CHAPTER 7

OBSERVATIONS OF THE TRANSFORMATION OF OCEAN WAVE CHARACTERISTICS NEAR COASTS BY USE OF ANCHORED BUOYS

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ABSTRACT

In order to clarify the transformation process of ocean waves in shallow water, a series of wave observations were carried out along some coasts in Japan by photographing two or three convenient buoys aligned in the direction of the waves with two 16 mm cine-cameras. The equipment and methods used in observations and analyses are here described together with some of the results obtained. By examining the motion of the buoys off the coast at Shirahama it was found that the method of wave observation by means of anchored buoys was very useful in the case of comparatively long waves.

INTRODUCTION

In designing coastal structures, it is necessary to decide the design wave for the estimation of external forces. Owing to the lack of sufficient data on waves, the waves coming to the coast are forecast or hindcast from weather maps or wind records. As coastal structures are constructed in relatively shallow water areas, the forecasting of deep water waves is an insufficient basis for determining their design. The transformation of waves which approach the shore through shallow water and reach the coastal structures must be accurately gauged. The main factors by which shallow water waves are transformed are generation and development due to wind, refraction, diffraction, bottom friction, percolation, change of water depth, breaking, and reflection, but there are still many obscure points in these phenomena, and therefore shallow water wave forecasting is very rough.

In order to clarify the transformation process of waves in shallow water, the authors have carried out a series of wave observations along some coasts in Japan by photographing two or three convenient buoys aligned in the direction of the waves with two 16 mm cine-cameras.

In this paper, the equipment and methods used in observations and analyses are described together with some of the results obtained.

EQUIPMENT

In this chapter are described the three kinds of buoys, the 16 mm cine-cameras, and the hand-tracing wave recorder used in wave observations, and the film motion analyzer and the spectrum analyzer used in the analyses.

(1) Buoy A series of wave observations was carried out with the use of three kinds of buoys.

1) Buoy I (Fig. 1) : This type of buoy is constructed with the tube of a car wheel of 1000 mm x 200 mm, a frame made of ϕ 15 mm bar iron, and a red tin-plate flag of 400 mm x 400 mm, which is connected to two anchors of 80 kg and 20 kg by a nylon rope of ϕ 16 mm. The two buoys were used off the Akita Coast (1961). They were damaged by the action of violent waves during wave observations ; one was lost due to the breaking of the rope and the other was punctured.

2) Buoy II (Fig. 2) : This type of buoy is constructed with a wheel with a tire of 1000 mm x 200 mm, and a tin-plate flag of 600 mm x 600 mm coloured with orange fluorescent paint, which is connected to two anchors of 20 kg by a nylon or vinylon rope of ϕ 24 mm. An auxiliary buoy for raising the anchors is attached. This type of buoy was used in Nagoya Harbor (1962), off the Izumisano Coast (1963), and off the Nishikinohama Coast (1964).

3) Buoy III (Fig. 3) : This type of buoy is constructed with four cylinders of 600 mm in diameter and 450 mm in length fixed by an angle-iron, and an iron flag of 1000 mm x 1000 mm coloured with orange fluorescent paint, which is connected to an anchor of 60 kg by a vinylon rope of ϕ 36 mm and a chain of ϕ 9 mm. An auxiliary buoy for weighing the anchor is attached. This type of buoy is about 200 kg in total weight and draws about 20 cm of water. This type of buoy was used off the Hiezu Coast (1963, 1964) and the Takahama Coast (1965).

(2) 16 mm Cine-Camera (Paillard Bolex H-16) This is used for photographing the motion of the buoys. The film speed is set at 2 frames per second by a specially designed attachment. Four kinds of telephoto lens were used ; 75 mm f : 2.8, 150 mm f : 3.3, 400 mm f : 4.5, and 1000 mm f : 6.3.

(3) Hand-Tracing Wave Recorder This is used for tracing the motion of a buoy by hand. The time change of the vertical motion of an improved transit is directly transmitted to a pen and recorded. This was used tentatively at the Akita Coast station (1961).

(4) Film Motion Analyzer Two kinds of instruments were used for reading out from the 16 mm cine-film. One was a cine-projector (improved Elmo DM 16 mm) and the other a 'NAC' motion analyzer.

The 'NAC' motion analyzer is a projection viewer with crosshair assembly for measuring coordinate positions on the screen and versatile means for advancing, counting and registering film. The magnifying power is 15, and the minimum scale for reading is 0.05 mm.

(5) Spectrum Analyzer This is to produce from the magnetic tape record of waves an amplitude or power density spectrum as a function of frequency. Its performance and characteristics are as follows : the time compression : 1/100 or 1/1000 ; the type of the analyzer : heterodyne ; the band width of the bandpass filter : 2 cps or 4 cps ; and the range of analyzing frequency : 5～1000 cps. The block diagram is shown in Fig. 4.

METHODS

Two or three buoys were set in position some hundreds of meters apart in the direction of the waves, which were photographed by the 16 mm cine-camera at the film speed of 2 frames per second for 15 minutes (Photo 1). The hand-tracing wave recorder was used, instead of the cine-camera, only in the case of the Akita Coast.

The vertical displacements of the buoys were read out through the cine-projector or the 'NAC' motion analyzer.

The various mean waves and the wave energy spectra were estimated from the wave data. Both the digital computer KDC-1 at Kyoto University and the spectrum analyzer were used in estimating the wave energy spectra.

In addition, wind observations and bottom material samplings were made during these periods.

STATIONS

Wave observations were carried out in Nagoya Harbor (1962), off the Izumisano Coast (1963), the Nishikinohama Coast (1964), and the Shirahama Coast (1965) on the Pacific Ocean side and off the Akita Coast (1961), the Hiezu Coast (1963, 1964), and the Takahama Coast (1965) on the Japan Sea side. At these stations, the contour lines of water depth were nearly parallel to the shore line except in the cases of the Takahama Coast and the Shirahama Coast. These stations and some operational conditions are shown in Fig. 5 and Table 1 respectively. The locations of wave observations off the Nishikinohama Coast and the Hiezu Coast (1963) are shown in Fig. 6 and 7 respectively.

RESULTS

(1) Ocean wave spectra in shallow water The wave energy spectra in shallow water obtained off each coast are expressed by kf^{-n}, in which the values of n are between 3 and 5 at the high frequencies, as shown in Table 2. The same tendency is obtained by use of a step resistance type wave recorder with 5 cm step intervals off the Ōgata Coast (Fig. 5), as shown in this table. In Fig. 8 (a) and (b) the wave energy spectra in shallow water obtained off the Nishikinohama Coast are shown with $E_f = f^{-3} \sim f^{-6}$.

(2) Transformation of ocean wave spectra in shallow water The typical examples of the transformation of the wave energy spectra obtained are illustrated in Fig. 9 (a) ~ (e). The wave energy spectra in Fig. 9 (a)~ (d) are estimated by the digital computer KDC-1 (the degree of freedom : 30 ~ 40) and those in Fig. 9 (e) are estimated by the spectrum analyzer (the band width of bandpass filter : 4 cps, the loop period : 1 sec).

EXAMINATIONS

In order to examine the characteristics of the buoys II and III, wave records were taken near the Shirahama Oceanographic Tower Station, Disaster Prevention Research Institute, Kyoto University, located on the Shirahama Coast (Fig. 5). By using a cine-camera, 2 photographs per second of the water surface at the leg of the tower and the buoys II and III were taken simultaneously over a period lasting 15 minutes and these records were evaluated. In Fig. 10 the three wave energy spectra are compared and the locations are shown. The spectrum by Buoy III is almost the same as that of the water surface except for the strong rise at 0.3 sec^{-1} frequency which has not always appeared in wave observations off each coast. The energy deficit at the peak of the spectrum by Buoy II may be due to its longer distance from the tower in the direction of the shore.

CONCLUSION

The authors have carried out a series of wave observations off some coasts in Japan and obtained some data by which the transformation process of waves in shallow water can be clarified.

