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49. *On the Aleutian Tsunami of February 4, 1965, as Observed along the Coast of Japan.*

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Abstract

Some features of tsunami generated at Middle Aleutian Islands, USA, at 05 h 01 m (GMT), Feb. 4, 1965 are investigated on the basis of tsunami records taken along the coast of Japan.

The predominant wave periods of 14 minutes in addition to seiches on the continental shelf were observed at Miyagi-Enoshima. The present tsunami contained waves of short periods as compared with the tsunamis of 1960 (Chile) and 1964 (Alaska). At Hachijo Island, conspicuous direct waves emitted from the source were observed. Tsunami waves along the coast of Japan were uniformly decayed with time. The decay coefficient is estimated to be approximately 0.038 per hour.

Introduction

At 05 h 01 m 21.8 s (GMT), a strong earthquake occurred at Middle Aleutian Islands, USA. According to the US Coast and Geodetic Survey (the Yellow Card), the magnitude of earthquake was $7\frac{3}{4}$ (PAS, BEK), the depth 40 km and the epicenter at 51.3°N, 178.6°E. A tsunami was generated and was propagated across the Pacific Ocean. Along the coast of Hokkaido in Japan, a weak tsunami was felt by the tide-gauge $3\frac{1}{2}$ hours after the earthquake and a crest-height above the ordinary tidal level of 20∼40 cm was observed all along the Pacific coast of Japan.

The epicenter of the present earthquake was situated in the Aleutian seismic zone, which has generated many tsunamis in the past. Fairly recent tsunamis occurred at the location as shown in Fig. 1 on April 1, 1946, March 9, 1957 off Aleutian Islands and on March 28, 1964 off Alaska. The 1946 tsunami[1)] is well known because the Hawaiian Islands

1) G. A. MACDONALD, F. R. SHEPARD and D. C. COX, "The Tsunami of April 1, 1946, in the Hawaiian Islands," *Pacific Science*, **1** (1947), No. 1, 21.

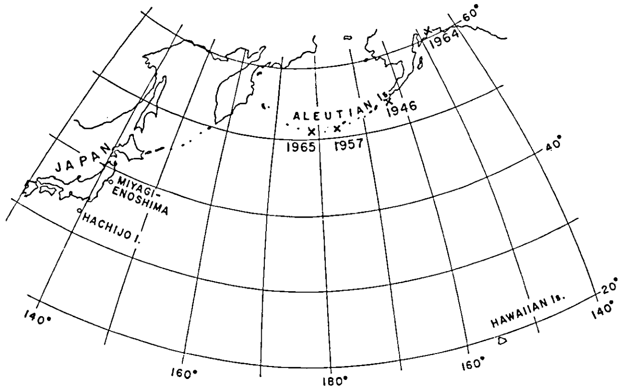

Fig. 1. Distribution of tsunami sources at Aleutian region in recent years.

suffered severe damage. However, the Pacific coast of Japan has suffered only small damage from these tsunamis.

In this paper, effects of the present tsunami along the coast of Japan are discussed mainly on the basis of tsunami records obtained at Miyagi-Enoshima, Hachijo Island, Izu-Ōshima and Kanaya in Chiba Prefecture, where the tsunami stations are operated by ERI, supplemented by tide-gauge records made available by the courtesy of the Japan Meteorological Agency, Japan Geographical Survey Institute and Japan Hydrographic Office. The predominant periods of tsunami observed at Miyagi-Enoshima and the decay of tsunami waves along the continental shelf of Japan are discussed, making use of the tide-gauge records.

Summary report on the tsunami observation along the coast of Japan

From every tsunami record obtained at stations of the Japanese Pacific coast, the initial motion of the tsunami was found to be directed upwards. Features of the tsunami at different localities can be seen in Table 1.

Fig. 2 shows a refraction diagram obtained from the arrival times of wave fronts and the distribution of the maximum crest-height in centimeters above the ordinary tidal level. As for the travel time of the wave, the initial wave front reached the coasts of Hokkaido, Sanriku, Kishu and Kyushu at 3 h 30 m, 3 h 50 m, 5 h 10 m and 5 h 50 m after the occurrence of earthquake respectively. The maximum crest-height was

Table 1. The tsunami of Feb. 4, 1965, as recorded by tide-gauges and tsunami recorders.

