Bulletin of the Earthquake
Research Institute
Vol. 47 (1969), pp. 863-874

39. *Analyses of Oceanic Long-period Waves at Hachijo Island.*

By Tokutaro Hatori,

Earthquake Research Institute.

(Read May 27, 1969.—Received July 31, 1969.)

Abstract

Long-period wave recorders were installed at Kaminato and Yaene, Hachijo Island. The observations at Yaene were carried out over a period of eight years in order to understand the characteristics of water level oscillations at an isolated island. According to spectral analyses, the seiche periods of 4 min and 5 min are always predominant in the fishing port at Kaminato. While features of wave spectra at Yaene are flat on ordinary days, predominant peaks are found in a band of periods of 5 min, 7 min and 10 min at the time of typhoons and cyclones. It is remarkable that long-period waves of more than 15 min are not significant at both stations. On the other hand, in cases of tsunamis, the predominant peaks of spectra fall in the band of long periods and its position moves to the low frequency part as earthquake magnitude increases.

1. Introduction

At the Miyagi-Enoshima and Izu-Oshima Tsunami Observatories of the ERI, observation of long-period ocean waves have continued, some results being reported (Takahasi *et al.*, 1961, Takahasi and Aida, 1962). As a satellite station, a portable long-wave recorder was installed at Kaminato, Hachijo Island in November 1958. Unoki and Nakano (1955) discussed the relation between wind waves at Hachijo Island and the weather condition from observations covering several years. In this paper, making use of the sampled long-period wave records observed in 1959 and 1967, spectral analyses are made. Seasonal variations of power spectra and the period of seiche at the island are investigated.

Moreover, for the 1964 Alaska and the 1965 Aleutian tsunamis observed by the long-wave recorder and a further three tsunamis (Boso of 1953, Chile of 1960 and Iturup of 1963) observed by a tide gauge, analyses are made. The power spectral analysis of tsunamis caused by the submarine volcano of 1952 (Myojinsho) are shown. The features of tsunami spectrum in relation to earthquake magnitude are discussed.

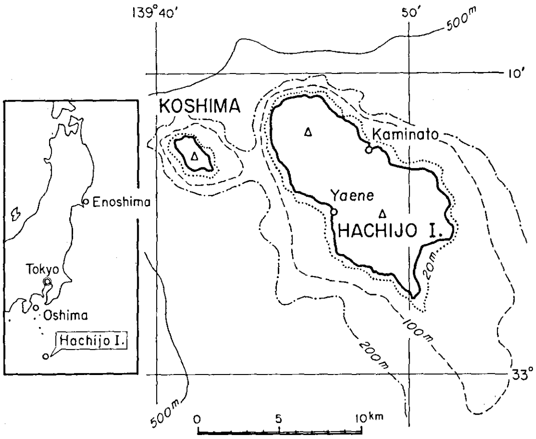

Fig. 1. Distribution of the tsunami observations.

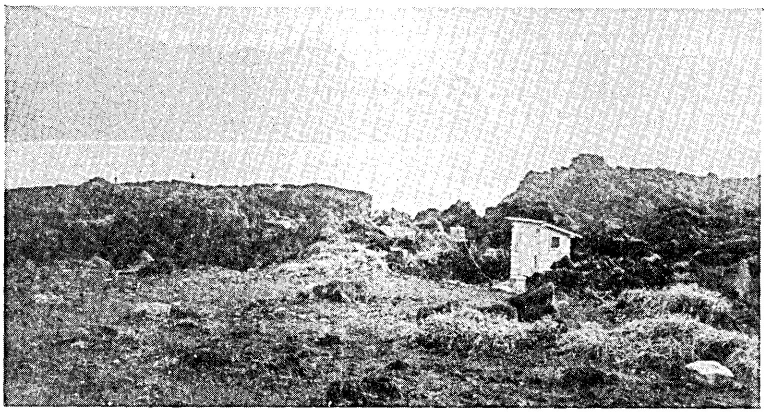

Fig. 2. General view of the temporary observation hut at Yaene.

