A FIELD STUDY OF WAVES
IN THE NEARSHORE ZONE

by

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ABSTRACT

Initial results are described of precise observations of waves shoaling in the nearshore zone. The key technique of the experiments is a 16 mm memo-motion camera system by which long term measurements of waves can be made simultaneously at many locations. Six or seven pairs of synchronized cameras were mounted on a research pier crossing the surf zone. The cameras were focused on target poles mounted on sleds which were towed about 200 m outside the breaker line, and on a line of poles jetted into the sea bottom across the surf zone. Waves transforming in the nearshore zone were observed from about 400 m offshore to the shoreline. At present only the characteristics of the statistical waves, wave height distributions, wave period distributions, and the joint distributions of wave height and period are described as part of the initial analysis.

INTRODUCTION

The authors have been carrying out extensive field studies to better understand the characteristics of waves in the nearshore zone. As a method of measuring waves, we have developed and applied a remote sensing photographic technique utilizing synchronized 16 mm memo-motion cameras to record the water surface elevation at fixed time intervals at poles installed in the nearshore zone. The basic function of this system is to take continuous synchronized pictures over a broad area of the nearshore zone. Some results with this method have been already presented (Hotta and Mizuguchi, 1980; Hotta, Mizuguchi and Isobe, 1981; Mizuguchi, 1982).

The observation time of a single camera is limited by the length of the film. Such a short length of time is insufficient for a quantitative discussion of some subjects, especially the statistical characteristics of waves. This problem was overcome by employing cameras in sets of two and running them alternately. Film changing can

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be done for the camera not in current use, enabling a continuous record without time limitation. Using this method, and poles mounted as targets on sleds, three observation of waves in the nearshore zone were conducted. Data sets long enough to discuss the statistical wave characteristics were obtained at several points from about 400 m offshore and through the breaker zone to a point near the shoreline. In the present article, only the characteristics of the wave height and period distributions and their joint distributions are described as part of the initial analysis.

2. FIELD OBSERVATION

2.1 Study site and observations

The field observation site was at Ajigaura beach facing the Pacific Ocean, and located about 200 km north of Tokyo (Fig. 1). At this beach there is a pier operated by the Public Works Research Institute, Ministry of Construction, for facilitating field studies in the nearshore zone. Observations have been carried out utilizing the pier as a platform for the 16 mm memo-motion camera system. The average tidal range at this beach is about 1.2 m and the beach slope is about 1/60 to 1/70. The beach sand size is in the range of 0.2 to 0.5 mm.

Three observations were carried out. The first was done on Sep. 2, 1980 using six pairs of 16 mm cameras and six sleds. The second and third observaions were done on Sep. 8 and 9, 1981. In the second observation, seven pairs of cameras, six sleds, and a single pole (installed by water jet and positioned near the shoreline) were used. The waves at seven locations from near the shoreline to a position about 400 m offshore were observed. In the third observation, five pairs of cameras were employed to record the shoaling deformation, and the remaining two sets of cameras were used for the observation of wave run-up in the swash zone.

The six sleds were linked together at about 50 m intervals and pulled offshore by a tug boat. The wave conditions were relatively rough and the breaking height of the larger waves was 1.8 to 2.2 m. The width of the surf zone by visual observation was about 200 m, and two or three broken waves existed in the surf zone.

Photo 1 shows the 16 mm camera system in operation on the pier for Ex810908 [The notation is: Ex (beach experiment), 81 (year), 09 (month) and 08 (day)]. Photo 2 shows the sleds before being pulled to sea. Photo 3 shows the sea condition and target poles on the sleds in Ex800902.

Figures 2 and 3 show the positions of the sleds and the beach profiles for the first and second observations, respectively. In Fig. 3, A' to E' are the positions of the sleds for the third observation. The average breaker line by visual observation was between Station C and D for Ex800902 and Ex810908. All stations were positioned seaward of the breaker line for Ex810909.

2.2 Instrumentation

The sleds on which the target poles (8 m high) were mounted are constructed of steel pipe 50 mm in diameter. The sleds are 5.5 m long, 2.4 m wide, and 0.5 m high, and weigh about 200 kgf. The cameras were mounted on the pier. Three kinds of zoom lenses were employed, 150 to 250 mm, 80 to 150 mm, and 17 to 85 mm. Each pair of cameras was equipped with the same type of lens.

The cameras were synchronized by a main control unit and connected by the same number of relay units in pairs. One camera of a set stops operation at a certain frame as directed by the main control unit, and the other camera of the set automatically begins to operate. This procedure is repeated and an observation can continue without time limitation. The sampling interval is variable between 0.1 to 10. In the present observations, a sampling interval of 0.2 s was used. The water surface variation photographed by the cameras is transferred to paper tape using a 16 mm film analyzer and an ultrasonic digitizer graph pen system. Records on the paper tapes are then transferred to magnetic tapes or disk for analysis by computer.

3. RESULTS

3.1 Effective data

Ten rolls of films per set of cameras were taken for Ex800902. Therefore 37,500 frames (7500 s) of data were completely obtained for Stations A to F. During observation Ex810908, it rained after four rolls of film were taken, and the observation had to be terminated early. We had difficulty in handling the film in the rain, and a portion of the data was lost. Effective data were 3800 s for Stations A, B, C, D and E, 3599.4 s for Station F, and 3350 s for Station G. Twelve rolls of film were taken for Ex810909. Data of 9120 s were obtained for Stations A, B, C and D. However, the sled at Station E was moved a few meters shoreward by large waves and went out of frame in the sixth roll. The camera angle was adjusted, but the sled again went out of frame in the twelfth roll. Thus a portion of the data at Station E was also lost. The effective data at Station E was 3508.4 s for the first part of the observation, and 4782 s for the latter part.

3.2 Number of waves defined by the zero-crossing method

Direct application of the zero-crossing methods creates a problem for defining waves in the nearshore zone. That is, many small amplitude short period waves are defined, especially in the surf zone. Figures 4 and 5 show the number of waves defined by the zero-up cross method for the three observations. The number of waves given from limited data were multiplied by the ratios of the total observaton time to the effective time. In Figs. 4 and 5, the number of waves defined with a minimum wave height of 4, 6, 8, 12, 16 and 20 cm are also shown. D indicates this minimum wave height (See also the number of waves defined in Table 1 and Fig. 7). A great number of small amplitude short period waves are defined both inside and outside the surf zone. It does not seem reasonabale to take into consideration such small waves. However, no firm physical criteria has yet been given for excluding small waves.

The problem of how to treat the small waves will not be discussed further here. This and some related matters were treated by Hotta and Mizuguchi (1980). In that reference, waves having a height smaller than 6 cm were ignored, based on accuracy limitations of the measurement process. We further investigated the accuracy of this type of measurement of the sea water surface elevation, and have found that a maximum error of $\pm$ 2.6 cm should be expected. Therefore, we will continue our discussion by ignoring waves lower than 6 cm. The treatment of the time interval associated with the omitted wave is also discussed by Hotta and Mizuguchi. In the present paper, the time intervals of the omitted waves were added to the trailing part of the preceding main wave, referred to as the B-method in the previously-mentioned paper.

Viewing Figs. 4 and 5, it is seen that the number of waves in the surf zone defined by the zero-crossing method is larger than the number in the offshore zone. The number of waves defined is constant in the offshore, although some difference appears at Station E in Ex810909 (attributed to missing data for that station). Therefore, the number of waves is conserved in the offshore zone. The increase in the number of waves defined in the surf zone is produced by the disturbance accompanying wave breaking.

