BULLETIN OF THE EARTHQUAKE
RESEARCH INSTITUTE
Vol. 43 (1965), pp. 399-408

25. *On the Alaska Tsunami of March 28, 1964, as Observed along the Coast of Japan.*

By Tokutaro HATORI,

Earthquake Research Institute.

(Read Feb. 23, 1965.—Received March 31, 1965.)

Abstract

Some features of the tsunami generated off the south coast of Alaska, USA, at 3h 36m (GMT), March 28, 1964 are investigated on the basis of tsunami records taken along the coast of Japan.

Dispersion curves obtained from the record at Miyagi-Enoshima coincide pretty well with the calculation for the case of a continental shelf with a width of 40 km and mean depth 500 m, bordering an ocean 5000 m deep.

An appreciable phase change was observed at Miyagi-Enoshima 31 h 34 m after the occurrence of the main shock. However, a cause for this phase change could not be defined.

Making use of records taken at Miyagi-Enoshima, the decay coefficient of the tsunami waves is estimated to be approximately 0.010 per hour.

Introduction

At 3h 36m (GMT), March 28, 1964, a strong earthquake occurred off the south coast of Alaska, USA. The earthquake caused casualties and damage to buildings and other structures at Anchorage and surroundings. An enormous tsunami was also generated and was propagated across the Pacific Ocean. Along the Japanese Pacific coast, a weak tsunami was felt by the tide-gauge 6.5 hours after the main shock and was observed for a few days following.

According to the US Coast and Geodetic Survey (the Yellow Card), the magnitude of the main shock was 8.5, the depth 20 km and the epicenter at 61.1° N, 147.6°W. As shown in Fig. 1, aftershocks lie in the area extending 500～600 km from the neighborhood of Anchorage to Kodiak I. These aftershocks shown in Fig. 1, occurred during the

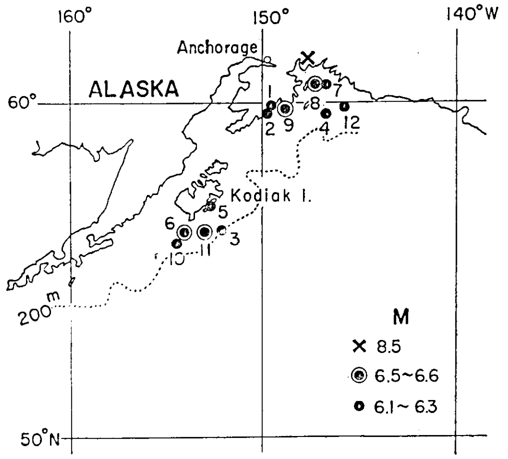

Fig. 1. Distribution of epicenters of earthquakes in Alaska during the period from 28 to 30 March, 1964.

period from 28 to 30 March, 1964.

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, Kanaya in Chiba Prefecture and Aoshima in Miyazaki Prefecture, the tsunami stations belonging to ERI, supplemented by tide-gauge records made available by the courtesy of the Japan Meteorological Agency, Japan Geographical Survey Institute and Japan Hydrographic Office. Possible existence of edge waves and the decay of tsunami waves are discussed by analysing the records obtained at Miyagi-Enoshima.

Summary report on the tsunami observation along the coast of Japan

At all stations of Japanese Pacific coast inspected, the initial motions of the tsunami were found to be directed upwards. Features of the tsunami at different localities can be seen in Table 1. Figs. 2 and 3 show tsunami records obtained at Miyagi-Enoshima, Hachijo Island, Kanaya and Aoshima.