Tide station	Initial wave				Maximum wave			
	Travel time		Height**	Period	Travel time		Height**	Period
	h	m	cm	min	h	m	cm	min
Monbetsu	3	59	6	20	18	35	9	33
Hanasaki	3	29	10	40	7	57	21	20
Hiroo	3	39	15	20	10	54	30	15
Urakawa	3	49	7	—	8	22	33	15
Hakodate	4	23	11	27	15	10	17	50
Hachinohe	4	01	18	48	13	16	48	35
Miyako	3	49	8	48	15	49	10	48
Kamaishi	3	43	20	30	11	19	40	25
Ōfunato	3	59	20	20	15	33	38	24
Enoshima*	3	49	9	14	7	44	12	32
Onagawa	4	07	26	35	21	11	28	46
Onahama	4	16	16	18	15	39	20	18
Kanaya*	4	23	4	13	18	24	13	30
Tokyo	5	29	4	70	9	49	10	64
Yokosuka	4	43	5	20	23	19	12	25
Aburatsubo	4	15	6	14	13	43	28	14
Izu-Ōshima*	4	09	3	20	5	21	4	14
Miyake I.	4	15	4	—	6	21	20	4
Hachijo I.*	4	13	2	7	6	05	>23	7
Minami-Izu	4	23	8	22	9	51	32	10
Onizaki	5	44	3	20	17	59	10	21
Uragami	5	09	8	19	12	09	30	15
Kushimoto	5	18	9	18	8	39	55	15
Kainan	6	09	5	25	10	05	14	30
Kōchi	5	42	4	—	15	49	20	16
Tosa-shimizu	5	39	12	30	11	51	36	23
Hosojima	5	54	4	15	19	29	7	18
Aburatsu	5	47	6	28	7	28	32	16
Naze	6	12	14	22	8	19	40	20

* Tsunami observatory.
** Crest-height above the ordinary tide level.

20～40 cm along the coast of Japan in general. Oyster-farming at the Sanriku coast weakly incurred losses by the tsunami. Wave-heights at the Sanriku coast and Kushimoto, the Kishu district, were higher than at other coasts. This phenomenon has been often experienced for distant

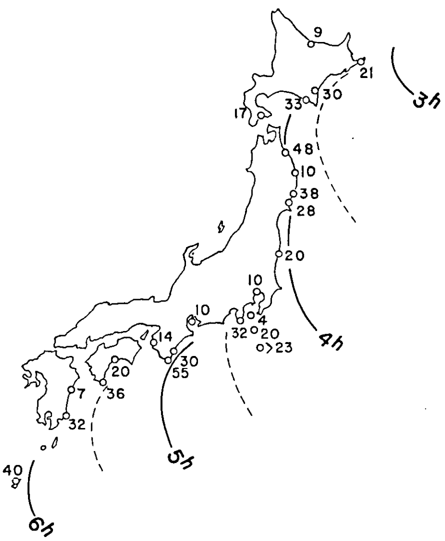

Fig. 2. Refraction diagram obtained from the arrival times of wave fronts and distribution of maximum crest-height in cm above ordinary tidal level.