The symbol * in Figs. 4 and 5 is the number of waves defined after applying a numerical filter which cuts waves lower than 0.04 Hz and passes waves higher than 0.05 Hz. Due to filtering, 380 data points (76 s) were cut from the beginning and end of the time series. Because the time periods of the defined waves with and without the filter are not the same, we can not compare the absolute number of waves defined. However, at Station A located near the shoreline in Ex800902 and Ex810908, the number of waves defined after applying the filter is larger than the number defined without the filter. At other stations, (more distant from the shoreline), the difference is small. This result is interpreted as follows. The wave height in the neighborhood of the shoreline is small, and anti-nodes of long period waves, such as edge waves or two-dimensional on-offshore standing waves, can exist there. The amplitudes of these long period waves rapidly decrease in the offshore direction, and the effect of the long period waves on the (ordinary) waves of period less than 20 s is small. We conclude that the long period waves will have a proportionately larger effect on the ordinary waves near the shoreline as compared to offshore.

3.3 Statistically representative waves

Values of the statistically representative waves, the wave grouping parameters, statistics of the sea water surface elevation and spectral parameters for each observation are listed in Tables 1 to 4. Table 2 gives the statistically representative waves defined without cutting the small waves for Ex800902. Table 3(a) (not filtered) shows values obtained by omitting waves lower than 6 cm and adding their time durations to the front part of the following main wave. It can be seen that the average wave heights and periods of the waves in Table 2 are much smaller than those in Table 3, due to the effect of the many small waves defined. However, the respective differences in the one-tenth and significant waves are relatively small. This indicates that the large waves in the wave distribution can be defined with little consideration of the small waves. Table 3(b) gives the statistically representative waves of Ex800902 after filtering. Concerning the mean wave, only the values for Station A were altered by use of the filter.

Table 4 gives results from Ex810900 and Ex810909. From Tables 3 and 4 it can be seen that in the surf zone, the maximum, one-tenth, and one-third waves defined by the zero-down crossing method are slightly larger than those given by the zero-up crossing method. The zero-down crossing method defines one large wave and one small wave, while the zero-up crossing method defines two waves of almost equal equal height when a wave trails a relatively smaller wave (Hotta and Mizuguchi, 1980). This kind of wave behavior is seen primarily at the breaking point and in the surf zone. This is also the reason why a bi-modal distribution of the wave height, and a double-peaked distribution in joint distribution of wave height and period, are found for waves in the surf zone.

3.4 Shoaling of the statistically representative waves

Figure 6 shows the shoaling deformation of the observed statistically representative waves. The shoaling deformation curve given by linear wave theory is also drawn. The corresponding wave height in deep water was calculated by linear wave theory using the wave period and depth at the furthermost station (Station F for Ex800902, Station G for Ex810908, and Station F for Ex810909). The shoaling coefficient was defined as the ratio of the measured (or calculated) wave height at each station to the wave height in deep water, assuming normal wave incidence. The reason why Station E for Ex810909 was not used is that the periods of the significant, the mean, and the root mean square waves differed somewhat from the respective quantities at the other stations, in spite of the fact that a constant wave period was found for the offshore zone. At present, we can not say why this happened. The one-tenth wave period at Station E for Ex810909 was almost the same as at other stations in the offshore zone.

As can be seen in Fig. 6, the prediction of linear theory agrees well with the shoaling deformation of the statistical waves in this limited distance of approximately 200 m. It is well known that the shoaling deformation given by linear wave theory does not give good agreement with the measured results regular waves in the laboratory and for individual irregular waves on field beaches offshore and in the neighborhood of the breaker line. However, the prediction by linear wave theory agrees very well with the shoaling deformation of statistical waves in the present field observation.

3.5 Wave height and period distributions

The distribution of wave height and period and the marginal distribution of wave height and period at each measuring station are shown in Figs. 7 to 11. Figure 7 shows distributions for Ex800902 including the small waves. Equi-number lines of 10, 30 and 50 waves are drawn respectively with dotted, broken, and solid lines. Figure 7 shows the process of change of the distribution. Figure 8 shows the distributions for Ex800902 omitting waves lower than 6 cm, and applying the filter. Figures 9, 10, and 11 show the distributions for Ex800902, Ex810908 and Ex810909 omitting waves smaller than 6 cm. The distributions in Figs. 8, 9, 10 and 11 are normalized by the mean wave height and the mean wave period for 1000 waves. Equi-probability density lines of 0.1, 0.5 and 1.0 are drawn with dotted, broken, and solid lines, respectively. The interval of $(H/\bar{H})$ and $(T/\bar{T})$ is 0.2. A probability density of unity requires 40 waves.

From these figures, the following may be pointed out:

1. There is a strong correlation between wave height and period for the waves lower than the mean wave.

2. The marginal distributions of the wave height and period becomes bi-modal, and the joint distribution exhibits two maxima in the neighborhood of the breaking point. This tendency is particularly strong if waves are defined by the zero-down crossing method. The marginal distributions of wave height and period in the offshore approach a distribution similar to the Rayleigh distribution, but one which has a peak on the smaller side of the mean.

3. The range of wave height distribution is broad at the offshore side of the breaking point, whereas the range of wave period distribution is broad in the surf zone. These phenomena can be interpreted from the shoaling and breaking deformation of waves. That is, with approach to the breaking point, the waves increase in height and broaden the range of the distribution. After breaking, the disturbance accompanying the wave breaking generates many secondary waves having small periods, and the range of the period distribution thus broadens.

4. The linear correlation coefficients between individual wave heights and periods for the surf zone are smaller than those at the seaward of the breaking point.

5. From Figs. 8 and 9, it is seen that the long period waves have little influence on the joint distributions.

4. COMMENTS ON THE MEASUREMENT SYSTEM

The photographic technique as described here has the distinguishing merit that the sea water surface elevation can be sampled directly and at closely spaced points over a long observation of time. Also, because the method is direct, the data can be easily reviewed and checked. However, the method has the disadvantage that it takes a great deal of time and much labor to transfer the sea surface elevation from the film to a form suitable for calculation. From the viewpoint of data handling, the 16 mm camera should be replaced by video television in the future. But at the present time, film gives higher resolution than video TV. We would like to suggest to researchers who intend to apply similar methods that a heavier sled than our sled be used to avoid movement as happened in Ex810909.

ACKNOWLEDGEMENTS

The field observations discussed in this paper were carried out under the supervision of Professor K. Horikawa, Department of Civil Engineering, University of Tokyo. The authors would like to thank him for his considerable assistance and advice. We appreciate the permission of the Public Works Institute, Ministry of Construction for use of the pier. We would also like to express our appreciation to our university students who supported the field work. Without their help we could not have carried out these field observations. We would also like to thank Dr. N. C. Kraus and Miss T. Kohno of the Nearshore Environment Research Center for proofreading and typing of the manuscript.

REFERENCES

Ezraty, R., Laurent, M., and Arhan, M.: Comparison with observation at sea of period or height dependent sea state parameters from a theoretical model, OTC 2744, 9th Offshore Tech. Conf., 1977.

Goda, Y.: The observed joint distribution of periods and heights of sea waves, Proc. 16th ICCE, Vol. 1, 1978, pp. 227-246.

Hotta, S. and M Mizuguchi: A field study of waves in the surf zone, Coastal Eng. in Japan, Vol. 23, JSCE, 1980. pp. 59-79.

Hotta, S., M. Mizuguchi and M. Isobe: Observations of long period waves in the nearshore zone, Coastal Eng. in Japan, Vol. 24, JSCE, 1981, pp. 41-76.

Mizuguchi, M.: Individual wave analysis of irregular wave deformation in the nearshore zone, Proc. 19th Coastal Eng. Conf. (in press), 1982.

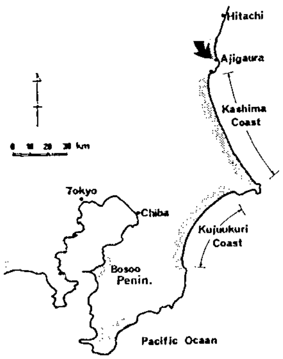


Fig. 1 Location map of the field observation site.

