.23	12.25	12.29	12.32	12.27	20	20	20	20	20	20	20	20	20	20
63	16.25	8.85	8.86	8.89	8.92	8.87	14	14	14	14	14	14	14	14	14	14
64	16.00	57.15	57.32	57.10	56.99	57.21	15	15	15	15	15	15	15	15	15	15
65	15.75	20.92	20.37	20.82	21.00	20.59	14	14	14	14	14	14	14	14	14	14
66	15.52	4.54	5.26	4.76	4.62	5.08	-23	-23	-23	-23	-23	-23	-21	-22	-23	-23
67	15.28	32.65	32.19	32.47	32.49	32.19	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
68	15.06	11.22	11.35	11.29	11.31	11.40	-21	-21	-21	-21	-21	-21	-21	-21	-21	-21
69	14.84	.03	.02	.03	.02	.02	-18	-17	-17	-18	-18	-18	-14	-16	-18	-18
70	14.63	.00	.00	.00	.00	.00	-13	-10	-11	-14	-15	-12	-2	-6	-12	-11
71	14.42	.00	.00	.00	.00	.00	-10	-5	-5	-14	-15	-5	6	3	-5	-4
72	14.22	.00	.00	.00	.00	.00	-7	-2	-2	-14	-15	0	11	9	0	0
73	14.03	.00	.00	.00	.00	.00	-5	-1	-1	-15	-16	2	14	12	2	1
74	13.84	.00	.00	.00	.00	.00	-3	0	0	-15	-16	2	15	14	1	1
75	13.65	.00	.00	.00	.00	.00	-2	0	0	-16	-16	1	16	15	1	1
76	13.47	.00	.00	.00	.00	.00	-1	0	0	-16	-17	1	16	16	1	0
77	13.30	.00	.00	.00	.00	.00	-1	0	0	-16	-17	0	17	16	0	0
78	13.13	.00	.00	.00	.00	.00	0	0	0	-17	-17	0	17	16	0	0
79	12.96	.00	.00	.00	.00	.00	0	0	0	-17	-17	0	17	17	0	0
80	12.80	.00	.00	.00	.00	.00	0	0	0	-17	-17	0	17	17	0	0
81	12.64	.00	.00	.00	.00	.00	0	0	0	-17	-17	0	17	17	0	0
82	12.49	.00	.00	.00	.00	.00	0	0	0	-17	-17	0	17	17	0	0
83	12.34	.00	.00	.00	.00	.00	0	0	0	-17	-17	0	17	17	0	0
84	12.19	.00	.00	.00	.00	.00	1	0	0	-17	-17	0	17	17	0	0
85	12.05	.00	.00	.00	.00	.00	0	0	0	-17	-17	0	17	17	0	0
86	11.91	.00	.00	.00	.00	.00	2	0	0	-17	-17	0	17	17	0	0
87	11.77	.00	.00	.00	.00	.00	0	0	0	-17	-17	0	17	17	0	0
88	11.64	.00	.00	.00	.00	.00	2	0	0	-17	-17	0	17	17	0	0
89	11.51	.00	.00	.00	.00	.00	1	0	0	-17	-17	0	17	17	0	0

SIMULATED MIXED SEA

PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
16.48	21.	11.43
15.97	21.	15.24
15.72	21.	11.43

LINE	PERIOD (SEC)	PRESSURE SPECTRA (SQ CM)					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE									
							1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
41	24.98	.00	.00	.00	.00	.00	-81	-178	-178	163	162	-179	-161	-160	-179	-179
42	24.38	.00	.00	.00	.00	.00	-81	-178	-178	163	162	-179	-161	-160	-179	-179
43	23.81	.00	.00	.00	.00	.00	-81	-177	-177	163	163	-179	-160	-160	-179	-179
44	23.27	.00	.00	.00	.00	.00	-80	-177	-177	163	163	-179	-160	-159	-179	-179
45	22.76	.00	.00	.00	.00	.00	-79	-176	-176	164	163	-179	-160	-159	-179	-179
46	22.26	.00	.00	.00	.00	.00	-79	-176	-176	164	163	-179	-160	-158	-179	-179
47	21.79	.00	.00	.00	.00	.00	-79	-175	-174	165	164	-179	-159	-157	-179	-179
48	21.33	.00	.00	.00	.00	.00	-80	-174	-174	166	164	-179	-159	-157	-179	-179
49	20.90	.00	.00	.00	.00	.00	-82	-172	-171	167	166	-179	-158	-155	-179	-179
50	20.48	.00	.00	.00	.00	.00	-87	-171	-169	169	167	-179	-157	-154	-178	-179
51	20.08	.00	.00	.00	.00	.00	-97	-168	-165	172	169	-178	-156	-151	-178	-178
52	19.69	.00	.00	.00	.00	.00	-110	-166	-162	175	173	-178	-155	-150	-177	-178
53	19.32	.00	.00	.00	.00	.00	-133	-163	-157	-177	-178	-177	-155	-149	-176	-177
54	18.96	.00	.00	.00	.00	.00	-144	-160	-153	-171	-164	-177	-155	-149	-174	-176
55	18.62	.00	.00	.00	.00	.00	-154	-157	-147	-160	-132	-175	-156	-151	-171	-174
56	18.29	.00	.00	.00	.00	.00	-158	-155	-143	-152	-105	-174	-156	-154	-168	-171
57	17.96	.00	.00	.00	.00	.00	-160	-151	-137	-142	-80	-173	-157	-156	-162	-165
58	17.66	.00	.00	.00	.00	.00	-160	-151	-138	-141	-83	-170	-158	-158	-159	-160
59	17.36	.00	.00	.00	.00	.00	20	24	27	29	49	18	21	21	22	22
60	17.07	.01	.01	.01	.01	.01	20	22	22	23	27	20	21	20	21	21
61	16.79	5.62	5.68	5.68	5.68	5.65	20	21	21	21	21	21	21	21	21	21
62	16.52	30.49	30.36	30.37	30.36	30.44	21	20	20	20	20	21	21	21	20	20
63	16.25	43.37	43.52	43.51	43.50	43.39	20	21	21	21	21	21	21	21	21	21
64	16.00	28.72	28.59	28.60	28.60	28.68	21	20	20	20	20	20	21	21	20	20
65	15.75	1.42	1.40	1.40	1.41	1.44	21	20	20	20	20	20	21	21	20	20
66	15.52	10.02	10.09	10.09	10.09	10.04	20	21	21	21	21	21	21	21	21	21
67	15.28	.04	.04	.04	.04	.04	21	20	20	19	18	20	20	21	20	20
68	15.06	.00	.00	.00	.00	.00	21	19	18	16	13	19	20	21	19	18
69	14.84	.00	.00	.00	.00	.00	22	17	17	11	7	16	20	21	17	15
70	14.63	.00	.00	.00	.00	.00	24	15	15	7	3	12	20	21	13	11
71	14.42	.00	.00	.00	.00	.00	26	13	14	2	-1	8	20	22	9	7
72	14.22	.00	.00	.00	.00	.00	29	11	12	-1	-4	5	20	22	7	5
73	14.03	.00	.00	.00	.00	.00	34	10	11	-4	-7	3	21	23	4	3
74	13.84	.00	.00	.00	.00	.00	39	9	10	-6	-9	2	20	23	3	2
75	13.65	.00	.00	.00	.00	.00	45	8	8	-8	-11	2	20	22	2	1
76	13.47	.00	.00	.00	.00	.00	52	7	7	-10	-12	1	20	22	1	1
77	13.30	.00	.00	.00	.00	.00	58	6	6	-11	-13	1	20	22	1	0
78	13.13	.00	.00	.00	.00	.00	64	5	5	-12	-14	1	20	21	1	0
79	12.96	.00	.00	.00	.00	.00	70	4	4	-13	-15	0	19	21	0	0
80	12.80	.00	.00	.00	.00	.00	73	4	4	-14	-15	0	19	21	0	0
81	12.64	.00	.00	.00	.00	.00	78	3	3	-15	-16	0	19	20	0	0
82	12.49	.00	.00	.00	.00	.00	79	2	3	-15	-16	0	19	20	0	0
83	12.34	.00	.00	.00	.00	.00	82	2	2	-15	-16	0	19	20	0	0
84	12.19	.00	.00	.00	.00	.00	84	2	2	-16	-16	0	19	19	0	0
85	12.05	.00	.00	.00	.00	.00	85	1	1	-16	-16	0	18	19	0	0
86	11.91	.00	.00	.00	.00	.00	86	1	1	-16	-17	0	18	19	0	0
87	11.77	.00	.00	.00	.00	.00	87	1	1	-16	-17	0	18	19	0	0
88	11.64	.00	.00	.00	.00	.00	88	1	1	-16	-17	0	18	19	0	0
89	11.51	.00	.00	.00	.00	.00	89	1	1	-17	-17	0	18	[illegible]	0	0

SIMULATED MIXED SEA

PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
16.48	21.	11.43
15.97	15.	15.24
15.72	-21.	11.43

LINE	PERIOD (SEC)	PRESSURE SPECTRA (SQ CM)					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE 1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
41	24.98	.00	.00	.00	.00	.00	-173	-179	-179	162	162	-179	-162	-162	-179	-179
42	24.38	.00	.00	.00	.00	.00	-174	-179	-179	162	162	-179	-162	-162	-179	-179
43	23.81	.00	.00	.00	.00	.00	-173	-179	-179	162	162	-179	-162	-162	-179	-179
44	23.27	.00	.00	.00	.00	.00	-174	-179	-179	162	162	-179	-162	-162	-179	-179
45	22.76	.00	.00	.00	.00	.00	-173	-179	-179	162	162	-179	-162	-162	-179	-179
46	22.26	.00	.00	.00	.00	.00	-174	-179	-179	162	162	-179	-162	-162	-179	-179
47	21.70	.00	.00	.00	.00	.00	-173	-179	-179	162	162	-179	-162	-162	-179	-179
48	21.33	.00	.00	.00	.00	.00	-173	-179	-179	162	162	-179	-162	-162	-179	-179
49	20.90	.00	.00	.00	.00	.00	-173	-179	-179	163	162	-179	-162	-162	-179	-179
50	20.48	.00	.00	.00	.00	.00	-173	-179	-179	163	162	-179	-162	-162	-179	-179
51	20.08	.00	.00	.00	.00	.00	-172	-179	-179	164	163	-179	-162	-162	-179	-179
52	19.69	.00	.00	.00	.00	.00	-173	-179	-179	164	163	-179	-162	-163	-179	-179
53	19.32	.00	.00	.00	.00	.00	-172	-178	-178	166	164	-178	-163	-163	-178	-179
54	18.96	.00	.00	.00	.00	.00	-173	-178	-178	167	166	-178	-163	-164	-178	-178
55	18.62	.00	.00	.00	.00	.00	-172	-176	-176	173	170	-178	-165	-166	-178	-178
56	18.29	.00	.00	.00	.00	.00	-172	-173	-173	-178	-178	-178	-168	-170	-178	-178
57	17.96	.00	.00	.00	.00	.00	-170	-168	-164	-162	-124	178	-175	-177	177	178
58	17.66	.00	.00	.00	.00	.00	154	154	143	154	142	143	153	134	122	132
59	17.36	.00	.00	.00	.00	.00	21	27	29	32	50	22	24	23	25	27
60	17.07	.01	.01	.01	.01	.01	20	21	21	22	26	20	20	20	20	21
61	16.79	5.62	5.62	5.65	5.68	5.64	20	20	20	20	21	20	20	20	20	20
62	16.52	30.49	30.67	30.47	30.37	30.56	21	21	21	21	21	21	21	21	21	21
63	16.25	43.37	42.16	43.16	43.47	42.78	17	17	17	17	17	17	17	17	17	17
64	16.00	28.72	54.74	35.96	29.84	47.14	18	22	22	26	32	22	18	18	22	23
65	15.75	1.42	38.02	11.74	3.14	27.26	-129	-56	-43	-61	-39	-49	-3	-14	-28	-22
66	15.52	10.02	11.08	10.34	10.15	10.85	-23	-22	-22	-23	-22	-22	-21	-22	-22	-22
67	15.28	.04	.03	.04	.04	.03	-12	-11	-11	-12	-12	-12	-11	-11	-12	-11
68	15.06	.00	.00	.00	.00	.00	-6	-5	-4	-8	-9	-4	0	-1	-4	-4
69	14.84	.00	.00	.00	.00	.00	-3	-2	-2	-8	-11	0	7	5	0	0
70	14.63	.00	.00	.00	.00	.00	0	0	0	-10	-12	3	11	10	3	2
71	14.42	.00	.00	.00	.00	.00	0	0	0	-12	-14	3	14	12	3	2
72	14.22	.00	.00	.00	.00	.00	1	0	0	-13	-15	3	15	14	3	2
73	14.03	.00	.00	.00	.00	.00	1	0	0	-14	-15	2	16	15	2	1
74	13.84	.00	.00	.00	.00	.00	2	0	0	-15	-16	1	16	16	1	1
75	13.65	.00	.00	.00	.00	.00	1	0	0	-16	-16	1	16	16	1	0
76	13.47	.00	.00	.00	.00	.00	3	0	0	-16	-16	1	17	16	0	0
77	13.30	.00	.00	.00	.00	.00	2	0	0	-16	-17	0	17	17	0	0
78	13.13	.00	.00	.00	.00	.00	3	0	0	-16	-17	0	17	17	0	0
79	12.96	.00	.00	.00	.00	.00	2	0	0	-17	-17	0	17	17	0	0
80	12.80	.00	.00	.00	.00	.00	3	0	0	-17	-17	0	17	17	0	0
81	12.64	.00	.00	.00	.00	.00	2	0	0	-17	-17	0	17	17	0	0
82	12.49	.00	.00	.00	.00	.00	4	0	0	-17	-17	0	17	17	0	0
83	12.34	.00	.00	.00	.00	.00	2	0	0	-17	-17	0	17	17	0	0
84	12.19	.00	.00	.00	.00	.00	4	0	0	-17	-17	0	17	17	0	0
85	12.05	.00	.00	.00	.00	.00	2	0	0	-17	-17	0	17	17	0	0
86	11.91	.00	.00	.00	.00	.00	4	0	0	-17	-17	0	17	17	0	0
87	11.77	.00	.00	.00	.00	.00	3	0	0	-17	-17	0	17	17	0	0
88	11.64	.00	.00	.00	.00	.00	4	0	0	-17	-17	0	17	17	0	0
89	11.51	.00	.00	.00	.00	.00	2	0	0	-17	-17	0	17	17	0	0

SIMULATED MIXED SEA

PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
8.18	-60.	11.43
7.99	-60.	15.24
7.81	-60.	11.43

LINE	PERIOD (SEC)	PRESSURE SPECTRA (80 CM)					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE 1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
94	10.89	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
95	10.78	.00	.00	.00	.00	.00	-17	-72	-35	138	109	131	29	125	-130	118
96	10.67	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
97	10.56	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
98	10.45	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
99	10.34	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
100	10.24	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
101	10.14	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
102	10.04	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
103	9.94	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
104	9.85	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
105	9.75	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
106	9.66	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
107	9.57	.00	.00	.00	.00	.00	-17	-73	-35	139	109	131	29	125	-130	118
108	9.48	.00	.00	.00	.00	.00	-17	-73	-35	139	109	132	29	125	-130	118
109	9.39	.00	.00	.00	.00	.00	-17	-73	-35	139	109	131	29	125	-130	118
110	9.31	.00	.00	.00	.00	.00	-17	-73	-35	139	109	132	29	125	-130	118
111	9.23	.00	.00	.00	.00	.00	-17	-74	-35	139	109	132	29	125	-130	119
112	9.14	.00	.00	.00	.00	.00	-17	-74	-35	140	109	132	29	125	-130	119
113	9.06	.00	.00	.00	.00	.00	-17	-75	-34	140	109	132	29	125	-130	119
114	8.98	.00	.00	.00	.00	.00	-17	-76	-34	140	110	132	30	125	-130	119
115	8.90	.00	.00	.00	.00	.00	-16	-78	-34	140	110	132	30	125	-130	119
116	8.83	.00	.0C	.00	.00	.00	-16	-80	-33	141	111	132	30	125	-131	119
117	8.75	.00	.00	.00	.00	.00	-15	-84	-33	141	111	133	30	124	-131	120
118	8.68	.00	.00	.00	.00	.00	-14	-93	-31	141	113	133	30	124	-132	120
119	8.61	.00	.00	.00	.00	.00	-13	-102	-29	141	115	133	31	123	-133	121
120	8.53	.00	.00	.00	.00	.00	-10	-114	-25	135	120	130	32	123	-135	122
121	8.46	.00	.00	.00	.00	.00	-3	-111	-12	116	124	117	33	124	-138	124
122	8.39	.00	.00	.00	.00	.00	174	86	164	-65	-55	-64	-148	-56	46	-56
123	8.33	.01	.01	.01	.01	.01	172	86	159	-61	-58	-60	-149	-59	49	-58
124	8.26	5.53	5.50	5.56	5.57	5.58	171	87	158	-60	-59	-60	-149	-59	49	-59
125	8.19	31.73	31.80	31.65	31.62	31.61	171	87	158	-59	-60	-59	-149	-60	49	-60
126	8.13	12.18	12.13	12.23	12.25	12.25	171	87	158	-60	-59	-60	-149	-59	49	-59
127	8.06	8.87	8.85	8.92	8.93	8.94	172	85	159	-60	-59	-60	-149	-59	48	-59
128	8.00	57.16	57.23	57.04	57.01	56.99	172	85	159	-59	-60	-59	-149	-60	48	-60
129	7.94	20.89	20.85	20.97	20.99	21.00	172	85	159	-60	-59	-60	-149	-59	48	-59
130	7.88	4.55	4.54	4.59	4.60	4.61	172	83	160	-60	-59	-60	-148	-59	47	-59
131	7.82	32.65	32.69	32.56	32.54	32.52	172	83	160	-59	-60	-59	-148	-60	47	-60
132	7.76	11.18	11.16	11.24	11.25	11.26	172	83	160	-60	-59	-60	-148	-59	47	-59
133	7.70	.03	.03	.03	.02	.02	171	84	159	-59	-60	-59	-149	-60	48	-60
134	7.64	.00	.00	.00	.00	.00	170	85	157	-56	-64	-58	-149	-60	48	-62
135	7.59	.00	.00	.00	.00	.00	169	88	154	-54	-68	-56	-149	-60	48	-64
136	7.53	.00	.00	.00	.00	.00	167	91	152	-50	-71	-54	-149	-58	48	-64
137	7.47	.00	.00	.00	.00	.00	165	94	149	-47	-72	-52	-149	-57	48	-64
138	7.42	.00	.00	.00	.00	.00	164	97	148	-45	-73	-51	-149	-56	48	-63
139	7.37	.00	.00	.00	.00	.00	164	[illegible]	147	-44	-72	-50	-149	-55	49	-62
140	7.31	.00	.00	.00	.00	.00	163	101	146	-43	-72	-50	-149	-55	49	-62
141	7.26	.00	.00	.00	.00	.00	163	102	146	-42	-71	-49	-149	-54	49	-62
142	7.21	.00	.00	.00	.00	.00	162	104	145	-42	-71	-49	-149	-54	49	-62
143	7.16	.00	.00	.00	.00	.00	162	104	145	-41	-71	-49	-150	-54	49	-61
144	7.11	.00	.00	.00	.00	.00	162	105	145	-41	-71	-49	-150	-54	49	-61
145	7.06	.00	.00	.00	.00	.00	162	105	144	-41	-71	-48	-150	-54	49	-61
146	7.01	.00	.00	.00	.00	.00	162	106	144	-41	-70	-48	-150	-54	49	-61
147	6.97	.00	.00	.00	.00	.00	162	106	144	-41	-71	-48	-150	-54	49	-61

SIMULATED MIXED SEA

PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
8.18	-60.	11.43
7.99	-40.	15.24
7.81	60.	11.43