Above all, by examining the motion of the buoys off the Shirahama Coast the authors found that the method of wave observation by means of anchored buoys is very useful in the case of comparatively long waves. Further examinations of these buoys should be made in respect to various other waves and a new model of buoy is to be developed.

Acknowledgement

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Table 1. Conditions at observation stations.

Station	Buoy		Water Depth (m)	Bottom Slope (x10^{-3})	d_{50} (mm)
	Type	Number			
1 Nagoya Harbor	II	2	2.5	-	-
2 Izumisano Coast	II	3	5.9, 4.3, 3.7	4.2	0.20
3 Nishikinohama Coast	II	3	8.6, 7.0, 6.2, 2.4	3.6	0.28
4 Shirahama Coast	II,III	2	5.5, 5.1, 4.0	-	-
5 Akita Coast	I	2	3.5, 5.2	5.8	0.40
6 Hiezu Coast (1963)	III	3	11.8, 9.4, 3.4	11.0	0.14
7 Hiezu Coast (1964)	III	3	13.5, 9.8	6.0	-
8 Takahama Coast	III	2	9.8, 6.3	5.7	0.16

Table 2. n values of kf^{-n} at the high frequencies of wave energy spectra.

Station	Watar Depth (m)	Period of Maximum Energy Density	n	Method of observation
Nishikinohama Coast	8.6, 7.0, 6.2, 2.4	3.1~4.4	3 ~ 5	Buoys and cine-cameras
Hiezu Coast ('63)	11.8, 3.4	5.7~10.0	3 ~ 5	
Hiezu Coast ('64)	13.5, 9.8	9.0~14.2	4 ~ 5	
Takahama Coast	9.8, 6.3	8.6~11.1	4 ~ 5	
Ōgata Coast	15	5.5~9.6	3 ~ 5	Step resistance type wave recorder

Photo 1. 16mm cine-cameras (Nishikinohama Coast).

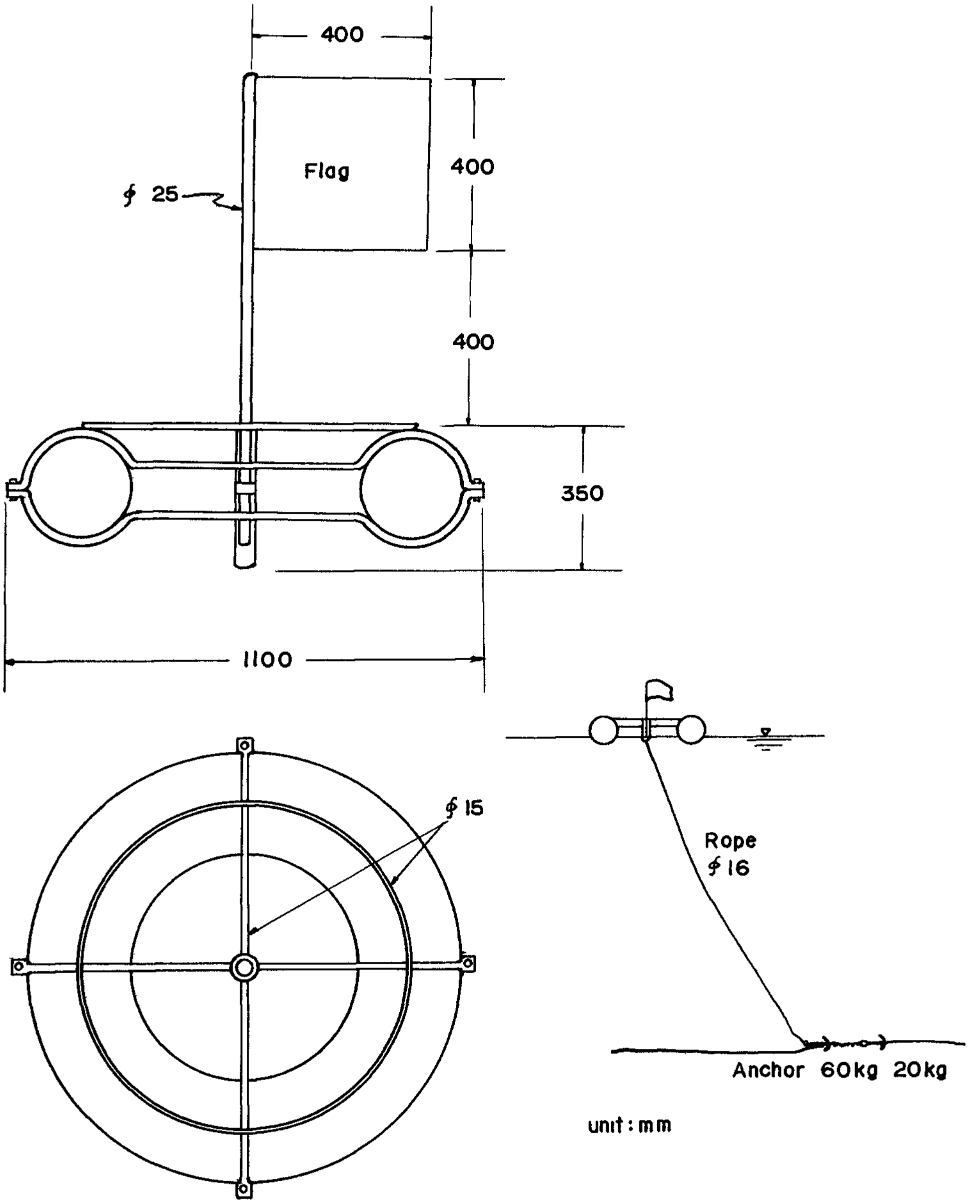


Fig. 1. Sketch of Buoy I for wave observation.