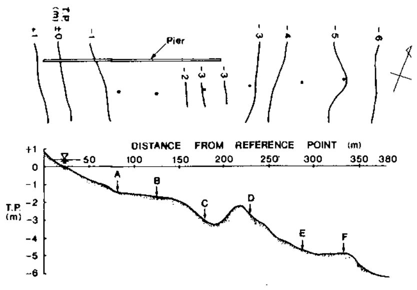


Fig. 2 Beach profile and positions of sleds for Ex800902.

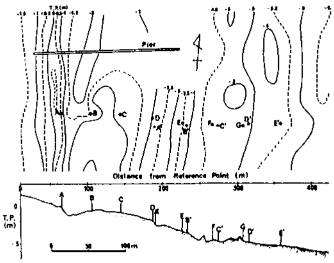


Fig. 3 Beach profile and positions of sleds for Ex810908 and Ex810909.

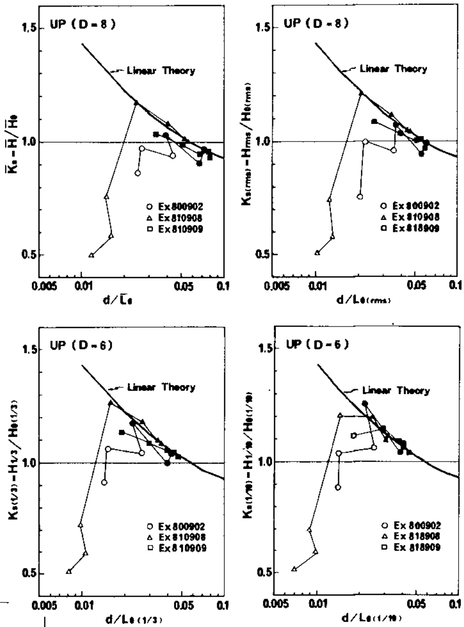


Fig. 6 Shoaling deformation of statistically representative waves.

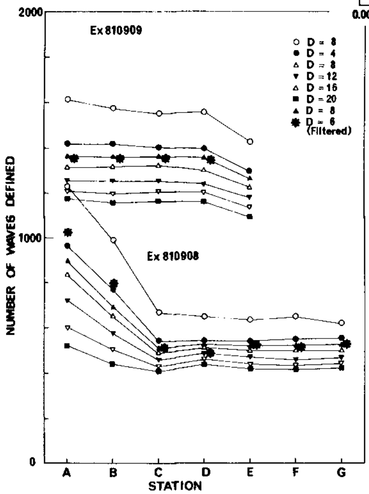


Fig. 5 Number of defined waves obtained by imposing a minimum wave height (D) for Ex810908 and Ex810909.

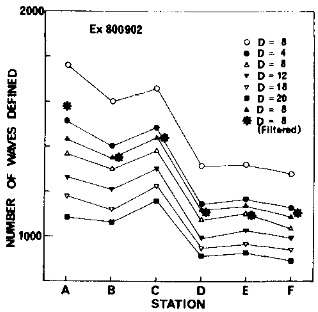
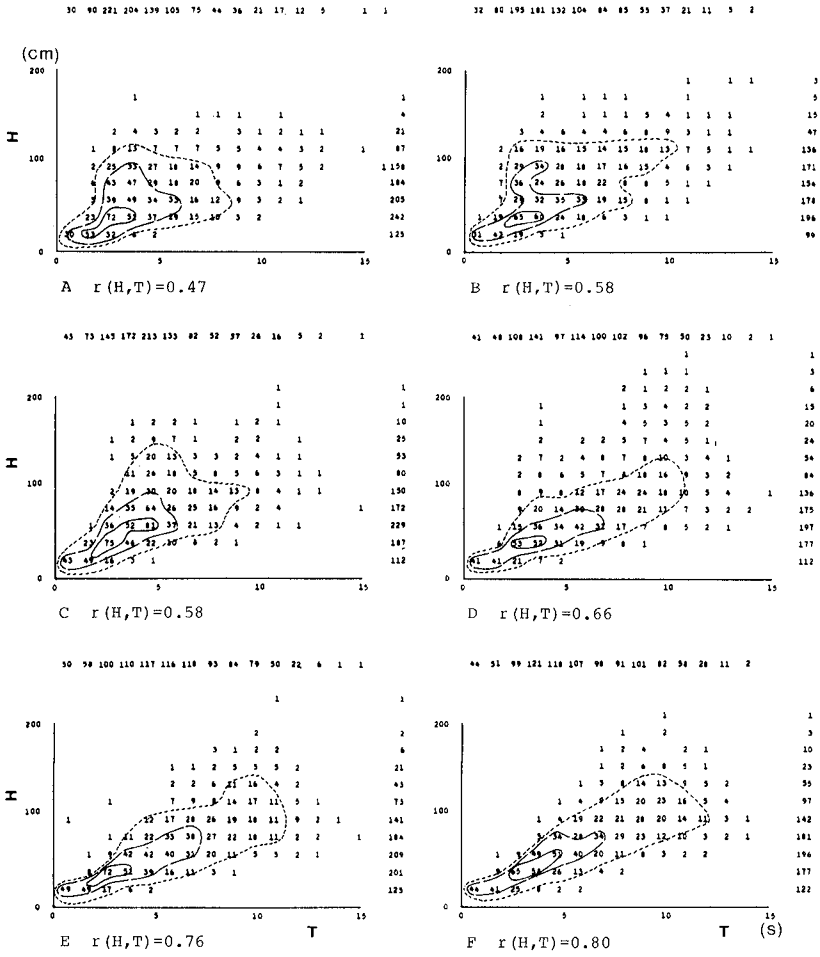
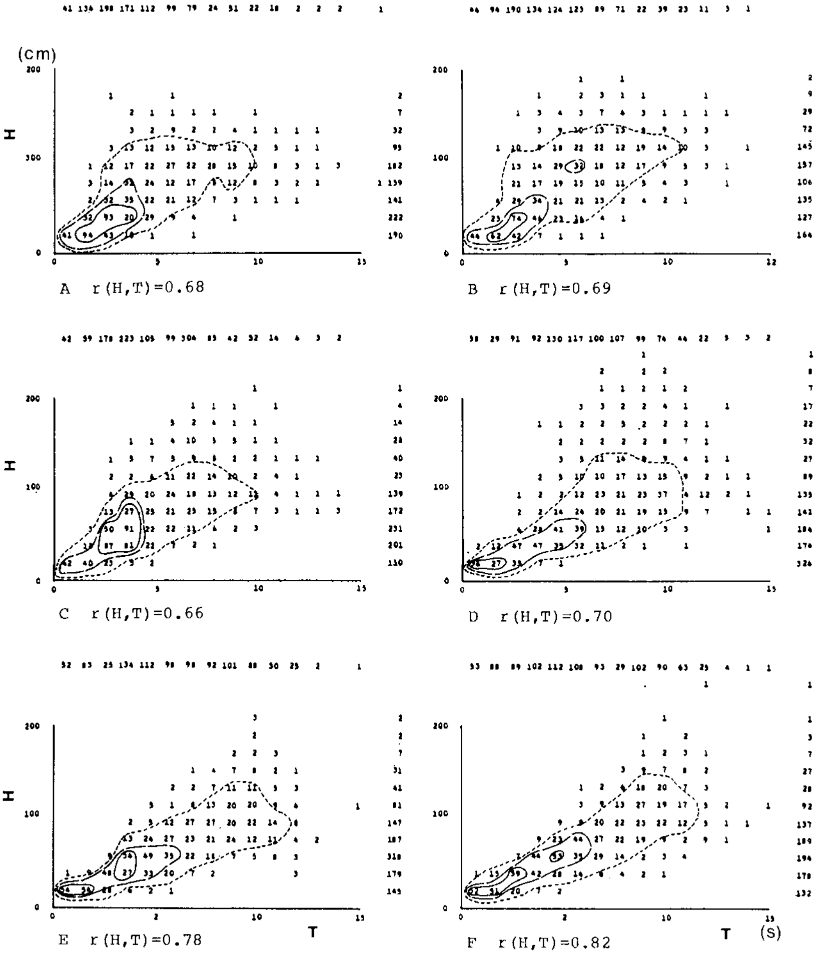


Fig. 4 Number of defined waves obtained by imposing a minimum wave height (D) for Ex800902.