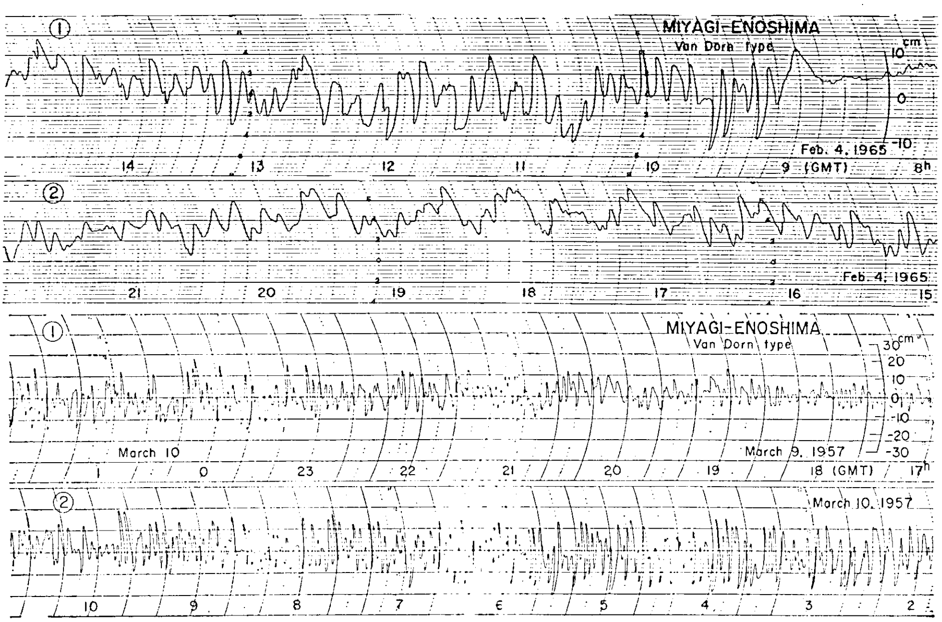

Fig. 3. Records of Aleutian tsunami observed at Miyagi-Enoshima (above: the present tsunami; below: the Aleutian tsunami of 1957).

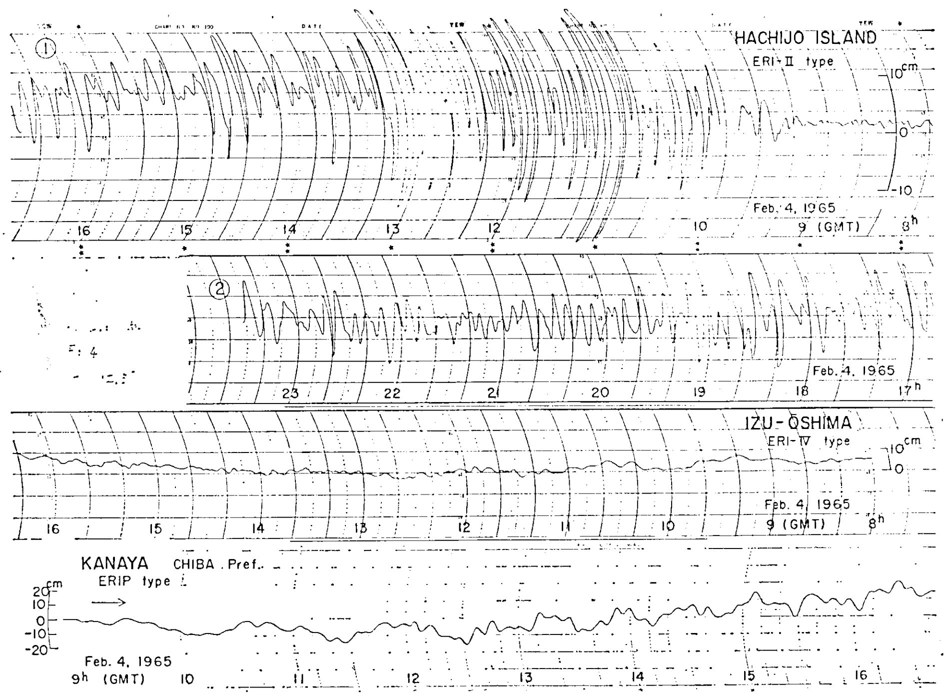

Fig. 4. Records of the Aleutian tsunami of Feb. 4, 1965, at different stations.

tsunamis.[2] It is noticeable that a conspicuous wave-height was observed at the Island of Hachijo for the present tsunami. (Fig. 4)

As compared with the 1957 tsunami, wave fronts of the present tsunami arrived about 30 min earlier at the Pacific coast of Japan. The intensity of tsunami was approximately similar to the tsunami of 1957. However, at the time of the 1957 tsunami, there was low atmospheric pressure to the east of Hokkaido, so that the waves of tsunami reinforced by a storm surge inundated the southern coast of Hokkaido.[3]

Figs. 3 and 4 show tsunami records obtained at Miyagi-Enoshima, Hachijo Island, Izu-Ōshima and Kanaya. Fig. 3 shows the nature of records of two Aleutian tsunamis, both obtained by the Van Dorn long-wave recorder at Miyagi-Enoshima. (above: the present tsunami; below: the 1957 Aleutian tsunami.) However, each record has different sensitivity and osillatory characteristics of the instrument. The records

2) T. HATORI, "Study on Distant Tsunamis along the Coast of Japan. Part 1," *Bull. Earthq. Res. Inst.*, **43** (1965), 499.

