Wind and Seismic Effects

Proceedings of the 30th Joint Meeting

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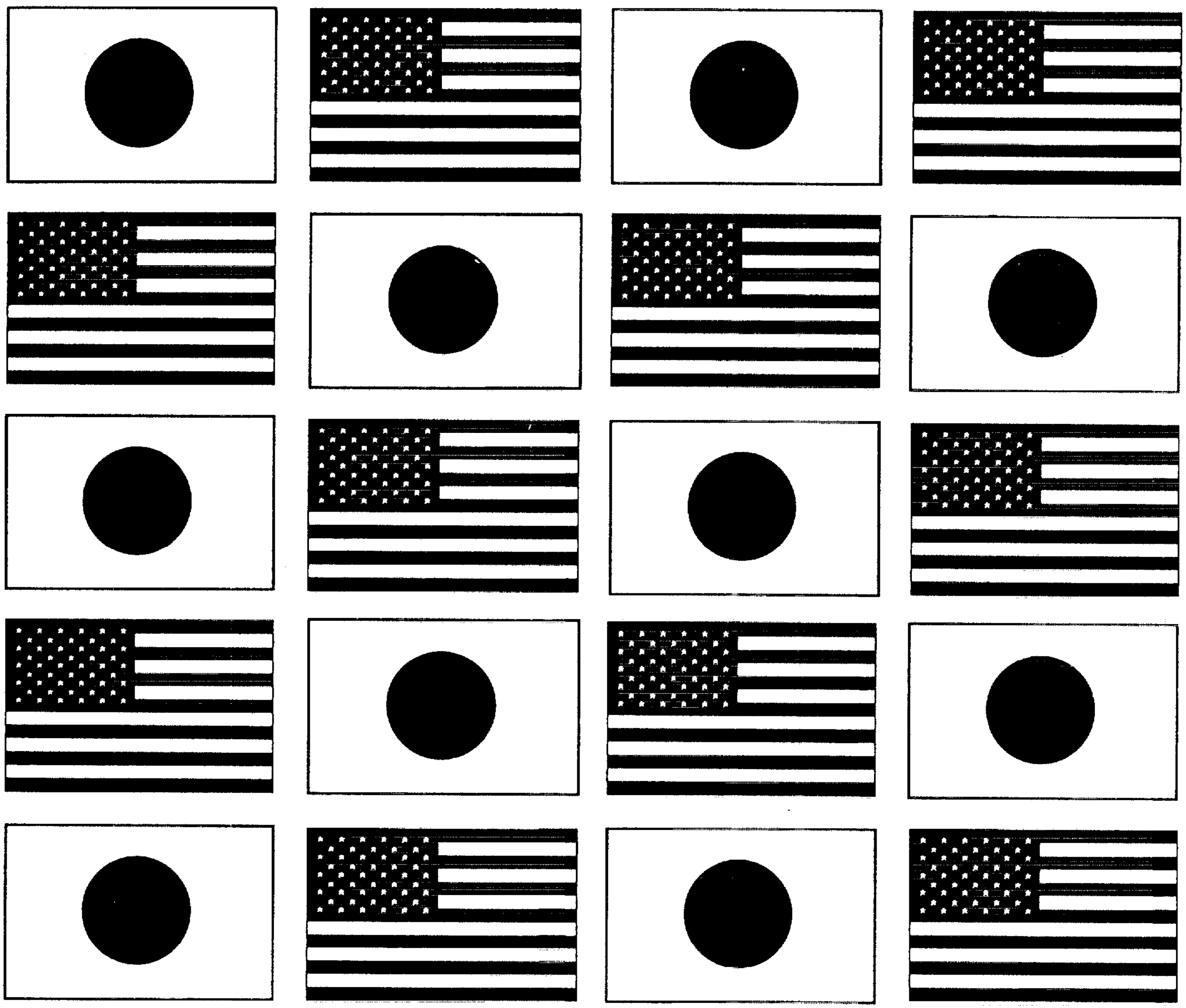

U.S. DEPARTMENT OF COMMERCE
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Wind and Seismic Effects

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PROCEEDINGS OF THE 30TH JOINT MEETING OF THE U.S.-JAPAN COOPERATIVE PROGRAM IN NATURAL RESOURCES PANEL ON WIND AND SEISMIC EFFECTS

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STORM SURGE and TSUNAMIS

TSUNAMI AND STORM SURGE CHARACTERISTICS BASED ON LONG-TERM TIDE OBSERVATIONS

by

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ABSTRACT

Based on the 38-year tide observation records digitized every hour between 1958 and 1995, long waves-characteristics including Tsunamis and Storm surges were investigated. Long-waves with double amplitudes greater than 15cm were observed for 180 cases during the 38 years including 4 tsunamis.

Key Words: Tide Observation,
Long Waves,
Tsunami

1. INTRODUCTION

This paper presents the analysis of observed long-term tide data ; to clarify profiles of long-waves including tsunamis and storm surges. (Nagai.et.al.,1996)

2. TIDE OBSERVATIONS AND DATA ANALYSIS

38 years of tide data, between 1958 and 1995, obtained at the Kurihama-Tide-Station were analysed. The station is located at the entrance of the Tokyo-Bay (N35° 13'28", E139° 43'27"), and employs the Fuse type tide gauge with a well. Figure 1 and 2 shows location of the tide station. Photo 1 shows the Fuse type tide gauge. The tide well is connected to the sea with a tube as the Figure 3 shows. The tube of the diameter 131mm works as a low-pass-filter by omitting the high frequency sea level fluctuations caused by wind waves.