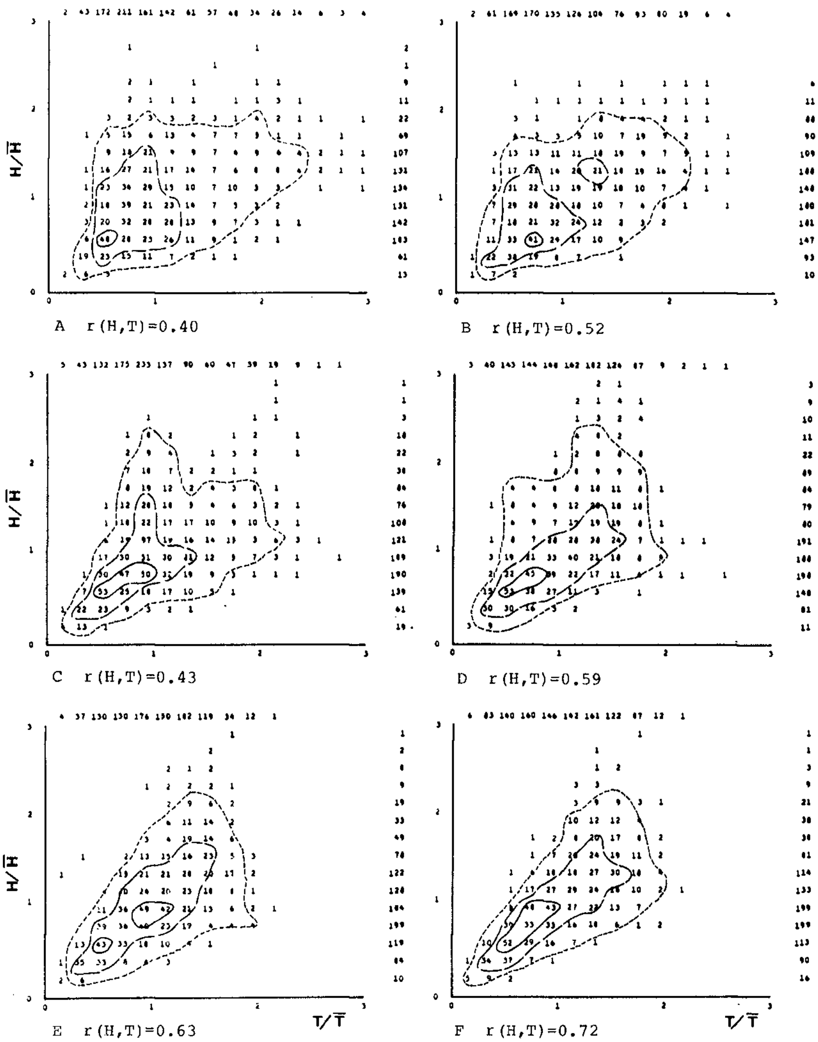
Ex800902 UP-CROSS RAW DATA D=0

Fig. 7 Joint distribution for Ex800902 including small waves.



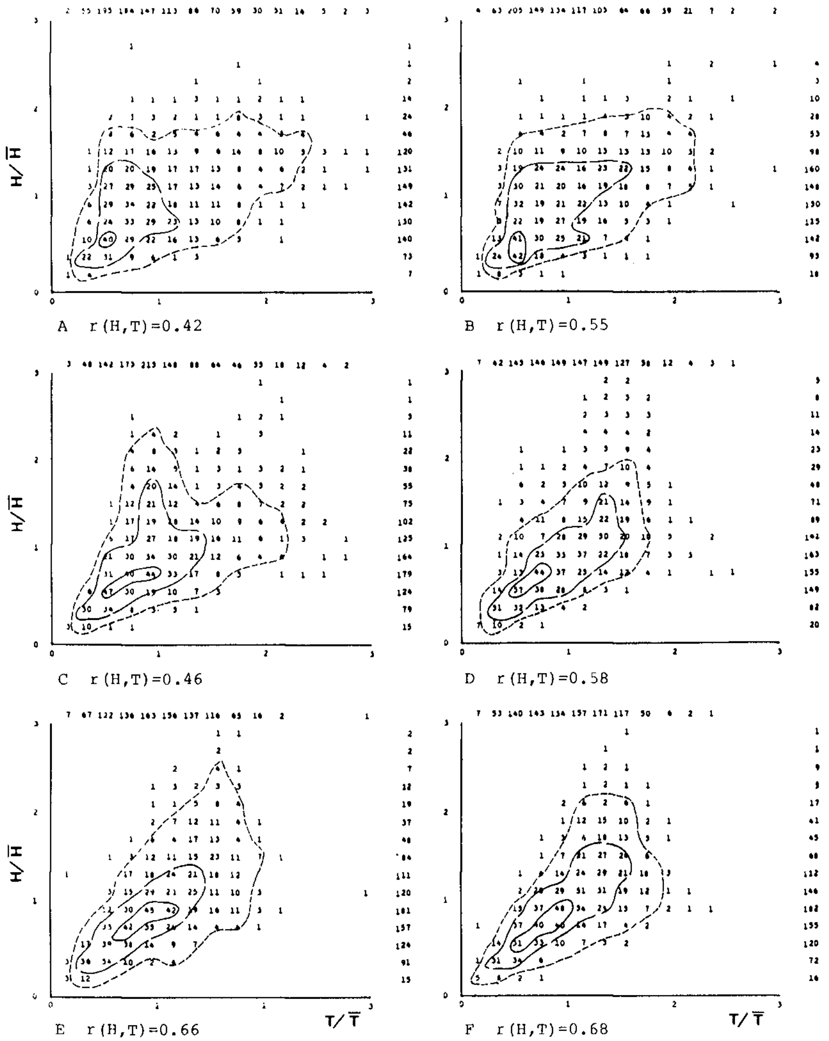
Ex800902 DOWN-CROSS RAW DATA D=0

Fig. 7 Joint distribution for Ex800902 including small waves.