3) HAKODATE MARINE OBSERVATORY, "The Storm Surge on March 9 to 10, 1957," *Rep. Hakodate Marine Obs.*, No. 108 (1957), 79, (in Japanese).

of Miyagi-Enoshima have usually a conspicuous period of 2.5 minutes due to seiches of the inlet. Thus this instrument has been improved to cut out the period of 2.5 minutes by mean of an electric filter after the tsunami generation of 1957. The record of 1957 shown in the lower figure of Fig. 3, therefore, contained short period waves, which was caused by the tsunami and above-mentioned storm surges.

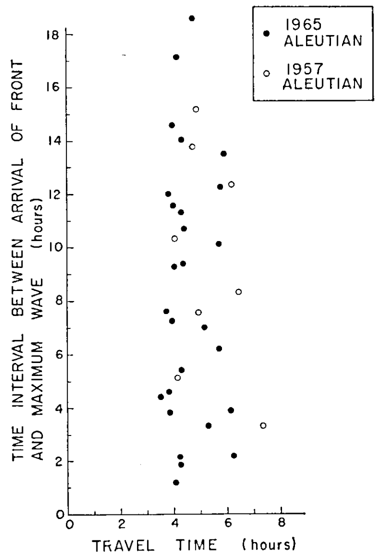

Fig. 5. The relation between travel time of the initial wave front and the time interval between arrival of front and maximum wave.

The time interval between the arrival of the front and the maximum wave seemed to increase as the distance from the tsunami origin increased. For instance, the tsunamis of 1952 (Kamchatka), 1958 (Iturup) and 1963 (Iturup) followed roughly this relationship. However, in the tsunamis of 1957 and 1965, this relation is not so well defined, as shown in Fig. 5. Feature of the 1964 Alaska tsunami was similar, too. Time of the occurrence of the maximum wave along a continental shelf seems to be prescribed not only by the distance of propagation but also by seiche periods of the bay and the shelf.

Periods

Fig. 6 shows arrival times of each crest for the tsunami waves of 1957 and 1965 observed at Miyagi-Enoshima, where the waves of 1957 are smoothed to cut out the period of 2.5 minutes. The initial wave of both tsunamis reached Miyagi-Enoshima at approximately the same time. However, the wave train of the present tsunami was propagated faster than those of the 1957 tsunami as shown in Fig. 6.

Edge waves propagated along the continental shelf appeared to be observed when dispersion curves were calculated from records at Miyagi-Enoshima in the Iturup tsunamis[4] of 1958 and 1963 and the 1964 Alaska

4) T. HATORI and R. TAKAHASI, "On the Iturup Tsunami of Oct. 13, 1963, as Observed along the Coast of Japan," *Bull. Earthq. Res. Inst.*, **42** (1964), 543.

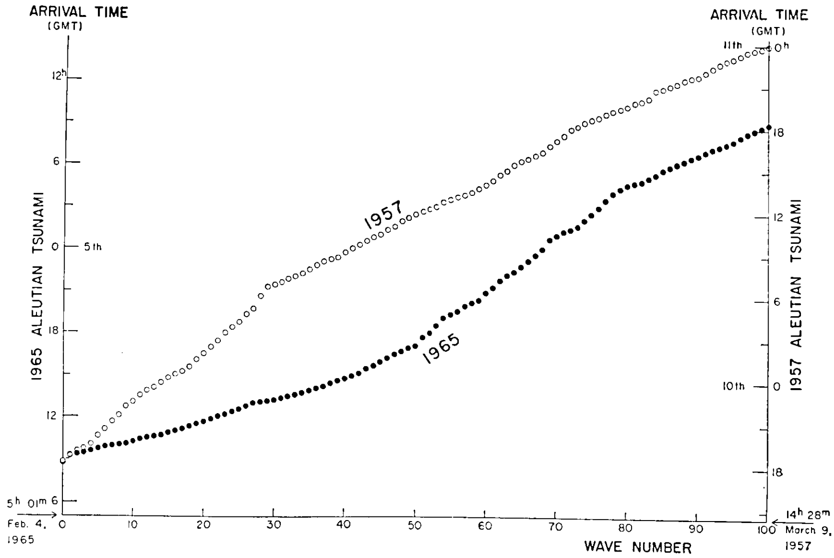

Fig. 6. Arrival times of each crest for the tsunami waves of 1957 and 1965 observed at Miyagi-Enoshima.