Observed data were recorded on an analog recorder for the entire observation term. All the data were digitized every hour in order to calculate the mean sea level and the harmonic components.

3. LONG-WAVE RECORDS

Figure 4 shows the observed long-waves with the heights (double amplitude) greater than 15cm. Among these 180 cases, 4 casese were tsunamis, andthe others were caused by weather disturbances. Table 1 shows joint distribution between double amplitudes and periods of the observed long waves. Observed periods were either between 2-3 minutes or 15-20 minutes, which corresponds to the local topographical resonance periods of the two different modes, except the 1960-Chile-Tsunami event with periods of around 80 minutes.

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4. THE 1960-CHILE-TSUNAMI PROFILES

Figure 5 shows the observed 1960-Chile-Tsunami profiles by digitizing with a shorter interval, every 36s. The lower figure shows the observed water surface level with astronomical tides, while the upper figure shows the tsunami profiles by omitting lower frequency astronomical tide components. The marks ①,②,③,④, and ①', ②', ③', ④', ⑤', ⑥', ⑦', ⑧' mean the data terms for frequency spectra analysis.

Frequency spectra analysis was conducted with different record lengths 1024, 2048, 4096, and 8192 data points, which corresponds to the sampling length of 10h, 20h, 40h, and 80h, respectively, as the Figure 6 shows. The results showed that the peak frequency of the tsunami was 0.0002Hz, and the second peak was at 0.001Hz. This second peak corresponded to the local topographic resonance frequency. The ratio of the second peak and the first peak increased with time. The results of this study provided more detailed tsunami spectra information than the previous study conducted in 1960's. (Hatori, 1969)

5. THE 1996-IRIANJAYA-TSUNAMI PROFILES

The frequency response of the well, connected with a tube to the sea water, was investigated at the occasion of the 1996 Irianjaya-Tsunami event by comparing the tide gauge data with the ultra-sonic direct sea surface elevation data. Photo 2 shows the Ultra-sonic direct sea surface measurement equipment.

Figure 7 is the tsunami profiles including the NOWPHAS offshore wave gauges continuous records (Nagai et.al. 1994), the low-pass-filtered Fuse type tide gauge records, and the ultra-sonic direct sea surface elevation records. The NOWPHAS offshore wave gauge is located 50km off the tide station near the Izu-Ohshima Island. (water depth 50m, N 34° 40'23", E 139° 27'19")

Figure 8 shows the results of the spectra analysis of the three records of the Figure 7. The peak frequency of the tsunami was 0.001Hz, near to the local topographic resonance frequency. The responce function indicates that the tsunami was amplified in the Kurihama Bay due to the topographic resonance. Figure 8 also proves that for longer period waves, greater than 5 minute periods, ratio is almost 1.0 between the two records of the low-pass-filtered Fuse type one and the direct sea surface elevation one.

5. STORM SURGE RECORDS

Harmonic analysis was conducted for every year from the hourly based observed data, and the 28 components' amplitudes and phases were obtained. Table 2 shows the results of the 4 principal components of M2 (period of 12.42h), S2(12h), K1(23.934h), and O1(25.819h). Z0 values defined as the sum of the amplitudes of the 4 components are also shown.

In addition to the each year's calculated 4 components and the Z0 value, maximum, minimum, and average amplitudes and the standard deviation (S.D.) are shown in Table 2. The 4 components' amplitudes fluctuations were small with the standard deviation less than 1%. Nevertheless, amplitudes of the longer period components such as Sa(1year) and SSa(0.5year), showed much larger fluctuations.

Astronomical tide was calculated from the 28 harmonic tide components' amplitudes and phases, and storm surge (meteorological tide) level was obtained as the diference between the observed tide and calculated one. Table 3 shows the records of the 40 highest storm surges during the 38 years with the meteorological cause. Figure 9 shows an example of the storm surge records.

6. CONCLUDING REMARKS

Interesting facts related to the tsunami and long-wave profiles were found from the analysis of long-term tide records. It is desirable to apply these methods of analysis to additional tide stations, and to compare the results, in order to obtain more precise information. Efforts are now underway to establish a digital network system of tide data stations, with the cooperation of the concerned organizations. (Nagai, et. al., 1994)

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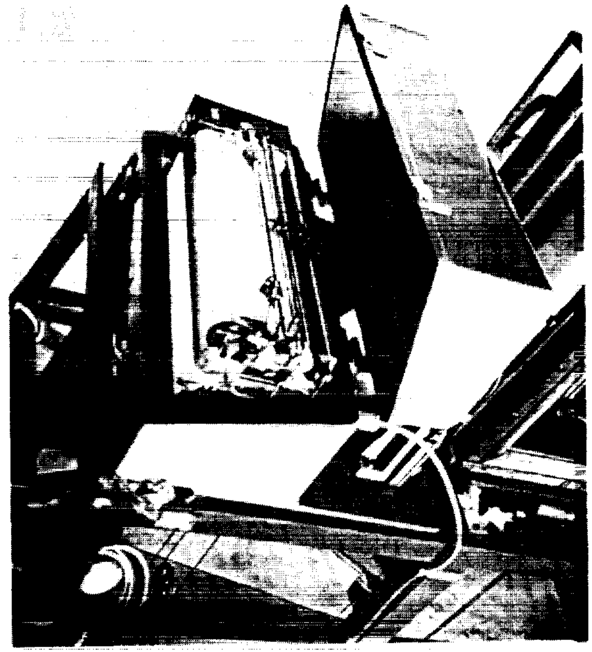

