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FORECASTING TSUNAMIS BY THE T-WAVES OF THE TSUNAMIGENIC EARTHQUAKE

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The forecasting of tsunamis in the Pacific has been improved by a system utilizing two triangular arrays of seismographs placed in Tahiti and Rangiroa and a method of recording T-waves which, if of sufficient intensity, are indicative of a tsunamigenic earthquake.

A strong Pacific earthquake whose epicenter is in the ocean or near a coast can generate a tsunami capable of causing damage several thousand kilometers away. The Tsunami Warning System is responsible for giving alarms, collecting and evaluating data by an intricate communication system, determining the earthquake epicenter and issuing a warning. For French Polynesia, these warnings and alarms are useful as long as they are received prior to the arrival of the waves. This however, may not be the case of tsunamis originating in the Tonga, Kermadec or Fiji Islands because of time limitations. Warnings must also be reliable because extensive and expensive local measures are taken to protect life and property. Unfortunately, all warnings are not always reliable and not all earthquakes investigated cause a tsunami. The constant watchful monitoring of the vast network of seismographs, tide gages and telecommunications system, however, has now resulted in a very efficient and improved system.

Since 1963 there has been established in Tahiti a tsunami forecasting system based on a simplified seismic network which, because of additional data, gives additional security.

The two islands of Tahiti and Moorea are equipped with five vertical short period seismographs from which data is transmitted to Pamatai by Hertzian Liaison or by telephonic line. Since 1967, the Atoll of Rangiroa, situated 400 km north-northeast of Tahiti, has also been equipped with a triangle of identical seismographs from which data are also transmitted to the same point by Hertzian Liaison. By the end of 1969, these three stations of Rangiroa will transmit continuously by radio their data to the principal station of Pamatai on Tahiti. Finally, an additional seismograph has been installed on the station of Rikitea (Archipelago of the Gambier situated 1700 km east of Tahiti). All of these instruments are spaced 15 to 50 km apart within each triangle, are equipped with filters which attenuate background noise caused by the sea-wave action and work with an amplification of approximately 110,000 at 1 Hz. The difference in the arrival time of the waves easily indicates an azimuth in the case of a distant earthquake and the time during which the signal reaches all the stations of the array, gives a rough but quick estimate of the distance of the earthquake. These two indications, therefore, suffice to locate the epicenters in Alaska, Peru and elsewhere.

An automatic safety device is activated by the simultaneous arrival of P-Waves of a set threshold amplitude, frequency and duration in at least two of the stations of each triangle and gives the first alarm. This system is activated by P-Waves from an earthquake of magnitude 7 whose epicenter can be as much as 9500 km away. This is an extreme distance for French Polynesia (Kuriles, Kamchatka, Japan). The two main stations of Tahiti and Rangiroa are presently equipped with this automatic device which by the end of the year will be also installed on eight seismographs in Tahiti. The Rikitea seismograph station will be equipped with the automatic detector of P-Waves to provide a local alarm. Also a U.S. tide gage was installed at Rikitea in early October 1969 as an integral part of the Tsunami Warning System.

Reception of T-phase waves, their amplitude and duration are also taken into consideration. These hydro-acoustic waves propagate in water at the speed of sound and arrive much later than the P-Waves (with a maximum delay of approximately 93 minutes for Tahiti) but well in advance of the waves of a tsunami. Several years of experience has taught that any earthquake followed by a tsunami has created T-phase waves of strong amplitude. In addition, knowledge of the difference in the times of arrival of P and T-phase waves determines with good accuracy (approximately 1%) the epicentral distance.

Consequently, the forecasting of tsunamis in French Polynesia is based on the rough estimation of the epicenter of the earthquake by the use of two triangular arrays of seismographs and on the fact that this earthquake has created T-phase waves of strong amplitude.

Although the P-Waves always have enough amplitude to activate the alarm system, for the correct forecasting of tsunamis it is important to use the amplitude of the surface waves as recorded on long-period seismographs (it is very useful for proximate archipelagos which frequently give T-phase waves of high amplitude).

The following is a summary of the tsunami alarms issued by the Tsunami Warning Center and by the Geophysical Laboratory in Tahiti from 1963 to 1969.

RESUME OF WARNINGS GIVEN BY HONOLULU OBSERVATORY AND BY GEOPHYSICAL LABORATORY OF PAMATAI (L.D.G.)

DATE	EPICENTER	EPICENTER DISTANCE FROM TAHITI in KM	MAGNITUDE	WARNING GIVEN BY HONOLULU	WARNING GIVEN BY L.D.G.	TSUNAMI OBSERVATIONS IN TAHITI	T - WAVES DURATION IN MINUTES	T - WAVES AMPLITUDE IN TAHITI EXCEPT WHEN SPECIFIED
1963 Oct 13	Kuril Is.	9,300	8 1/4 PAS.	Yes	Yes	Yes: Some damages in Tahiti and other islands (22 cm at Fare-ute)	14	Saturated during 4 minutes
1963 Oct 20	Kuril Is.	9,200	6 3/4 PAS.	Yes	No	No	3	Small amplitude
1963 Dec 18	Tonga	2,920	6.5	No	Yes	No: Very heavy swell	30	Saturated during 15 minutes
1964 Mar.28	Alaska	8,600	8.5 PAS.	Yes	Yes	Yes: Some damages in Tahiti and other islands (60 cm at Fare-ute)	30	Saturated during 14 minutes
1965 Feb 4	Aleutian Is.	8,200	7 3/4 PAS.	Yes	Yes	Yes	12	Saturated during 7 minutes
1965 Mar 30	Aleutian Is.	8,100	7 PAS.	Yes	No	No	3	Intermediate saturate
1965 Apr 29	Seattle	7,700	6.6 PAS.	Yes	No	No	-	No T-waves
1965 Jul 2	Aleutian Is.	8,100	7 PAS.	Yes	No	No	5	Saturated during 1 minute
1966 Oct 17	Peru	7,700	7 1/2 PAS.	Yes	Yes	Yes: 7 cm at MATAVAI	5	Saturated during 3 minutes in RIKITEA
1966 Dec 28	Chile	8,200	7 3/4 PAS.	Yes	Yes	Yes	?	Saturated in RIKITEA
1968 May 16	Japan	9,500	8.2 PAS.	Yes	Yes	Yes: 11 cm at PUEU and MATAVAI	12	Saturated during 3 minutes
1969 Aug 11	Kuril Is.	9,300	8.0	Yes	Yes	Yes: 15 cm at Fare-ute	11	Saturated during 3 minutes