LINE	PERIOD (SEC)	PRESSURE SPECTRA (SQ CM)					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE 1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
94	10.89	.00	.00	.00	.00	.00	-17	-143	-35	161	132	143	36	126	-143	126
95	10.78	.00	.00	.00	.00	.00	161	153	143	161	135	143	35	126	-143	126
96	10.67	.00	.00	.00	.00	.00	161	153	143	161	134	143	35	126	-143	126
97	10.56	.00	.00	.00	.00	.00	161	153	143	161	134	143	35	126	-143	126
98	10.45	.00	.00	.00	.00	.00	161	153	143	161	134	143	35	126	-143	126
99	10.34	.00	.00	.00	.00	.00	161	153	143	161	136	143	35	126	-143	126
100	10.24	.00	.00	.00	.00	.00	161	153	143	161	133	143	35	126	-143	126
101	10.14	.00	.00	.00	.00	.00	161	153	143	161	136	143	35	126	-143	126
102	10.04	.00	.00	.00	.00	.00	161	153	143	161	132	143	35	126	-143	126
103	9.94	.00	.00	.00	.00	.00	161	153	143	161	136	143	35	126	-143	-54
104	9.85	.00	.00	.00	.00	.00	161	153	143	161	135	143	35	126	-143	126
105	9.75	.00	.00	.00	.00	.00	161	153	143	161	134	143	35	126	-143	126
106	9.66	.00	.00	.00	.00	.00	161	153	143	161	135	143	35	126	-143	-54
107	9.57	.00	.00	.00	.00	.00	161	153	143	161	136	143	35	126	-143	126
108	9.48	.00	.00	.00	.00	.00	161	153	143	161	133	143	35	126	-143	126
109	9.39	.00	.00	.00	.00	.00	161	153	143	161	137	143	35	126	-143	-54
110	9.31	.00	.00	.00	.00	.00	-17	-143	-35	161	134	143	35	126	-143	126
111	9.23	.00	.00	.00	.00	.00	161	153	143	160	135	143	35	126	-143	-54
112	9.14	.00	.00	.00	.00	.00	-17	-143	-35	160	136	143	35	126	-143	-54
113	9.06	.00	.00	.00	.00	.00	-17	-143	-35	160	136	143	35	126	-143	-54
114	8.98	.00	.00	.00	.00	.00	-16	-142	-35	159	136	143	35	126	-143	-54
115	8.90	.00	.00	.00	.00	.00	-16	-142	-35	159	137	143	35	127	-143	-55
116	8.83	.00	.00	.00	.00	.00	-15	-142	-34	158	136	143	35	127	-142	-55
117	8.75	.00	.00	.00	.00	.00	-14	-141	-34	156	137	142	35	128	-142	-56
118	8.68	.00	.00	.00	.00	.00	-13	-140	-33	152	136	141	34	130	-141	-58
119	8.61	.00	.00	.00	.00	.00	-11	-138	-31	148	137	140	34	134	-141	-61
120	8.53	.00	.00	.00	.00	.00	-9	-135	-27	138	136	137	33	141	-139	-66
121	8.46	.00	.00	.00	.00	.00	5	150	33	120	132	124	-151	-79	58	-68
122	8.39	.00	.00	.00	.00	.00	173	101	162	-68	-63	-68	-150	-66	52	-64
123	8.33	.01	.01	.01	.01	.01	171	89	159	-61	-60	-61	-149	-61	50	-60
124	8.26	5.53	5.51	5.54	5.57	9.52	171	87	158	-60	-60	-60	-149	-60	49	-60
125	8.19	31.73	31.84	31.74	31.70	31.94	171	87	158	-60	-60	-60	-149	-60	49	-60
126	8.13	12.18	11.89	12.03	11.95	11.53	171	86	158	-59	-59	-59	-149	-59	49	-59
127	8.06	8.87	9.22	8.98	9.27	9.61	-39	-39	-39	-39	-39	-39	-150	-39	47	-39
128	8.00	57.16	56.97	57.69	56.89	57.05	-39	-40	-40	-40	-40	-40	-150	-40	47	-39
129	7.94	20.89	20.86	19.37	20.88	20.32	-40	-39	-40	-39	-40	-40	-150	-40	47	-40
130	7.88	4.55	4.77	6.51	4.79	5.35	-5	-26	-89	58	149	-47	58	62	62	58
131	7.82	32.65	32.43	31.42	32.45	32.15	-6	-27	-82	60	148	-47	60	59	59	60
132	7.76	11.18	11.28	11.56	11.26	11.34	-6	-27	-84	59	148	-47	59	60	60	59
133	7.70	.03	.02	.02	.02	.02	-6	-28	-75	60	148	-46	60	55	56	59
134	7.64	.00	.00	.00	.00	.00	-6	-28	-59	58	147	-44	59	47	50	57
135	7.59	.00	.00	.00	.00	.00	-6	-28	-49	49	146	-41	49	43	46	-122
136	7.53	.00	.00	.00	.00	.00	-15	-27	-43	-13	154	-39	-146	-67	42	-68
137	7.47	.00	.00	.00	.00	.00	-18	-27	-40	-18	164	-38	-145	-60	40	-60
138	7.42	.00	.00	.00	.00	.00	-18	-27	-38	-19	-177	-37	-145	-57	39	-57
139	7.37	.00	.00	.00	.00	.00	-18	-27	-38	-19	-161	-37	-144	-55	38	-55
140	7.31	.00	.00	.00	.00	.00	-18	-26	-37	-18	-144	-36	-144	-55	37	-55
141	7.26	.00	.00	.00	.00	.00	-18	-26	-37	-19	-102	-36	-144	-54	37	-54
142	7.21	.00	.00	.00	.00	.00	-18	-26	-36	-18	-94	-36	-144	-54	37	-54
143	7.16	.00	.00	.00	.00	.00	-18	-26	-36	-18	-118	-36	-144	-54	36	-54
144	7.11	.00	.00	.00	.00	.00	-18	-26	-36	-18	-59	-36	-144	-54	36	-54
145	7.06	.00	.00	.00	.00	.00	-18	-26	-36	-18	-114	-36	-144	-54	36	-54
146	7.01	.00	.00	.00	.00	.00	-18	-26	-36	-18	-67	-36	-144	-54	36	-54
147	6.97	.00	.00	.00	.00	.00	-18	-26	-36	-18	-59	-36	-144	-54	36	-54

SIMULATED MIXED SEA

PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
8.12	-60.	11.43
7.99	-60.	15.24
7.93	-60.	11.43

LINE	PERIOD (SEC)	PRESSURE SPECTRA (SQ CM)					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE									
							1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
99	10.34	.00	.00	.00	.00	.00	-17	-72	-35	139	110	132	29	125	-130	119
100	10.20	.00	.00	.00	.00	.00	-17	-72	-35	139	110	131	29	125	-130	118
101	10.14	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
102	10.04	.00	.00	.00	.00	.00	-17	-72	-35	139	110	132	29	125	-130	119
103	9.94	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
104	9.85	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
105	9.75	.00	.00	.00	.00	.00	-17	-72	-35	139	110	132	29	125	-130	119
106	9.66	.00	.00	.00	.00	.00	-17	-72	-35	139	109	131	29	125	-130	118
107	9.57	.00	.00	.00	.00	.00	-17	-73	-35	139	109	132	29	125	-130	119
108	9.48	.00	.00	.00	.00	.00	-17	-73	-35	139	110	132	29	125	-130	119
109	9.39	.00	.00	.00	.00	.00	-17	-73	-35	139	109	131	29	125	-130	119
110	9.31	.00	.00	.00	.00	.00	-17	-73	-35	139	110	132	29	125	-130	119
111	9.23	.00	.00	.00	.00	.00	-17	-74	-35	139	110	132	29	125	-130	119
112	9.14	.00	.00	.00	.00	.00	-17	-74	-35	140	110	132	29	125	-130	119
113	9.06	.00	.00	.00	.00	.00	-17	-75	-34	140	110	132	29	125	-130	119
114	8.98	.00	.00	.00	.00	.00	-17	-75	-34	140	110	132	30	125	-130	119
115	8.90	.00	.00	.00	.00	.00	-16	-78	-34	140	111	132	30	125	-130	119
116	8.83	.00	.00	.00	.00	.00	-16	-79	-33	141	111	132	30	125	-130	119
117	8.75	.00	.00	.00	.00	.00	-16	-83	-33	141	112	133	30	124	-131	120
118	8.68	.00	.00	.00	.00	.00	-15	-88	-32	142	113	133	30	124	-131	120
119	8.61	.00	.00	.00	.00	.00	-14	-97	-30	141	115	133	31	123	-132	121
120	8.53	.00	.00	.00	.00	.00	-12	-108	-28	140	118	133	31	123	-134	122
121	8.46	.00	.00	.00	.00	.00	-8	-116	-21	129	122	127	32	123	-136	123
122	8.39	.00	.00	.00	.00	.00	-1	-105	-5	110	125	111	34	125	-141	125
123	8.33	.00	.00	.00	.00	.00	174	85	163	-64	-56	-63	-148	-57	46	-56
124	8.26	.01	.01	.01	.01	.01	172	86	160	-61	-58	-60	-149	-59	48	-58
125	8.19	5.62	5.59	5.66	5.67	5.67	171	86	158	-60	-59	-60	-149	-59	49	-59
126	8.13	30.49	30.56	30.41	30.38	30.37	171	87	158	-59	-60	-59	-149	-60	49	-60
127	8.06	43.37	43.18	43.45	43.50	43.49	171	86	159	-60	-59	-60	-149	-59	48	-59
128	8.00	28.67	28.73	28.59	28.57	28.55	171	85	159	-59	-60	-59	-149	-60	48	-60
129	7.94	1.42	1.45	1.41	1.40	1.40	172	83	160	-59	-60	-59	-148	-60	47	-60
130	7.88	9.97	9.95	10.03	10.04	10.05	172	84	159	-60	-59	-60	-149	-59	48	-59
131	7.82	.04	.04	.04	.04	.04	171	85	159	-59	-60	-59	-149	-60	48	-60
132	7.76	.00	.00	.00	.00	.00	170	86	157	-57	-62	-58	-149	-60	48	-61
133	7.70	.00	.00	.00	.00	.00	169	87	155	-55	-66	-57	-149	-60	49	-63
134	7.64	.00	.00	.00	.00	.00	168	89	153	-52	-69	-55	-149	-59	48	-64
135	7.59	.00	.00	.00	.00	.00	166	92	151	-49	-71	-53	-149	-58	48	-64
136	7.53	.00	.00	.00	.00	.00	165	95	149	-47	-72	-52	-149	-57	48	-63
137	7.47	.00	.00	.00	.00	.00	164	97	148	-45	-72	-51	-149	-56	49	-63
138	7.42	.00	.00	.00	.00	.00	164	100	147	-44	-72	-50	-149	-55	49	-62
139	7.37	.00	.00	.00	.00	.00	163	101	146	-43	-71	-50	-149	-55	49	-62
140	7.31	.00	.00	.00	.00	.00	163	102	145	-42	-71	-49	-149	-54	49	-62
141	7.26	.00	.00	.00	.00	.00	163	103	145	-42	-71	-49	-149	-54	49	-61
142	7.21	.00	.00	.00	.00	.00	162	104	145	-42	-71	-49	-150	-54	49	-61
143	7.16	.00	.00	.00	.00	.00	162	105	144	-41	-70	-48	-150	-54	49	-61
144	7.11	.00	.00	.00	.00	.00	162	105	144	-41	-70	-48	-150	-54	49	-61
145	7.06	.00	.00	.00	.00	.00	162	106	144	-41	-70	-48	-150	-54	49	-61
146	7.01	.00	.00	.00	.00	.00	162	106	144	-41	-70	-48	-150	-54	49	-61
147	6.97	.00	.00	.00	.00	.00	162	106	144	-41	-70	-48	-150	-54	49	-61

SIMULATED MIXED SEA

PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
8.12	-60.	11.43
7.99	-40.	15.24
7.93	60.	11.43

LINE	PERIOD (SEC)	PRESSURE SPECTRA (80 CM)					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE									
							1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
99	10.34	.00	.00	.00	.00	.00	161	153	143	161	134	143	35	126	-143	126
100	10.24	.00	.00	.00	.00	.00	161	153	143	161	126	143	35	125	-143	125
101	10.14	.00	.00	.00	.00	.00	161	153	143	161	136	143	35	126	-143	-54
102	10.04	.00	.00	.00	.00	.00	161	153	143	161	124	143	35	125	-143	125
103	9.94	.00	.00	.00	.00	.00	161	153	143	161	134	143	35	126	-143	126
104	9.85	.00	.00	.00	.00	.00	161	153	143	161	133	143	35	126	-143	126
105	9.75	.00	.00	.00	.00	.00	161	153	143	161	131	143	35	126	-143	126
106	9.66	.00	.00	.00	.00	.00	161	153	143	161	133	143	35	126	-143	126
107	9.57	.00	.00	.00	.00	.00	161	153	143	161	135	143	35	126	-143	126
108	9.48	.00	.00	.00	.00	.00	161	153	143	161	128	143	35	126	-143	126
109	9.39	.00	.00	.00	.00	.00	161	153	143	161	135	143	35	126	-143	-54
110	9.31	.00	.00	.00	.00	.00	161	153	143	161	131	143	35	126	-143	126
111	9.23	.00	.00	.00	.00	.00	161	153	143	161	133	143	35	126	-143	126
112	9.14	.00	.00	.00	.00	.00	161	153	143	160	134	143	35	126	-143	126
113	9.06	.00	.00	.00	.00	.00	161	153	143	160	133	143	35	126	-143	126
114	8.98	.00	.00	.00	.00	.00	160	153	143	160	133	143	35	126	-143	126
115	8.90	.00	.00	.00	.00	.00	160	152	143	159	135	143	35	126	-143	126
116	8.83	.00	.00	.00	.00	.00	160	152	142	159	132	143	35	126	-142	126
117	8.75	.00	.00	.00	.00	.00	-15	-141	-34	157	135	142	35	127	-142	-55
118	8.68	.00	.00	.00	.00	.00	-14	-140	-33	155	134	142	35	128	-141	-55
119	8.61	.00	.00	.00	.00	.00	-13	-138	-32	152	135	141	34	130	-140	-57
120	8.53	.00	.00	.00	.00	.00	-11	-135	-30	147	135	139	33	133	-139	-59
121	8.46	.00	.00	.00	.00	.00	-8	-124	-26	133	134	133	30	144	-133	-64
122	8.39	.00	.00	.00	.00	.00	175	128	49	-80	-30	116	-153	-79	62	-64
123	8.33	.00	.00	.00	.00	.00	172	93	160	-64	-60	-64	-150	-64	52	-61
124	8.26	.01	.01	.01	.01	.01	171	86	158	-59	-59	-59	-149	-60	50	-59
125	8.19	5.62	5.54	5.56	5.60	5.54	171	86	158	-59	-59	-59	-149	-59	49	-59
126	8.13	30.49	31.18	31.12	31.06	31.57	171	87	159	-60	-60	-60	-149	-60	49	-60
127	8.06	43.37	34.89	36.94	34.74	24.07	169	75	153	-50	-50	-50	-149	-50	48	-50
128	8.00	28.67	33.02	100.06	34.77	58.79	-36	-45	-36	-42	-36	-36	-149	-35	45	-30
129	7.94	1.42	7.81	102.54	10.43	47.78	-4	-14	-146	39	150	-47	46	91	135	26
130	7.88	9.97	10.27	12.87	10.32	11.25	-6	-28	-88	58	149	-48	58	61	61	59
131	7.82	.04	.04	.01	.04	.03	-6	-31	-67	64	148	-46	68	50	53	63
132	7.76	.00	.00	.00	.00	.00	-6	-32	-54	67	147	-44	93	39	49	66
133	7.70	.00	.00	.00	.00	.00	-22	-31	-48	-25	-159	-42	-147	-65	46	-63
134	7.64	.00	.00	.00	.00	.00	-24	-30	-43	-26	-68	-40	-147	-57	43	-56
135	7.59	.00	.00	.00	.00	.00	-21	-29	-40	-23	-71	-38	-146	-56	41	-55
136	7.53	.00	.00	.00	.00	.00	-20	-28	-39	-22	-68	-38	-145	-55	40	-55
137	7.47	.00	.00	.00	.00	.00	-20	-27	-38	-21	-64	-37	-145	-54	38	-54
138	7.42	.00	.00	.00	.00	.00	-19	-27	-37	-20	-57	-37	-144	-54	38	-54
139	7.37	.00	.00	.00	.00	.00	-19	-27	-37	-19	-69	-36	-144	-54	37	-54
140	7.31	.00	.00	.00	.00	.00	-19	-27	-37	-19	-52	-36	-144	-53	37	-53
141	7.26	.00	.00	.00	.00	.00	-18	-26	-36	-19	-64	-36	-144	-54	37	-54
142	7.21	.00	.00	.00	.00	.00	-18	-26	-36	-19	-53	-36	-144	-54	36	-54
143	7.16	.00	.00	.00	.00	.00	-18	-26	-36	-18	-56	-36	-144	-54	36	-54
144	7.11	.00	.00	.00	.00	.00	-18	-26	-36	-18	-55	-36	-144	-54	36	-54
145	7.06	.00	.00	.00	.00	.00	-18	-26	-36	-18	-57	-36	-144	-54	36	-54
146	7.01	.00	.00	.00	.00	.00	-18	-26	-36	-18	-50	-36	-144	-53	36	-53
147	6.97	.00	.00	.00	.00	.00	-18	-26	-36	-18	-64	-36	-144	-54	36	-54

SIMULATED MIXED SEA

PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
16.48	-60.	11.43
15.97	-60.	15.24
15.72	-60.	11.43

LINE	PERIOD (SEC)	PRESSURE SPECTRA (80 CM)					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE 1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
41	24.98	.00	.00	.00	.00	.00	131	128	124	128	121	126	124	122	121	122
42	24.38	.00	.00	.00	.00	.00	130	128	124	129	121	127	126	122	120	122
43	23.81	.00	.00	.00	.00	.00	130	128	124	129	121	127	126	122	120	122
44	23.27	.00	.00	.00	.00	.00	130	128	124	129	121	127	125	122	120	122
45	22.76	.00	.00	.00	.00	.00	130	128	124	129	121	127	126	122	120	122
46	22.26	.00	.00	.00	.00	.00	130	128	124	129	121	127	126	122	120	122
47	21.79	.00	.00	.00	.00	.00	130	128	124	129	121	127	127	122	119	122
48	21.33	.00	.00	.00	.00	.00	129	129	124	129	121	127	128	122	119	122
49	20.90	.00	.00	.00	.00	.00	129	129	124	129	121	127	128	122	119	122
50	20.48	.00	.00	.00	.00	.00	128	129	123	129	121	127	130	122	118	122
51	20.08	.00	.00	.00	.00	.00	128	129	123	129	121	127	131	122	118	122
52	19.69	.00	.00	.00	.00	.00	127	130	123	129	121	127	133	122	117	122
53	19.32	.00	.00	.00	.00	.00	125	130	122	129	121	127	137	121	115	122
54	18.96	.00	.00	.00	.00	.00	122	131	121	130	121	127	142	121	113	122
55	18.62	.00	.00	.00	.00	.00	114	133	119	130	121	128	151	121	108	122
56	18.29	.00	.00	.00	.00	.00	99	135	116	130	122	128	163	120	102	123
57	17.96	.00	.00	.00	.00	.00	52	135	103	126	123	125	-179	118	89	123
58	17.66	.00	.00	.00	.00	.00	20	110	76	109	125	109	-164	111	74	125
59	17.36	.00	.00	.00	.00	.00	-110	-62	-74	-64	-59	-64	-21	-64	-80	-60
60	17.07	.01	.01	.01	.01	.01	-68	-60	-62	-61	-60	-61	-51	-60	-64	-60
61	16.79	5.62	5.67	5.60	5.64	5.60	-60	-60	-60	-60	-60	-60	-59	-60	-60	-60
62	16.52	30.49	30.39	30.55	30.44	30.54	-59	-59	-59	-59	-59	-59	-60	-59	-59	-59
63	16.25	43.37	43.46	43.29	43.43	43.30	-60	-60	-60	-60	-60	-60	-59	-60	-60	-60
64	16.00	28.72	28.62	28.77	28.67	28.77	-59	-59	-59	-59	-59	-59	-60	-59	-59	-59
65	15.75	1.42	1.41	1.43	1.41	1.43	-59	-59	-59	-59	-59	-59	-60	-59	-59	-59
66	15.52	10.02	10.09	9.98	10.05	9.99	-60	-60	-60	-60	-60	-60	-59	-60	-60	-60
67	15.28	.04	.04	.05	.04	.05	-56	-59	-58	-59	-59	-59	-63	-59	-58	-59
68	15.06	.00	.00	.01	.00	.00	-50	-59	-56	-58	-59	-58	-70	-58	-54	-59
69	14.84	.00	.00	.00	.00	.00	-45	-58	-54	-56	-59	-57	-75	-58	-50	-59
70	14.63	.00	.00	.00	.00	.00	-43	-57	-53	-54	-59	-55	-76	-57	-49	-58
71	14.42	.00	.00	.00	.00	.00	-42	-56	-53	-53	-59	-55	-75	-57	-49	-58
72	14.22	.00	.00	.00	.00	.00	-43	-55	-53	-53	-58	-54	-72	-57	-51	-58
73	14.03	.00	.00	.00	.00	.00	-44	-54	-53	-52	-58	-54	-68	-57	-52	-58
74	13.84	.00	.00	.00	.00	.00	-44	-53	-53	-52	-58	-53	-66	-57	-53	-57
75	13.65	.00	.00	.00	.00	.00	-45	-53	-54	-51	-58	-53	-63	-57	-55	-57
76	13.47	.00	.00	.00	.00	.00	-46	-52	-54	-51	-58	-53	-62	-57	-55	-57
77	13.30	.00	.00	.00	.00	.00	-46	-52	-54	-51	-58	-53	-60	-57	-56	-57
78	13.13	.00	.00	.00	.00	.00	-47	-52	-54	-51	-58	-53	-59	-57	-56	-57
79	12.96	.00	.00	.00	.00	.00	-47	-52	-54	-51	-58	-53	-59	-57	-57	-57
80	12.80	.00	.00	.00	.00	.00	-47	-52	-54	-51	-58	-53	-57	-57	-57	-57
81	12.64	.00	.00	.00	.00	.00	-47	-52	-54	-51	-58	-53	-57	-57	-57	-57
82	12.49	.00	.00	.00	.00	.00	-47	-52	-54	-51	-58	-53	-57	-57	-57	-57
83	12.34	.00	.00	.00	.00	.00	-48	-51	-55	-51	-58	-53	-56	-57	-58	-57
84	12.19	.00	.00	.00	.00	.00	-48	-51	-55	-51	-58	-53	-57	-57	-58	-57
85	12.05	.00	.00	.00	.00	.00	-48	-51	-55	-51	-58	-53	-55	-57	-58	-57
86	11.91	.00	.00	.00	.00	.00	-48	-51	-55	-51	-58	-53	-57	-57	-58	-57
87	11.77	.00	.00	.00	.00	.00	-48	-51	-55	-51	-58	-53	-56	-57	-58	-57
88	11.64	.00	.00	.00	.00	.00	-49	-51	-55	-51	-58	-53	-54	-57	-59	-57
89	11.51	.00	.00	.00	.00	.00	-47	-52	-54	-51	-58	-53	-57	-57	-57	-57

SIMULATED MIXED SEA

PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
16.48	-60.	11.43
15.97	-40.	15.24
15.72	60.	11.43