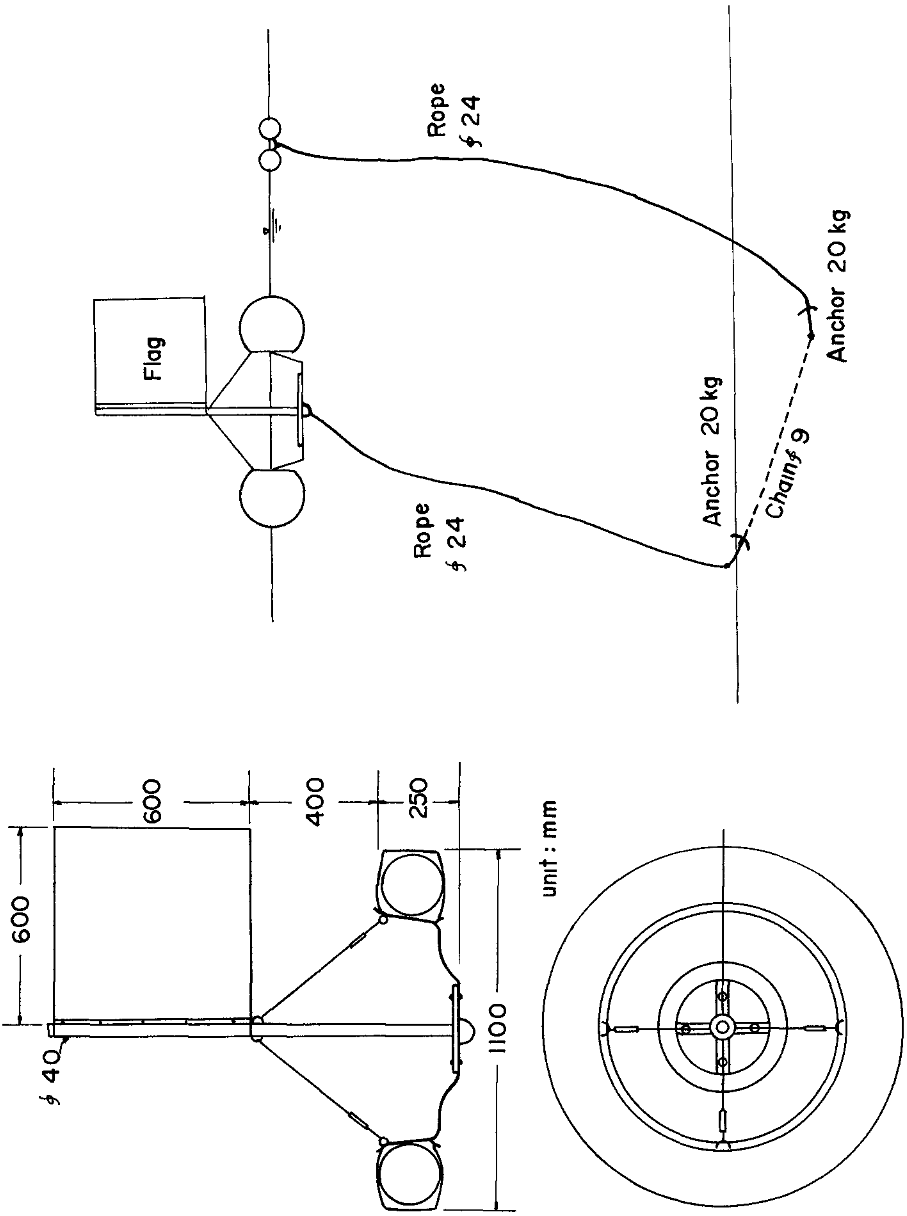


Fig. 2. Sketch of Buoy II for wave observation.

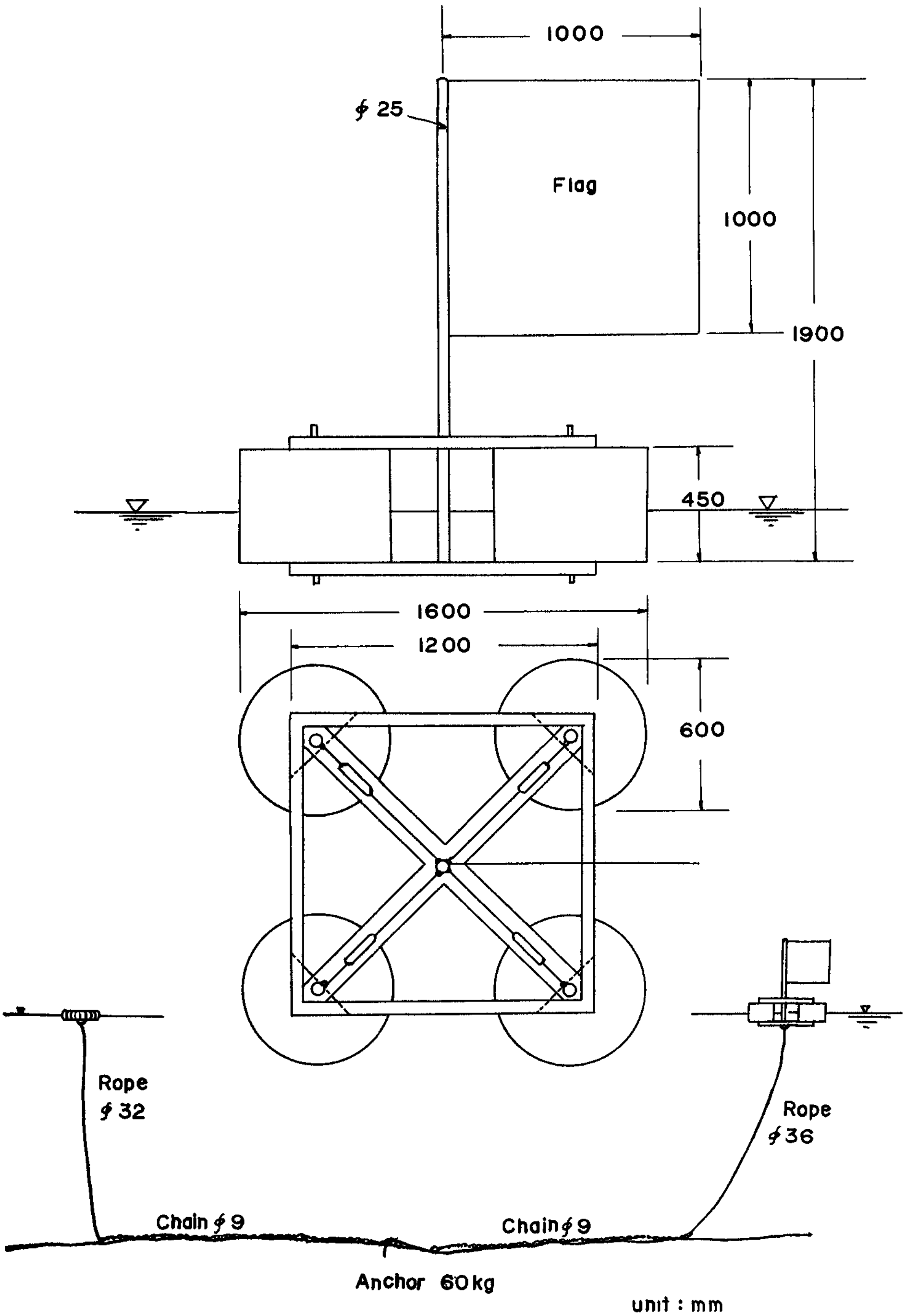


Fig. 3. Sketch of Buoy III for wave observation.