Photo 1 Fuse Type Tide Gauge

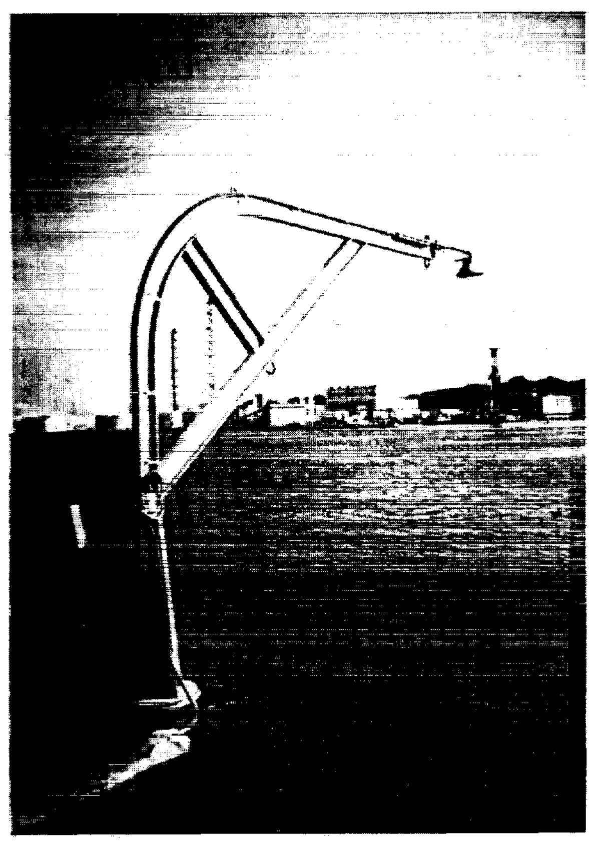

Photo 2 Ultra-Sonic Direct Sea Surface

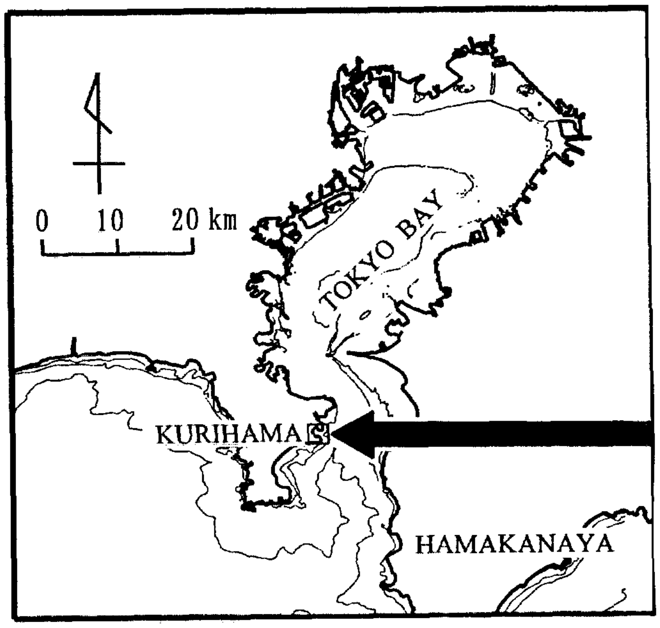

Figure 1 Location of the Tide Station (1)

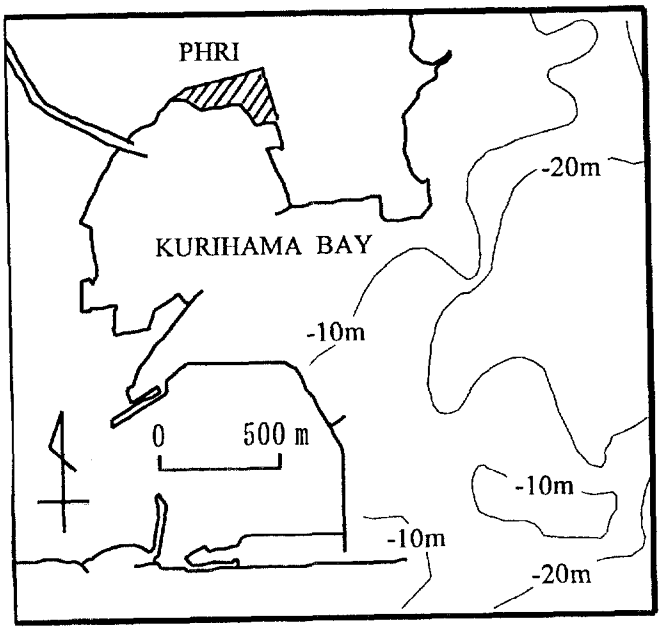

Figure 2 Location of the Tide Station (2)