2. Observation of long-period waves

Hachijo Island is situated on the Izu-Mariana Ridge, about 300 km south of Tokyo. The long-wave recorder was set at Kaminato on the east coast of this island (Fig. 1) in November 1958. This observation was carried out over a period of six months. Another observation was started at Yaene on the west coast from March 1959 and continued over a period of eight years. Fig. 2 shows the observational hut at Yaene. The instrument of a hydraulic filtering type (Aida, 1962) is used at both stations. Different capillary tubes (diameters: 1.25 mm and 0.94 mm; length: 14 mm) are attached in two brass tanks (diameter: 15 cm; length: 60 cm), respectively, and electric transformer oil of quantity of 10 l is put in both tanks. Pressure difference caused by the resistance of oil viscosity

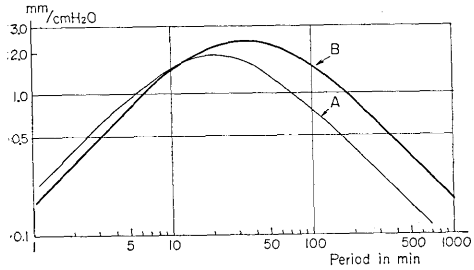

Fig. 3. Spectral response curves of the portable long-wave recorder. A: before improvement, B: after improvement.

due to wave motions, is conducted through vinyle tubes (diameter: 5 mm) by two metal bellows. The differential motion of the metal bellows is magnified with a lever mechanism, and is recorded by a mechanical pen-recorder system. The sensitivity characteristic is shown in Fig. 3. The maximum range of recording is 40 cm.

At Kaminato, the hydraulic tanks (sensitivity: A in Fig. 3) are set near the tide station in a fishing port. At the station of Yaene, the tanks are set at an inlet outside of a fishing port. The recorder is set at a distance of 80 m from the coast. Since May 1964, the recording system has been improved to that of electric transformation because the pressure in the vinyle tubes drops within a few months. The motion of bellows is transformed to an electric variation, using a differential transformer located near the coast. The transducer is connected with the recorder, a pen galvanometer, by a 6-conductor electric cable. The recorder, oscillating amplifier and the electric source 12V-battery are set in the hut. Spectral response curve of the improved instrument is shown with symbol B in Fig. 3. The maximum sensitivity is in the band of 34 min period.

Some examples of the long-wave records at Kaminato are shown in Fig. 4: (A) for an ordinary day, (B) for a day when a conspicuous "beat" is observed, and (C) at the time when a cyclone with minimum pressure of 980 mb passed east off Hachijo Island. Fig. 5 shows some examples

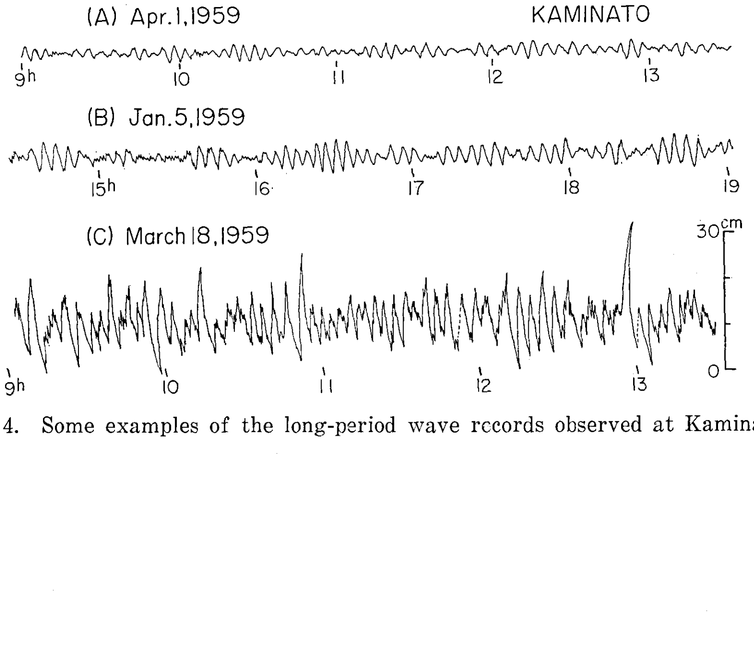

Fig. 4. Some examples of the long-period wave records observed at Kaminato.