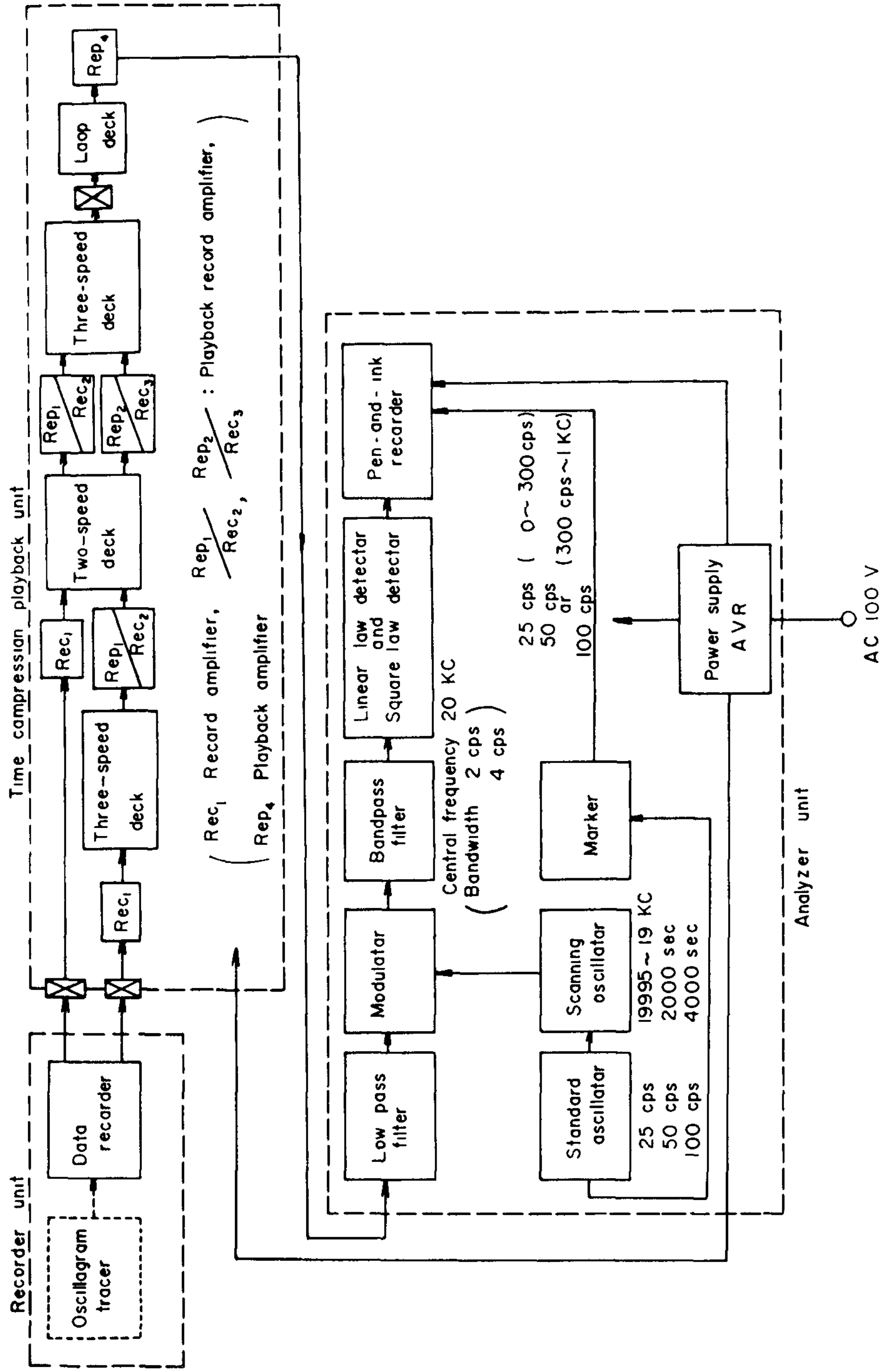


Fig. 4. Block diagram of time compression playback and spectrum analyzer.

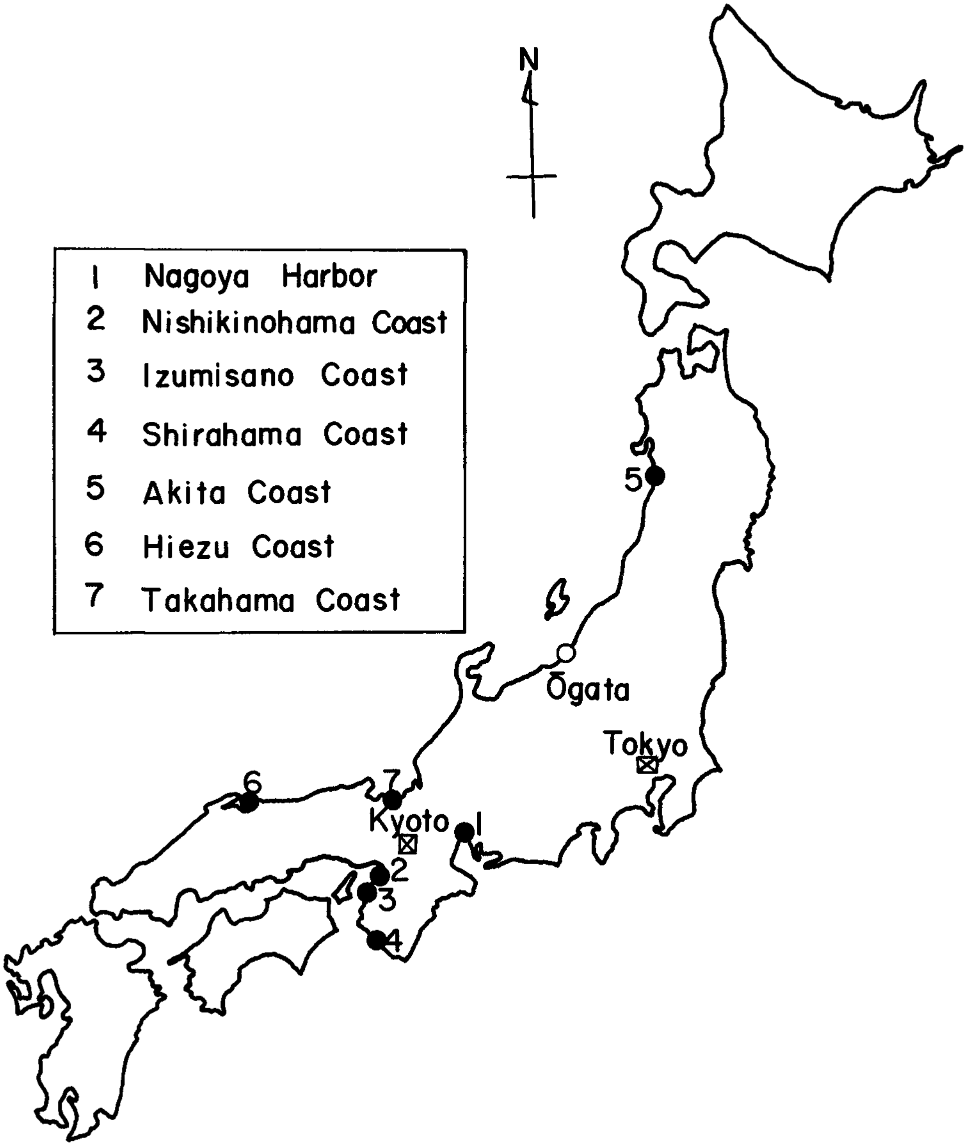


Fig. 5. Wave observation stations.

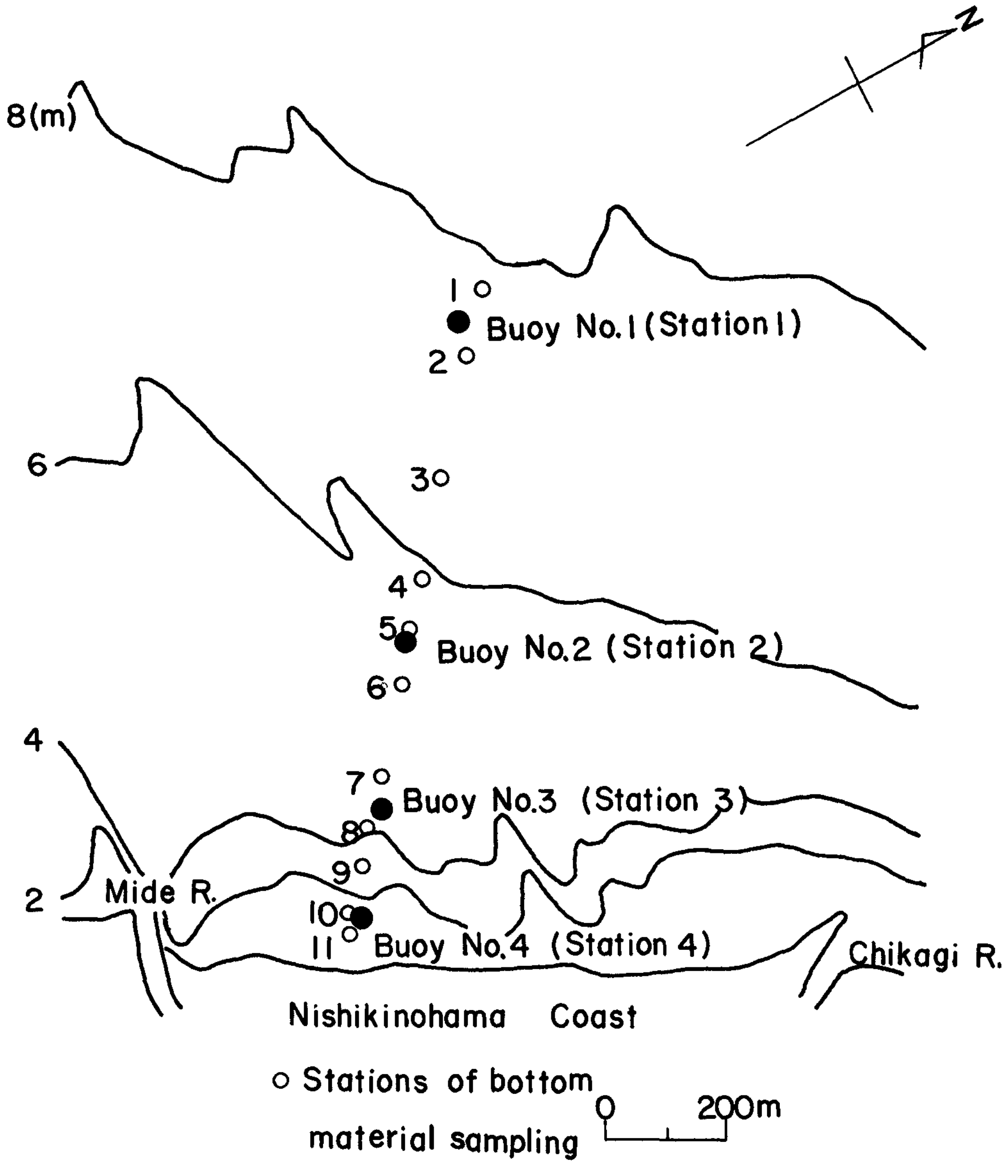


Fig. 6. Locations of wave observation and bottom material sampling at Nishikinohama Coast.