Fig. 4 shows a refraction diagram obtained from the arrival times of wave fronts and the distribution of the maximum crest-height in cm 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 6.5, 7, 9 and 10 hours respectively after the main shock. Although the maximum crest-height was 20∼50 cm along the coast of Japan in general, the crest-heights at Hachinohe, Ōfunato and Kushimoto were conspicuously 60, 75 and 45 cm respectively. It is notable that the period between the first and the second crests on the tide-gauge records differs in two regions as shown in Fig. 5. Periods of 40 min or more and 30 min or less distribute along the coasts of NE and SW Japan

Table 1. The tsunami of March 28, 1964, 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
Wakkanai	6 39	6	50	39 09	34	35
Monbetsu	7 16	7	70	18 34	10	40
Abashiri	6 04	4	46	30 49	12	50
Hanasaki	6 34	8	60	15 04	36	10
Kushiro	6 55	20	45	45 40	40	42
Urakawa	7 12	5	40	18 14	25	28
Hakodate	7 34	11	150	22 17	38	35
Aomori	9 04	8	140	26 14	32	100
Asamushi	8 29	10	130	25 09	46	100
Hachinohe	7 24	18	50	26 44	60	30
Miyako	7 04	9	60	16 02	14	44
Kamaishi	6 44	15	30	16 34	38	22
Ōfunato	7 14	18	40	12 44	75	40
Enoshima*	7 08	7	80	15 39	15	60
Onagawa	7 24	17	70	17 44	50	45
Onahama	7 29	7	50	16 34	35	23
Chōshi	7 39	7	55	20 04	36	40
Mera	7 06	6	7	23 34	33	23
Kanaya*	7 30	7	70	21 14	17	35
Tokyo	9 02	4	65	22 59	10	56
Yokosuka	8 00	5	60	22 30	17	30
Aburatsubo	7 48	6	15	22 32	18	15
Hachijo I.*	7 47	2	8	22 14	7	20
Uchiura	7 34	6	50	16 29	12	28
Shimizu	7 44	4	20	25 19	6	40
Omaezaki	7 04	8	18	22 12	30	22
Onizaki	9 41	6	25	19 54	10	35
Toba	11 24	4	50	18 24	15	15
Uragami	9 29	8	26	18 36	25	28
Kushimoto	9 14	6	15	26 24	45	23
Kainan	10 12	5	30	20 24	15	28
Kōchi	11 06	8	40	25 04	20	20
Tosa-Shimizu	11 24	4	26	22 30	24	22
Hosojima	12 44	2	20	27 07	12	20
Aoshima*	10 44	2	—	26 57	15	30
Aburatsu	10 28	8	23	25 06	39	25
Naze	10 32	8	18	22 32	20	23

* Tsunami observatory.