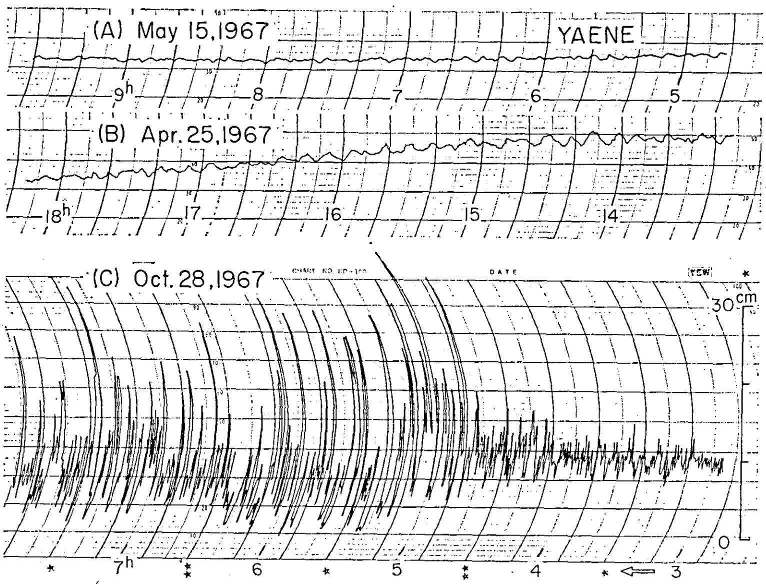

Fig. 5. Some examples of the long-period wave records observed at Yaene.

of the records at Yaene: (A) for an ordinary day, (B) for the occurrence of seiches and (C) at the time when a typhoon moved through the western part of Japan. Scales of wave amplitude in Figs. 4 and 5 are those for the maximum sensitivity at periods of 20 min and 34 min, respectively.

3. Spectral analyses of long-period waves

The spectral analyses of the sampled records in a semi-monthly interval are made by Tukey's method. Analyized time length of the record is 12 hours for which the records were sampled every 1 minute. Total number of data points is 720 and the lag is taken at 80. Fig. 6 shows the power spectra of simultaneous records at Kaminato and Yaene during the period from March to June, 1959. Noise level at Kaminato is conspicuously greater than that at Yaene and the seiche periods of 4-5 min in the port always predominate. Weather conditions at the time of occurrence of conspicuous peaks of the spectra are as follows: Low pressure of 980 mb is located far east of the Kuril Islands on 15 March. On May 1, a cyclonic wind was blowing at Hachijo Island. For the simultaneous records at Kaminato and Yaene, the average coherence is 0.05 and the maximum value of 0.3 is found at the period of 5 min. This may indicate that seiches around the island are not so distinct.

Making use of the sampled records observed at Yaene during the year 1967 listed in Table 1, spectral analyses are made by the same

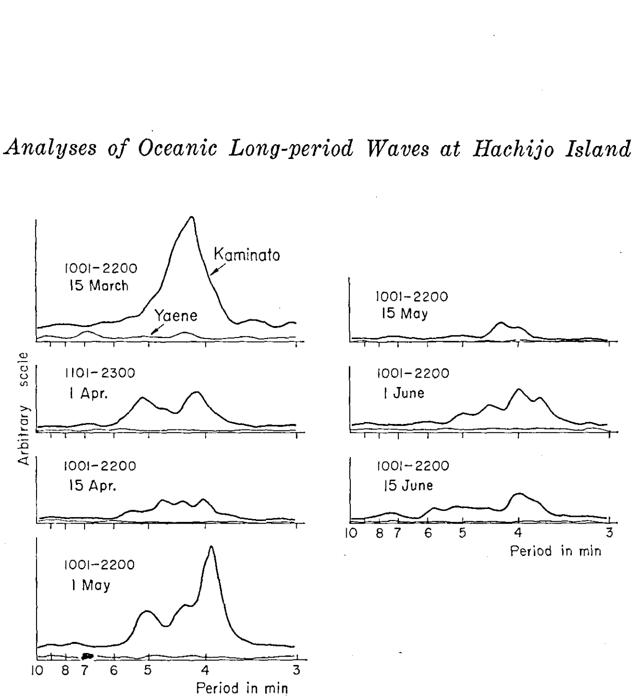

Fig. 6. Power spectra of the records simultaneously observed at Kaminato and Yaene during the period from March to June, 1959.