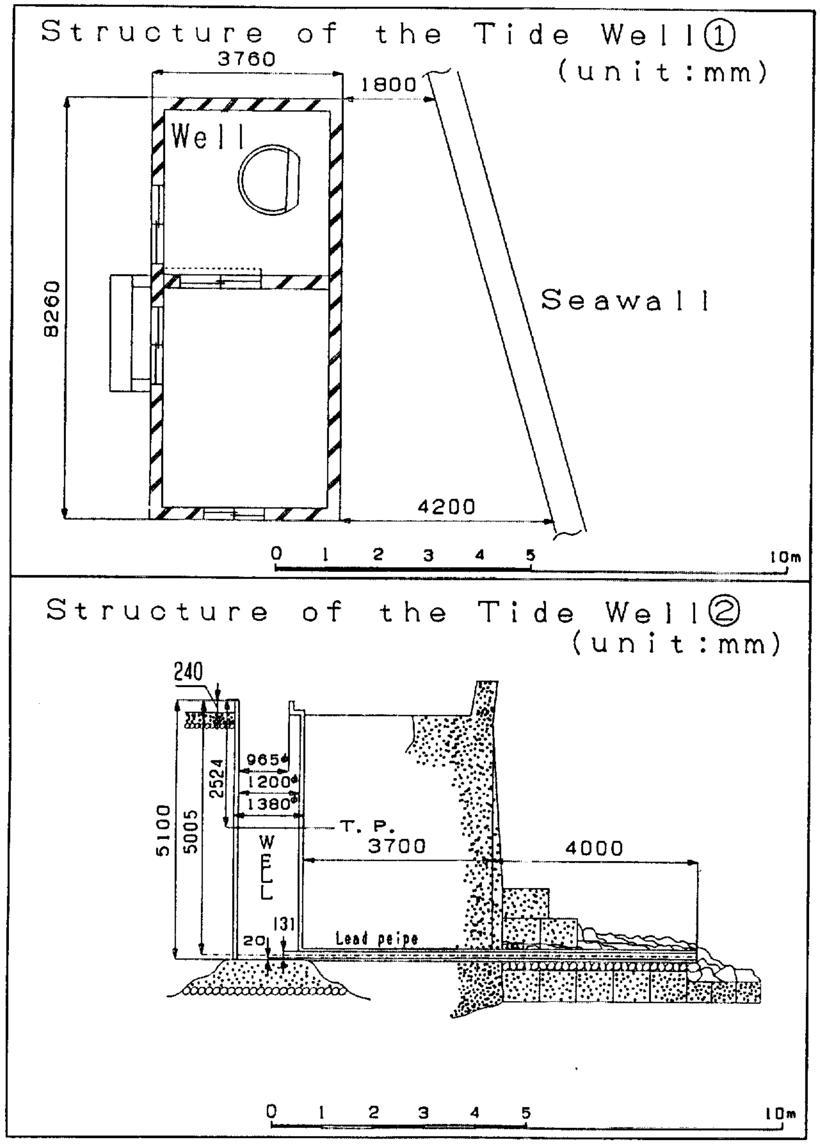

Figure 3 Structure of the Tide Well

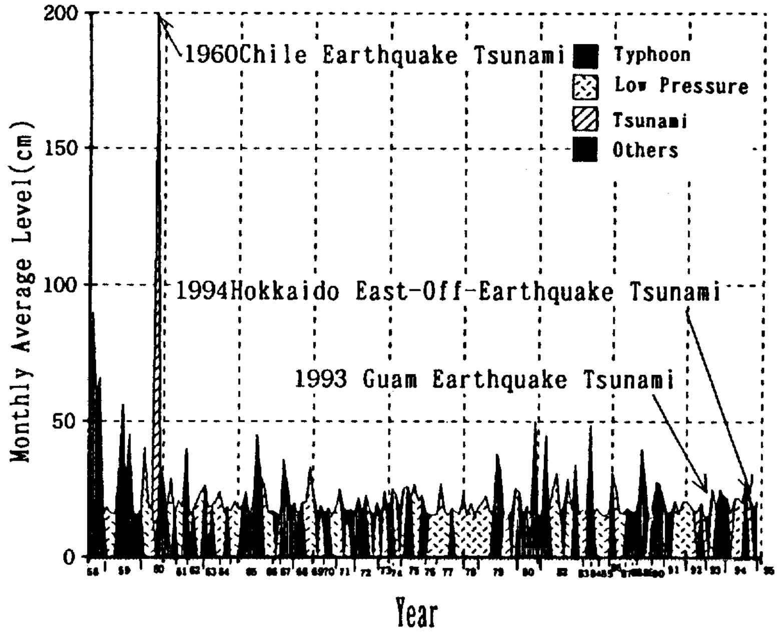

Figure 4 Observed Long-Waves

Table 1 Joint Distribution of the Observed Long Waves

Double Amplitude (cm)	Period (min)			Total
	-10	10-20	20-	
15 - 20	17	80	0	97
20 - 25	17	22	1	40
25 - 30	12	7	1	20
30 - 40	6	4	0	10
40 - 50	6	1	0	7
50 -100	5	0	0	5
100 -	0	0	1	1
Total	63	114	3	180