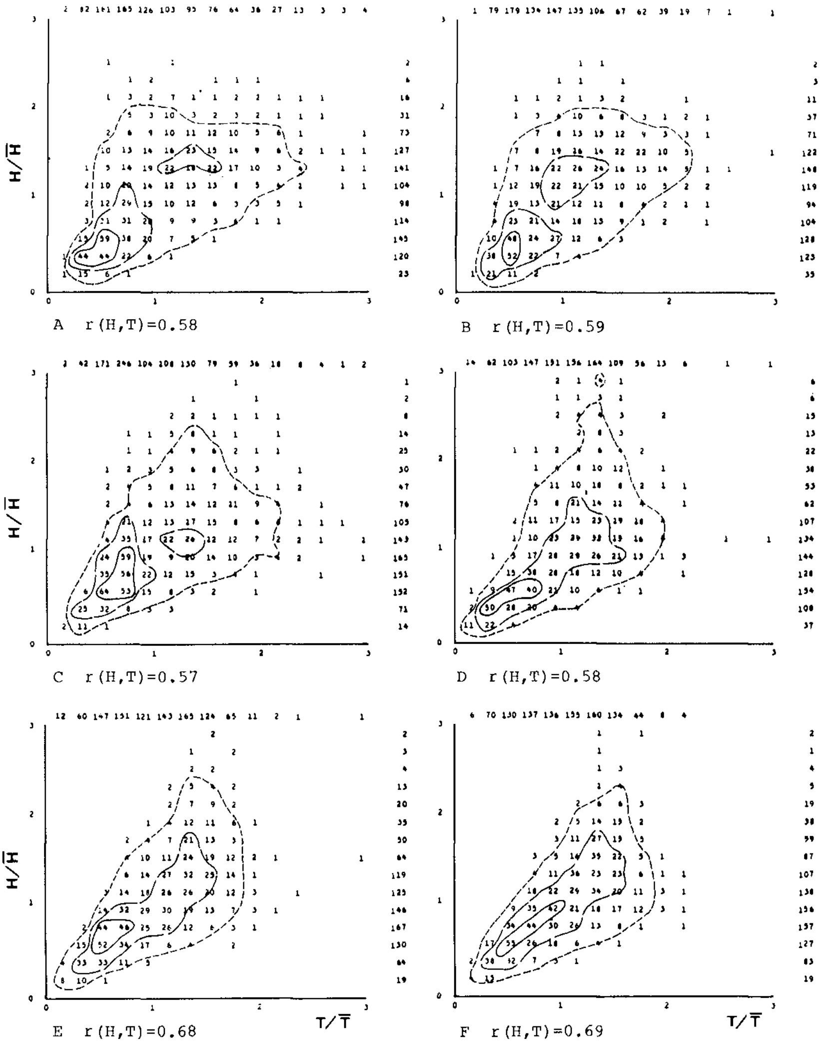
Ex800902 UP-CROSS FILTERED D=6

Fig. 8 Normalized joint distribution after filtering for Ex800902.



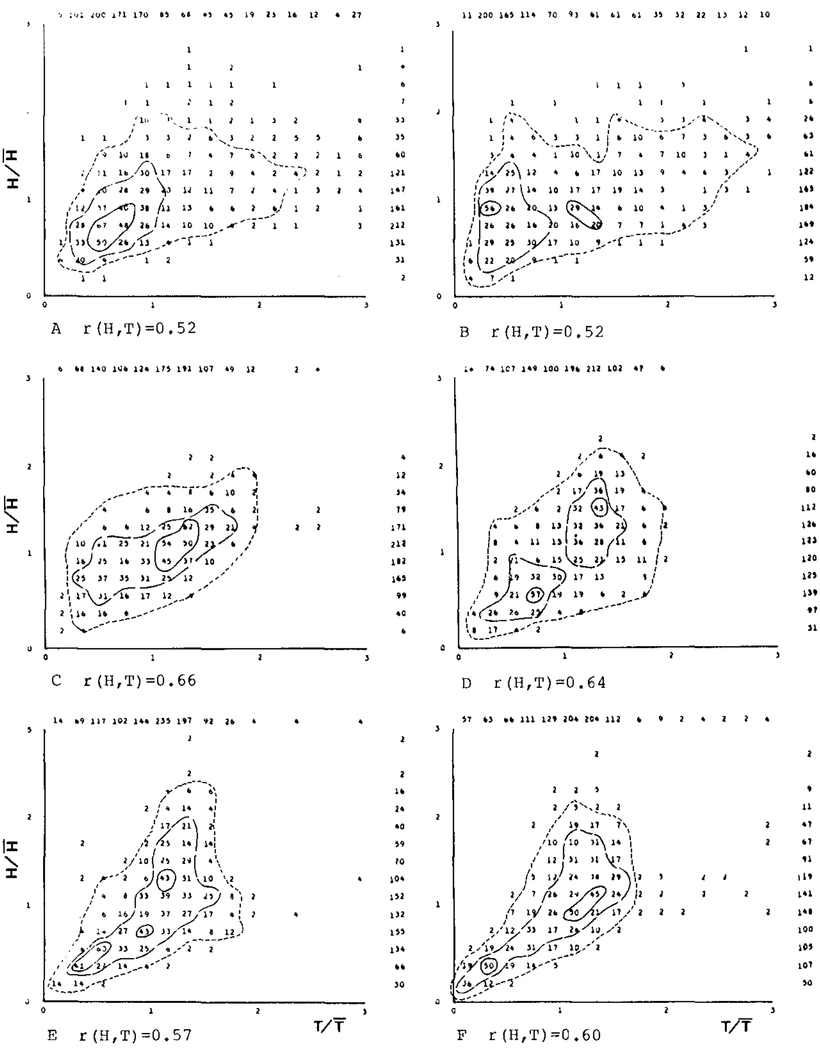
Ex800902 UP-CROSS D=6

Fig. 9 Normalized joint distribution for Ex800902.



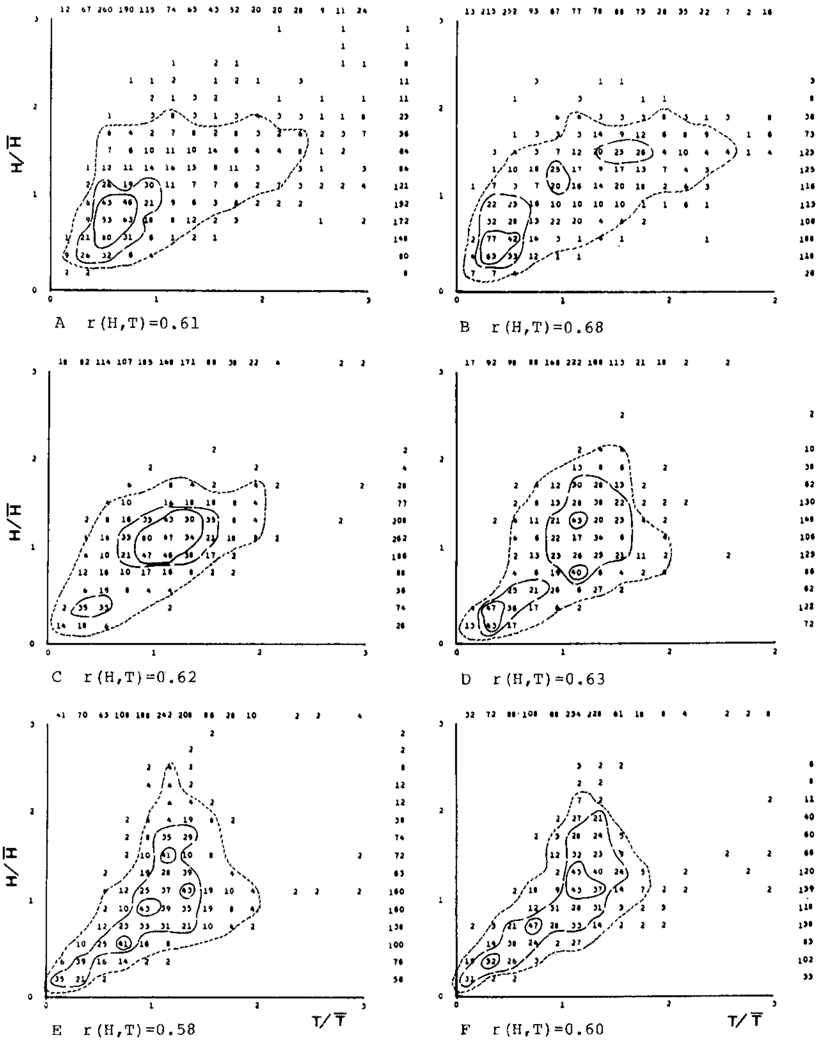
Ex800902 DOWN-CROSS D=6

Fig. 9 Normalized joint distribution for Ex800902.