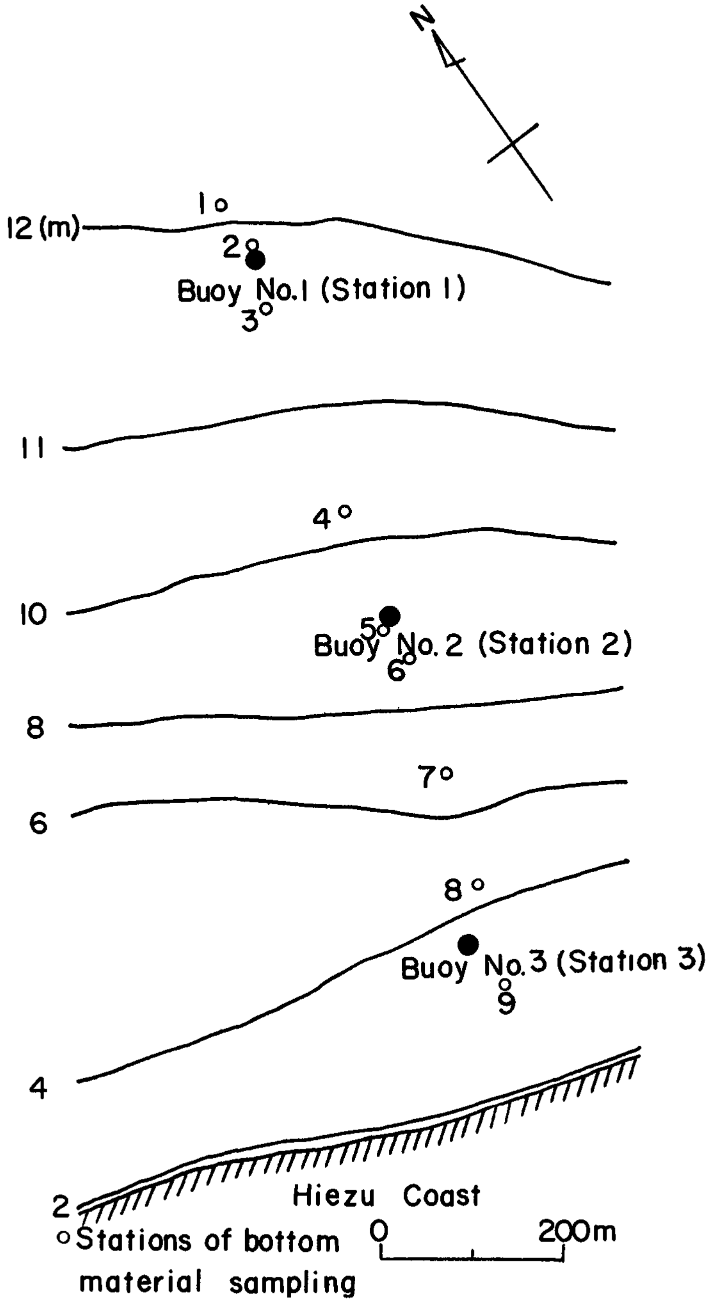


Fig. 7. Locations of wave observation and bottom material sampling at Hiezu Coast (1963).

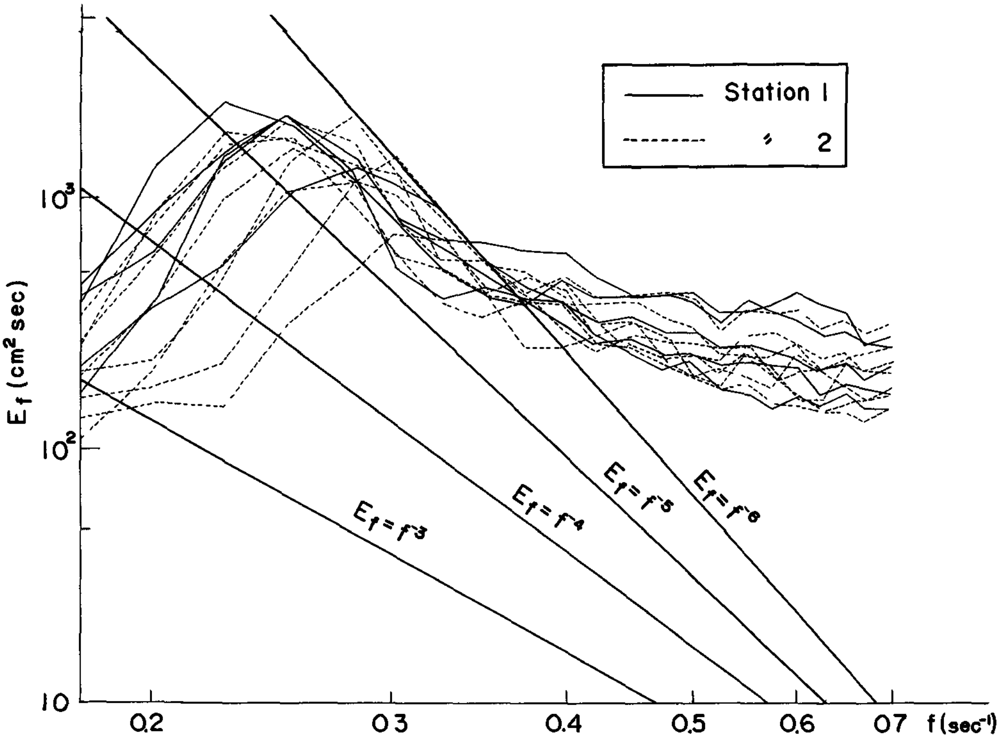


Fig. 8 (a). Comparison of observed wave spectra at Station 1 and 2 at Nishikinohama Coast with $E_f = f^{-3}$, f^{-4}, f^{-5} and f^{-6}.