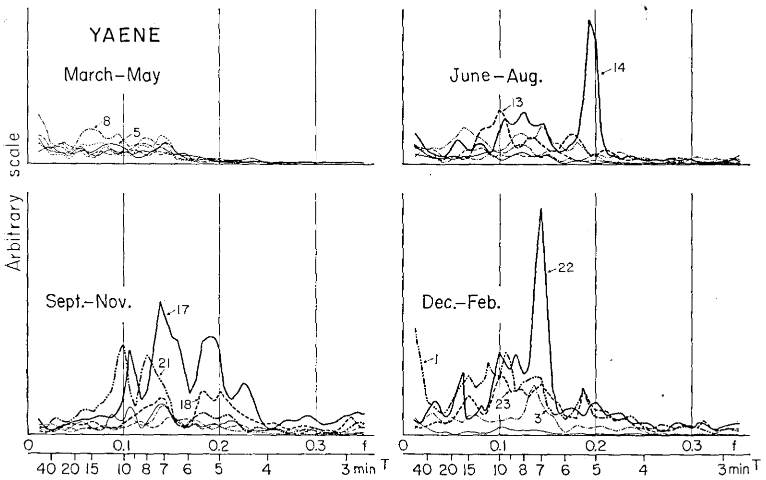

Fig. 7. Seasonal variation of power spectra of the records observed at Yaene during the period of one year in 1967.

method. The weather at Hachijo Island observed by the Japan Meteorological Agency (JMA) at 3 o'clock and the range of sea states at Yaene due to visul observation made by Mr. M. Kobayashi, are also shown in Table 1. Seasonal variations of the power spectra are shown in Fig. 7, where the numerals on spectra are the serial numbers in Table 1. As seen in Fig. 7, the spectra are flat in spring, while those in autumn and winter have predominant peaks at periods of 5 min, 7 min and 10 min.

Table 1. Date of spectral analyses at Yaene during 1967.

No.	Date	Weather at Hachijo I.	Range of sea states*	Remarks
	h m h m			
1	00 01-12 00 Jan. 15		6-7	
2	00 01-12 00 Jan. 31		6	
3	20 01-08 00 Feb. 16-17		6-7	
4	00 01-12 00 March 1		2	
5	20 01-08 00 March 14-15		3-4	
6	00 01-12 00 March 29		3	
7	00 01-12 00 Apr. 14		3	
8	00 01-12 00 May 1		2	
9	05 01-17 00 May 15		2	
10	00 01-12 00 June 1		2	
11	00 01-12 00 June 15		2	
12	07 01-19 00 July 2		2	
13	00 01-12 00 July 15		2	
14	11 01-23 00 Aug. 2		2	Typhoon No. 11 and 13
15	00 01-12 00 Aug. 15		2	
16	00 01-12 00 Sept. 1		1	
17	08 01-20 00 Sept. 15		3	Typhoon No. 22
18	00 01-12 00 Oct. 1		2	Cyclone
19	13 01-01 00 Oct. 15		2	
20	00 01-12 00 Nov. 1		2	
21	00 01-12 00 Nov. 12		3	Monsoon
22	21 01-09 00 Dec. 2-3		2	Cyclone
23	00 01-12 00 Dec. 17		3	

* Beaufort of visual observation at Yaene by M. Kobayashi.

According to weather maps, meteorological conditions were as follows: On 2 August (No. 14), two typhoons of 878 mb and 980 mb were located far east of Honshu and at the Ogasawara Islands, respectively. On 15 September (No. 17), a typhoon of 974 mb was passing near Hachijo Island. On 1 October (No. 18), a cyclone of 998 mb was off Sanriku from which a cold front was extended to Hachijo Island. On 2 December (No. 22), there were two low pressure areas in the Japan Sea and the Ogasawara Islands, respectively and a cold front was passing over Hachijo Island.