LINE	PERIOD (SEC)	PRESSURE SPECTRA (SQ CM)					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE									
							1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
41	24.98	.00	.00	.00	.00	.00	155	163	139	157	132	142	176	128	99	126
42	24.38	.00	.00	.00	.00	.00	156	166	140	159	129	143	-179	126	94	126
43	23.81	.00	.00	.00	.00	.00	154	163	138	157	127	142	175	126	98	126
44	23.27	.00	.00	.00	.00	.00	156	166	141	159	134	143	-179	128	94	126
45	22.76	.00	.00	.00	.00	.00	154	163	137	157	125	142	176	125	97	125
46	22.26	.00	.00	.00	.00	.00	156	165	139	158	129	142	179	126	95	126
47	21.79	.00	.00	.00	.00	.00	154	164	138	157	129	142	177	127	96	126
48	21.33	.00	.00	.00	.00	.00	155	165	138	158	124	142	179	125	94	125
49	20.90	.00	.00	.00	.00	.00	154	164	138	157	127	142	177	126	96	126
50	20.48	.00	.00	.00	.00	.00	155	165	138	158	125	142	-179	125	93	125
51	20.08	.00	.00	.00	.00	.00	153	164	136	157	123	142	178	125	95	125
52	19.69	.00	.00	.00	.00	.00	154	165	137	158	124	142	-178	125	92	125
53	19.32	.00	.00	.00	.00	.00	153	164	135	157	121	141	179	124	93	125
54	18.96	.00	.00	.00	.00	.00	152	165	135	157	120	142	-178	124	92	125
55	18.62	.00	.00	.00	.00	.00	150	163	132	156	116	141	179	122	92	124
56	18.29	.00	.00	.00	.00	.00	146	160	128	153	108	139	175	118	93	122
57	17.96	.00	.00	.00	.00	.00	111	148	47	141	6	125	24	53	-93	95
58	17.66	.00	.00	.00	.00	.00	-120	-82	-67	-80	-52	-87	-39	-50	-56	-51
59	17.36	.00	.00	.00	.00	.00	-62	-62	-58	-62	-56	-61	-62	-57	-55	-57
60	17.07	.01	.01	.01	.01	.01	-54	-58	-57	-57	-59	-58	-62	-58	-57	-58
61	16.79	5.62	5.57	5.57	5.64	5.53	-59	-59	-59	-59	-59	-59	-60	-59	-59	-59
62	16.52	30.49	31.00	30.86	30.57	31.25	-61	-60	-60	-60	-60	-60	-59	-60	-60	-60
63	16.25	43.37	39.53	41.21	41.49	36.78	-48	-50	-49	-49	-50	-49	-52	-50	-49	-50
64	16.00	28.72	100.33	62.09	30.10	86.87	-102	-44	-47	-51	-42	-46	-7	-28	-50	-37
65	15.75	1.42	102.61	47.96	3.52	83.38	18	37	46	55	106	26	160	20	38	58
66	15.52	10.02	12.90	11.41	10.17	12.43	51	59	58	61	66	60	63	57	58	62
67	15.28	.04	.01	.03	.04	.01	123	63	75	42	24	53	49	74	76	45
68	15.06	.00	.00	.00	.00	.00	147	62	98	16	8	25	45	89	135	22
69	14.84	.00	.00	.00	.00	.00	65	18	32	1	7	-4	26	39	-13	-5
70	14.63	.00	.00	.00	.00	.00	-10	-12	-17	-9	10	-24	-19	-30	-40	-34
71	14.42	.00	.00	.00	.00	.00	-11	-10	-19	-12	11	-29	-6	-34	-60	-42
72	14.22	.00	.00	.00	.00	.00	-14	-11	-25	-15	4	-32	-4	-40	-70	-47
73	14.03	.00	.00	.00	.00	.00	-14	-9	-25	-15	9	-33	1	-42	-79	-49
74	13.84	.00	.00	.00	.00	.00	-16	-11	-28	-17	-11	-33	0	-43	-78	-49
75	13.65	.00	.00	.00	.00	.00	-15	-8	-27	-16	5	-34	4	-44	-84	-50
76	13.47	.00	.00	.00	.00	.00	-18	-11	-32	-18	-21	-34	1	-46	-82	-51
77	13.30	.00	.00	.00	.00	.00	-15	-8	-27	-16	-4	-34	5	-43	-85	-50
78	13.13	.00	.00	.00	.00	.00	-19	-11	-33	-18	-26	-35	1	-48	-84	-51
79	12.96	.00	.00	.00	.00	.00	-17	-8	-30	-17	-12	-34	5	-44	-86	-51
80	12.80	.00	.00	.00	.00	.00	-19	-10	-32	-18	-24	-35	2	-46	-84	-51
81	12.64	.00	.00	.00	.00	.00	-18	-9	-32	-18	-19	-35	4	-48	-87	-52
82	12.49	.00	.00	.00	.00	.00	-19	-11	-33	-19	-27	-35	2	-46	-83	-51
83	12.34	.00	.00	.00	.00	.00	-17	-8	-31	-17	-10	-35	5	-47	-88	-51
84	12.19	.00	.00	.00	.00	.00	-21	-12	-35	-19	-35	-35	1	-48	-83	-51
85	12.05	.00	.00	.00	.00	.00	-16	-8	-29	-17	-9	-34	6	-44	-88	-51
86	11.91	.00	.00	.00	.00	.00	-20	-12	-36	-19	-36	-36	1	-49	-84	-52
87	11.77	.00	.00	.00	.00	.00	-18	-9	-31	-18	-22	-35	5	-45	-87	-51
88	11.64	.00	.00	.00	.00	.00	-20	-11	-34	-19	-31	-35	2	-48	-84	-52
89	11.51	.00	.00	.00	.00	.00	-18	-9	-33	-18	-25	-35	4	-49	-88	-52

SIMULATED MIXED SEA

PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
8.18	21.	11.43
7.99	21.	15.24
7.81	21.	11.43

LINE	PERIOD (SEC)	PRESSURE SPECTRA (SQ CM)					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE 1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
117	8.75	.00	.00	.00	.00	.00	-161	-145	-19	-129	-30	131	-157	-160	-148	-138
118	8.68	.00	.00	.00	.00	.00	-161	-146	-19	-130	-30	132	-157	-160	-148	-138
119	8.61	.00	.00	.00	.00	.00	-161	-147	-20	-133	-30	133	-157	-160	-148	-138
120	8.53	.00	.00	.00	.00	.00	-161	-150	-19	-139	-30	133	-158	-160	-149	-140
121	8.46	.00	.00	.00	.00	.00	-160	-161	-8	-163	-24	126	-160	-161	-150	-142
122	8.39	.00	.00	.00	.00	.00	20	12	172	4	155	-51	19	19	20	20
123	8.33	.01	.01	.01	.01	.01	20	18	167	16	153	-49	20	20	20	20
124	8.26	5.53	5.56	5.57	5.50	5.57	21	20	166	20	152	-49	20	20	20	20
125	8.19	31.73	31.64	31.62	31.78	31.62	21	21	166	21	152	-49	21	21	21	21
126	8.13	12.18	12.23	12.25	12.14	12.24	21	20	166	20	152	-49	20	20	20	20
127	8.06	8.87	8.92	8.93	8.85	8.95	21	20	166	20	152	-48	20	20	20	20
128	8.00	57.16	57.06	57.03	57.23	57.00	21	21	166	21	152	-48	21	21	21	21
129	7.94	20.89	20.96	20.98	20.85	20.99	21	20	166	20	152	-48	20	20	20	20
130	7.88	4.55	4.58	4.59	4.54	4.61	21	20	165	20	152	-48	20	20	20	20
131	7.82	32.65	32.58	32.55	32.70	32.53	21	21	165	21	152	-48	21	21	21	21
132	7.76	11.18	11.23	11.24	11.15	11.26	21	20	165	20	152	-48	20	20	20	20
133	7.70	.03	.03	.03	.03	.02	20	22	164	23	151	-48	21	21	21	21
134	7.64	.00	.00	.00	.00	.00	20	25	163	30	151	-48	21	21	23	23
135	7.59	.00	.00	.00	.00	.00	19	28	162	36	150	-47	22	22	24	26
136	7.53	.00	.00	.00	.00	.00	19	30	161	43	150	-48	22	21	26	29
137	7.47	.00	.00	.00	.00	.00	18	32	161	46	150	-48	23	21	27	32
138	7.42	.00	.00	.00	.00	.00	18	33	161	48	150	-48	23	21	28	33
139	7.37	.00	.00	.00	.00	.00	18	34	161	50	150	-48	23	21	29	35
140	7.31	.00	.00	.00	.00	.00	18	34	161	51	150	-48	23	20	29	36
141	7.26	.00	.00	.00	.00	.00	18	34	161	51	150	-48	23	20	29	36
142	7.21	.00	.00	.00	.00	.00	18	35	161	52	150	-49	23	20	30	37
143	7.16	.00	.00	.00	.00	.00	18	35	161	52	150	-49	22	20	30	37
144	7.11	.00	.00	.00	.00	.00	18	35	161	53	150	-49	22	20	30	37
145	7.06	.00	.00	.00	.00	.00	18	35	161	53	150	-49	22	20	30	38
146	7.01	.00	.00	.00	.00	.00	18	35	161	53	150	-49	22	20	30	38
147	6.97	.00	.00	.00	.00	.00	18	35	161	53	150	-49	22	20	30	38

SIMULATED MIXED SEA

PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
8.18	21.	11.43
7.99	15.	15.24
7.81	-21.	11.43

LINE	PERIOD (SEC)	PRESSURE SPECTRA (80 CM)					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE									
							1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
117	8.75	.00	.00	.00	.00	.00	-159	-150	-16	-140	-28	130	-154	-150	-166	-170
118	8.68	.00	.00	.00	.00	.00	-159	-153	-15	-146	-28	130	-157	-155	-165	-167
119	8.61	.00	.00	.00	.00	.00	-159	-156	-14	-152	-27	130	-158	-158	-162	-164
120	8.53	.00	.00	.00	.00	.00	-161	-161	-12	-161	-27	131	-161	-161	-158	-157
121	8.46	.00	.00	.00	.00	.00	-168	-175	-2	171	-20	125	-163	18	43	74
122	8.39	.00	.00	.00	.00	.00	21	17	169	14	154	-51	20	20	23	25
123	8.33	.01	.01	.01	.01	.01	20	19	167	18	153	-49	20	20	21	21
124	8.26	5.53	5.56	5.57	5.50	5.55	20	20	166	20	152	-49	20	20	20	20
125	8.19	31.73	31.69	31.63	31.79	31.70	21	21	166	21	152	-49	21	21	21	21
126	8.13	12.18	12.12	12.21	12.14	12.16	20	20	166	20	152	-49	20	20	20	20
127	8.06	8.87	8.90	8.91	8.84	8.83	14	14	169	14	153	-49	14	14	14	14
128	8.00	57.16	57.66	57.29	57.30	57.67	14	15	169	15	153	-49	14	14	15	15
129	7.94	20.89	19.44	20.31	20.72	19.61	15	14	169	14	153	-49	15	15	14	14
130	7.88	4.55	6.45	5.42	4.69	6.19	-23	-21	-21	-23	-22	-21	-152	-19	48	-20
131	7.82	32.65	31.49	32.04	32.60	31.64	-20	-20	-20	-20	-20	-20	-152	-21	48	-20
132	7.76	11.18	11.53	11.39	11.18	11.48	-21	-21	-21	-21	-21	-21	-152	-20	48	-21
133	7.70	.03	.02	.02	.03	.02	-18	-19	-19	-18	-18	-19	-151	-21	47	-20
134	7.64	.00	.00	.00	.00	.00	-14	-18	-17	-13	-13	-16	-150	-140	-165	-17
135	7.59	.00	.00	.00	.00	.00	-12	-18	-16	-9	-8	-11	-149	-135	-167	-11
136	7.53	.00	.00	.00	.00	.00	-10	-20	-16	-1	2	-5	-147	-125	-170	-6
137	7.47	.00	.00	.00	.00	.00	-9	-23	-17	7	22	-3	39	89	-170	-4
138	7.42	.00	.00	.00	.00	.00	-8	-25	-17	20	70	-1	38	83	-169	-2
139	7.37	.00	.00	.00	.00	.00	-7	-26	-18	34	106	-1	37	82	-168	-2
140	7.31	.00	.00	.00	.00	.00	-7	-26	-18	42	116	0	37	78	-168	-1
141	7.26	.00	.00	.00	.00	.00	-6	-26	-18	44	118	0	37	79	-167	-2
142	7.21	.00	.00	.00	.00	.00	22	36	72	48	121	0	36	73	-161	0
143	7.16	.00	.00	.00	.00	.00	21	36	72	49	122	0	36	77	-168	-1
144	7.11	.00	.00	.00	.00	.00	20	35	71	49	123	0	35	69	-1	0
145	7.06	.00	.00	.00	.00	.00	19	36	72	51	124	0	36	74	-167	0
146	7.01	.00	.00	.00	.00	.00	19	35	71	51	124	0	35	68	7	0
147	6.97	.00	.00	.00	.00	.00	19	35	71	51	124	0	35	68	4	0

SIMULATED MIXED SEA	PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
	8.12	21.	11.43
	7.99	21.	15.24
	7.93	21.	11.43

PRESSURE SPECTRA (80 CM)

DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE

LINE	PERIOD (SEC)	PRESSURE SPECTRA (80 CM)					1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
117	8.75	.00	.00	.00	.00	.00	-161	-145	-18	-128	-30	131	-157	-159	-148	-139
118	8.68	.00	.00	.00	.00	.00	-161	-146	-19	-130	-30	132	-157	-160	-148	-139
119	8.61	.00	.00	.00	.00	.00	-161	-147	-19	-132	-30	132	-157	-160	-148	-139
120	8.53	.00	.00	.00	.00	.00	-161	-148	-20	-135	-30	133	-158	-160	-148	-139
121	8.46	.00	.00	.00	.00	.00	-160	-153	-17	-145	-29	132	-159	-160	-150	-142
122	8.39	.00	.00	.00	.00	.00	-160	-171	-3	176	-20	122	-161	-161	-151	-143
123	8.33	.00	.00	.00	.00	.00	20	14	170	7	155	-50	19	19	19	20
124	8.26	.01	.01	.01	.01	.01	21	19	167	17	153	-49	20	20	20	20
125	8.19	5.62	5.66	5.67	5.60	5.67	21	20	166	20	152	-49	20	20	20	20
126	8.13	30.49	30.40	30.38	30.54	30.38	21	21	166	21	152	-49	21	21	21	21
127	8.06	43.37	43.45	43.48	43.25	43.40	21	20	166	20	152	-49	20	20	20	20
128	8.00	28.67	28.60	28.58	28.73	28.57	21	21	166	21	152	-48	21	21	21	21
129	7.94	1.42	1.41	1.41	1.44	1.41	20	21	165	21	152	-48	21	21	21	21
130	7.88	9.97	10.02	10.03	9.94	10.04	21	20	165	20	152	-48	20	20	20	20
131	7.82	.04	.04	.04	.04	.04	20	21	165	23	152	-48	21	21	21	21
132	7.76	.00	.00	.00	.00	.00	20	24	164	27	151	-48	21	21	22	22
133	7.70	.00	.00	.00	.00	.00	20	26	163	33	151	-48	22	22	23	24
134	7.64	.00	.00	.00	.00	.00	19	29	162	39	150	-48	22	22	25	27
135	7.59	.00	.00	.00	.00	.00	19	31	161	44	150	-48	23	22	26	29
136	7.53	.00	.00	.00	.00	.00	18	32	161	47	150	-48	23	21	27	31
137	7.47	.00	.00	.00	.00	.00	18	33	161	49	150	-48	23	21	28	33
138	7.42	.00	.00	.00	.00	.00	18	34	161	50	150	-48	23	21	28	34
139	7.37	.00	.00	.00	.00	.00	18	34	161	51	150	-48	23	21	29	35
140	7.31	.00	.00	.00	.00	.00	18	35	161	52	150	-49	23	20	29	36
141	7.26	.00	.00	.00	.00	.00	18	35	161	52	150	-49	23	20	29	36
142	7.21	.00	.00	.00	.00	.00	18	35	161	52	150	-49	23	20	29	36
143	7.16	.00	.00	.00	.00	.00	18	35	161	53	150	-49	22	20	29	37
144	7.11	.00	.00	.00	.00	.00	18	35	161	53	150	-49	23	20	30	37
145	7.06	.00	.00	.00	.00	.00	18	35	161	53	150	-49	22	20	30	37
146	7.01	.00	.00	.00	.00	.00	18	35	161	53	150	-49	22	20	30	37
147	6.97	.00	.00	.00	.00	.00	18	35	161	53	150	-49	23	20	30	37

SIMULATED MIXED SEA

PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
8.12	21.	11.43
7.99	15.	15.24
7.93	-21.	11.43

LINE PERIOD (SEC) — PRESSURE SPECTRA (80 CM) — DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE

LINE	PERIOD (SEC)	PRESSURE SPECTRA (80 CM)					1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-'
117	8.75	.00	.00	.00	.00	.00	-159	-148	-16	-137	-28	130	-153	-147	-166	-1
118	8.68	.00	.00	.00	.00	.00	-159	-150	-16	-141	-28	130	-154	-150	-165	-1
119	8.61	.00	.00	.00	.00	.00	-159	-153	-15	-146	-28	130	-156	-154	-164	-1
120	8.53	.00	.00	.00	.00	.00	-160	-155	-14	-150	-27	130	-159	-158	-161	-1
121	8.46	.00	.00	.00	.00	.00	-163	-163	-10	-163	-26	130	-163	-162	-157	-1
122	8.39	.00	.00	.00	.00	.00	114	173	2	157	-17	119	-165	19	42	
123	8.33	.00	.00	.00	.00	.00	22	17	169	13	154	-50	20	20	22	
124	8.26	.01	.01	.01	.01	.01	21	19	167	17	153	-49	21	21	20	
125	8.19	5.62	5.57	5.63	5.59	5.57	21	20	166	20	152	-49	21	21	20	
126	8.13	30.49	31.02	30.65	30.58	30.91	20	21	166	21	152	-49	21	21	21	
127	8.06	43.37	39.49	42.15	43.06	41.08	18	18	168	17	153	-49	18	18	18	
128	8.00	28.67	98.20	58.92	35.06	89.23	11	14	168	20	152	-48	7	9	13	
129	7.94	1.42	99.39	43.87	10.36	86.37	-82	-32	-24	-41	-29	-17	-3	-6	-10	
130	7.88	9.97	12.79	11.27	10.21	12.43	-22	-21	-21	-22	-22	-21	-152	-20	48	
131	7.82	.04	.01	.02	.04	.01	-14	-18	-17	-12	-11	-16	-151	-22	47	
132	7.76	.00	.00	.00	.00	.00	-9	-14	-12	-5	-3	-8	-151	-140	-172	
133	7.70	.00	.00	.00	.00	.00	-9	-16	-13	0	2	-3	-149	-131	-175	
134	7.64	.00	.00	.00	.00	.00	125	34	69	7	16	0	35	70	-37	
135	7.59	.00	.00	.00	.00	.00	99	33	66	13	35	0	34	67	-2	
136	7.53	.00	.00	.00	.00	.00	58	33	64	22	69	0	34	63	7	
137	7.47	.00	.00	.00	.00	.00	44	34	68	30	95	0	35	67	3	
138	7.42	.00	.00	.00	.00	.00	29	33	65	37	108	0	33	59	9	
139	7.37	.00	.00	.00	.00	.00	26	35	69	41	115	0	34	66	8	
140	7.31	.00	.00	.00	.00	.00	23	34	67	44	118	0	33	58	9	
141	7.26	.00	.00	.00	.00	.00	21	35	69	47	121	0	34	61	10	
142	7.21	.00	.00	.00	.00	.00	20	35	69	48	121	0	33	58	10	
143	7.16	.00	.00	.00	.00	.00	20	35	70	50	123	0	33	61	10	
144	7.11	.00	.00	.00	.00	.00	19	35	69	50	123	0	32	54	11	
145	7.06	.00	.00	.00	.00	.00	19	35	71	51	124	0	34	63	9	
146	7.01	.00	.00	.00	.00	.00	18	35	70	51	124	0	31	50	11	
147	6.97	.00	.00	.00	.00	.00	18	35	71	52	124	0	33	61	10	

SIMULATED MIXED SEA

PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
16.48	16.	11.58
15.97	21.	10.67
15.72	26.	11.28