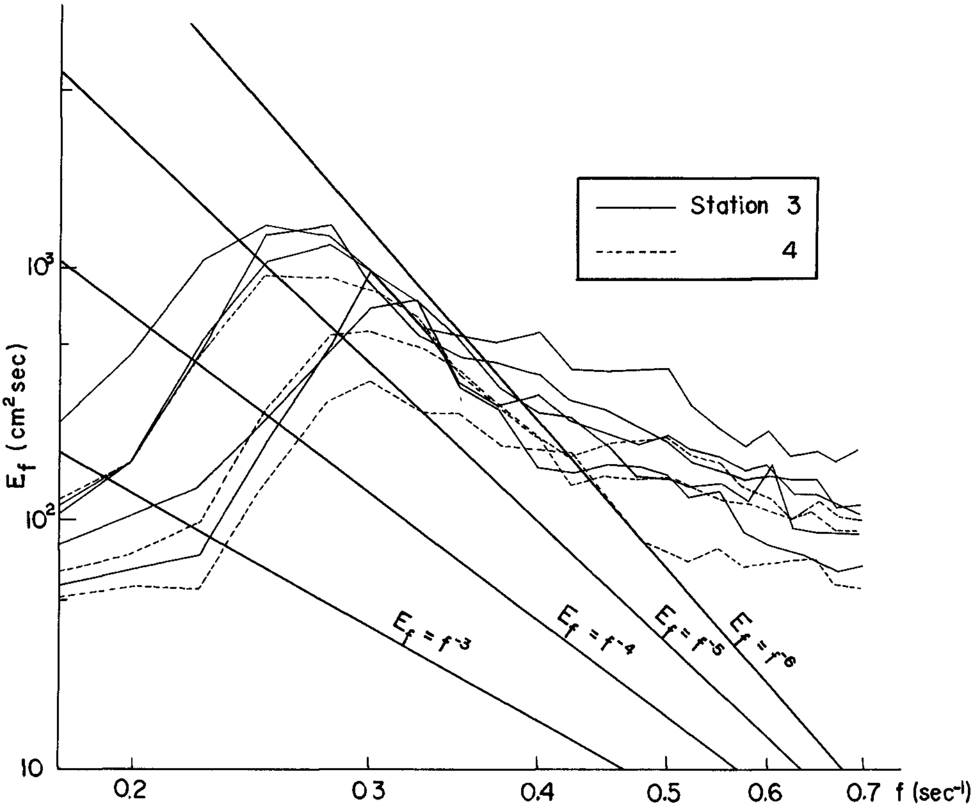


Fig. 8 (b). Comparison of observed wave spectra at Station 3 and 4 at Nishikinohama Coast with $E_f = f^{-3}$, f^{-4}, f^{-5} and f^{-6}.

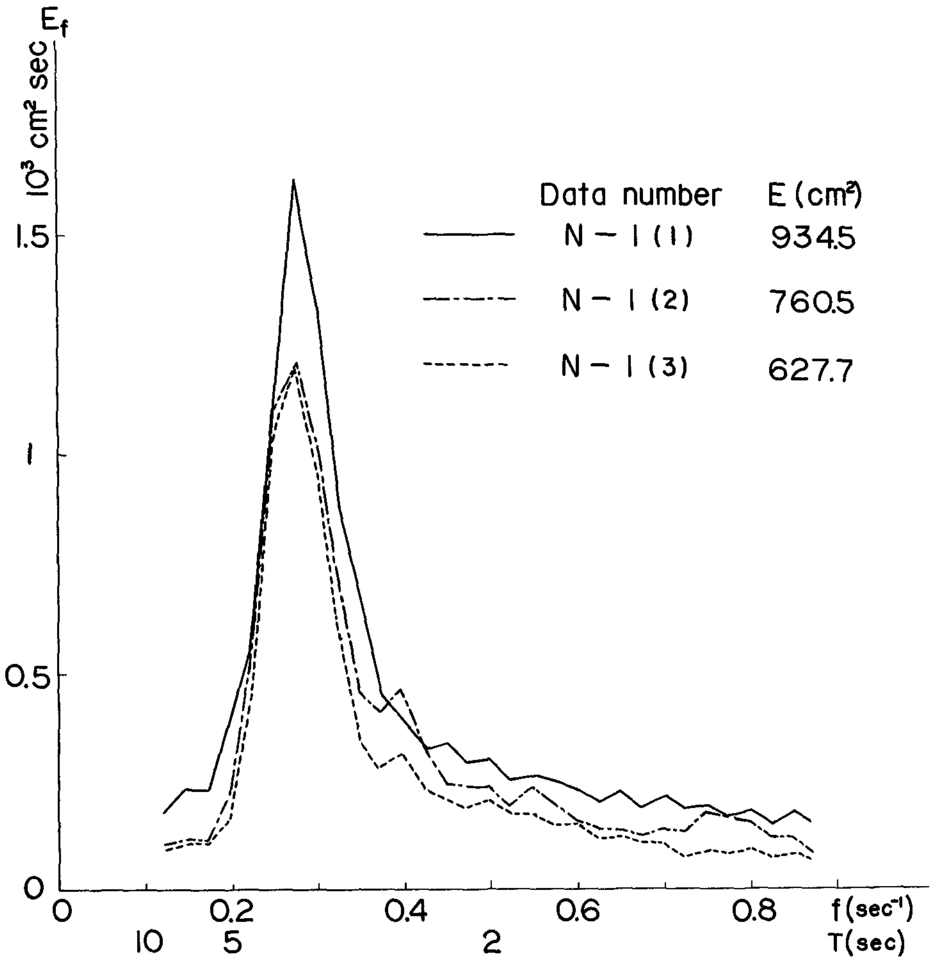
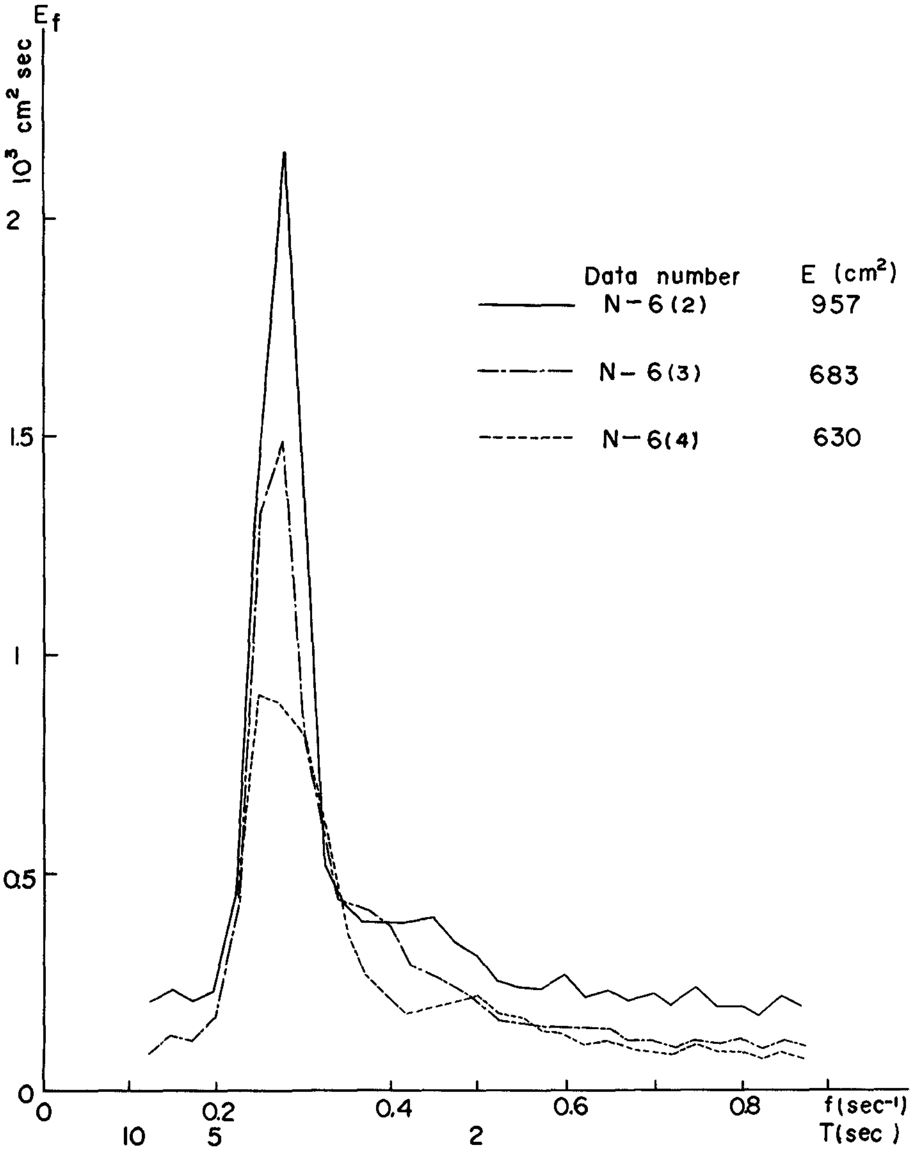


Fig. 9 (a).