** Crest-height above the ordinary tide level.

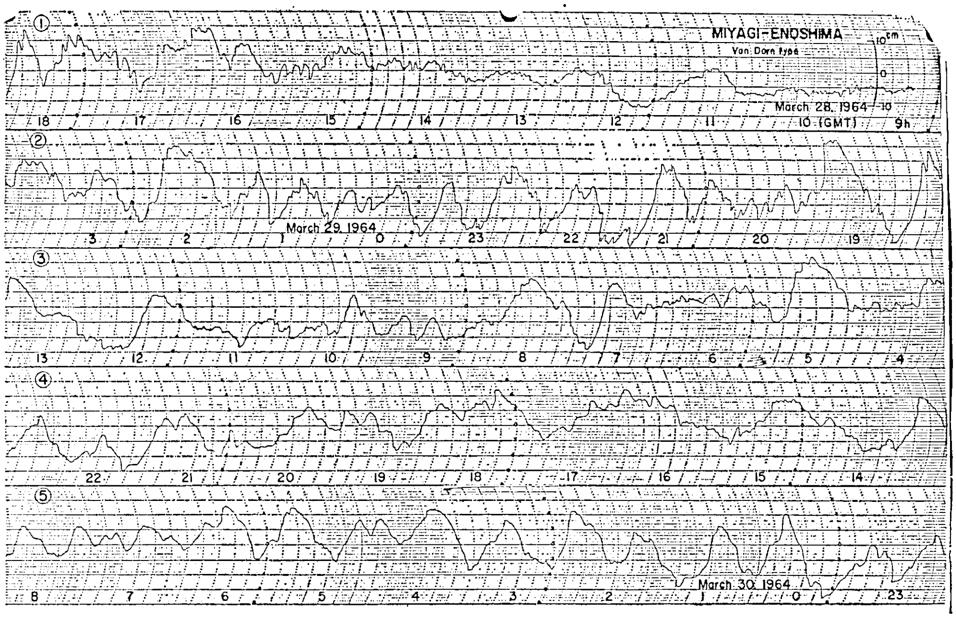

Fig. 2. Records of Alaska tsunami of 1964 observed at Miyagi-Enoshima.

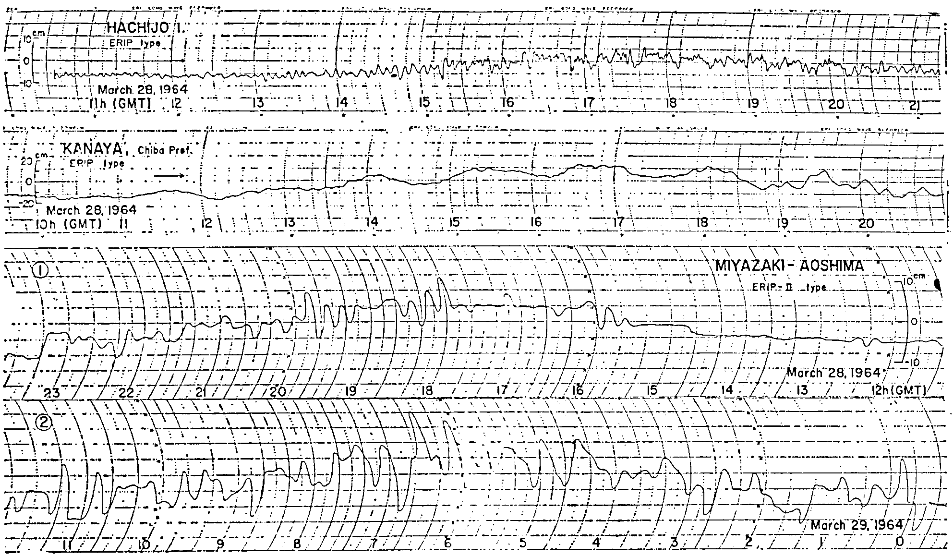

Fig. 3. Records of Alaska tsunami of 1964, at different stations.

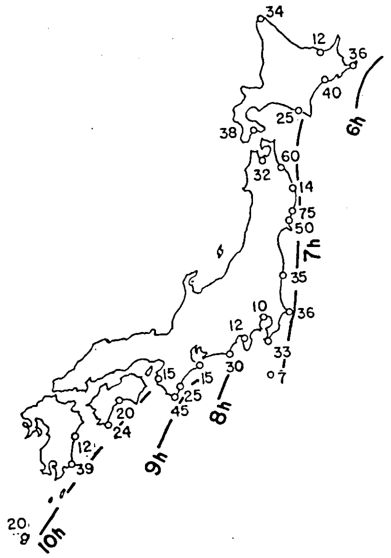

Fig. 4. Refraction diagram obtained from the arrival times of wave fronts and the distribution of maximum crest-height in cm above the ordinary tidal level.

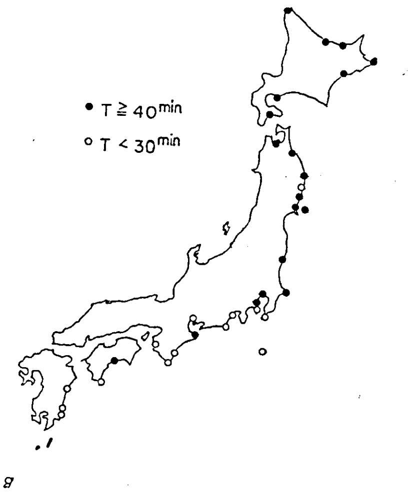

Fig. 5. Distribution of the period between the first and the second crests on the tide-gauge records.