LINE	PERIOD	PRESSURE SPECTRA					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE									
							1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
53	19.32	.00	.00	.00	.00	.00	-130	-162	-156	-177	-177	-177	-154	-148	-176	-177
54	18.96	.00	.00	.00	.00	.00	-143	-159	-151	-170	-161	-177	-154	-148	-174	-176
55	18.62	.00	.00	.00	.00	.00	-153	-156	-145	-159	-126	-175	-155	-149	-171	-174
56	18.29	.00	.00	.00	.00	.00	-157	-153	-140	-150	-99	-174	-155	-151	-166	-170
57	17.96	.00	.00	.00	.00	.00	-159	-149	-132	-139	-76	-172	-154	-151	-159	-162
58	17.66	.00	.00	.00	.00	.00	-129	-114	-85	-109	-62	-141	-100	-74	-63	-83
59	17.36	.00	.00	.00	.00	.00	15	19	21	23	40	13	14	14	16	16
60	17.07	.01	.01	.01	.01	.01	16	17	17	18	22	16	16	16	16	16
61	16.79	5.73	5.77	5.78	5.78	5.75	16	16	16	16	16	16	16	16	16	16
62	16.52	31.72	31.64	31.62	31.60	31.68	15	15	15	15	15	15	15	15	15	15
63	16.25	32.42	32.22	32.45	32.52	32.26	18	18	18	18	18	18	18	18	18	18
64	16.00	9.79	10.15	9.82	9.73	9.96	17	17	17	16	16	17	17	17	17	16
65	15.75	6.09	6.60	6.16	6.04	6.35	31	31	31	31	31	31	31	31	31	31
66	15.52	10.11	10.20	10.18	10.17	10.13	26	26	26	26	26	26	26	26	26	26
67	15.28	.04	.03	.03	.03	.04	24	24	24	23	22	24	24	24	24	23
68	15.06	.00	.00	.00	.00	.00	24	21	21	19	16	21	23	23	21	20
69	14.84	.00	.00	.00	.00	.00	25	19	19	13	9	18	22	23	18	16
70	14.63	.00	.00	.00	.00	.00	26	16	17	8	4	13	21	23	14	12
71	14.42	.00	.00	.00	.00	.00	28	14	15	2	0	9	21	23	10	8
72	14.22	.00	.00	.00	.00	.00	31	12	13	0	-4	6	21	23	7	5
73	14.03	.00	.00	.00	.00	.00	37	10	12	-4	-7	4	21	23	5	3
74	13.84	.00	.00	.00	.00	.00	42	9	10	-6	-9	2	21	23	3	2
75	13.65	.00	.00	.00	.00	.00	49	8	9	-8	-11	2	21	23	2	1
76	13.47	.00	.00	.00	.00	.00	55	7	7	-10	-12	1	20	22	1	1
77	13.30	.00	.00	.00	.00	.00	63	6	6	-11	-13	1	20	22	1	0
78	13.13	.00	.00	.00	.00	.00	67	5	5	-12	-14	1	20	22	1	0
79	12.96	.00	.00	.00	.00	.00	74	4	4	-13	-15	0	20	21	0	0
80	12.80	.00	.00	.00	.00	.00	76	4	4	-14	-15	0	19	21	0	0
81	12.64	.00	.00	.00	.00	.00	81	3	3	-15	-16	0	19	20	0	0
82	12.49	.00	.00	.00	.00	.00	81	2	3	-15	-16	0	19	20	0	0

SIMULATED MIXED SEA

PERIODS(SEC)	DIRECTIONS(DEGREES)	AMPLITUDES(CM)
16.48	11.	11.58
15.97	21.	10.67
15.72	31.	11.28

LINE	PERIOD	PRESSURE SPECTRA					DIRECTION (DEGREES FROM SEAWARD NORMAL) POSITIVE VALUES ARE COUNTERCLOCKWISE									
							1-2-3	1-2-4	1-2-5	1-3-4	1-3-5	1-4-5	2-3-4	2-3-5	2-4-5	3-4-5
53	19.32	.00	.00	.00	.00	.00	-125	-162	-155	-178	-178	-177	-154	-147	-176	-177
54	18.96	.00	.00	.00	.00	.00	-140	-159	-150	-170	-162	-177	-154	-146	-174	-176
55	18.62	.00	.00	.00	.00	.00	-151	-155	-143	-158	-125	-175	-154	-147	-170	-174
56	18.29	.00	.00	.00	.00	.00	-155	-152	-138	-149	-96	-174	-154	-148	-165	-170
57	17.96	.00	.00	.00	.00	.00	-157	-147	-127	-138	-74	-172	-150	-145	-155	-160
58	17.66	.00	.00	.00	.00	.00	-109	-97	-69	-95	-56	-119	-87	-58	-44	-59
59	17.36	.00	.00	.00	.00	.00	11	13	15	18	34	8	8	8	10	10
60	17.07	.01	.01	.01	.01	.01	12	12	13	14	17	11	11	11	12	12
61	16.79	5.73	5.76	5.77	5.78	5.76	11	11	11	11	11	11	11	11	11	11
62	16.52	31.72	31.73	31.64	31.60	31.70	10	10	10	10	10	10	10	10	10	10
63	16.25	32.42	31.41	32.27	32.52	31.85	15	15	15	15	15	15	15	15	15	15
64	16.00	9.79	11.23	10.03	9.72	10.29	14	13	13	13	12	13	14	14	13	13
65	15.75	6.09	8.04	6.43	6.04	6.80	39	41	40	42	42	41	41	40	41	42
66	15.52	10.11	10.25	10.19	10.17	10.15	31	31	31	31	31	31	31	31	31	31
67	15.28	.04	.03	.03	.03	.04	28	27	27	27	26	27	28	28	27	27
68	15.06	.00	.00	.00	.00	.00	27	24	24	21	18	24	25	26	24	23
69	14.84	.00	.00	.00	.00	.00	27	21	21	15	11	19	24	25	20	18
70	14.63	.00	.00	.00	.00	.00	28	17	18	9	5	14	22	24	15	13
71	14.42	.00	.00	.00	.00	.00	31	15	16	3	0	9	22	24	11	8
72	14.22	.00	.00	.00	.00	.00	34	12	14	0	-4	6	21	24	7	5
73	14.03	.00	.00	.00	.00	.00	40	11	13	-3	-7	4	21	24	5	3
74	13.84	.00	.00	.00	.00	.00	44	9	10	-6	-9	3	21	23	3	2
75	13.65	.00	.00	.00	.00	.00	52	8	9	-8	-11	2	21	23	2	1
76	13.47	.00	.00	.00	.00	.00	57	7	7	-10	-12	1	20	22	1	1
77	13.30	.00	.00	.00	.00	.00	65	6	6	-12	-13	1	20	22	1	1
78	13.13	.00	.00	.00	.00	.00	67	5	5	-13	-14	1	20	21	1	0
79	12.96	.00	.00	.00	.00	.00	75	4	4	-14	-15	0	20	21	0	0
80	12.80	.00	.00	.00	.00	.00	75	3	4	-14	-15	0	19	21	0	0
81	12.64	.00	.00	.00	.00	.00	80	3	3	-15	-16	0	19	20	0	0
82	12.49	.00	.00	.00	.00	.00	80	2	2	-15	-16	0	19	20	0	0

APPENDIX E

HIGH-RESOLUTION SPECTRA FOR FIELD WAVE DATA

Figures E-1 to E-44 show high-resolution spectra for pressure gages 1 to 5 at Pt. Mugu, California. Date and significant wave height are indicated for each figure.

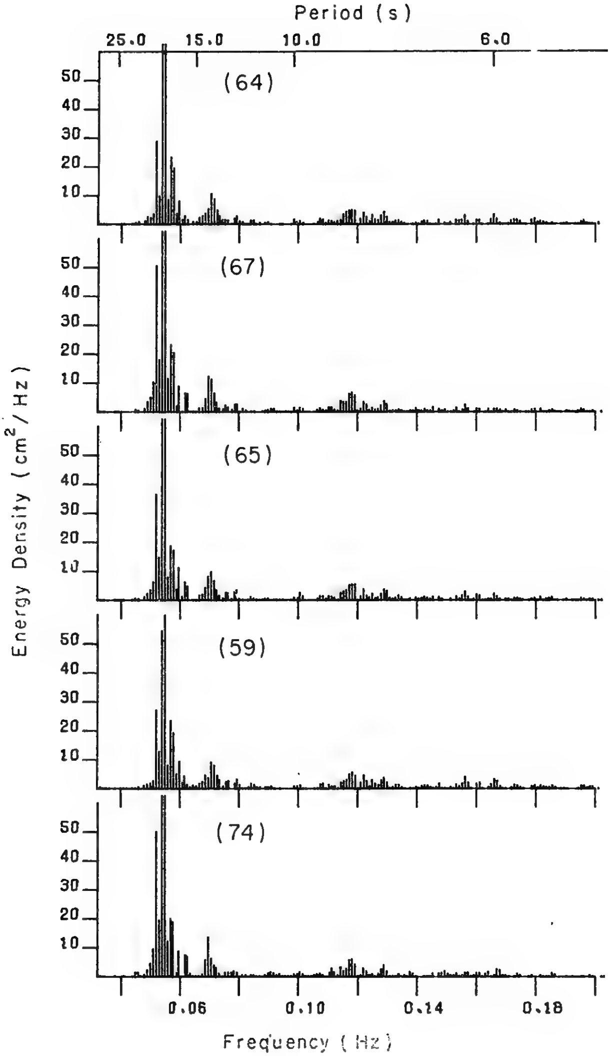


Figure E-1. Significant wave height 93.6 centimeters (3.1 feet), 10 April 1970, 2206 hours.

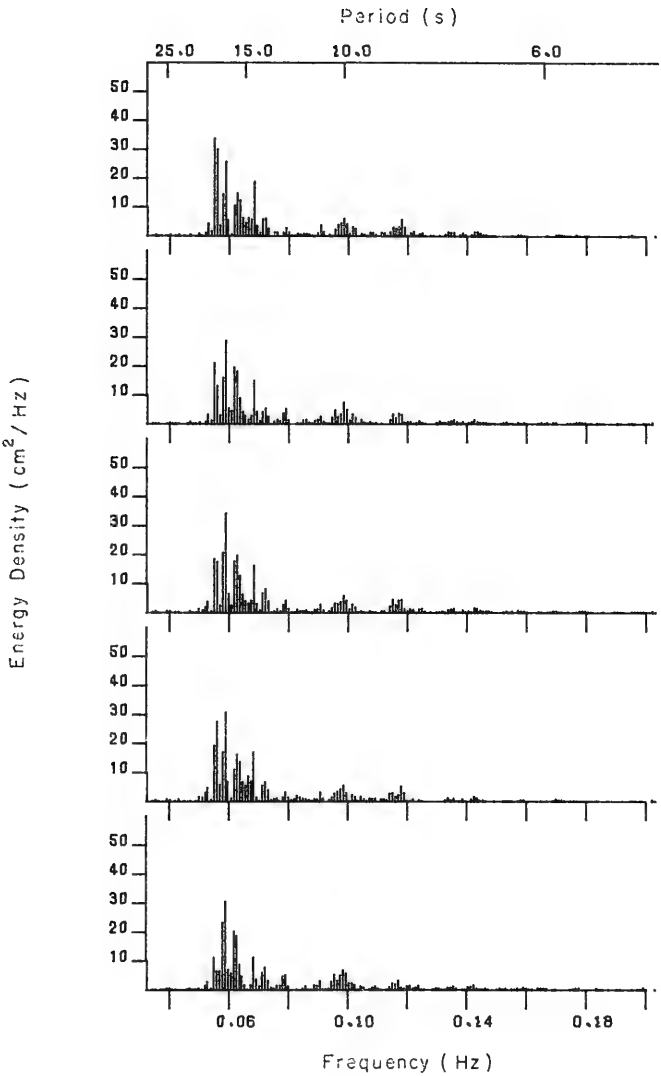


Figure E-2. Significant wave height 84.3 centimeters (2.8 feet), 20 April 1970, 0928 hours.

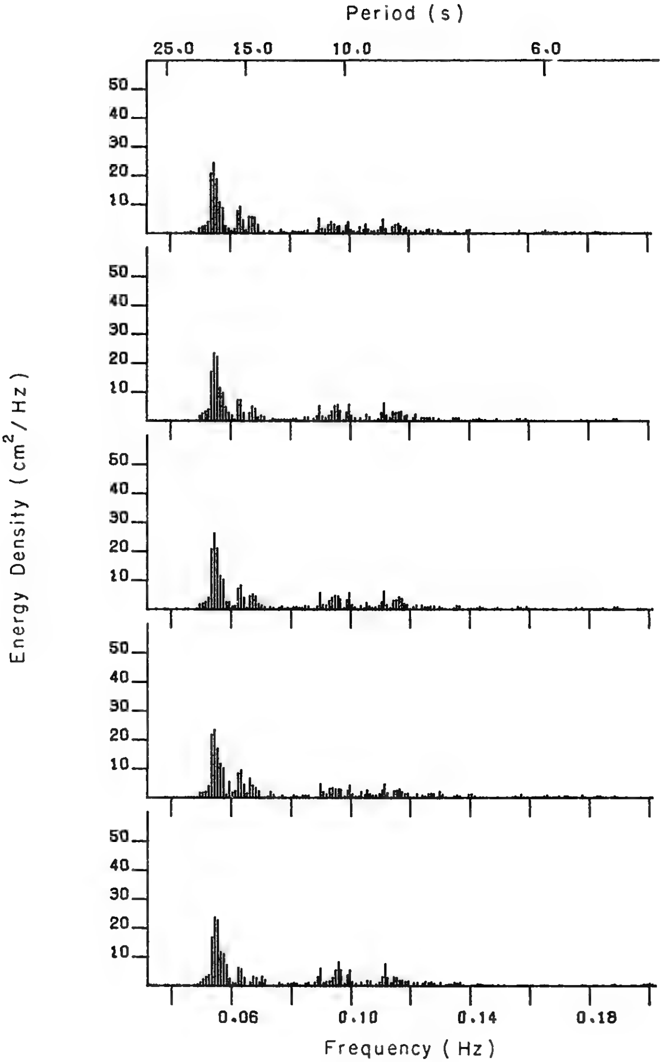


Figure E-3. Significant wave height 81.0 centimeters (2.7 feet), 20 April 1970, 1228 hours.

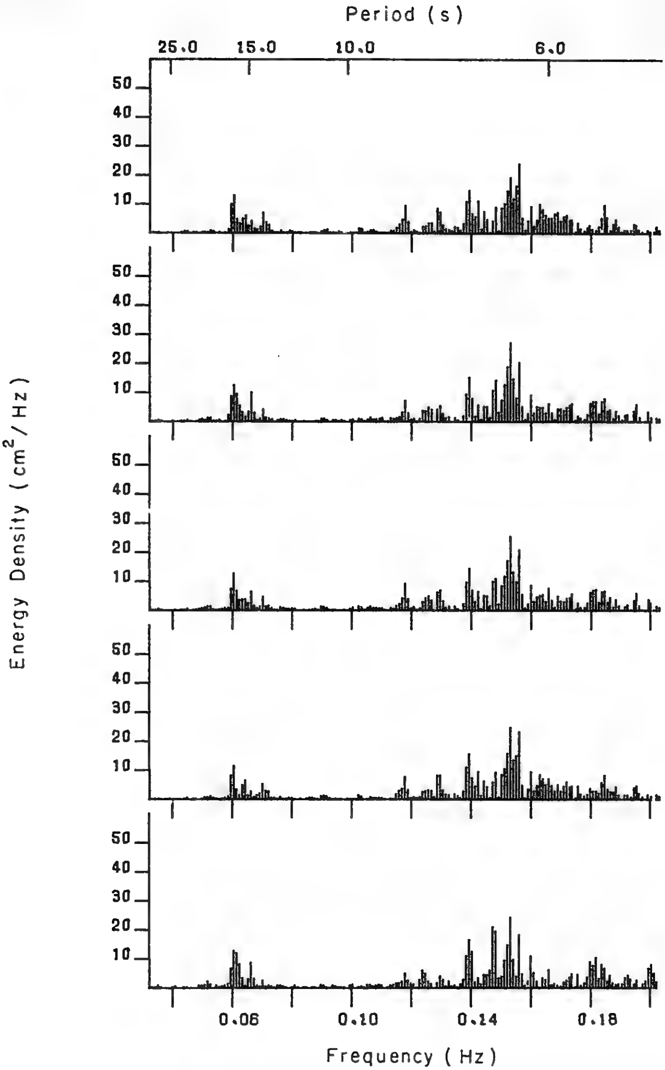


Figure E-4. Significant wave height 105.3 centimeters (3.5 feet), 21 April 1970, 0028 hours.

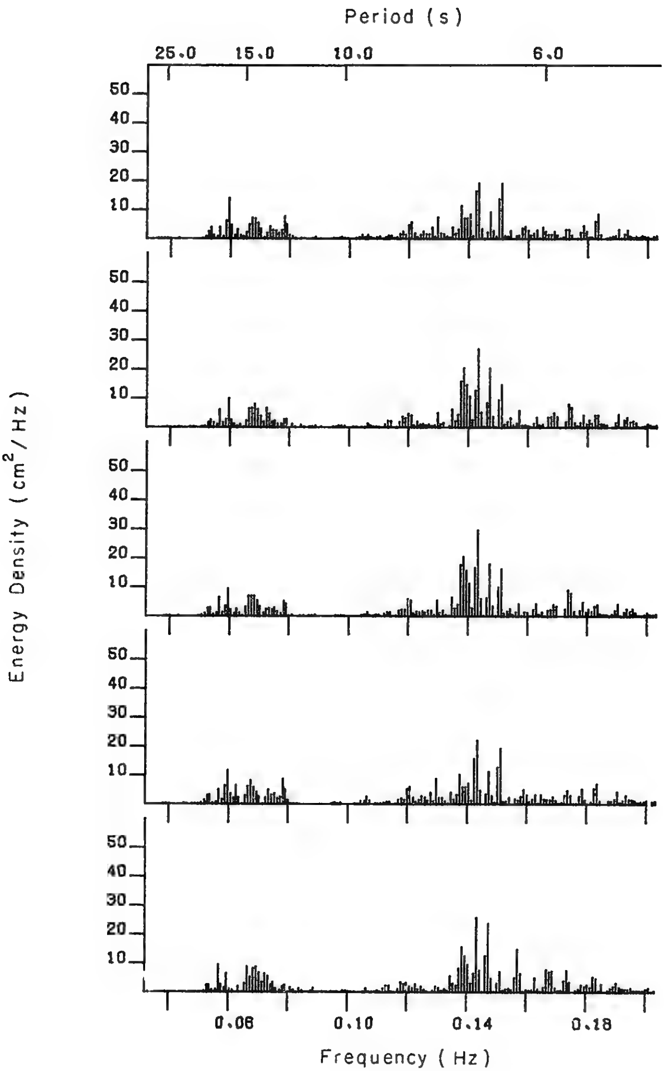


Figure E-5. Significant wave height 95.2 centimeters (3.1 feet), 21 April 1970, 0229 hours.

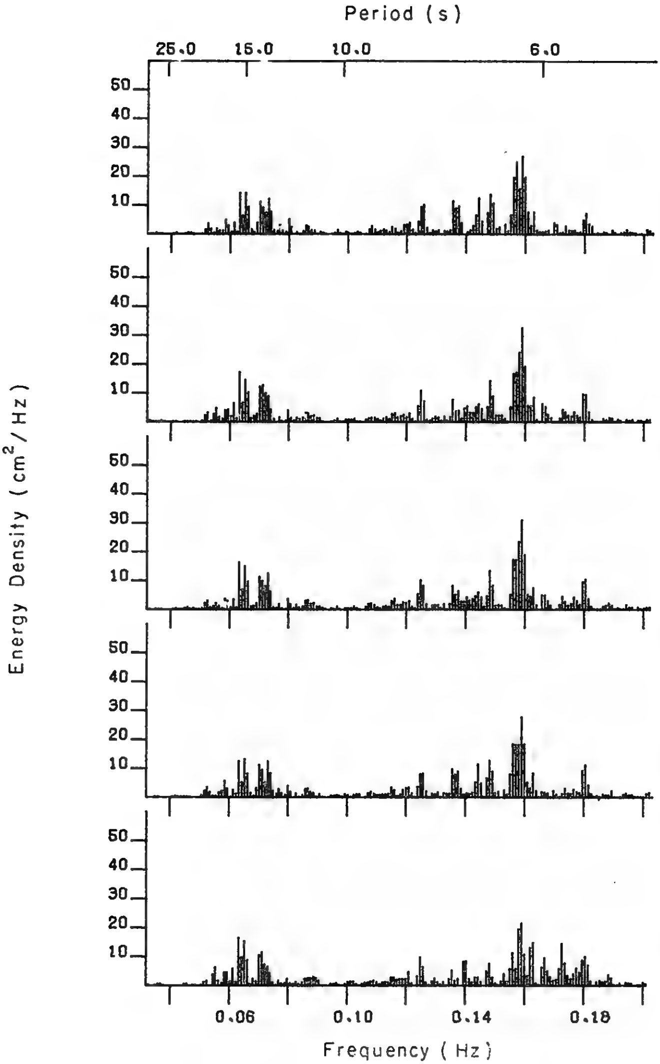


Figure E-6. Significant wave height 100.7 centimeters (3.4 feet), 21 April 1970, 0929 hours.

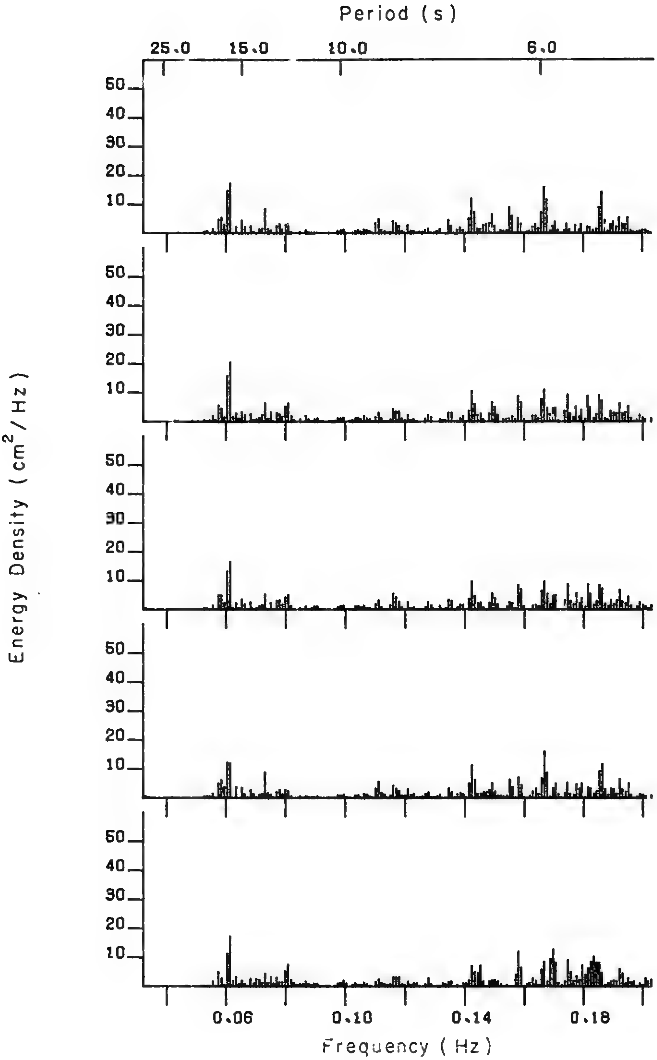


Figure E-7. Significant wave height 94.7 centimeters (3.1 feet), 21 April 1970, 1229 hours.