Noise levels of the spectra have a tendency to increase when the west wind is strong and the predominant peaks of spectra are often caused by typhoons and cyclones. It is remarked that the conspicuous peaks are not found in the band of long periods of more than 15 min in spectra at both stations. This feature of spectra at Hachijo Island is different from that for Enoshima and Oshima.

4. Spectral analyses of tsunamis

Tsunamis listed in Table 2 have been observed at Hachijo Island. The 1953 Boso-oki and the 1960 Chile tsunamis were observed at Kaminato by Honda's tide gauge belonging to the Japan Hydrographic Office. The 1963 Iturup tsunami was observed at Yaene by Fuess's tide gauge belonging to JMA. As shown in Fig. 8, features of two tsunami records at Kaminato are quite different. By the long-wave recorder, the 1964 Alaska and the 1965 Aleutian tsunamis were observed at Yaene. As seen in Fig. 9, the initial wave of the Alaska taunami is obscure but the waves of later arrival are clearly seen and are of long periods. In contrast, for the Aleutian tsunami, waves of a conspicuous short period were recorded which somewhat resemble the wave feature of nearly tsunamis. During the period from September 1952 to August 1953, many small tsunamis caused by the eruption of a submarine volcano named Myojinsho, about 130 km distant to the south of Hachijo Island, were recorded by a wind wave gauge installed at Yaene (Unoki and Nakano, 1953).

These records are analyzed. Analyzed time intervals of records for tsunamis caused by earthquakes are 6 hours and those caused by eruptions 45 min, including the initial wave. The calculated results are shown in Figs. 10 and 11. It is found that the predominating peak of spectrum for the Boso-oki tsunami falls in the band of short periods, in contrast to that of the Chile tsunami which falls in that of long periods. For the Iturup, Alaska and Aleutian tsunamis, several peaks exist in wide bands of periods, in which the peaks in the range from 6 min to 8 min are the seiches in the neighborhood of Yaene. In cases of the tsunamis caused by eruptions, the predominat peaks fall in the bands of periods of 1.2 min and 1.3 min, and the features of spectra not being so simple.

Table 2. Maximum period of tsunami spectra.

Date (GMT)	Location	Earthquake magnitude M	Max. period T_m (min) Hachijo I.	Enoshima
1953 Nov. 25	Boso	7.5	17	
1958 Nov. 6	Iturup	8.2	—	60
1960 May 22	Chile	8.5	80	80*
1963 Oct. 13	Iturup	$8-8^1/_4$	36	50
1964 March 28	Alaska	8.4	53	120
1965 Feb. 4	Aleutian	$7^3/_4$	32	

* Calculated value by R. Takahasi.

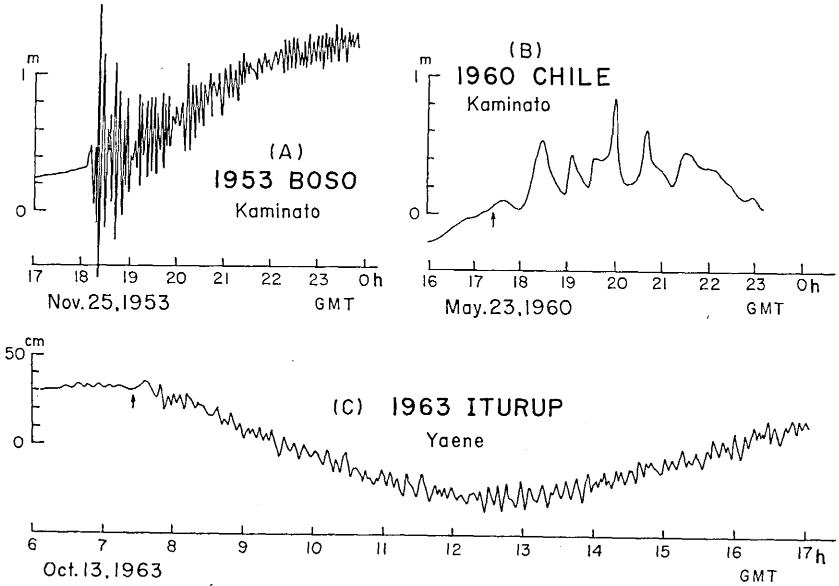

Fig. 8. Records of the different tsunamis observed by tide gauge. A, B: records at Kaminato, C: record at Yaene.