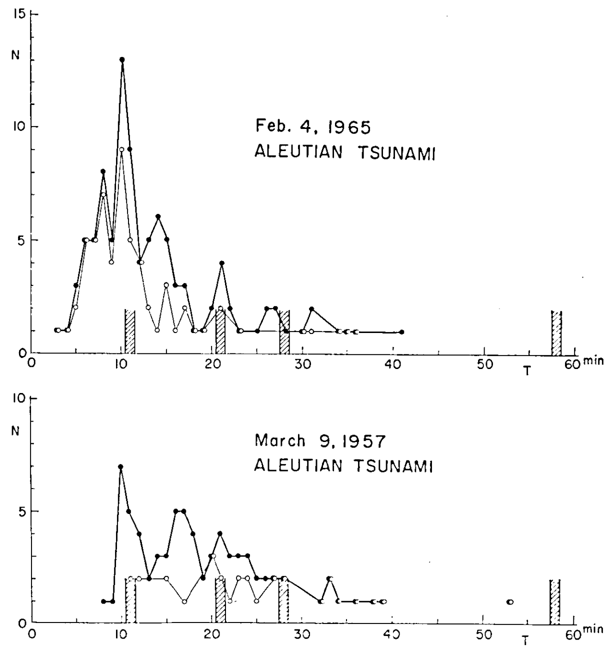

Fig. 7. Frequency distribution of periods on the Aleutian tsunamis observed at Miyagi-Enoshima.

tsunami[5] in accordance with the Nakamura's theoretical model[6]. However, for the tsunamis of 1957 and 1965, dispersed waves were not observed, as shown in Fig. 6. Direct waves emitted from the tsunami source might be mostly observed. The record obtained at Hachijo Island may be considered a typical example of direct waves as the shape of the envelope of the wave train is triangular in Fig. 4. The records of triangular type have often been obtained at the Pacific islands when tsunamis generated at the circum-Pacific zone.

The frequency distribution of periods obtained from the record at Miyagi-Enoshima in the Aleutian tsunami of 1957 and 1965 is shown in Fig. 7, where the solid and the hollow circles denote the frequency from arrival times of wave front to 24 and 12 hours respectively. At ordinary times, the predominant periods[7] of 11, 21, 28, 58 and 84 minutes due to seiches on the continental shelf have been frequently observed at Miyagi-Enoshima. Columns in Fig. 7 indicate the bands of these predominant periods. In the Aleutian tsunamis of 1957 and 1965, the periods of 11, 21 and 28 minutes predominate in the order of short period as shown in Fig. 7. Although, in the tsunamis of 1957 and 1965, the periods of 16 and 14 minutes respectively can be conspicuously seen in addition to seiches on the continental shelf. Waves of long period of about 60 minutes were observed at Miyagi-Enoshima in the cases of the tsunamis of 1960 (Chile) and 1964 (Alaska). However, the predominant period of 11 minutes was conspicuous in the Aleutian tsunamis, so that periods of the present tsunami seem to be comparatively short.

Decay of tsunami waves

Tsunami waves at five stations along the coast of Japan seem to have uniformly decayed as shown in Fig. 8. Decay of the wave-height, the envelopes of the wave train of tsunami records, has a form $\eta \propto e^{-\varepsilon t}$. Decay coefficient ε obtained graphically is 0.038 per hour. This value is approximately similar as compared with the value of the Chilean

5) T. HATORI, "On the Alaska Tsunami of March 28, 1964, as Observed along the Coast of Japan," *Bull. Earthq. Res. Inst.*, 43 (1965), 399.

6) K. NAKAMURA, "The Generation of Edge Waves by Cylindrical Waves impinging from the Outer Sea," *Sci. Rep. Tohoku Univ., Geophys.* [V], **14** (1962), 27.

7) R. TAKAHASI and I. AIDA, "Studies on the Spectrum of Tsunami," *Bull. Earthq. Res. Inst.*, **39** (1961), 523, (in Japanese).