Ex810908 UP-CROSS D=6

Fig. 10 Normalized joint distribution for Ex810908.



Ex810908 DOWN-CROSS D=6

Fig. 10 Normalized joint distribution for Ex810908.

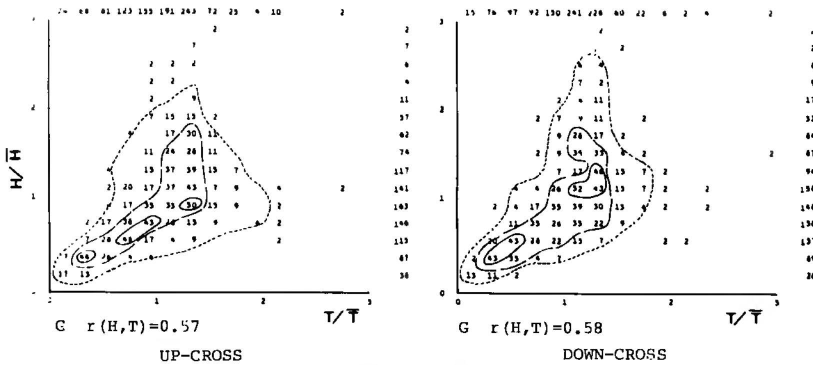


Fig. 10 Normalized joint distribution for Ex810908.

Photo 1 16 mm camera system in operation on pier for Ex810909.

Photo 2 Sleds prior to being pulled out.

Photo 3 Sea condition and target poles.

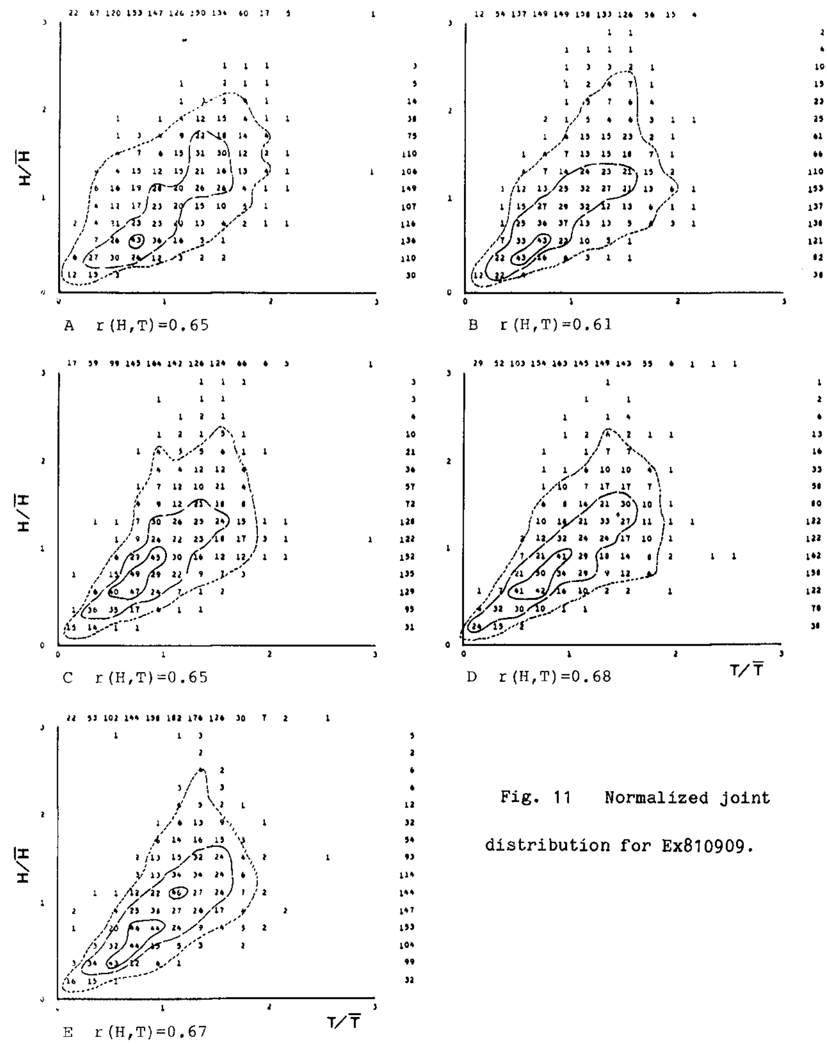


Fig. 11 Normalized joint distribution for Ex810909.

Ex810909 UP-CROSS D=6

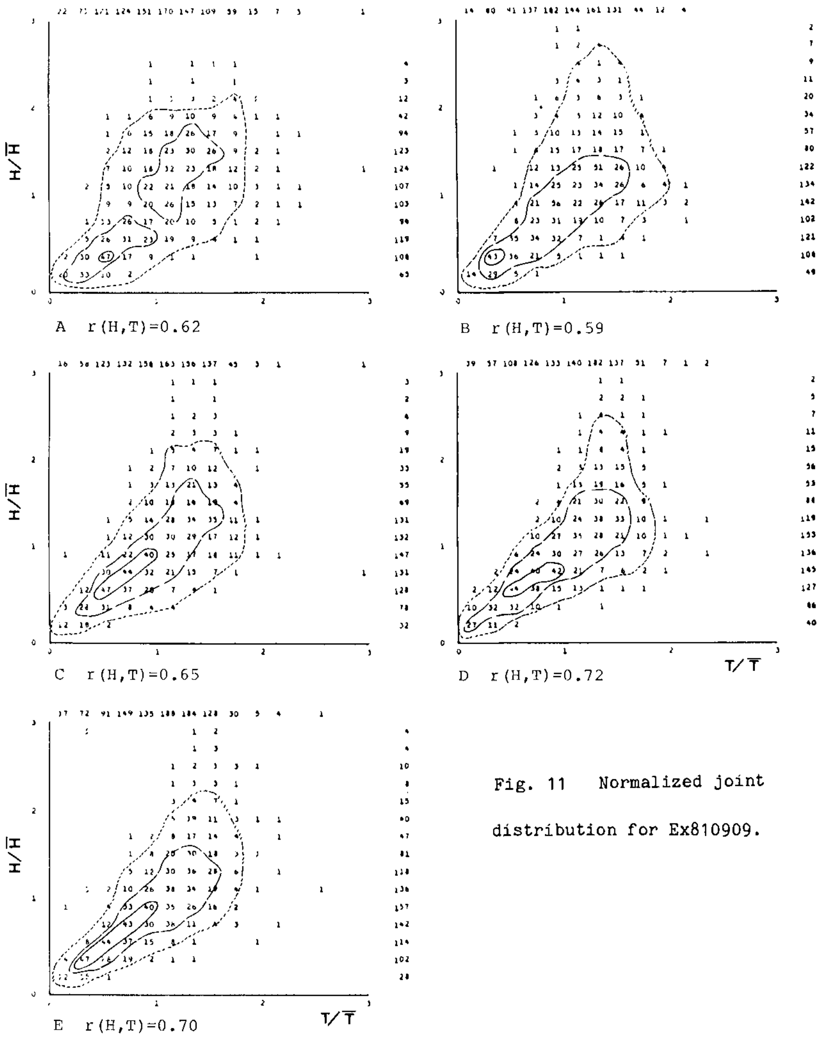


Fig. 11 Normalized joint distribution for Ex810909.