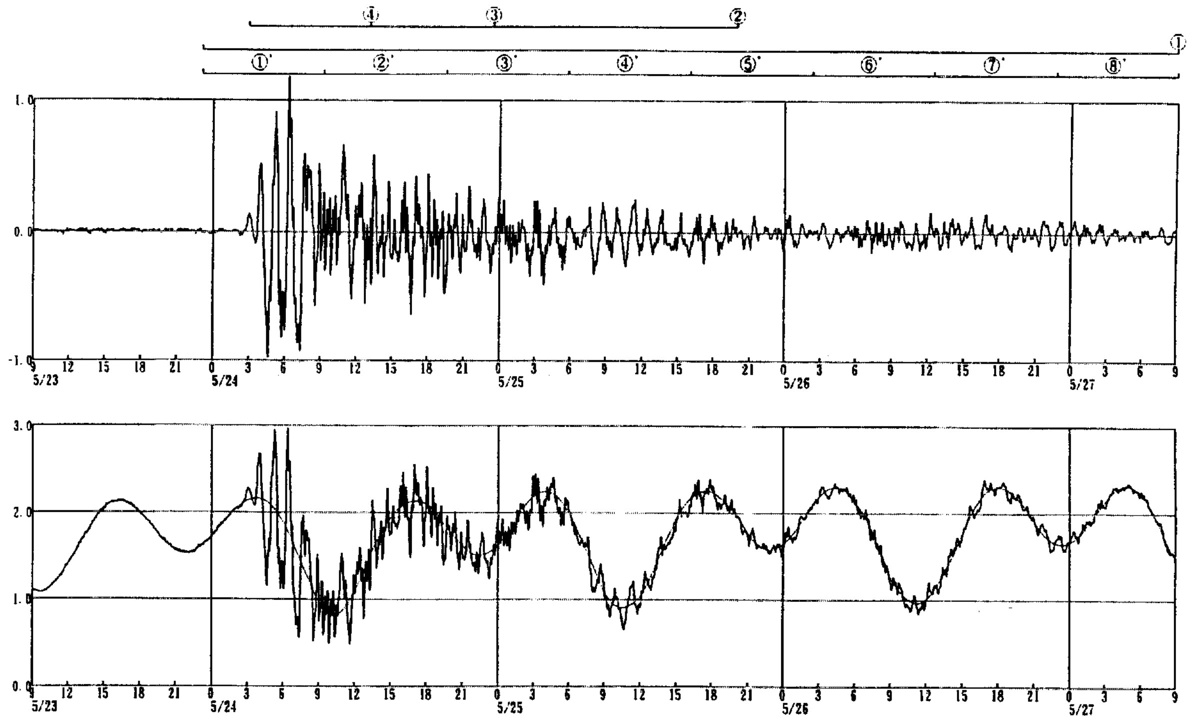

Figure 5 1960-Chile-Tsunami Profiles

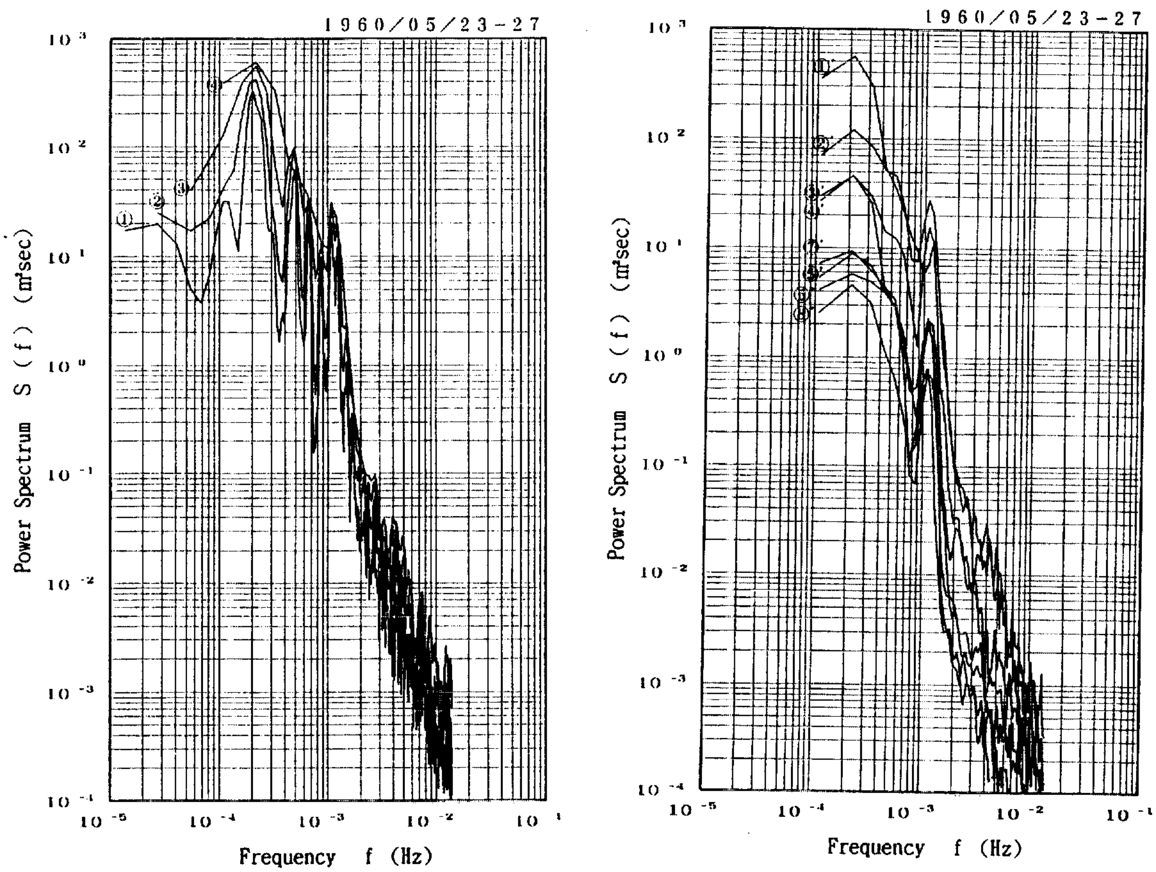

Figure 6 Spectra Analysis of the 1960-Chile-Tsunami

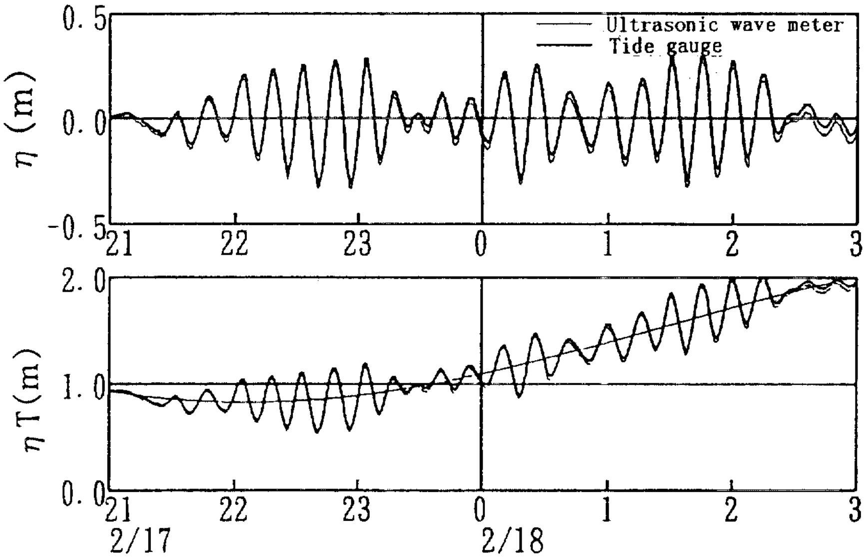

Figure 7 Comparison of the Observed 1996-Irianjaya-Tsunami Profile

Table 2 Results of the Harmonic Analysis

	M2		S2		K1		O1		Z0
Year	amp. (cm)	pha. (°)	amp. (cm)	pha. (°)	amp. (cm)	pha. (°)	amp. (cm)	pha. (°)	(cm)
1958	35.851	147.174	17.103	175.561	23.259	176.155	18.653	○157.503	94.866
1959	36.283	148.890	17.400	177.502	23.322	175.840	18.336	158.489	95.341
1960	36.359	149.025	☆ 17.492	177.282	○ 22.985	175.924	18.453	157.851	95.289
1961	36.657	148.703	17.255	177.196	23.558	176.107	18.390	158.695	95.860
1962	36.409	148.588	17.283	176.549	23.367	176.397	18.461	158.798	95.520
1963	36.613	148.305	17.155	176.745	23.839	177.234	18.608	158.830	96.215
1964	36.322	147.703	17.273	176.151	23.758	177.406	18.832	158.756	96.185
1965	☆ 36.684	147.691	17.360	176.240	23.836	177.252	18.741	158.410	☆ 96.621
1966	36.111	147.768	17.089	176.167	23.330	176.683	18.553	158.464	95.083
1967	36.135	148.356	17.311	176.840	23.441	177.708	18.361	159.506	95.248
1968	36.022	148.286	17.300	☆177.755	23.665	177.742	18.737	159.494	95.724
1969	35.872	148.018	17.195	176.796	23.365	177.056	18.606	158.766	95.038
1970	36.106	148.227	17.241	176.343	23.527	177.685	18.519	159.058	95.393
1971	35.934	148.554	17.143	177.036	23.533	177.778	18.400	158.878	95.010
1972	35.717	148.323	17.202	177.354	23.216	176.795	18.342	159.066	94.477
1973	35.968	147.557	17.210	176.490	23.482	177.142	18.725	158.799	95.385
1974	35.932	148.005	17.329	177.023	23.483	177.646	18.638	158.196	95.382