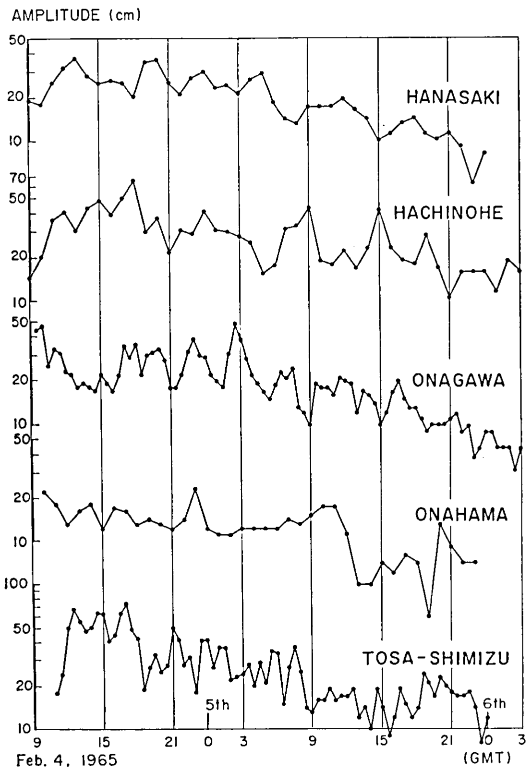

Fig. 8. Decay of tsunami waves at five stations along the coast of Japan.

tsunami of 1960 obtained by W. H. Munk[8] and this coefficient is about four times as large again as the Alaska tsunami of 1964.

In conclusion, the author wishes to express his hearty thanks to the Japan Meteorological Agency, Japan Geographical Survey Institute, and the Japan Hydrographic Office for putting their tide-gauge records at his disposal.

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8) W. H. MUNK, "Some Comments regarding Diffusion and Absorption of Tsunami," *Proceeding of the Tsunami Meeting associated with the Tenth Pacific Science Congress* (1961), 53.

49. 日本における1965年2月4日のアリューシャン津波について

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1965年2月4日05時01分21.8秒 (GMT)，アリューシャン列島中部に大地震が起こり，これに伴なつた津波は全太平洋に伝播し，北海道では地震後3時間30分して第1波を感じ，全日本太平洋岸で波高 20～40 cm (平常時の潮位上) の津波が観測された．U.S.C.G.S. の観測報告によれば震央は 51.3°N, 178.6°E 深さ 40 km, $M=7\frac{3}{4}$ (PAS, BEK) である．

日本に伝播した津波について，気象庁，水路部，国土地理院から提供された検潮記録および，地震研究所で観測した宮城江ノ島，八丈島，伊豆大島，千葉県金谷の津波計記録を用い津波の概要を紹介し，二，三の考察を行なつた．

Fig. 2 は各地の伝播時間および最高波高 (平常時の潮位上，　cm) の分布を示し，津波の規模は1957年のアリューシャン津波とほぼ同程度である．三陸沿岸は過去の遠地津波と同様に，他地域より高い波高が観測され，浅海漁業施設に若干の被害が生じた．特に今回の津波で注目すべきは，八丈島において遠地津波としては比較的顕著な，浪源からの直接波と思われる波高が観測された．(Fig. 4)

宮城江ノ島で観測した今回の津波および1957年のアリューシャン津波の記録を Fig. 3 に示す．両記録はいずれも Van Dorn 型津波計で観測されたものであるが，計器の感度および周期特性がそれぞれ異なり，1957年の記録では津波のほかに低気圧が本邦沖合にあつたため，風浪によつて2.5分の周期が卓越している．これら両記録から各波の到達時刻を Fig. 6 に示す．ただし1957年のは2.5分の周期の波を消去し，平滑化した記録を読取つた．Fig. 6 に示すように両津波の第1波はほぼ同時刻に江ノ島に到達したが，その後の波の伝播時間は可成り異なる．しかしいずれの津波も分散性が認められず，主として直接波が観測され，陸棚に沿つて伝わる Edge waves の検出は困難であつた．

Fig. 7 は江ノ島の記録から求めた両アリューシャン津波の周期頻度分布を示す (黒丸は24時間，白丸は12時間の頻度)．図中斜線で示した帯域は，江ノ島において常時長波の出現し易い周期で，11分，21分，28分，58分および84分である．両津波はこれら陸棚のセイシュと思われる周期に，顕著に卓越したが，この周期以外に今回の津波では14分，1957年の津波では16分の周期が顕著である．このことから両アリューシャン津波の周期は1960年のチリ津波，1964年のアラスカ津波と比較して短周期であると思われる．

5箇所の検潮記録から津波の減衰を求めると，Fig. 8 のように波高はほぼ一様に減衰し，減衰係数は1時間に付き0.038を得た．この価は今回の津波の，陸棚における減衰の平均値を表すものと考えられる．