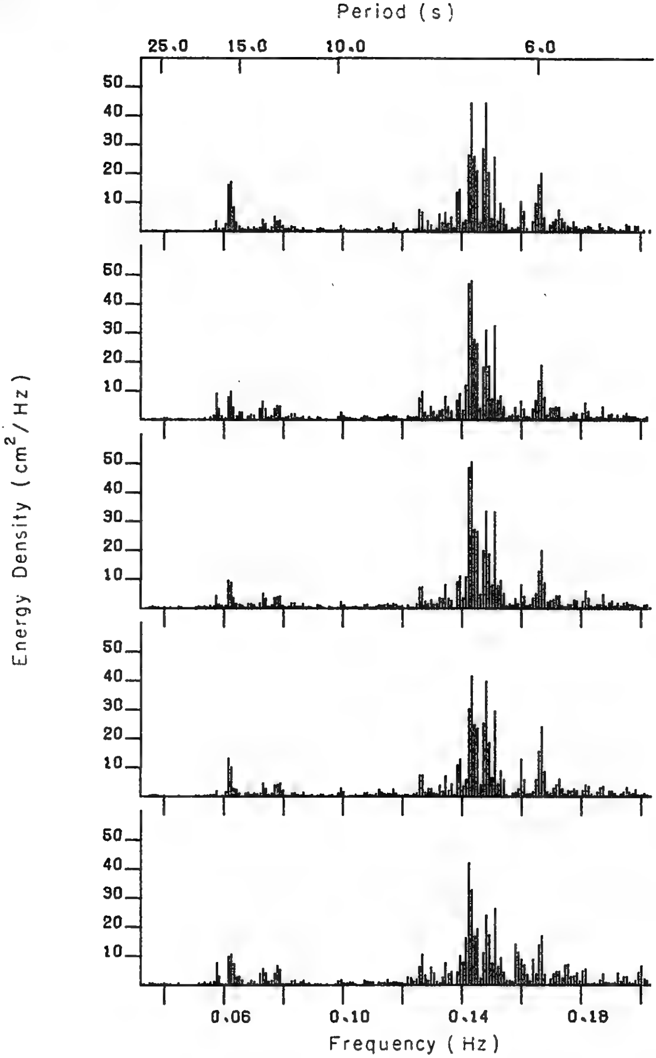


Figure E-8. Significant wave height 113.8 centimeters (3.7 feet), 21 April 1970, 1829 hours.

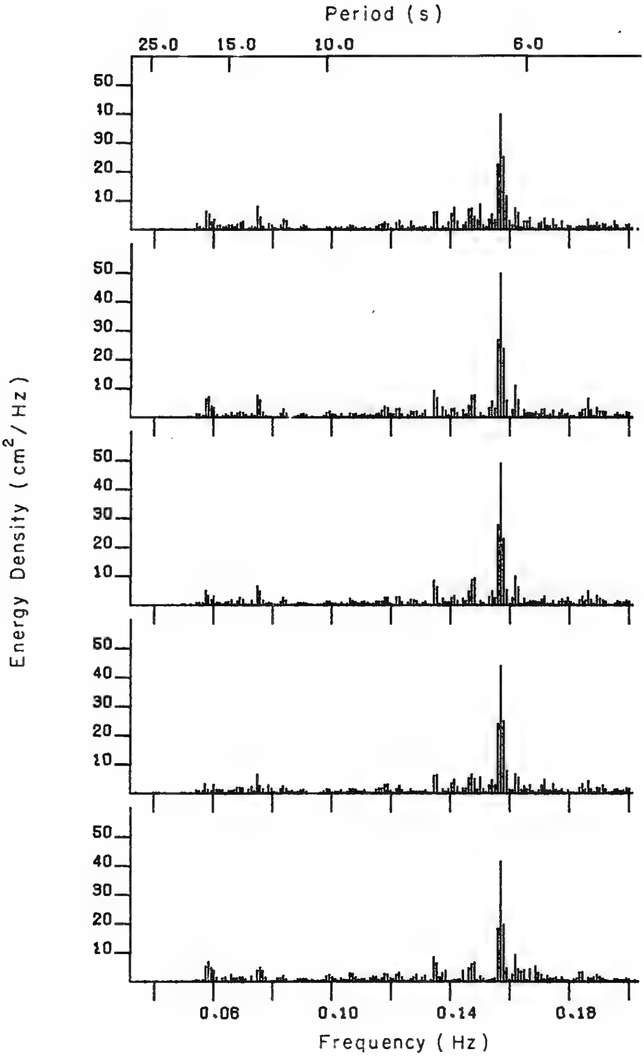


Figure E-9. Significant wave height 85.1 centimeters (2.8 feet), 21 April 1970, 2129 hours.

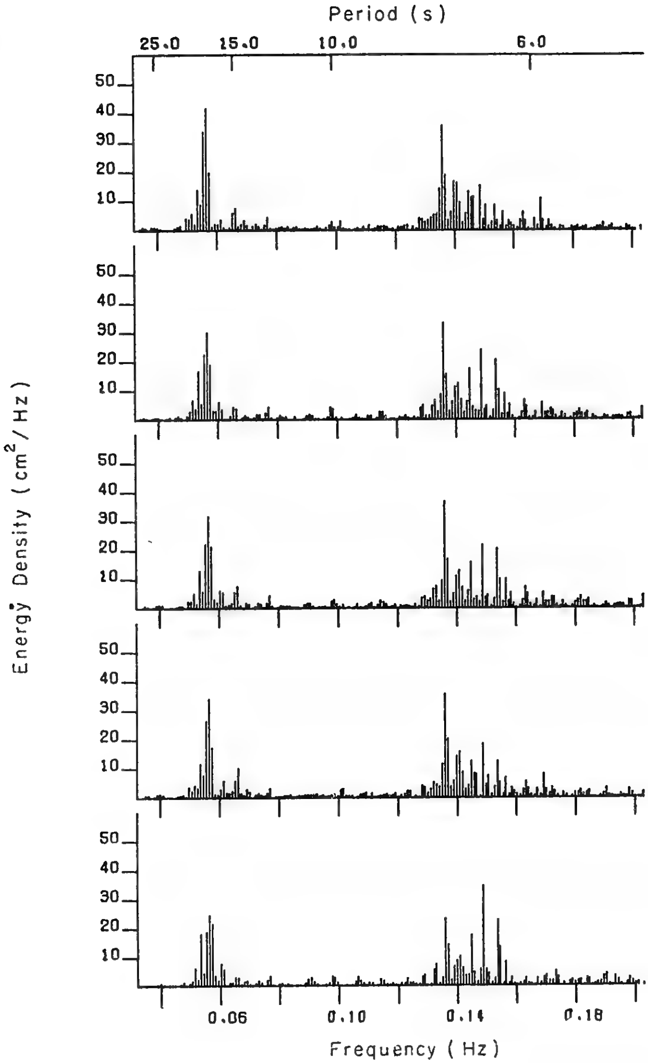


Figure E-10. Significant wave height 109.3 centimeters (3.6 feet), 10 June 1970, 1421 hours.

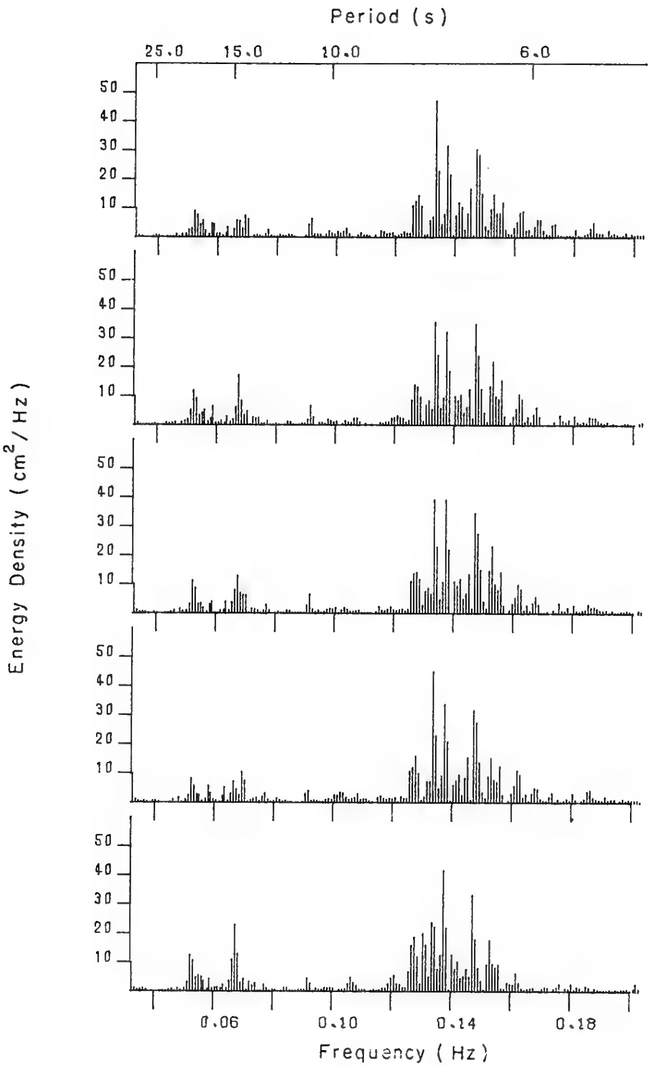


Figure E-11. Significant wave height 117.9 centimeters (3.9 feet), 10 June 1970, 1731 hours.

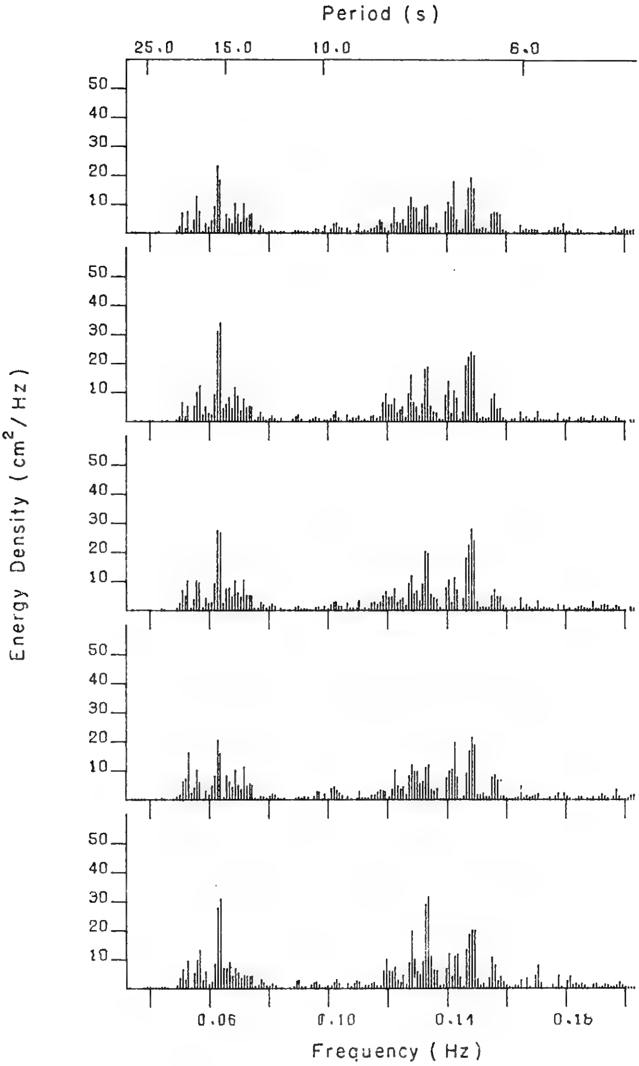


Figure E-12. Significant wave height 113.1 centimeters (3.7 feet), 10 June 1970, 2041 hours.

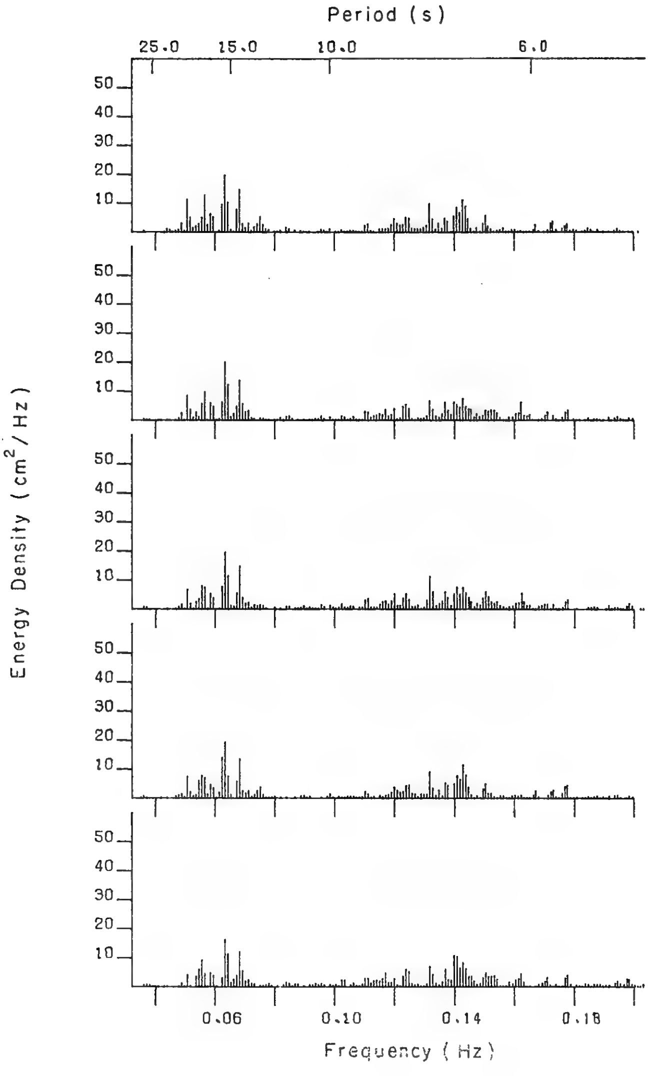


Figure E-13. Significant wave height 87.5 centimeters (2.9 feet), 10 June 1970, 2351 hours.

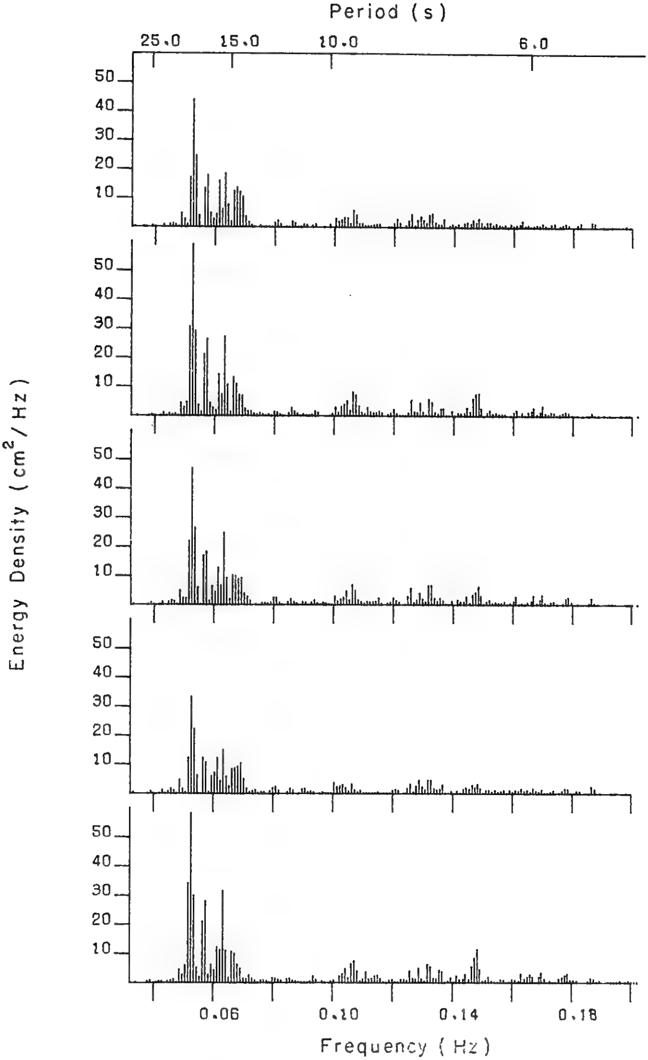


Figure E-14. Significant wave height 93.3 centimeters (3.1 feet), 11 June 1970, 0301 hours.

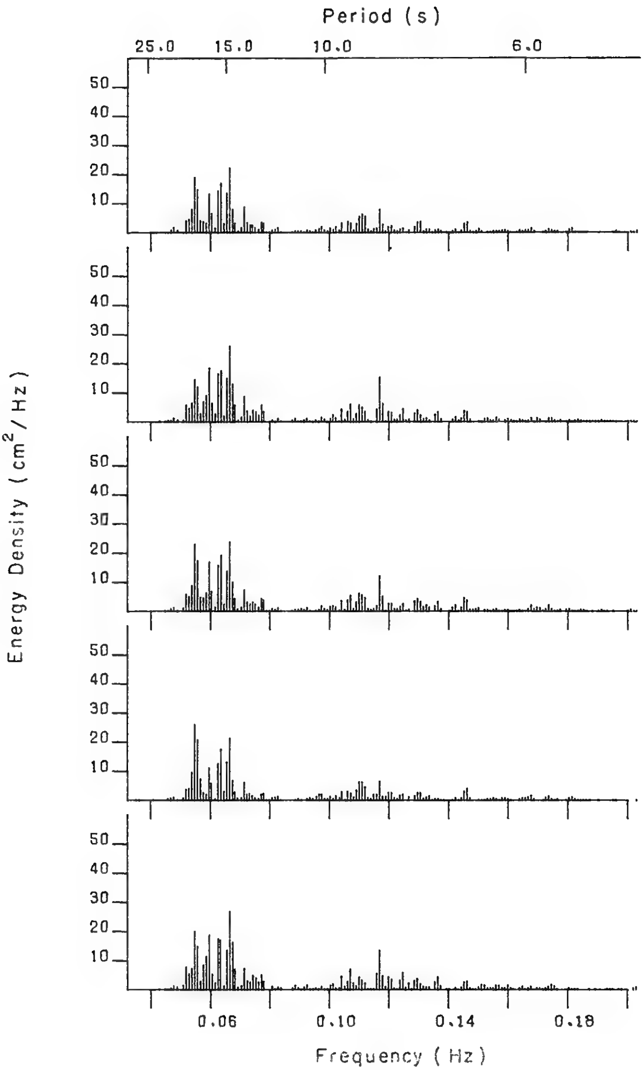


Figure E-15. Significant wave height 81.0 centimeters (2.7 feet), 11 June 1970, 0631 hours.

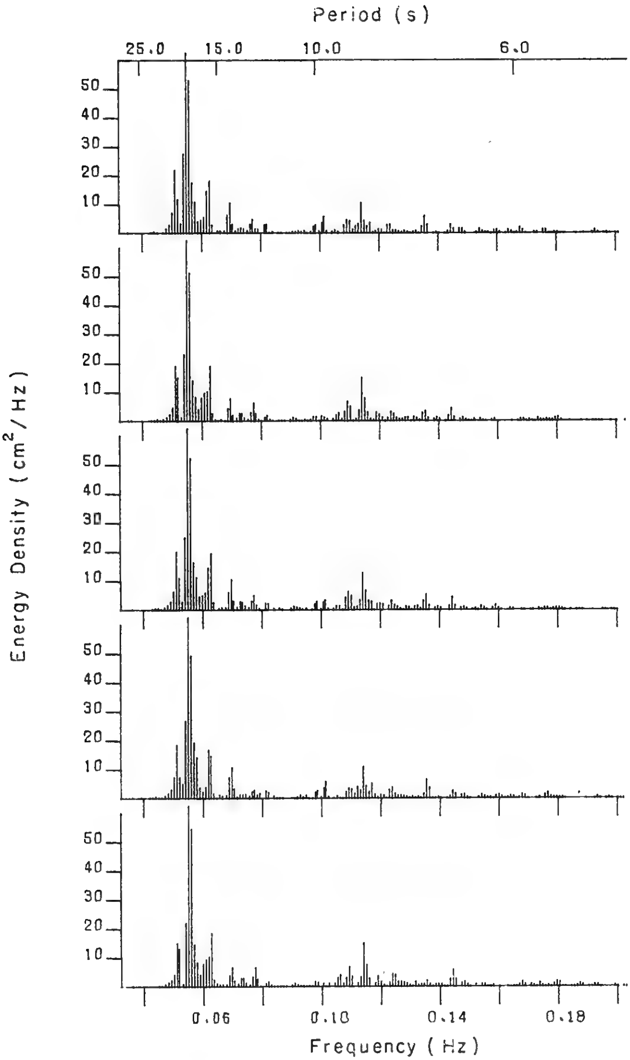


Figure E-16. Significant wave height 88.6 centimeters (2.9 feet), 11 June 1970, 0942 hours.