Fig. 9. Transformation of ocean wave spectra in shallow water.
(a) Nishikinohama Coast. (b) Nishikinohama Coast.
(c) Hiezu Coast (1963). (d) Hiezu Coast (1964).
(e) Takahama Coast.



E_f
10^3 cm^2 sec
2
1.5
1
0.5
0
Data number
E (cm^2)
N-6(2) 957
N-6(3) 683
N-6(4) 630
0
0.2
0.4
0.6
0.8
f(sec^{-1})
10
5
2
T(sec)

Fig. 9 (b).

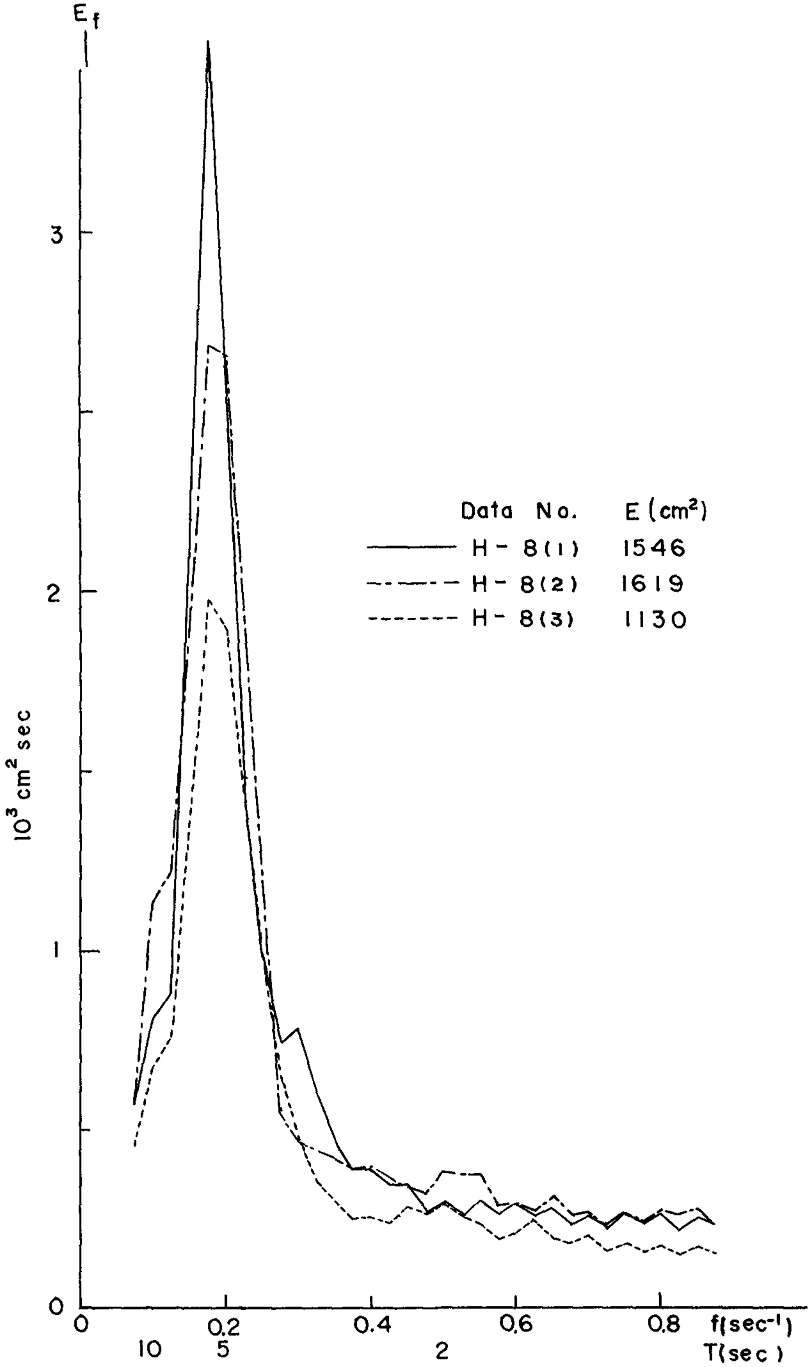

E_f
3
2
1
0
$10^3 cm^2 sec$
Data No. E (cm²)
H - 8(1) 1546
H - 8(2) 1619
H - 8(3) 1130
0
0.2
0.4
0.6
0.8
f(sec⁻¹)
10
5
2
T(sec)

Fig. 9 (c).

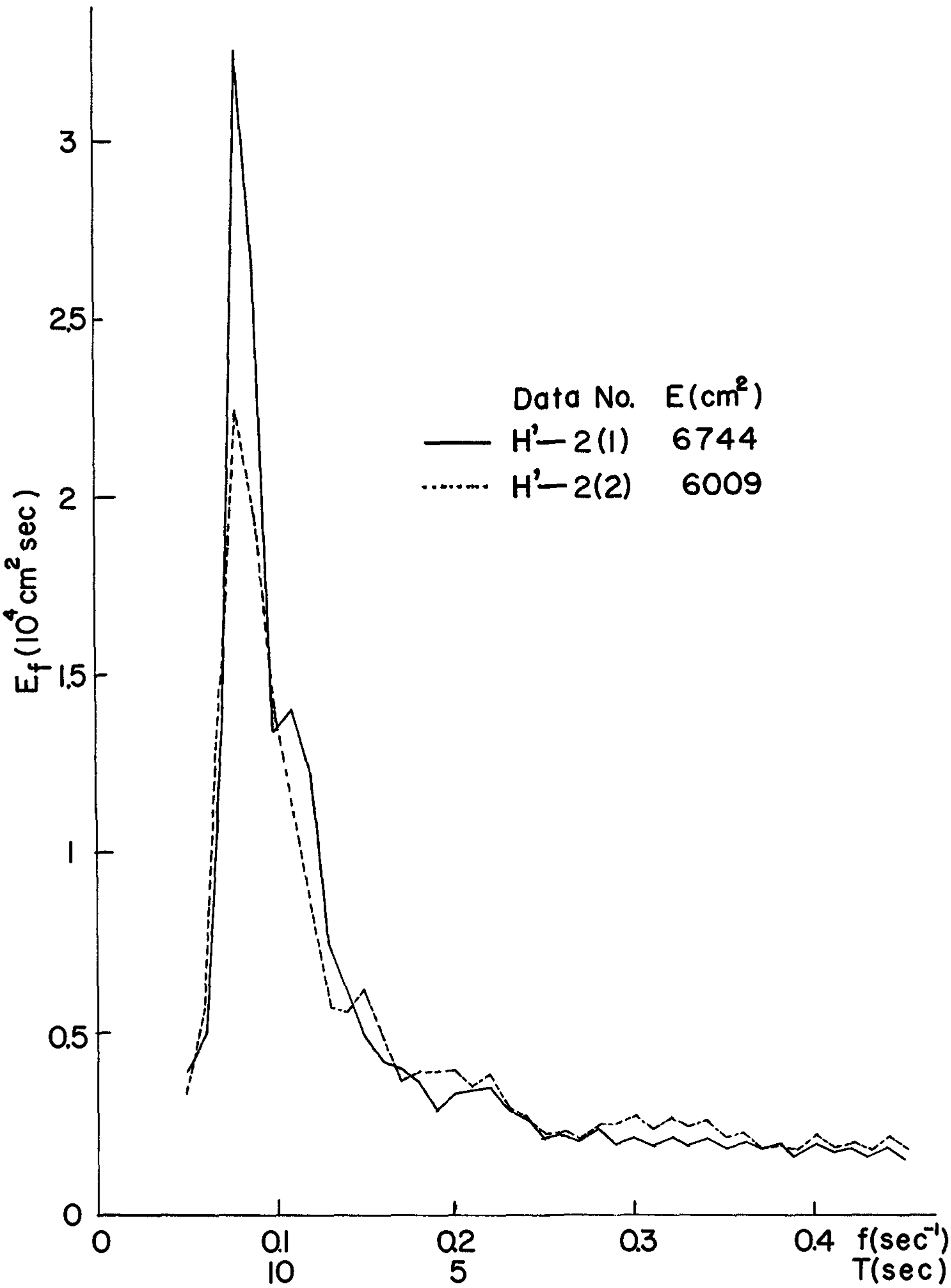

Data No. E(cm²)
H'—2(1) 6744
H'—2(2) 6009
E_f (10⁴ cm² sec)
3
2.5
2
1.5
1
0.5
0
0
0.1
10
0.2
5
0.3
0.4
f(sec⁻¹)
T(sec)

Fig. 9 (d).