1975	35.765	148.623	17.208	176.858	23.306	177.203	18.410	159.367	94.689
1976	35.881	148.163	17.170	177.034	23.118	176.123	○ 18.247	158.766	○ 94.416
1977	36.143	147.877	17.160	176.725	23.240	176.045	18.789	158.331	95.332
1978	36.215	148.242	17.118	176.825	23.452	○175.720	18.473	157.551	95.258
1979	36.157	☆149.297	17.078	177.653	23.353	176.711	18.342	158.068	94.930
1980	36.073	148.018	17.009	176.002	23.552	177.001	18.533	158.661	95.167
1981	36.488	147.103	17.231	○174.517	23.581	177.594	18.504	159.102	95.804
1982	35.873	148.513	17.115	176.502	23.398	176.664	18.517	159.451	94.903
1983	○ 35.610	148.327	○ 16.968	176.335	23.333	176.854	18.558	158.549	94.469
1984	35.982	147.877	17.340	176.165	23.688	177.357	18.532	158.382	95.542
1985	35.881	148.448	17.214	176.760	23.722	177.825	18.689	☆159.536	95.506
1986	36.246	148.788	17.301	176.891	☆ 23.944	☆178.198	☆ 19.006	159.474	96.497
1987	36.051	149.077	17.191	177.094	23.431	176.478	18.579	158.408	95.252
1988	36.169	148.087	17.409	176.662	23.436	177.100	18.516	158.727	95.530
1989	35.967	147.579	17.229	175.407	23.611	177.118	18.546	159.232	95.353
1990	35.739	147.573	17.240	176.442	23.178	176.204	18.633	158.962	94.790
1991	35.698	147.228	17.261	175.832	23.680	176.978	18.819	158.129	95.458
1992	35.848	147.281	17.380	175.770	23.464	176.785	18.598	158.040	95.290
1993	35.911	○146.524	17.165	175.275	23.583	176.723	18.572	158.205	95.231
1994	35.761	147.616	17.147	175.612	23.519	176.296	18.759	158.445	95.186
1995	35.867	147.550	17.177	175.608	23.545	176.611	18.909	157.870	95.498
mean	36.061	148.078	17.222	176.500	23.476	176.898	18.576	158.653	95.335
S.D.	0.268	0.6	0.11	0.697	0.204	0.626	0.168	0.533	0.492