Ex810909 DOWN-CROSS D=6

	EX800902 (0=0)											
	DOWN						UP					
	A	B	C	D	E	F	A	B	C	D	E	F
d	1.81	1.84	3.22	2.79	4.93	5.14	1.81	1.84	3.22	2.79	4.93	5.14
N	1737	1597	1657	1308	1319	1282	1738	1597	1657	1308	1318	1283
H max	166	189	217	243	217	242	173	186	208	241	228	208
T max	2.94	7.51	9.29	8.21	9.56	12.0	3.17	12.5	10.3	10.2	10.8	9.40
H 1/10	119	137	140	167	135	139	112	131	138	160	135	138
T 1/10	6.53	6.89	6.74	8.18	8.89	9.20	6.11	7.25	5.89	8.35	8.93	9.05
H 1/3	98	114	107	123	105	109	92	108	107	119	104	108
T 1/3	6.36	6.73	6.37	8.04	8.34	8.65	5.50	6.22	5.95	7.88	8.12	8.63
$\bar{H}$	56	65	64	69	61	64	56	65	64	69	61	64
$\bar{T}$	4.31	4.69	4.52	5.73	5.68	5.84	4.31	4.68	4.52	5.73	5.68	5.84
H rms	66	78	74	84	72	75	64	75	74	82	72	74
T rms	5.02	5.37	5.11	6.47	6.43	6.57	4.94	5.34	5.05	6.43	6.39	6.55
r(H,T)	0.68	0.69	0.66	0.70	0.78	0.82	0.47	0.58	0.58	0.66	0.76	0.80
r(H)	-.13	-.14	0.02	0.11	0.25	0.30	0.01	0.00	0.08	0.26	0.29	0.32
r(T)	-.04	-.04	-.05	0.13	0.22	0.24	0.05	0.01	0.05	0.21	0.24	0.28
WG 1/3	217	198	201	131	116	119	205	178	199	121	117	120
$\bar{J}$ 1/3	1.14	1.11	1.13	1.30	1.47	1.48	1.19	1.20	1.14	1.36	1.45	1.49
$\bar{T}$ 1/3	7.95	8.06	8.24	10.0	11.3	10.8	8.47	8.97	8.32	10.9	11.3	10.8
WG a	511	464	421	314	292	265	480	430	407	279	285	248
$\bar{J}$ a	1.58	1.66	1.75	1.88	2.03	2.25	1.72	1.83	1.80	2.04	2.12	2.31
$\bar{T}$ a	3.40	3.44	3.94	4.17	4.51	4.84	3.62	3.71	4.08	4.69	4.62	5.19

Table 2 Statistically representative waves for Ex800902 including small waves.

	Ex810908						
	A	B	C	D	E	F	G
σ	18	19	22	36	34	35	35
$\sqrt{\beta_1}$	0.72	1.02	0.95	1.37	0.98	0.68	0.89
β_2	4.08	4.43	4.06	5.14	4.45	3.55	4.34
$\overline{\eta^2}$	319	344	462	1305	1160	1228	1215
η	40	11	18	-2	-11	-30	-6
ε	0.95	0.95	0.96	0.97	0.98	0.99	0.99
ν	1.22	1.17	1.16	1.00	0.96	1.22	1.08

	Ex800902						Ex810909				
	A	B	C	D	E	F	A	B	C	D	E
σ	23	27	28	30	28	30	41	40	40	43	46
$\sqrt{\beta_1}$	1.26	1.25	0.93	1.16	0.64	0.51	1.37	1.09	0.88	0.81	0.52
β_2	5.05	4.89	4.36	5.43	3.73	3.43	5.05	4.84	4.16	4.03	3.53
$\overline{\eta^2}$	528	748	960	926	777	872	1692	1594	1631	1851	1768
η	27	23	0	-2	13	24	3	-3	-17	18	15
ε	0.94	0.94	0.97	0.97	0.98	0.98	0.97	0.98	0.98	0.99	0.99
ν	0.86	0.86	0.85	0.83	0.85	0.85	1.03	0.86	0.92	1.00	0.99

Table 1 Statistical parameters of sea water surface elevation, and spectral parameters.

LIST OF SYMBOLS

d : water depth (m)
N : number of waves defined by zero-crossing method
H max : maximum wave height (cm)
T max : maximum wave period (s)
H 1/10 : one-theth wave height (cm)
T 1/10 : one-tenth wave period (s)
H 1/3 : significant wave height (cm)
T 1/3 : significant wave period (s)
$\bar{H}$: mean wave height (cm)
$\bar{T}$: mean wave period (s)
H rms : root mean square wave height (cm)
T rms : root mean square wave period (s)
r(H,T) : correlation coefficient between individual wave height and period
r(H) : correlation coefficient between successive two wave height
r(T) : correlation coefficient between successive two wave period
WG 1/3 : number of run exceeding significant wave height
$\bar{J}$ 1/3 : mean length of run for WG 1/3
$\bar{I}$ 1/3 : mean length of total run for WG 1/3
WG a : number of run exceeding mean wave height
$\bar{J}$ a : mean length of run for WG a
$\bar{I}$ a : mean length of total run for WG a
σ : standard deviation of sea water surface variation
$\sqrt{\beta_1}$: skewness of sea water surface variation
β_2 : kurtosis of sea water surface variation
$\overline{\eta^2}$: mean root square of sea water surface variation (variance) (cm^2)
η : mean water level from reference elevation (cm)
ε : spectral width parameter defined by $\varepsilon = [1-m_2^2/(m_0 m_4)]^{1/2}$
ν : spectral width parameter defined by $\nu = [m_0 m_2/m_1^2 - 1]^{1/3}$

$$m_n = \int_{-\infty}^{\infty} f^n S(f)\,df$$

	EX800902 (D=8)											
	DOWN						UP					
	A	B	C	D	E	F	A	B	C	D	E	F
d	1.81	1.84	3.22	2.79	4.93	5.14	1.81	1.84	3.22	2.79	4.93	5.14
N	1434	1348	1445	1118	1142	1082	1435	1348	1445	1118	1141	1083
H max	166	189	217	243	217	242	173	191	208	241	228	208
T max	2.94	7.51	9.29	8.21	9.56	12.0	3.17	16.2	1.26	9.92	10.8	10.5
H 1/10	122	140	144	173	139	143	117	139	142	168	139	142
T 1/10	7.00	7.26	7.02	8.50	9.13	9.36	7.02	8.33	6.17	9.01	9.07	9.16
H 1/3	103	119	112	130	110	115	98	115	112	127	109	114
T 1/3	6.90	7.21	6.76	8.34	8.71	8.97	6.53	7.19	6.35	8.40	8.49	8.95
$\bar{H}$	65	75	71	79	69	74	65	75	71	79	69	74
$\bar{T}$	5.22	5.55	5.18	6.70	6.57	6.92	5.22	5.50	5.18	6.71	6.56	6.92
H rms	73	85	79	91	78	82	71	83	79	89	78	82
T rms	5.90	6.16	5.74	7.28	7.14	7.46	5.87	6.18	5.69	7.27	7.11	7.45
r(H,T)	0.58	0.59	0.57	0.58	0.68	0.69	0.42	0.55	0.46	0.58	0.66	0.68
r(H)	-.15	-.14	-.03	0.17	0.24	0.29	-.01	-.03	0.04	0.29	0.29	0.32
r(T)	0.00	0.02	-.03	0.12	0.15	0.20	0.04	0.30	0.08	0.18	0.21	0.23
WG 1/3	182	163	170	110	104	99	158	148	163	107	99	93
$\bar{J}$ 1/3	1.12	1.14	1.19	1.35	1.48	1.52	1.25	1.20	1.20	1.35	1.48	1.48
$\bar{T}$ 1/3	7.84	8.27	8.51	10.2	11.0	11.0	8.98	9.10	8.88	10.5	11.6	11.7
WG a	412	378	379	250	233	206	381	357	363	227	231	211
$\bar{J}$ a	1.75	1.83	1.70	2.02	2.21	2.39	1.85	1.90	1.73	2.13	2.14	2.35
$\bar{T}$ a	3.48	3.56	3.82	4.48	4.91	5.26	3.77	3.78	3.98	4.93	4.95	5.15