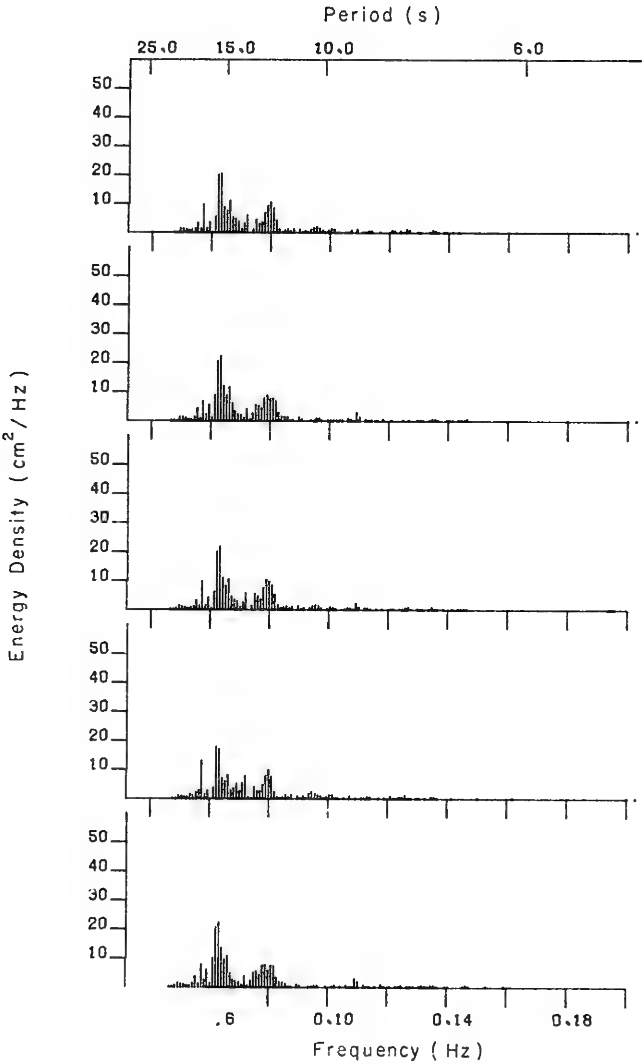


Figure E-17. Significant wave height 71.0 centimeters (2.3 feet), 24 June 1970, 0906 hours.

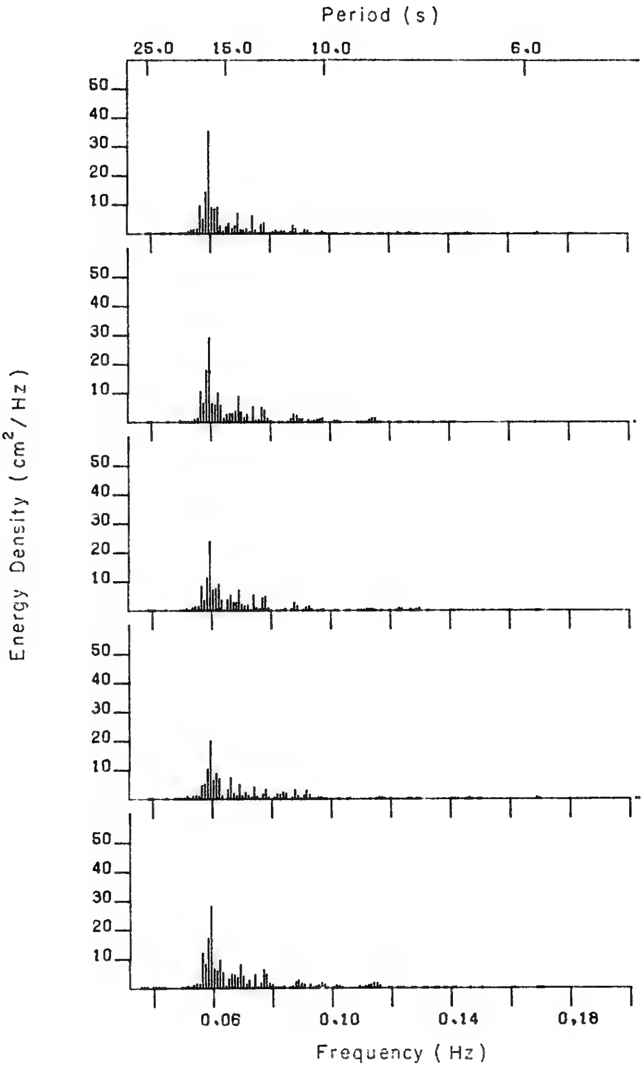


Figure E-18. Significant wave height 69.3 centimeters (2.3 feet), 24 June 1970, 1206 hours.

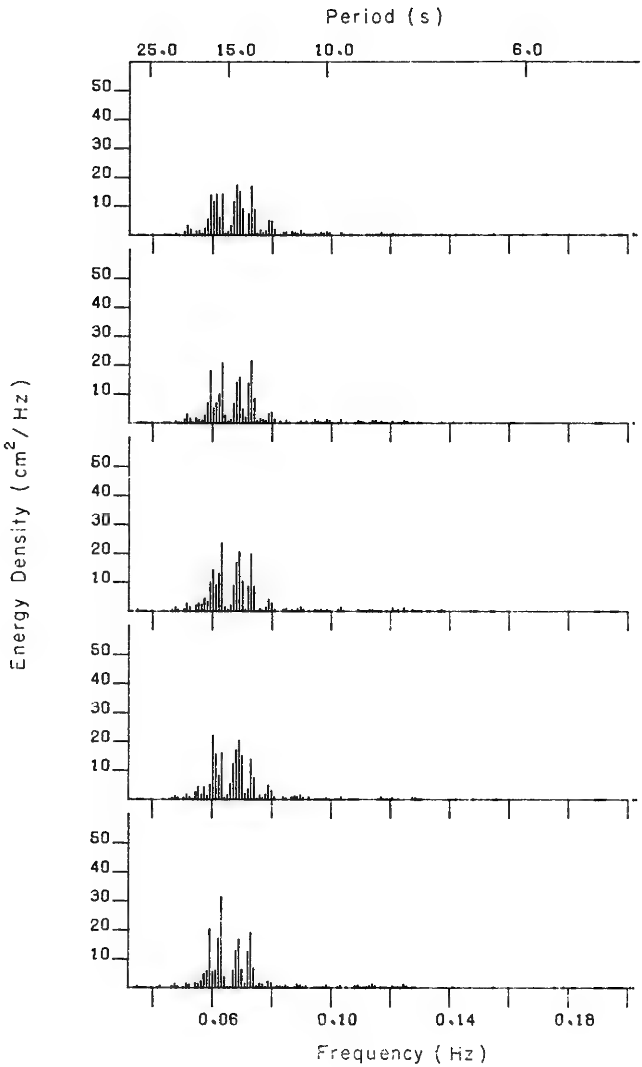


Figure E-19. Significant wave height 79.5 centimeters (2.6 feet), 24 June 1970, 1506 hours.

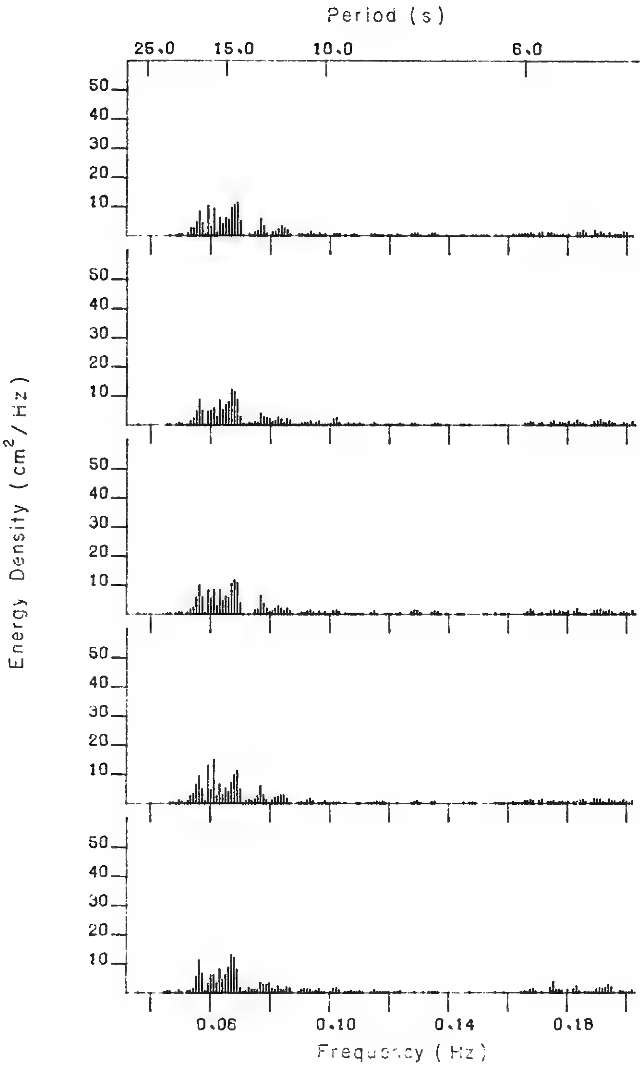


Figure E-20. Significant wave height 72.5 centimeters (2.4 feet), 24 June 1970, 1807 hours.

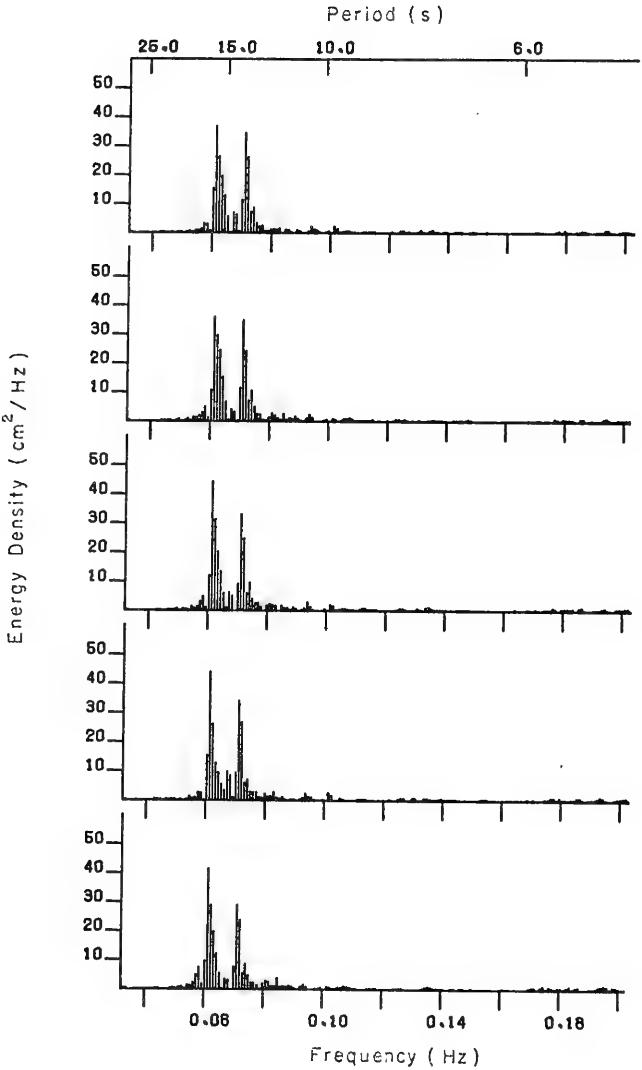


Figure E-21. Significant wave height 70.1 centimeters (2.3 feet), 25 June 1970, 0007 hours.

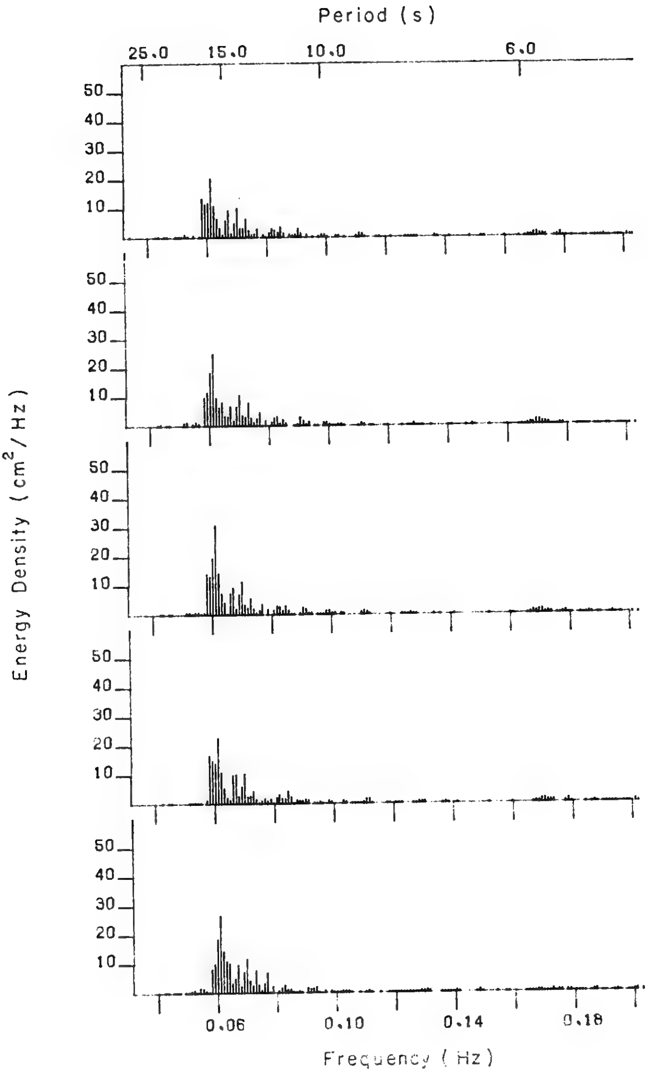


Figure E-22. Significant wave height 76.9 centimeters (2.5 feet), 25 June 1970, 0307 hours.

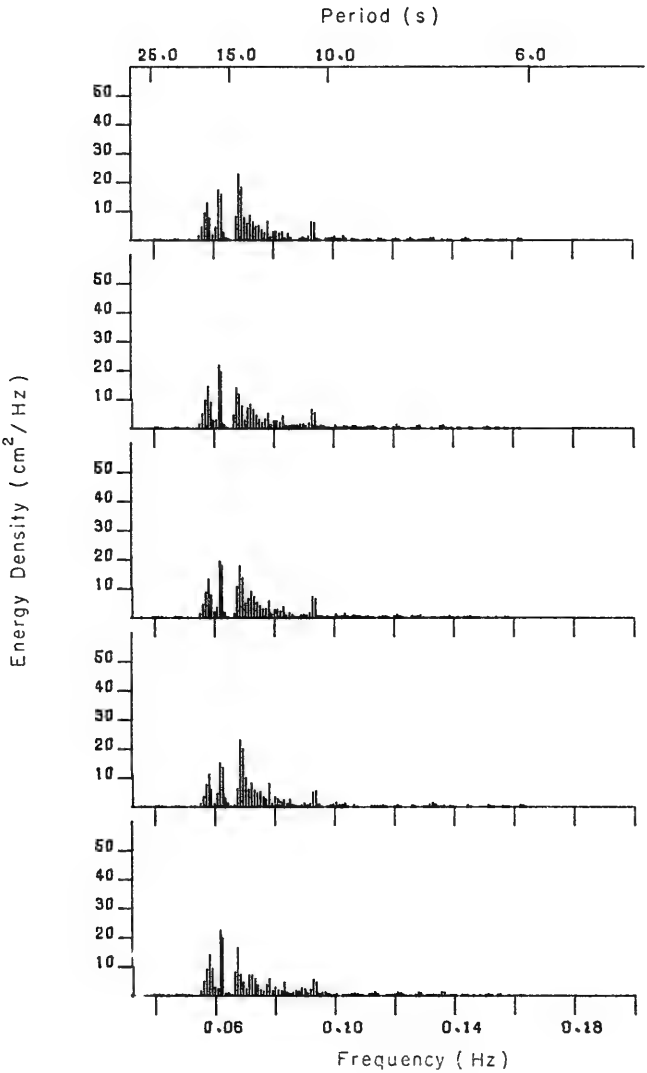


Figure E-23. Significant wave height 66.7 centimeters (2.2 feet), 25 June 1970, 1808 hours.

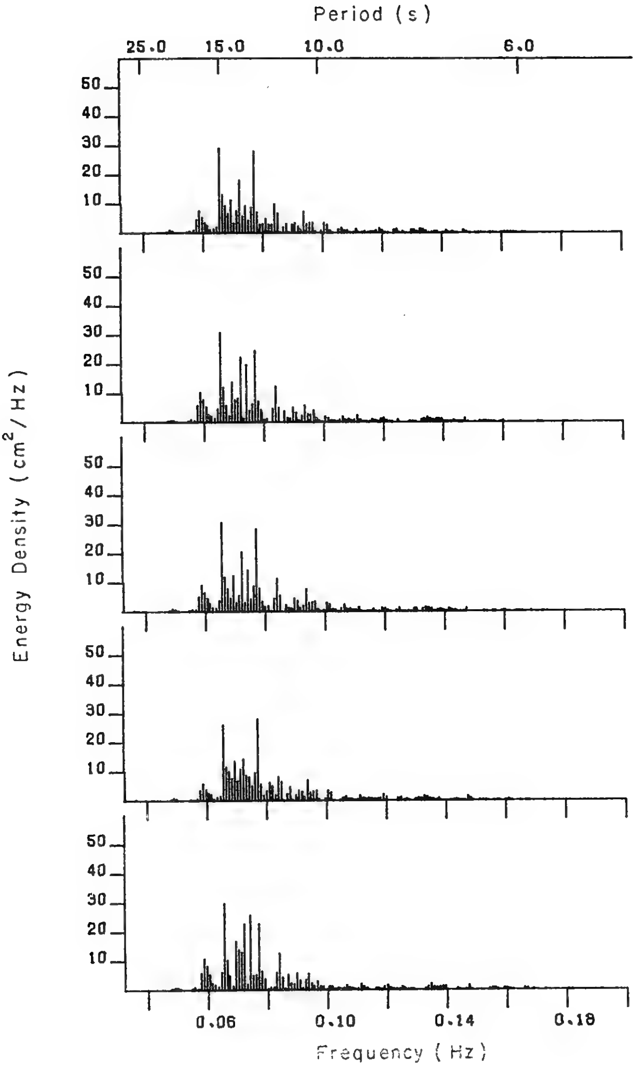


Figure E-24. Significant wave height 70.3 centimeters (2.3 feet), 25 June 1970, 2108 hours.

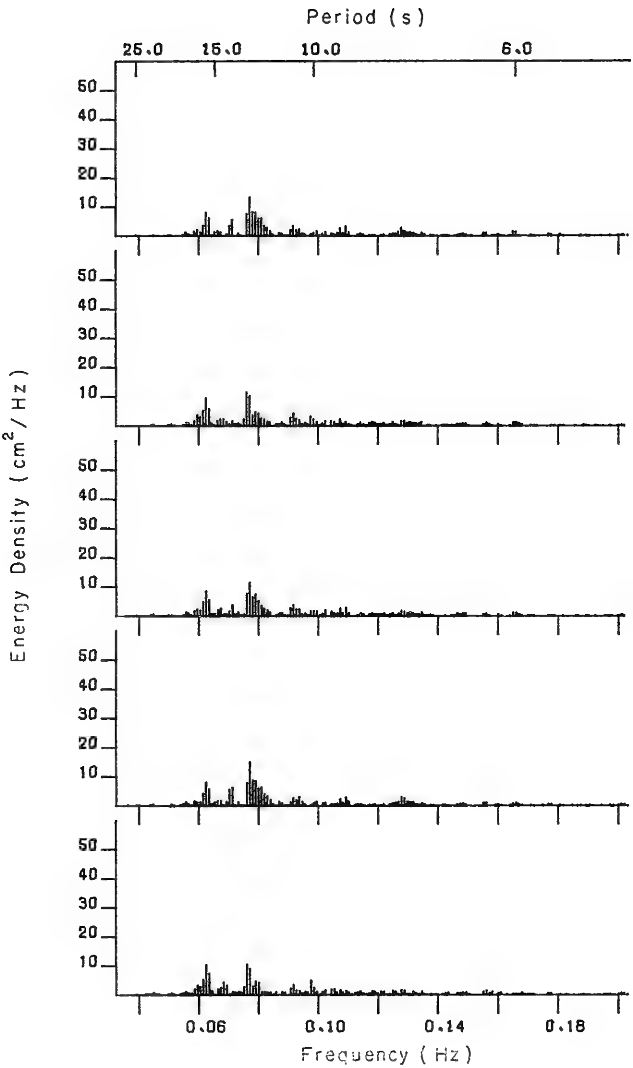


Figure E-25. Significant wave height 61.2 centimeters (2.0 feet), 26 June 1970, 1758 hours.