☆ : maximum, ○ : minimum, S.D. : Standard deviation

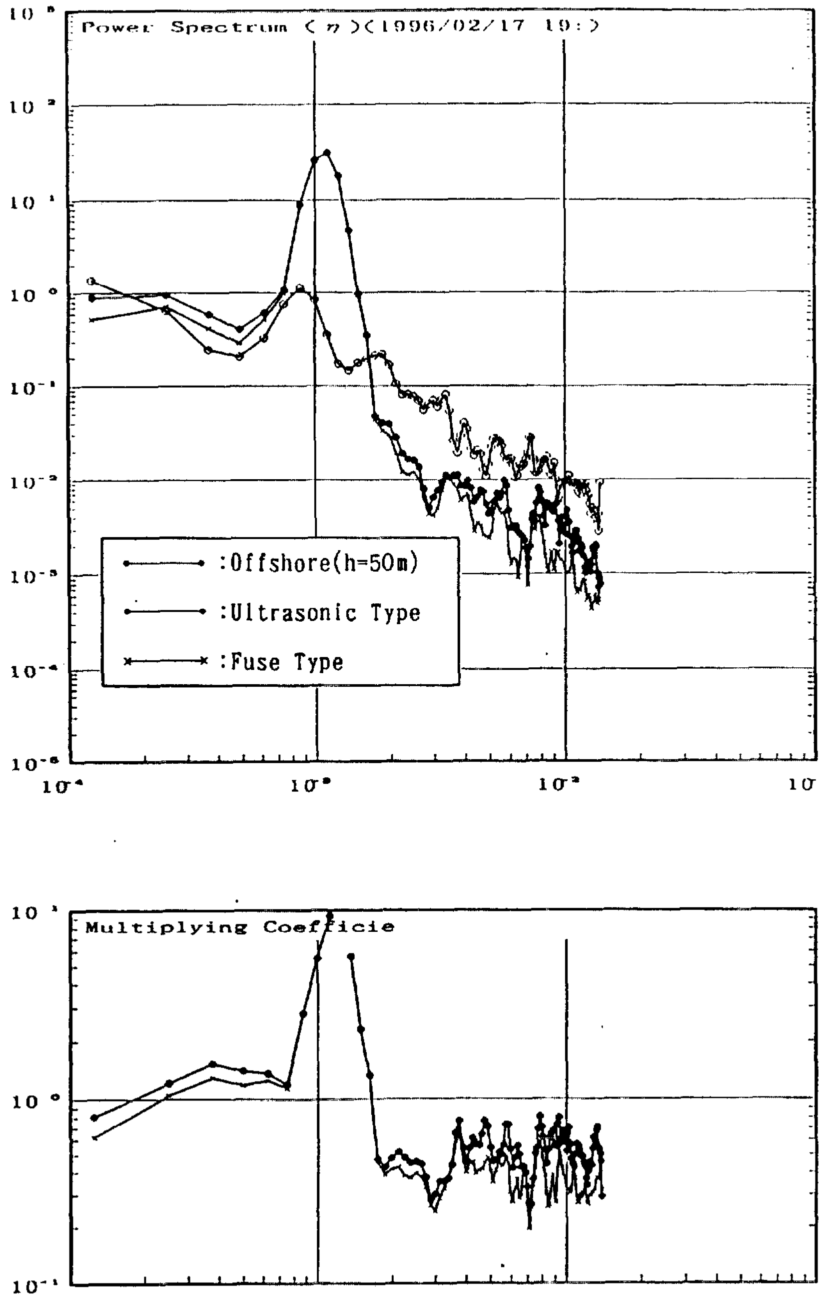

Figure 8 Observed Spectra of the 1996-Irianjaya-Tsunami

Table 3 Storm Surge Records

NO	Year/Mon/Day Time	Maximum Tide Diviation(cm)	Primary Factor
1	79/10/19 16:00	5 1	Typhoon7920
2	58/ 7/23 9:00	4 7	Typhoon5811
3	82/ 9/12 22:00	4 2	Typhoon8218
4	70/ 1/31 9:00	4 1	Low Pressurae
5	85/ 7/ 1 3:00	4 1	Typhoon8506
6	67/ 9/15 2:00	4 0	Typhoon6722
7	58/ 9/18 8:00	3 8	Typhoon5821
8	59/ 9/26 23:00	3 7	※Typhoon5915
9	69/ 8/23 15:00	3 7	Typhoon6909
10	58/12/26 16:00	3 6	Low Pressurae
11	66/ 4/16 14:00	3 6	Low Pressurae
12	91/10/13 8:00	3 6	Typhoon9121
13	86/12/19 7:00	3 6	Low Pressurae
14	91/ 2/16 6:00	3 6	Low Pressurae
15	89/ 8/ 6 7:00	3 5	Typhoon8913
16	77/ 9/19 20:00	3 5	Typhoon7711
17	72/ 2/27 15:00	3 4	Low Pressurae
18	83/ 3/13 16:00	3 4	Low Pressurae