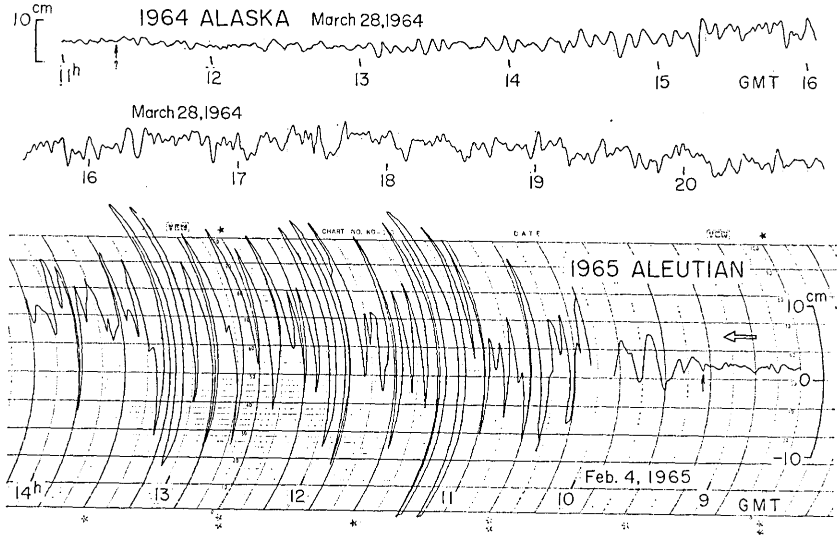

Fig. 9. Records of the 1964 Alaska and the 1965 Aleutian tsunamis observed by the portable long-wave recorder at Yaene.

Takahasi (1961) discussed the relation between the effective period T_e of tsunami spectrum and earthquake magnitude M. Form spectral analyses of the records observed at Miyagi-Enoshima, the empirical equation was given as

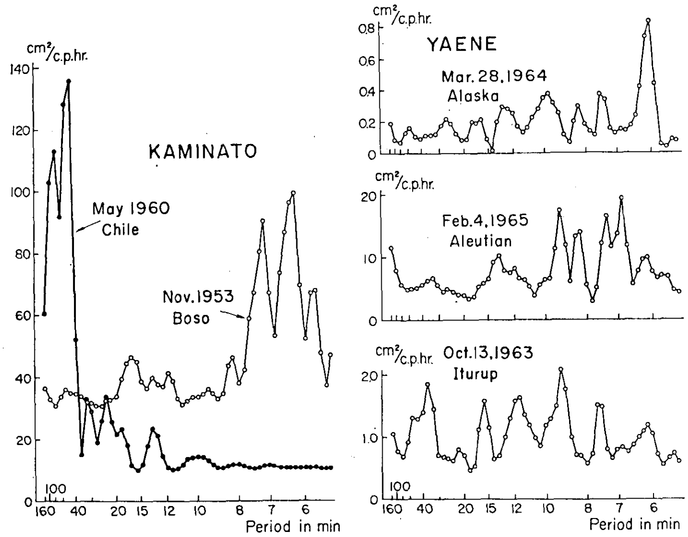

Fig. 10. Power spectra of the different tsunamis observed at Hachijo Island.

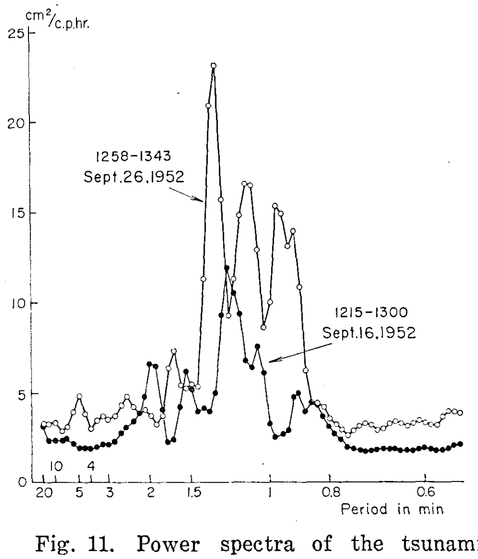

Fig. 11. Power spectra of the tsunamis caused by the eruption of submarine volcano (Myojinsho).