(a)

	EX800902 (D=8) FILTERED											
	DOWN						UP					
	A	B	C	D	E	F	A	B	C	D	E	F
d												
N	1508	1344	1440	1093	1098	1092	1508	1344	1440	1084	1097	1091
H max	173	188	223	244	216	229	172	178	201	236	222	217
T max	5.62	7.41	9.57	9.15	9.29	10.9	3.14	11.1	10.2	10.2	11.1	10.1
H 1/10	121	141	144	172	139	141	115	135	140	165	138	140
T 1/10	6.69	7.30	7.16	8.73	9.13	9.36	6.31	7.95	5.86	8.89	9.04	9.15
H 1/3	101	118	111	130	110	113	95	113	110	126	109	112
T 1/3	6.62	7.22	6.66	8.44	8.68	8.94	6.01	7.03	6.05	8.38	8.52	8.96
$\bar{H}$	62	75	70	79	70	72	62	75	70	79	70	72
$\bar{T}$	4.87	5.46	5.10	6.72	6.69	6.72	4.87	5.46	5.10	6.72	6.69	6.72
H rms	70	84	79	91	78	81	68	82	78	89	78	80
T rms	5.50	6.06	5.63	7.24	7.23	7.27	5.44	6.06	5.56	7.24	7.19	7.25
r(H,T)	0.60	0.60	0.57	0.60	0.66	0.73	0.40	0.52	0.43	0.59	0.63	0.72
r(H)	-.14	-.14	-.06	0.18	0.26	0.32	0.01	-.01	0.02	0.29	0.32	0.36
r(T)	0.00	0.06	-.09	0.14	0.18	0.22	0.06	0.06	0.05	0.18	0.26	0.26
WG 1/3	136	159	170	109	101	95	174	154	176	105	97	89
$\bar{J}$ 1/3	1.15	1.13	1.13	1.29	1.47	1.57	1.24	1.19	1.16	1.38	1.53	1.60
$\bar{T}$ 1/3	8.05	8.33	8.44	10.0	10.9	11.5	8.67	8.60	8.09	10.4	10.7	11.7
WG a	439	378	385	242	218	207	401	351	372	216	208	200
$\bar{J}$ a	1.68	1.81	1.64	2.02	2.31	2.43	1.81	1.91	1.69	2.19	2.30	2.46
$\bar{T}$ a	3.44	3.55	3.72	4.49	5.05	5.28	3.76	3.83	3.87	5.04	5.28	5.47

(b)

Table 3 Statistical representative waves for Ex800902.

	EX810908 (D=8)													
	DOWN							UP						
	A	B	C	D	E	F	G	A	B	C	D	E	F	G
d	0.95	1.31	1.19	1.95	3.28	4.22	4.34	0.95	1.31	1.19	1.95	3.28	4.22	4.34
N	898	691	516	530	516	422	460	899	691	515	530	516	421	461
H max	122	117	145	253	265	218	247	114	136	137	242	268	241	255
T max	8.66	4.12	11.3	10.1	10.8	7.75	8.89	5.40	15.1	10.0	9.87	9.40	8.74	10.8
H 1/10	86	93	103	186	189	170	175	81	93	108	188	188	169	174
T 1/10	7.29	9.32	9.67	8.61	8.70	9.31	8.56	7.37	9.81	10.5	9.62	9.25	9.80	8.69
H 1/3	68	79	99	162	150	138	138	64	75	92	160	149	139	137
T 1/3	6.29	8.32	8.90	8.53	8.74	9.29	9.02	5.93	7.72	9.85	9.04	8.93	9.37	8.83
$\bar{H}$	43	50	66	102	94	88	87	43	50	66	102	94	88	87
$\bar{T}$	4.22	5.46	7.35	7.16	7.35	7.19	7.27	4.23	5.47	7.36	7.15	7.35	7.19	7.26
H rms	48	56	71	115	106	98	98	47	55	70	114	106	99	98
T rms	5.09	6.54	8.01	7.72	7.98	8.13	7.81	5.08	6.57	8.00	7.71	7.95	8.16	7.82
r(H,T)	0.61	0.68	0.62	0.63	0.56	0.60	0.58	0.52	0.52	0.66	0.64	0.57	0.60	0.57
r(H)	-.11	0.11	-.07	0.12	0.30	0.33	0.27	-.00	0.05	0.03	0.22	0.36	0.28	0.29
r(T)	-.03	-.02	0.09	0.10	0.12	0.20	0.10	0.02	-.02	0.15	0.12	0.20	0.21	0.13
WG 1/3	116	80	49	64	53	41	48	106	78	56	61	49	40	45
$\bar{J}$ 1/3	1.10	1.17	1.31	1.31	1.43	1.39	1.31	1.10	1.24	1.16	1.30	1.55	1.47	1.36
$\bar{T}$ 1/3	7.67	8.57	10.4	8.06	9.79	10.4	9.62	8.40	8.83	9.27	9.52	10.6	10.3	10.3
WG a	249	198	131	121	94	76	92	220	170	118	112	92	77	93
$\bar{J}$ a	1.59	1.72	2.26	2.25	2.59	2.76	2.30	1.80	1.89	2.23	2.33	2.61	2.68	2.29
$\bar{T}$ a	3.59	3.50	3.92	4.39	5.48	5.53	4.98	4.06	4.08	4.35	4.75	5.59	5.45	4.92

	EX810909 (D=8)									
	DOWN					UP				
	A	B	C	D	E	A	B	C	D	E
d	2.28	3.52	4.73	5.08	5.45	2.28	3.52	4.73	5.08	5.45
N	1370	1365	1362	1353	1163	1370	1364	1362	1353	1164
H max	278	323	316	322	345	288	335	328	328	336
T max	8.00	5.44	7.60	9.66	10.6	12.4	9.34	8.63	8.72	8.37
H 1/10	212	221	206	213	207	213	219	207	207	200
T 1/10	8.46	8.13	8.78	9.23	9.82	9.53	8.75	8.80	8.92	9.20
H 1/3	181	173	162	167	161	178	170	163	165	159
T 1/3	8.20	8.23	8.56	8.94	9.29	8.79	8.49	8.53	8.73	9.11
$\bar{H}$	112	106	102	104	101	113	106	102	104	101
$\bar{T}$	6.65	6.68	6.69	6.74	7.17	6.66	6.68	6.69	6.73	7.17
H rms	128	121	115	118	114	126	120	115	117	113
T rms	7.26	7.23	7.22	7.32	7.71	7.26	7.24	7.24	7.30	7.73
r(H,T)	0.62	0.59	0.65	0.72	0.70	0.65	0.61	0.65	0.68	0.67
r(H)	0.05	0.14	0.27	0.24	0.29	0.15	0.22	0.28	0.29	0.33
r(T)	0.12	0.16	0.23	0.19	0.20	0.14	0.19	0.24	0.23	0.22
WG 1/3	146	136	126	124	112	150	140	126	126	104
$\bar{J}$ 1/3	1.31	1.29	1.45	1.38	1.35	1.30	1.36	1.45	1.40	1.39
$\bar{T}$ 1/3	9.20	9.98	10.8	10.9	10.1	9.13	9.76	10.6	10.7	10.9
WG a	325	320	283	283	231	310	299	274	266	224
$\bar{J}$ a	2.14	2.02	2.23	2.24	2.31	2.21	2.16	2.27	2.35	2.43
$\bar{T}$ a	4.20	4.26	4.87	4.78	5.02	4.42	4.54	4.97	5.08	5.21

Table 4 Statistical representative waves for Ex810908 and Ex810909.