19	90/12/ 1 4:00	3 4	Typhoon9028
20	87/ 9/18 16:00	3 4	Typhoon8713
21	79/10/ 1 14:00	3 2	Typhoon7916
22	67/10/28 15:00	3 2	Typhoon6734
23	91/ 9/19 16:00	3 2	Typhoon9118
24	75/ 8/23 18:00	3 2	Typhoon7506
25	62/10/30 17:00	3 2	Typhoon6224
26	69/ 4/ 5 6:00	3 2	Low Pressurae
27	75/10/ 8 7:00	3 2	Low Pressurae
28	65/11/ 9 16:00	3 2	Low Pressurae
29	88/10/ 7 3:00	3 1	Low Pressurae
30	90/11/10 11:00	3 1	Low Pressurae
31	65/ 6/ 4 7:00	3 1	Typhoon6508
32	68/10/26 9:00	3 1	Typhoon6819
33	82/10/20 7:00	3 1	Low Pressurae
34	90/11/ 4 17:00	3 1	Low Pressurae
35	58/ 3/18 16:00	3 0	Low Pressurae
36	85/ 2/21 17:00	3 0	Low Pressurae
37	64/ 5/25 17:00	3 0	Low Pressurae
38	80/ 5/ 9 11:00	3 0	Low Pressurae
39	80/12/26 19:00	3 0	Low Pressurae
40	93/10/ 4 7:00	3 0	Low Pressurae

※ Isewan-Typhoon

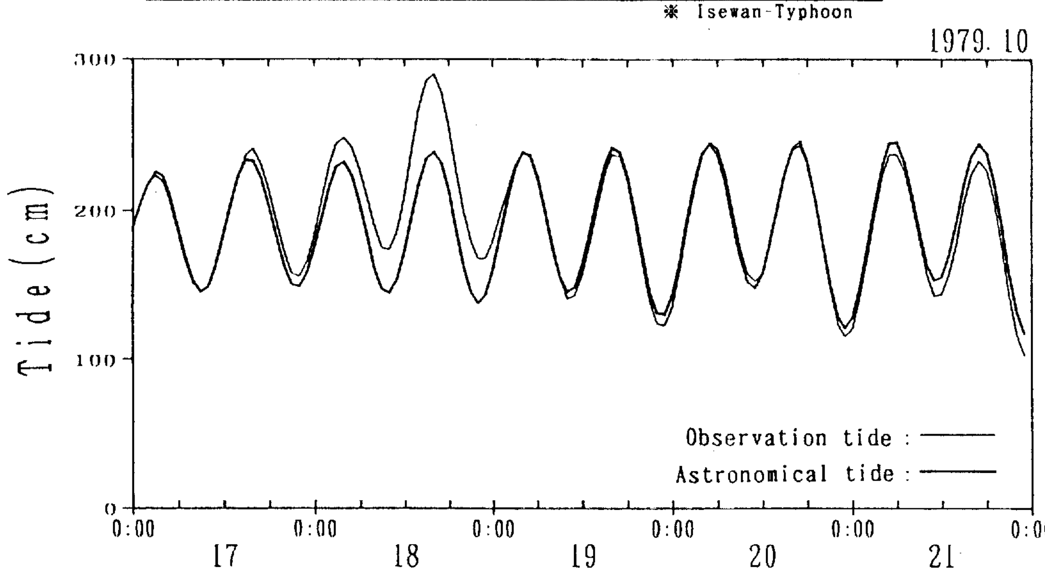

Figure 9 Astronomical and Observed Tide (Typhoon 7920)