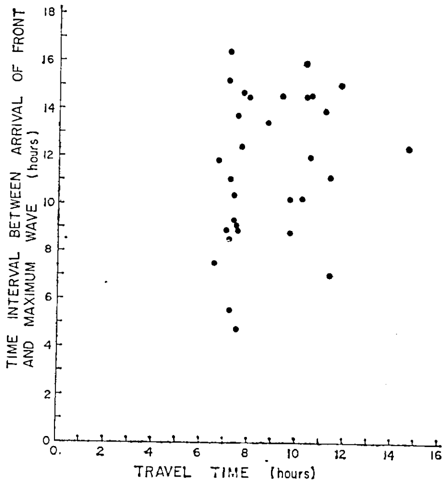

Fig. 6. The relation between travel time of the initial wave front and the time interval between arrival of front and maximum wave.

respectively.

In general, the time interval between the arrival of the front and the maximum wave seems to increase as the distance from the tsunami origin increases. The tsunamis of 1952 (Kamchatka), 1958 (Iturup) and 1963 (Iturup), followed roughly this relationship. However, in the present tsunami, this relation is not so well defined as shown in Fig. 6. One of the reasons may be due to the fact that the present tsunami waves had comparatively long duration, so that the tsunami energy would have been preserved on a continental shelf. The tsunami energy might be exchanged between the continental shelf and the bay for a long time.

Edge wave

K. Nakamura[1] calculated a dispersion curve of edge waves which are generated along a model continental shelf as shown in Fig. 7, when cylindrical long waves are incident to a continental shelf from a source in the outer sea. From records at Miyagi-Enoshima in the 1958 and 1963 Iturup tsunamis[2], edge waves seemed to be observed in accordance

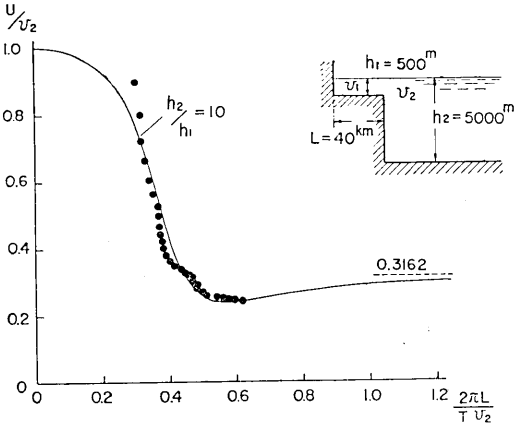

Fig. 7. Dispersion curves of Alaska tsunami record obtained at Miyagi-Enoshima. The figure shows also a model of continental shelf and the theoretical dispersion curve (solid) of the first mode edge wave after Nakamura.

---

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

2) 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.

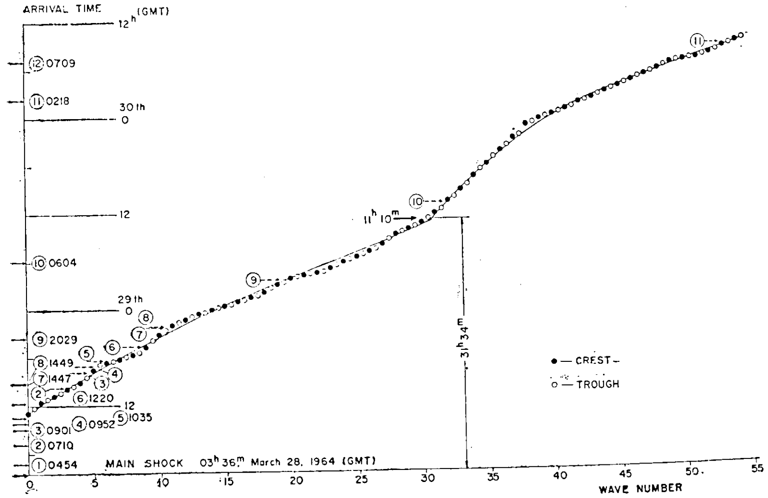

Fig. 8. Crests and troughs of tsunami waves at Miyagi-Enoshima. Arrows show times of occurrence of the aftershocks.