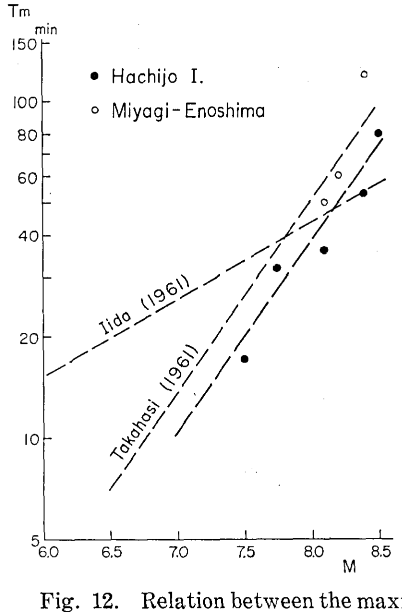

Fig. 12. Relation between the maximum predominant period of tsunami T_m and earthquake magnitude M.

$$\log\ T_e = 0.57M - 2.85. \qquad (1)$$

As shown in Fig. 12, the additional data obtained at Enoshima (Hatori, 1967) have a close relation with the Takahasi's equation. Iida (1961) presented another equation,

$$\log T_{m}=0.23M-0.20, \tag{2}$$

where the maximum value T_m of the predominant periods of tsunami spectrum obtained from different stations is related to M. Taking the maximum value of the predominant period of each tsunami observed at Hachijo Island, the relation between T_m and M, is shown in Fig. 12 together with Takahasi's and Iida's equations. The empirical equation may be represented by

$$\log T_{m}=0.57M-2.97, \tag{3}$$

where T_m is measured in minutes. The coefficient of M in (3) is equal to that of the Takahasi's equation but the maximum periods obtained in Hachijo I. are shorter than that in Enoshima.

5. Conclusion

The spectra of oceanic long-period waves and tsunami at Hachijo Island were investigated, and the following results were obtained: (1) Features of spectra at Yaene are ordinarily flat, but predominant peaks are formed in a band of periods of 5 min, 7 min and 10 min, when the disturbances are caused by typhoons and cyclones. (2) Seiche periods of 4 min and 5 min are always observed in the fishing port of Kaminato. (3) Waves of long periods of more than 15 min are small in the spectra of both stations except for the case of tsunamis. (4) The position of the predominant peak of a tsunami spectrum moves to the low frequency part as the earthquake magnitude increases. However, the predominant periods at Hachijo I. are shorter than those at Enoshima. The different features of spectrum seem to be caused by the relative location between the tsunami source and the observation site, and the source direction.

Acknowledgements

The author wishes to express his heartfelt thanks to Prof. R. Takahasi and Prof. K. Kajiura for their guidance and to Dr. I. Aida for his helpful advice. His thanks are also due to the Tokyo Harbor Construction Bureau and Mr. M. Kobayashi for their devoted observations over a long period, and to Mr. M. Koyama who has assisted in reading out many records. The computations were made at the Computer Center, the University of Tokyo.

References

AIDA, I., 1962, Design and construction of long-period wave recorders (in Japanese), *Bull. Earthq. Res. Inst.*, **40**, 545-560.

HATORI, T., 1967, The wave form of tsunami on the continental shelf, *Bull. Earthq. Res. Inst.*, **45**, 79-90.

IIDA, K., 1961, On the estimation of tsunami energy, *Proc. Tsunami meeting associated with the Tenth Pacific Science Congress*, IUGG Monograph, No. **24**, 167-173.

TAKAHASI, R., HIRANO, K., AIDA, I., HATORI, T., and S. SHIMIZU, 1961, Observations at Miyagi-Enoshima Tsunami Observatory during the IGY Period, *Bull. Earthq. Res. Inst.*, **39**, 491-521.

TAKAHASI, R., 1961, On the spectra and the mechanism of generation of tsunamis, *Proc. Tsunami meeting associated with the Tenth Pacific Science Congress*, IUGG Monograph, No. **24**, 19-25.