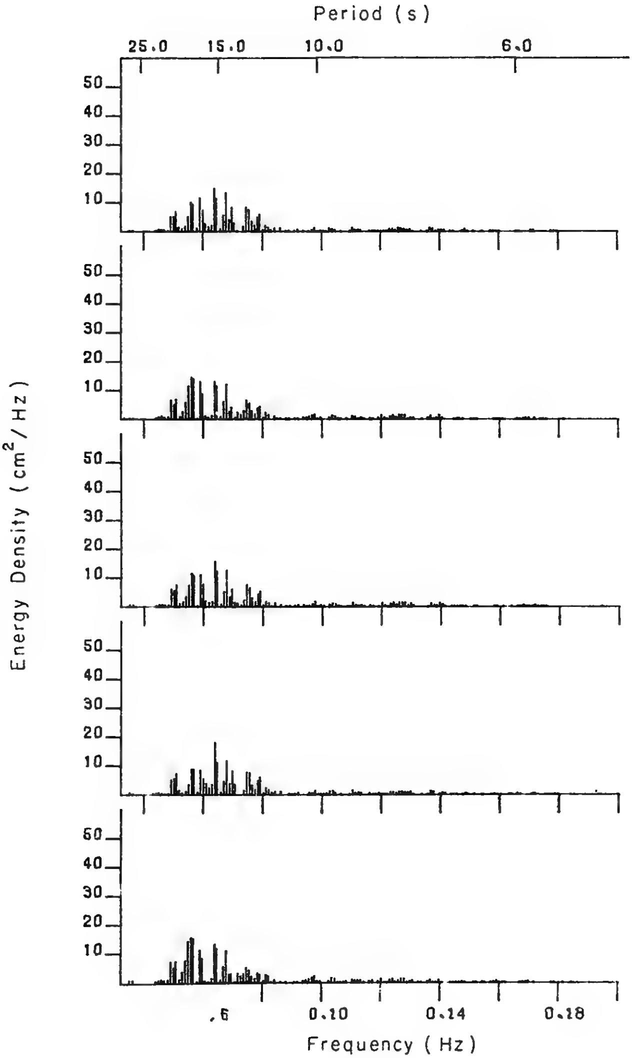
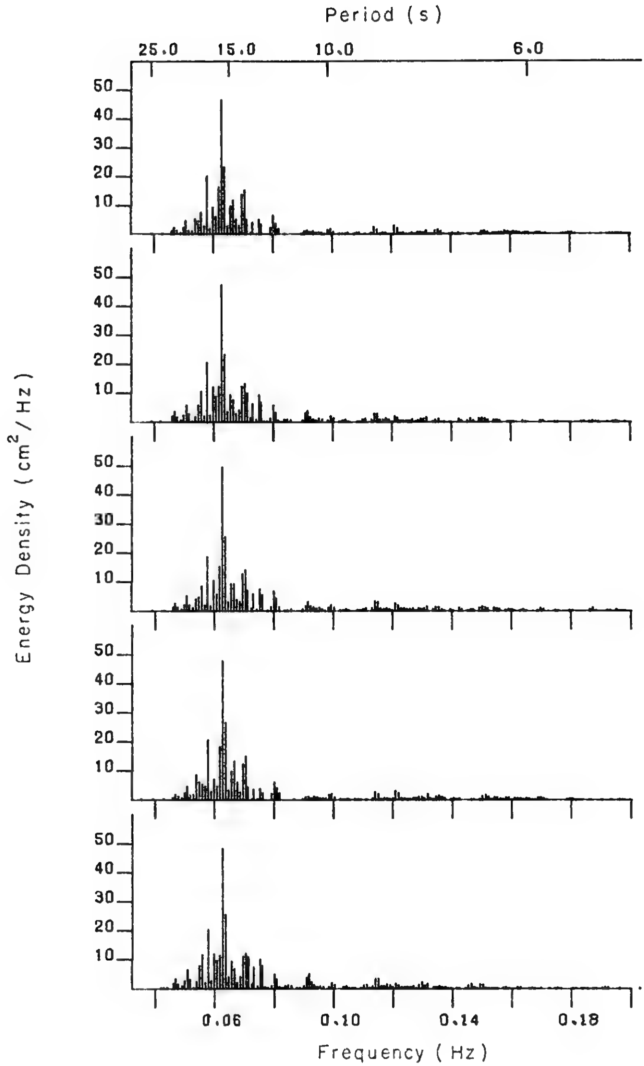


Figure E-26. Significant wave height 79.7 centimeters (2.6 feet), 26 June 1970, 2358 hours.



gure E-27. Significant wave height 92.3 centimeters (3.0 feet), 28 June 1970, 2010 hours.

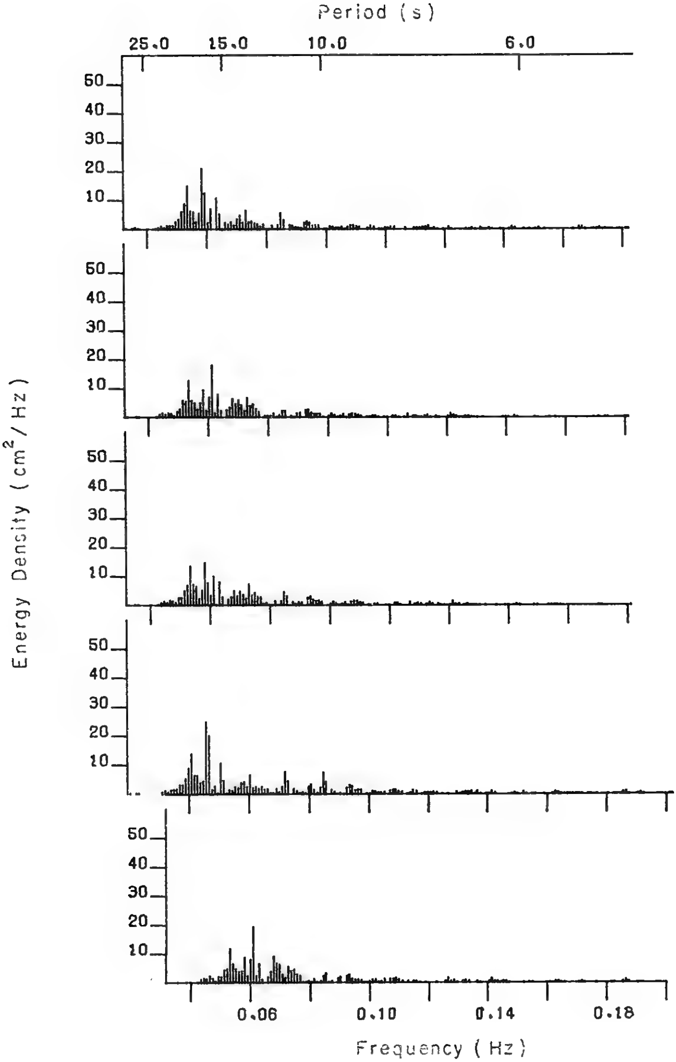


Figure E-28. Significant wave height 83.2 centimeters (2.7 feet), 28 June 1970, 2310 hours.

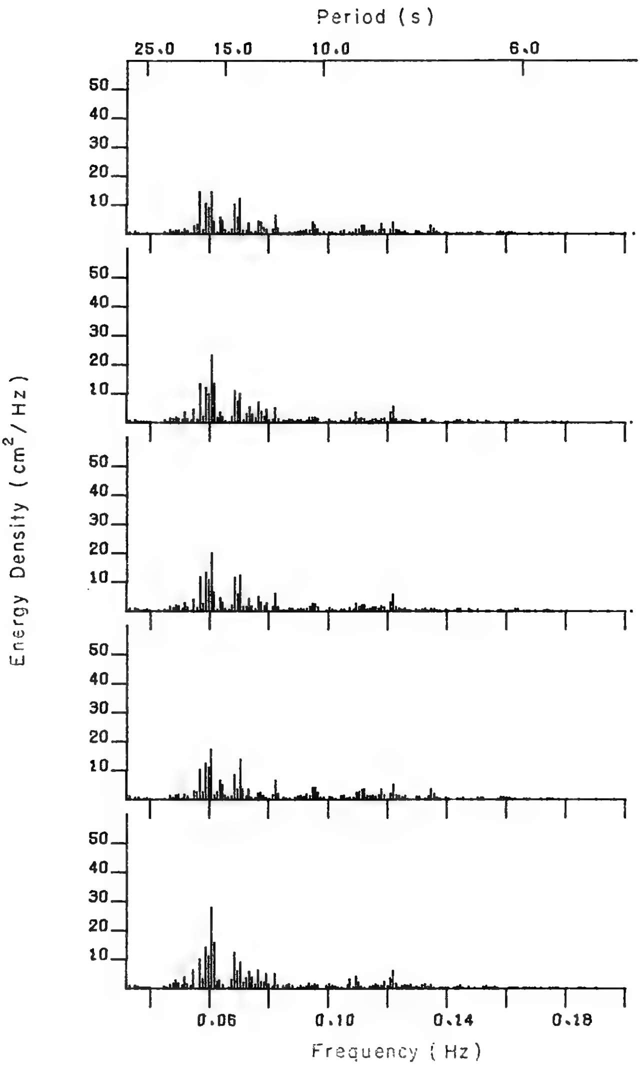


Figure E-29. Significant wave height 78.7 centimeters (2.6 feet), 29 June 1970, 0510 hours.

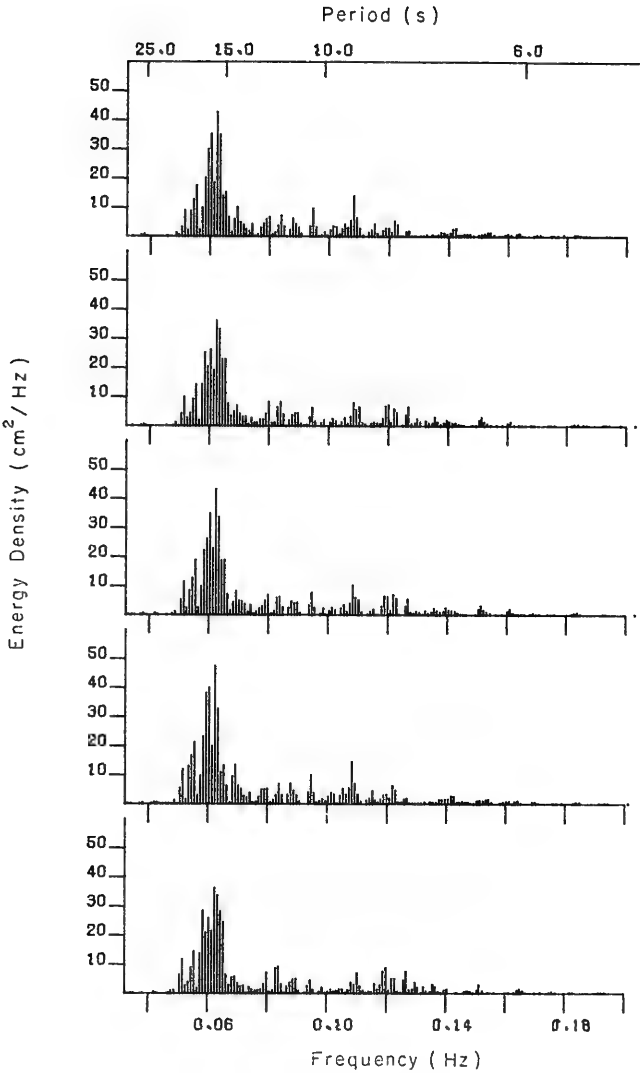


Figure E-30. Significant wave height 64.0 centimeters (2.1 feet), 16 November 1970, 1607 hours.

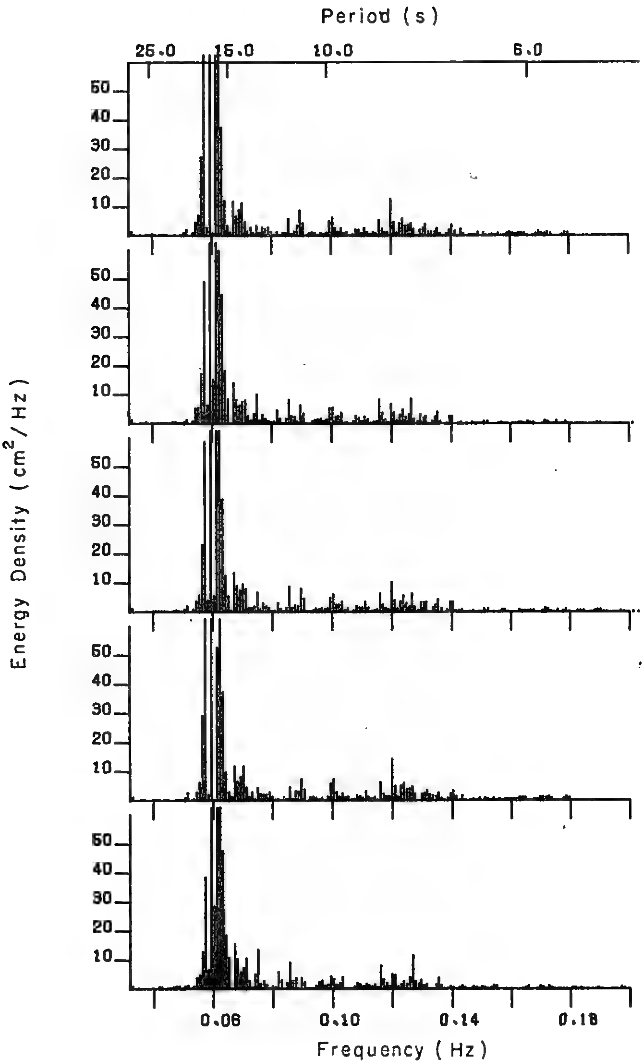


Figure E-31. Significant wave height 80.9 centimeters (2.7 feet), 16 November 1970, 1907 hours.

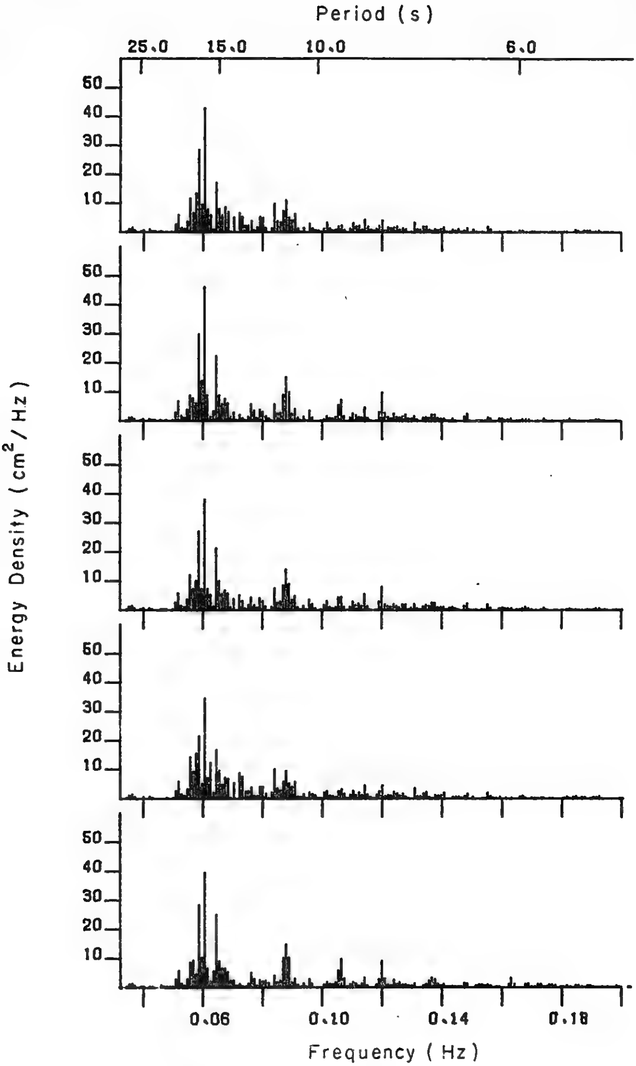


Figure E-32. Significant wave height 63.0 centimeters (2.1 feet), 17 November 1970, 0407 hours.

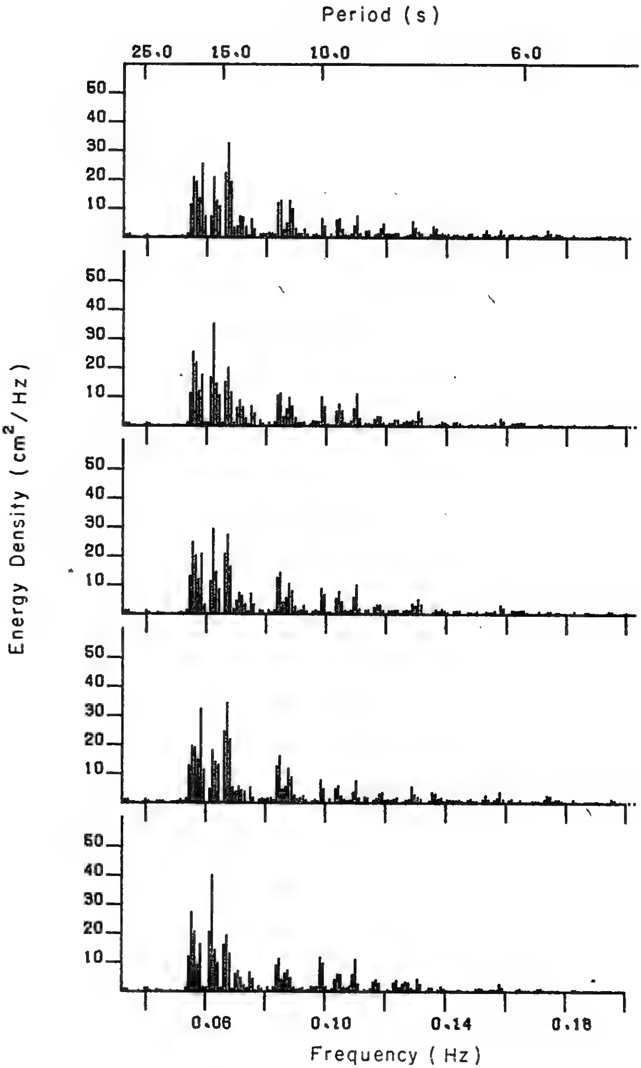


Figure E-33. Significant wave height 74.6 centimeters (2.4 feet), 16 December 1970, 1700 hours.

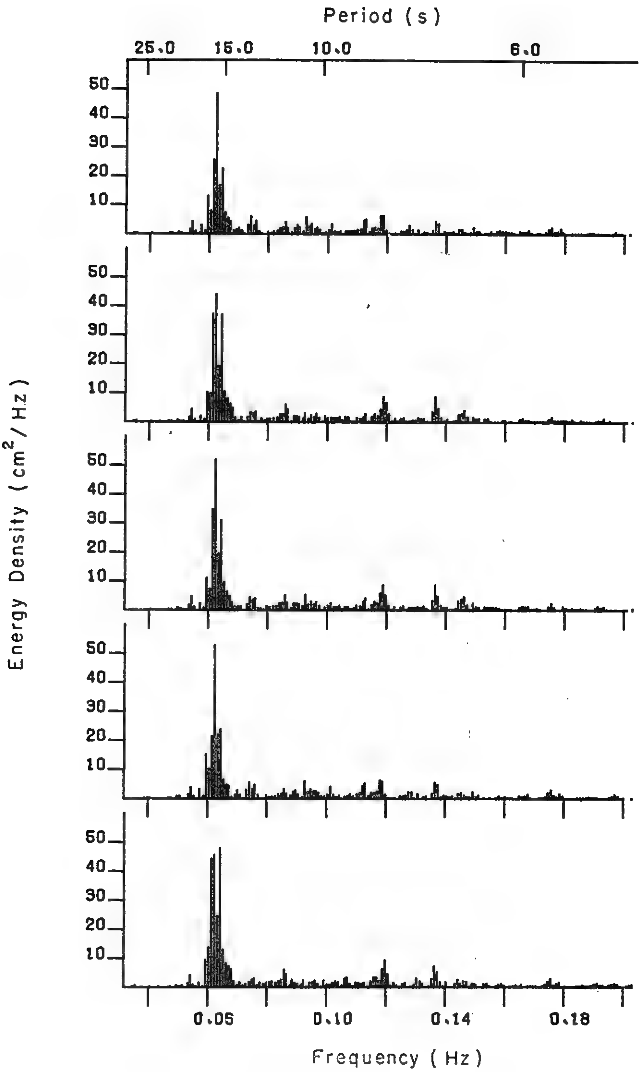


Figure E-34. Significant wave height 95.3 centimeters (3.1 feet), 16 December 1970, 2000 hours.

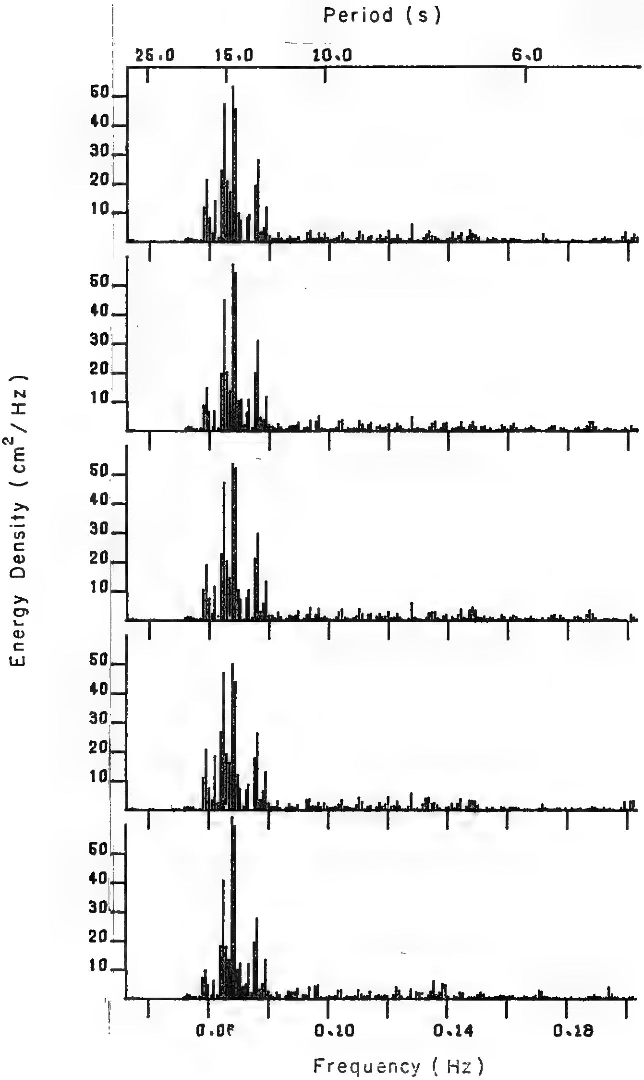


Figure E-35. Significant wave height 85.3 centimeters (2.8 feet), 16 December 1970, 2300 hours.