with the Nakamura's theoretical model. Fig. 8 shows crests and troughs of tsunami waves at Miyagi-Enoshima. Based on this record, up to 11h 10 m (GMT), March 29, the dispersion curve of waves was plotted by the same method as shown in Fig. 7, in which the distance of propagation along the continental shelf from the source to Miyagi-Enoshima is estimated to be 5750 km. The breadth L of the shelf was assumed to be 40 km, depths of the shelf and the outer sea are $h_1=500$ m and $h_2=5000$ m respectively. Theoretical dispersion curve for the present tsunami seems to fit roughly into these observed values.

In the record at Miyagi-Enoshima, an appreciable change of phase is observed at 11h 10m (GMT), March 29 (at 31h 34m after the occurrence of the main shock as shown in Fig. 8). On the other hand, in the records at Kanaya and Aoshima, an appreciable change of phase and amplitude are also observed at 13h 46m and 15h 5m, March 29 (GMT) respectively. The following causes might be considered to explain the phase change:

On the ordinate in Fig. 8, times of occurrence of the aftershocks, $M > 6.1$, are indicated by arrows. A number attached to an arrow of the aftershock corresponds to the epicenter number shown in Fig. 1. Dotted arrows indicate the possible waves observed at Miyagi-Enoshima 7h 8m later, if the tsunami waves were generated by the aftershock.

The travel time at Miyagi-Enoshima due to the main shock was 7h 8m. The possibility of tsunami generation by aftershocks seems to be poor because no significant change in phase is observed as shown in Fig. 8. According to the report of field investigation, such a phenomenon could not be found.

As for the effect of reflected waves on the record of Miyagi-Enoshima, an appreciable phase change was observed in the case of the 1963 Iturup tsunami2) 8.5 hours after the main shock and it might have been explained as reflected waves from the reef between East Caroline and Marshall Islands. However, on the present tsunami, it is impossible to find such reflected waves which are propagated from some regions to extend 31h 34m after the main shock.

Decay of tsunami waves

Duration of the present tsunami waves observed along the coast of Japan was a few days, so that decay of tsunami waves was small. Decay of the wave-height of tsunami waves has a form $\eta \propto e^{-\varepsilon t}$ and Table 2 shows decay coefficient ε per hour for some tsunamis generated in the Pacific Ocean. Fig. 9 shows decay of wave-heights of the present tsunami at Miyagi-Enoshima, in which an arrow shows the time of the appreciable phase change. Decay coefficient ε obtained graphically is 0.010 per hour and is small when compared with the tsunamis of 1933

Table 2. Decay coefficient of the tsunami waves at the Pacific Ocean. $\eta \propto e^{-\varepsilon t}$, t: per 1 hour.

Tsunami	ε	Calculator
1933 Sanriku	0.033	Takahasi3)
1957 Aleutian	0.010	Van Dorn4)
1960 Chile	0.039	Munk5)
1964 Alaska	0.010	Author

---

3) R. TAKAHASI, "Decay of Tsunami Waves," Meeting of the Seismological Society of Japan, Tokyo, April 1952.

4) W. G. VAN DORN, "The Source Motion of the Tsunami of March 9, 1957 as deduced from Wave Measurements at Wake Island," *Proceeding of the Tsunami Meeting associated with the Tenth Pacific Science Congress* (1961), 39.