TAKAHASI, R., and I. AIDA, 1962, Spectral analyses of long-period ocean waves observed at Izu-Oshima (in Japanese), *Bull. Earthq. Res. Inst.*, **40**, 561-573.

UNOKI. S., and M. NAKANO, 1953, On the Cauchy-Poisson waves caused by the eruption of a submarine volcano (1st paper), *Oceanograph. Mag.*, **4**, 119-141.

UNOKI, S., and M. NAKANO, 1955, On the ocean waves at Hachijo Island, *Meteorol. Geophys.*, **6**, 63-86.

---

39. 八丈島における海洋長周期波の解析

地震研究所　羽　鳥　徳太郎

宮城江ノ島と伊豆大島津波観測所の補助ステーションとして，1958 年 11 月八丈島の神湊に携帯用長波計を据付け，長周期波の観測を行なってきた．しかし神湊では，常時 4 分と 5 分の漁港のセイシュが卓越していることが判り，観測は 6 ケ月間で中止した．一方，同島西部の八重根において，1959 年 3 月より 1967 年 12 月まで同様な長周期波の観測を行ない，この間に 1964 年 3 月アラスカ津波と 1965 年 2 月アリューシャン津波を記録した．

観測に使用した器械は，水理沪波器の方式を採用する（相田 1962）．その構成は，2 個の長筒形タンク内に，それぞれ直径の違ったキャピラリー管を設け，タンクに変圧器用油を約 1/2 ほど入れ，海中に据付ける．海水運動によって，キャピラリー管を通る油の粘性抵抗で，両タンク内に圧力差が生じる．タンクとベローズとはそれぞれビニール管で連結し，2 個のベローズの変位差を挺子で拡大して，器械的にペン書きで記録した．測定範囲は 0-40 cm とし，沪波器の中心周期は 20 分に選んだ．八重根では，台風時にかなりの風浪が予想されるので，記録計は沪波器タンクから約 80 m 離れた地点に小屋を設けて，据付けた．この程度の距離になると，ビニール管で直接圧力を伝達すると，数ケ月で圧力の低下が起り，1964 年 5 月以後，記録方式を電気的に改良する．すなわち沪波器付近に差動トランスを用いた圧力変換装置のみを据付け，6 芯ケーブルを観測小屋まで配線して，12 V の電池と発振増幅器の組合せで記録電流計によって記録した．改良後計器の感度は多少変更され，沪波器の中心周期は 34 分となっている．

八重根の解析には 1967 年の観測から，1 ケ月間に 1 日と 15 日前後の記録を 12 時間分サンプリングして，計 23 個の記録のパワースペクトルを求めた．計算の結果，平常時にはスペクトルの形は平坦で，卓越する周期は見あたらない．しかし秋とか冬季のように，台風または低気圧が発生すると，6 分から 12 分の間にノイズレベルが上昇し，5 分，7 分，10 分に顕著なピークが現われる．神湊も同様に，10 数分以上の長周期部分には顕著な周期は認められない．このことは江ノ島，大島で得られたスペクトルの形と様子が違っている．

八丈島では長波計以外に，多数の津波が観測されている．まず 1952 年 9 月，明神礁の海底火山の

噴火による津波を波浪計で観測したのをはじめ(宇野木，中野 1953)，1953年9月房総沖津波，1960年5月チリ津波，1963年10月エトロフ津波が水路部と気象庁の検潮儀によって観測された．明神礁の津波では，スペクトルのピークは数個あって，なかでも 1.2 分と 1.3 分のピークが顕著で，スペクトルの形は単純でない．房総沖津波とチリ津波のスペクトルでは，顕著なピークの位置がはっきりと短周期と長周期帯域に分れる．各津波のスペクトルの最大卓越周期と地震規模との関係をみると，地震規模の大きな津波ほど，最大周期の現われる位置は長周期部分に移っていると言える．しかし同様な関係を江ノ島の解析結果と比較したとき，八丈島の場合は短周期となっている．これは波源と観測点との相対的な地理的条件と，波源の向きが関係しているものと思われる．