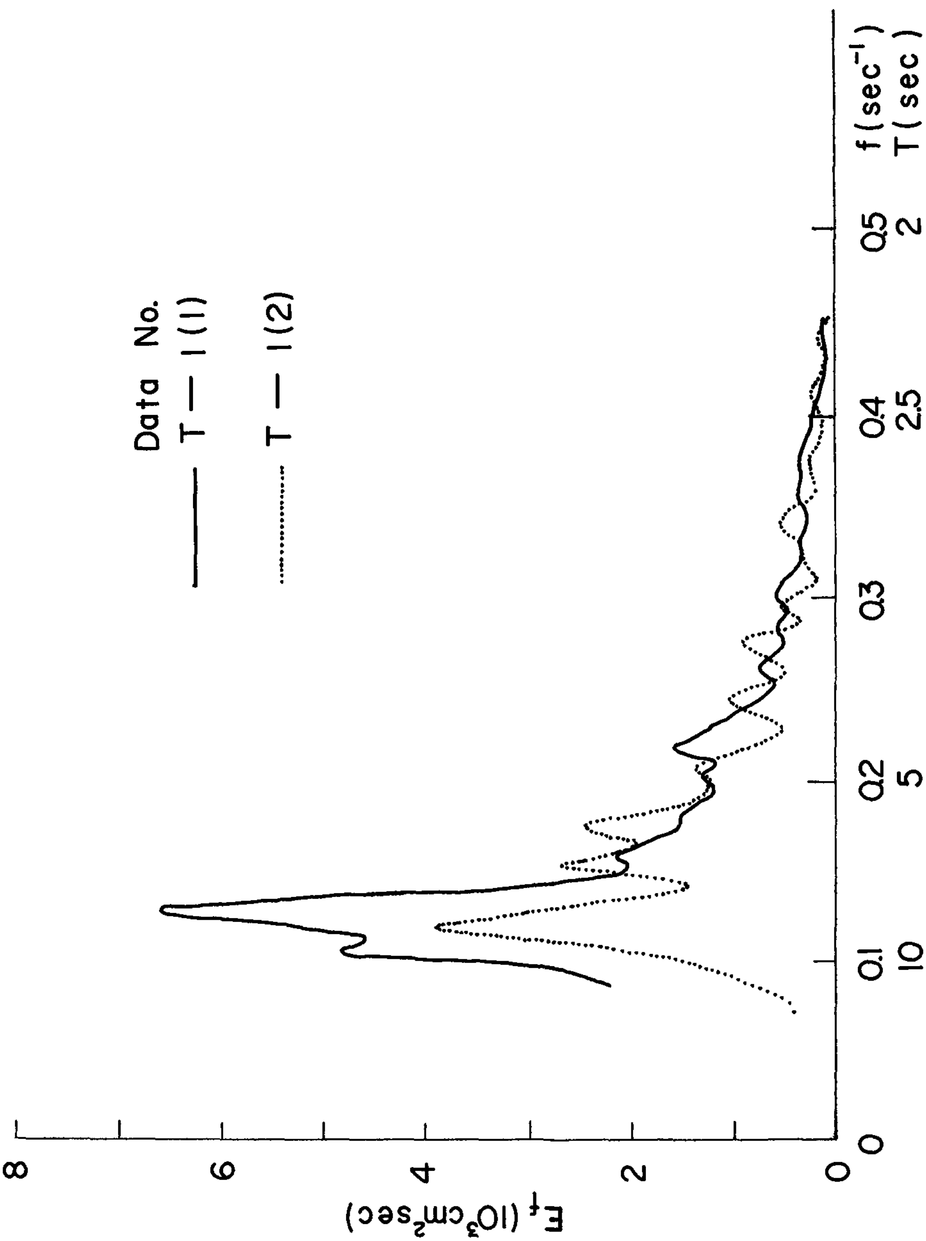

Data No.
T — 1(1)
T — 1(2)
E_f ($10^3 cm^2 sec$)
0
2
4
6
8
0.1
0.2
0.3
0.4
0.5
10
5
2.5
2
f(sec^{-1})
T(sec)

Fig. 9 (e).

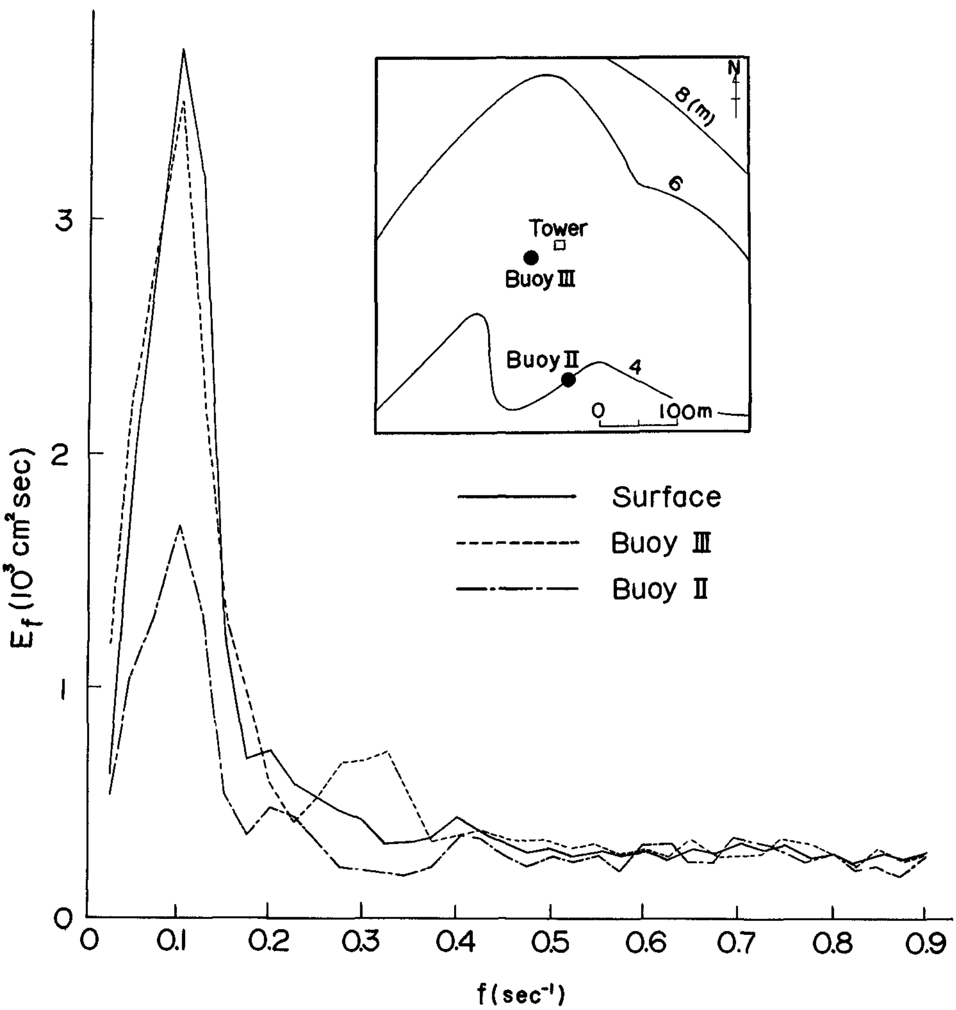


Fig. 10. Comparison of spectra by Buoy II and III with that of water surface.