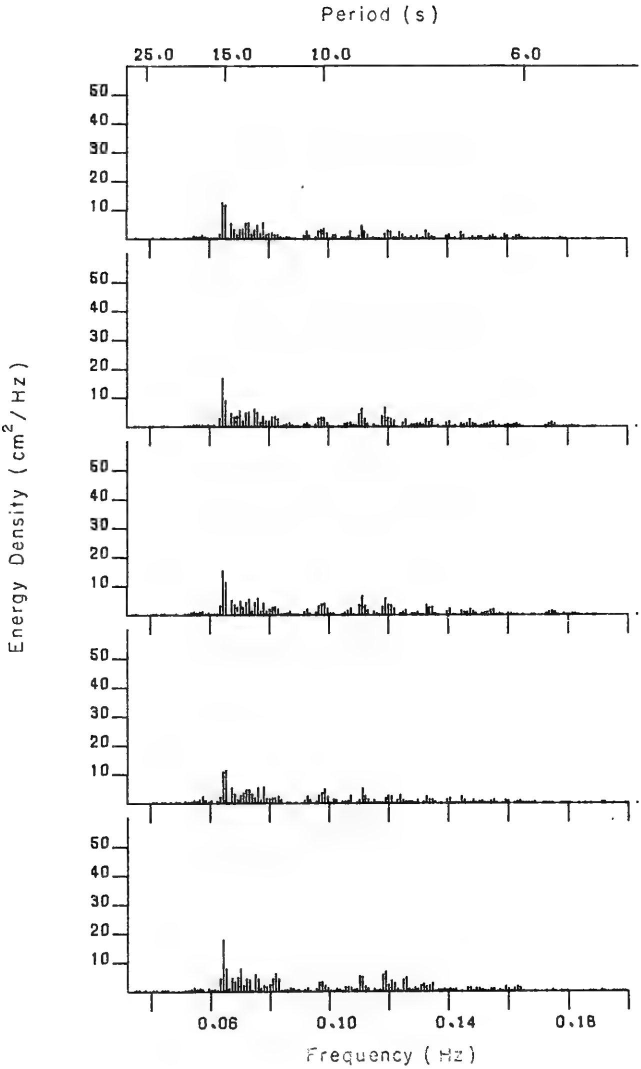


Figure E-36. Significant wave height 90.9 centimeters (3.0 feet), 17 December 1970, 0200 hours.

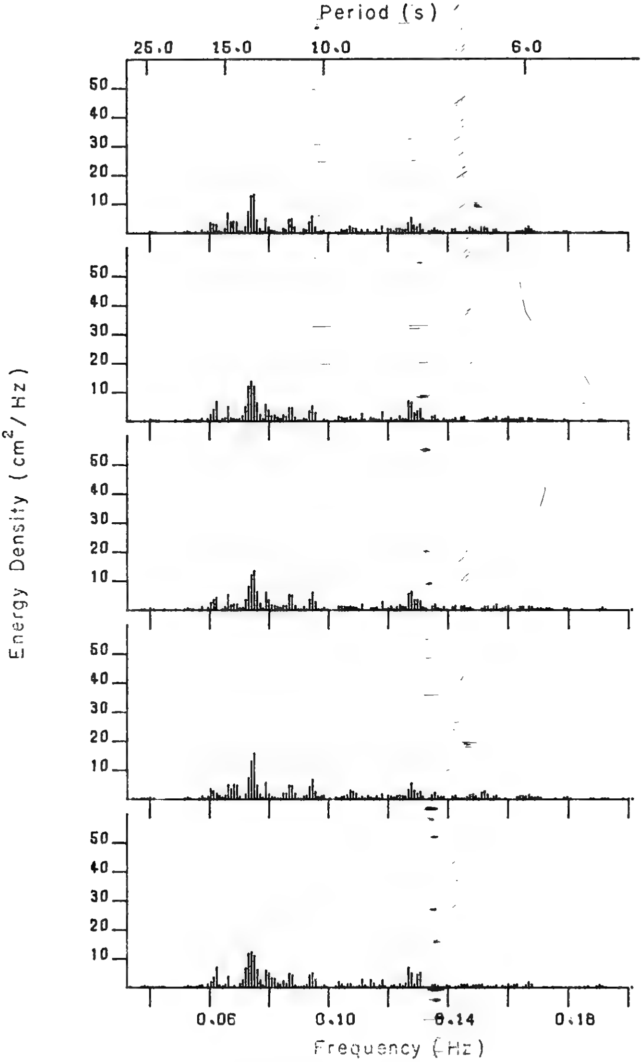


Figure E-37. Significant wave height 103.5 centimeters (3.4 feet), 17 December 1970, 0500 hours.

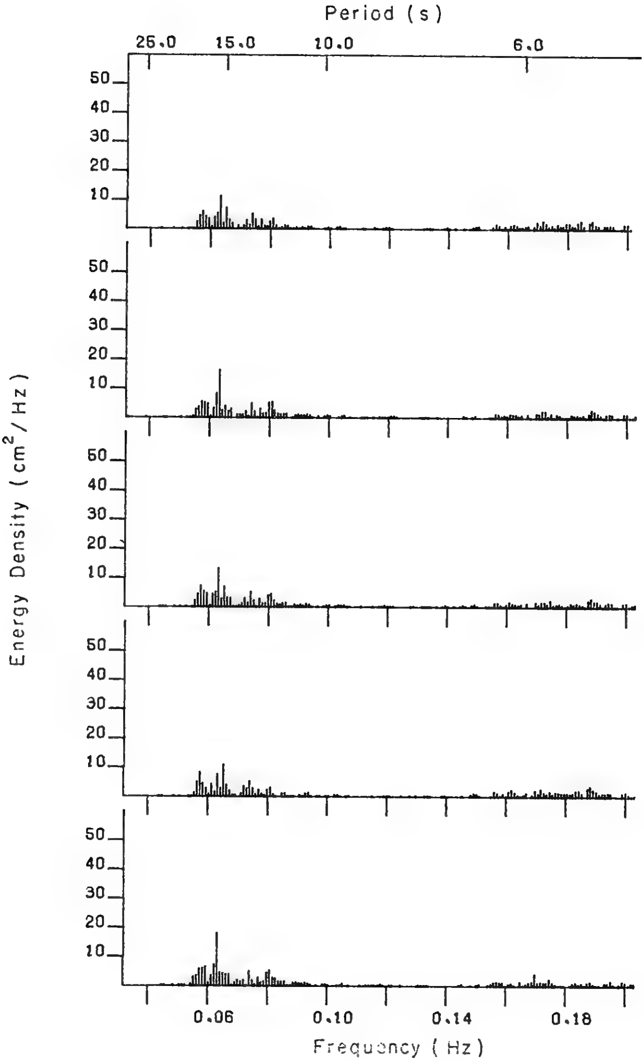


Figure E-38. Significant wave height 120.7 centimeters (4.0 feet), 17 December 1970, 0800 hours.

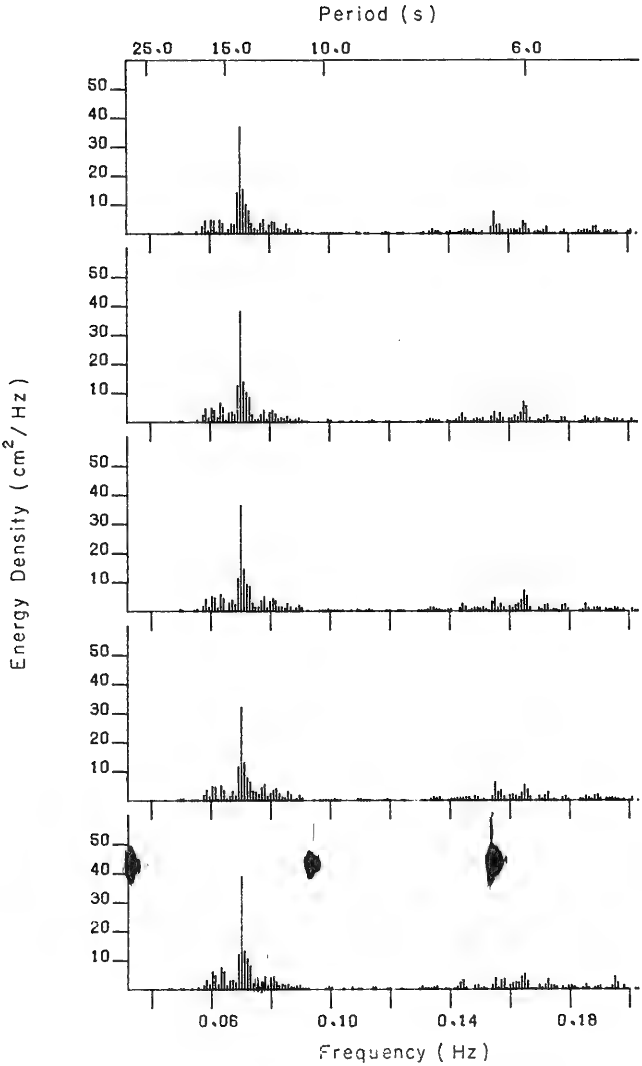


Figure E-39. Significant wave height 97.4 centimeters (3.2 feet), 17 December 1970, 1044 hours.

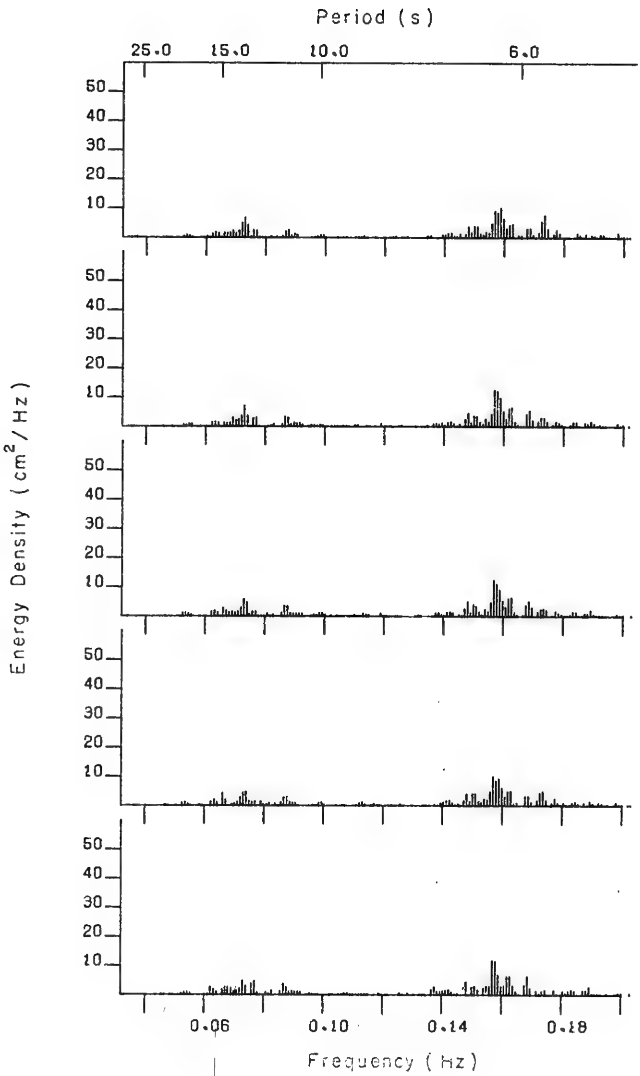


Figure E-40. Significant wave height 93.4 centimeters (3.1 feet), 17 December 1970, 1344 hours.

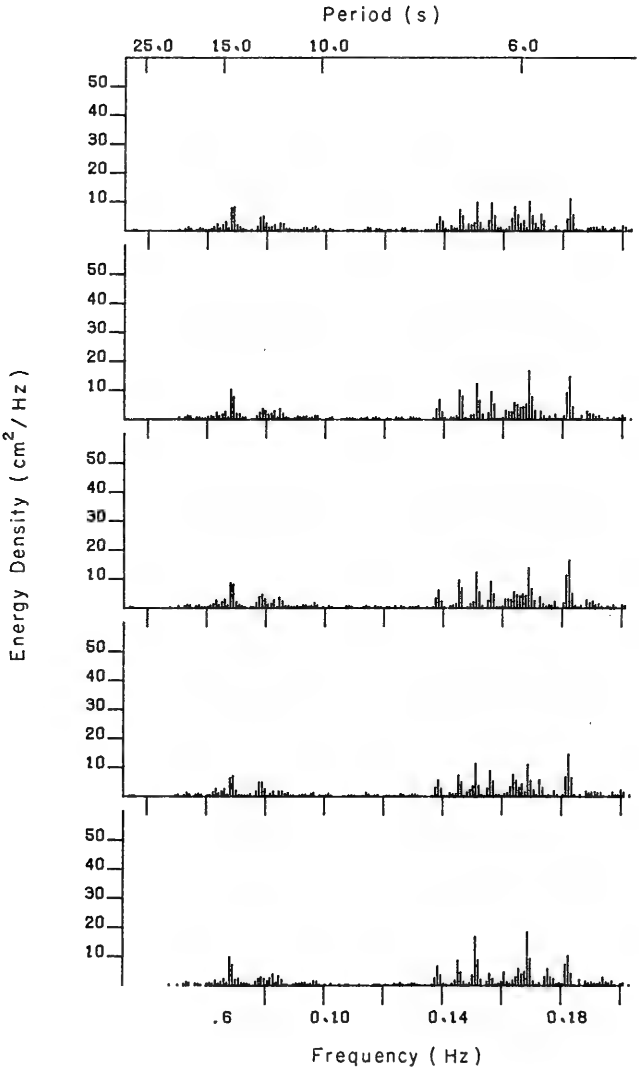


Figure E-41. Significant wave height 91.2 centimeters (3.0 feet), 17 December 1970, 1644 hours.

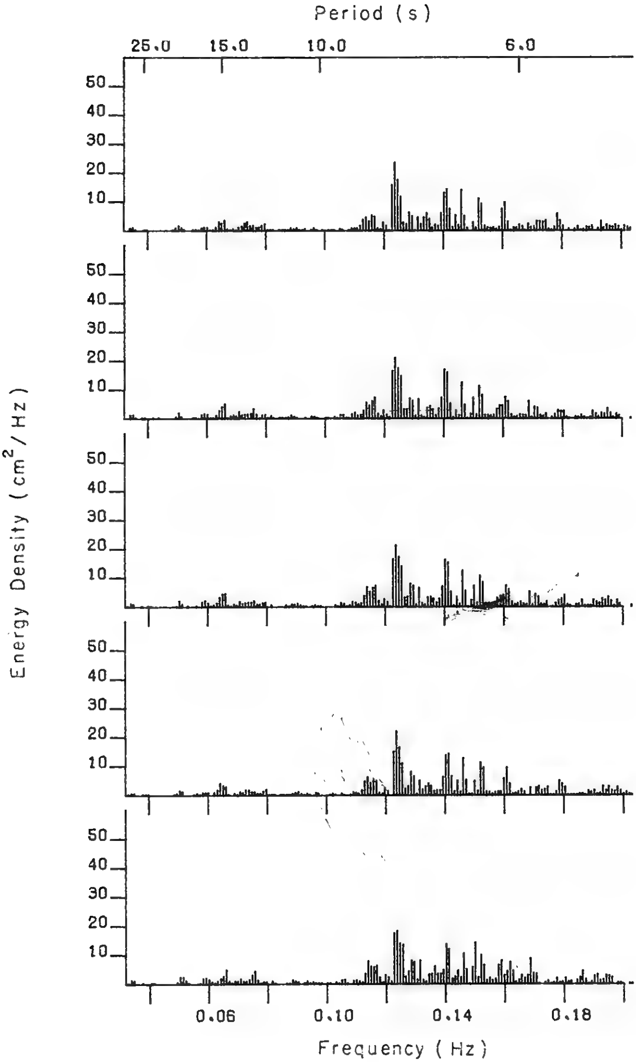


Figure E-42. Significant wave height 108.1 centimeters (3.5 feet), 17 December 1970, 1944 hours.

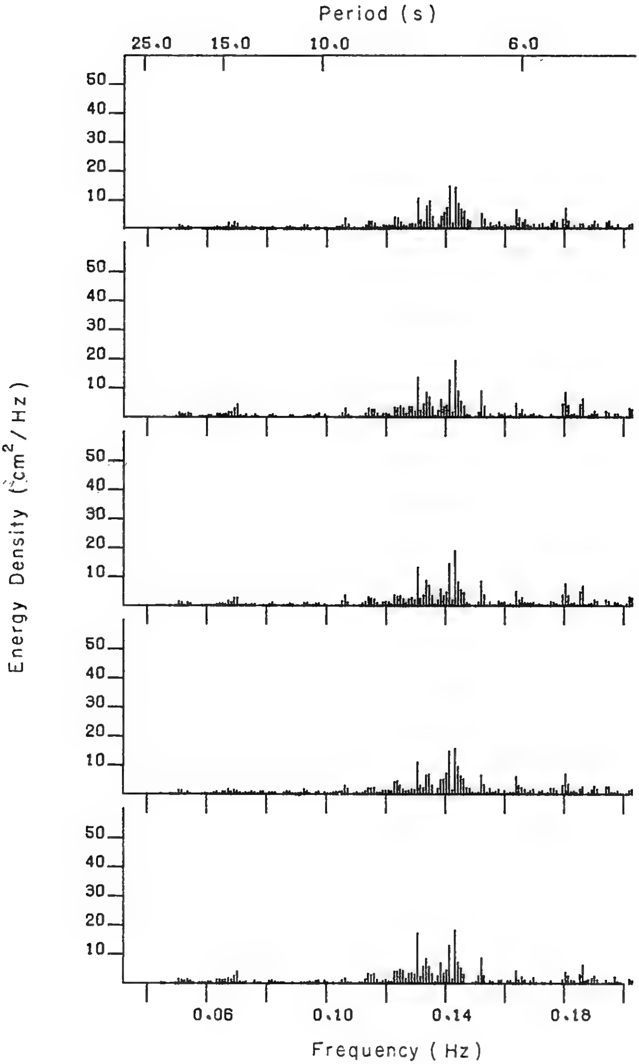


Figure E-43. Significant wave height 71.5 centimeters (2.3 feet), 18 December 1970, 0445 hours.

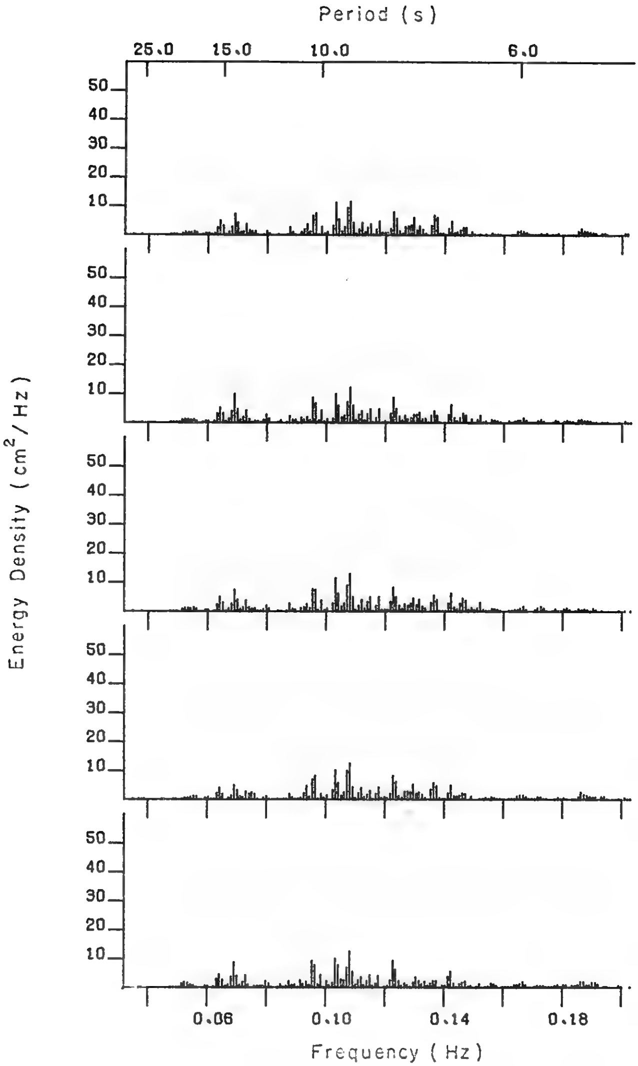


Figure E-44. Significant wave height 66.9 centimeters (2.2 feet), 18 December 1970, 0745 hours.

Esteva, Dinorah C.
Evaluation of the computation of wave direction with three-gage arrays / by Dinorah C. Esteva. – Fort Belvoir, Va. : U.S. Coastal Engineering Research Center, 1977.
123 p. : ill. (Technical paper – U.S. Coastal Engineering Research Center ; no. 77-7)
Bibliography: p. 32.
A description of the collection and analyses of data obtained with an array of five pressure sensors near Pt. Mugu, California, is presented. The 10 three-gage arrays possible with five gages are used to compare redundant values of the direction of wave propagations. The dependence of directional determination on array orientation relative to incident wave direction and wavelength at the array site is revealed by calculations based on simulated narrow-banded wave trains.
1. Waves. 2. Wavepropagation. 3. Wave direction. 4. Pt. Mugu, Calif. I. Title. II. Series: U.S. Coastal Engineering Research Center. Technical paper no. 77-7.

TC203 .U581tp no. 77-7 627

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