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

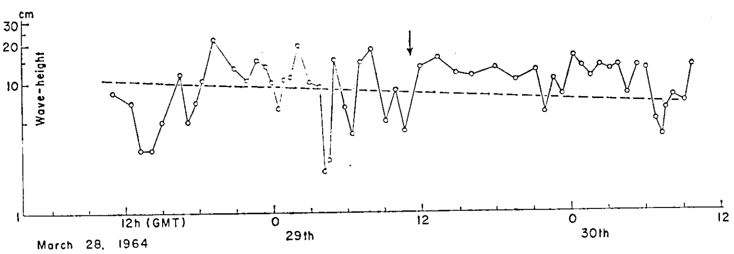

Fig. 9. Decay of wave-heights at Miyagi-Enoshima.

(Sanriku) and 1960 (Chile).

In conclusion, the author wishes to express his hearty thanks to Japan Meteorological Agency, Japan Geographical Survey Institute, and Japan Hydrographic Office for putting their tide-gauge records at his disposal. His thanks are also due to Prof. R. Takahasi for his guidance.

---

25. 日本における1964年3月のアラスカ津波について

地震研究所　羽鳥徳太郎

1964年3月28日3時36分(GMT)ころ，米国アラスカ南部近海に大地震が起り，アンカレヂに多大の被害が生じた．この地震に伴ない津波が発生し，全太平洋に伝搬した．日本でも地震より約6.5時間後から太平洋沿岸で津波を感じ，数日間観測された．

U.S.C.G.S. の観測報告によれば，本震は61.1°N, 147.6°W，深さ20Kmに発生し，マグニチュードは8.5で，3月28, 29, 30日の3日間に起きたマグニチュード6.1以上の余震はFig. 1に示すように，500～600kmの広範囲に分布している．

日本における津波の概要について，気象庁，水路部および国土地理院から提供された検潮記録および，筆者らが観測した宮城江ノ島，八丈島，金谷および青島の津波計記録で検討し，特に江ノ島の記録を用い Edge wave の存在，津波の減衰について考察した．

Table 1 は各地の記録から得た津波の概要を示すもので，伝搬時間および最高波高 cm (潮汐上の片振幅) を図示すると Fig. 4 のようになる．最高波高は概して20～50cm程度で，この内，八戸60cm，大船渡75cm，串本45cmと，附近の波高に比し顕著に高い．

検潮記録における第1波と第2波間の周期について，その分布は Fig. 5 に示すように，東北日本は40分以上，西南日本は30分以下の周期が観測され，可成り明瞭な差異がみられた．

第1波が届いてから最高波が到達するまでの時間は遠地津波ほど長くなり，1952年のカムチャツカおよび1958, 1963年のエトロフ津波の場合，伝搬距離にほぼ比例したが，今回の津波は Fig. 6 に示すように，この関係は非常にバラついた．その原因の一つとして，今回の津波は比較的継続時間が長く，津波エネルギーが陸棚にたまり，長時間に亘り湾の副振動を誘発したものと思われる．

中村 (1962) は Fig. 7 に示す陸棚のモデルに沿つて伝搬する Edge wave の分散曲線を計算した．いま陸棚 $L=40\text{km}$, $h_1=500\text{m}$, $h_2=5000\text{m}$ と仮定し，浪源から江ノ島までの陸棚に沿つた伝搬

距離を5750kmとして，江ノ島の記録につき分散曲線を求めると，中村の理論と近似しEdge wageが実際に観測されたようにみえる．なお，1958年および1963年のエトロフ津波についても，陸棚のモデルは多少異なるが，同様な観測結果を得た．その他，江ノ島の記録で，Fig. 8に示すように地震後31時間34分に顕著な位相変化を認めた．この波の生因について二，三考察を試みたが，よく判らない．

今回の津波は減衰が極めて小さく，江ノ島の記録から減衰係数εは1時間に付き，0.010を得た．