TSUNAMIS IN THE KURILE ISLANDS IN 1968 - S. Lapshin

According to the Sakhalin Office of the Hydrometeorological Service of USSR, two small tsunamis were recorded in 1968 in the Kurile Islands.

The first one was generated by the earthquake of January 29 (10:19 UT, M=7½, 43.8° N, 148.5° E). The shock had an intensity of VI - VII (on the 12-grade scale) in Malokurilsk, Krabozavodsk, Yuzhno-Kurilsk and other settlements on the Shikotan and Kunashir Islands. Forty minutes later the tide gage at Yuzhno-Kurilsk began to register small waves that lasted for 3 hours and had an average period of 25 minutes. The heights of the first three waves were 15, 25 and 19 cm respectively. The tide gage at Burevestnik (Pacific coast of Iturup Is.) began to record the tsunami waves fifty-two minutes after the earthquake. The oscillations lasted about 4 hours and had periods of about 30 minutes. The height of the first wave was 17 cm but the sixth and seventh waves were greater (23 cm). No other tide gage recorded this tsunami and no warning was issued by the Regional Warning System.

The second tsunami occurred after the large earthquake of May 16 in Japan (0:49 UT, M=8, 40.7°N, 143.7°E). This earthquake had intensity V in Yuzhno-Kurilsk and III in Malokurilsk. It was recorded by the tsunami stations of Yuzhno-Sakhalinsk and Kurilsk. Forty-five minutes after the earthquake the District Tsunami Warning System issued a public warning for the southern part of the Kurile Islands. After two hours, reports were received from Yuzhno-Kurilsk and Burevestnik that waves were recorded having amplitudes of about ½ m and periods of about 20 minutes. Irregular water fluctuations with heights less than 1 m were observed visually in Malokurilsk, Krabozavodsk and at some other points on Shikotan, Kunashir and Iturup Islands. At the Urup and Simushir Islands, situated farther to the north, no such oscillations were observed.

A second tsunami warning was issued by the Yuzhno-Sakhalinsk tsunami station after the strong (M=7½) aftershock of the May 16 earthquake (10:39 UT), but no tsunami was registered by the tide gages.

No tsunamis were recorded on the Soviet coasts after the tsunamigenic Japanese earthquake of April 1, (0:42 UT), M=7¾, 32.6°N, 132.2°E). No public tsunami warning was issued for this event.

WARNING SYSTEM EXPANSION

Tide stations at Yakutat in Alaska and Malakal Island in the Palau Islands have joined the Tsunami Warning System, providing wave data to Honolulu Observatory. Yakutat also participates in the Alaskan Regional System and all data are telemetered to Palmer Observatory for use in Alaskan tsunami watches and warnings.

TSUNAMI INVESTIGATIONS - JUNE-OCTOBER 1969

GMT Date & Time 1969	Epicenter	Magnitude & Depth	Region	Comments
June 17, 2358	52.6 S 159.7 E	6 Normal	SW New Zealand	No evidence of tsunami
July 8, 0525	38.3 N 119.4 E	7.3 Normal	NE China	No evidence of tsunami
Aug 5, 0213	1.3 N 126.2 E	7.0 34 km	Molucca Passage	No evidence of tsunami
Aug 11, 2128	43.5 N 147.4 E	7.8 28 km	Kuril Is.	Tsunami Watch issued. Small tsunami observed and recorded throughout the Pacific. Maximum wave heights measured near Japan. Eastern Hokkaido 2.60m SW Hokkaido 0.94 S Hokkaido 1.32 Hachinohe 1.10 Central NE Honshu 0.64 Ayukawa 0.58 E. Kwanto 0.42 Midway .49 Kahului, Hawaii .43 Wake Is. .24 Not more than 1 meter in Kurils.
Aug 12, 0503	43.6 N 148.0 E	6.5 Normal	Kuril Is.	Aftershock of Aug 11 earthquake. No evidence of tsunami.
Aug 13, 2257	44.0 N 148.1 E	6.1 Normal	Kuril Is.	Aftershock of Aug 11 earthquake. No evidence of tsunami.
Aug 14, 1419	43.1 N 147.5 E	6.5 Normal	Kuril Is.	Aftershock of Aug 11 earthquake. No evidence of tsunami.
Aug 17, 2013 & 2015	25.3 N 109.2 W 25.0 N 109.5 W	5.7 Normal 6.6 Normal	Gulf of California	No evidence of tsunami.

GMT Date & Time 1969	Epicenter Epicenter	Magnitude & Depth	Reg Region	Comments
Sept 12, 0857	51.2 N 179.2 E	6.6 48 km	Andreanof Is., Aleutian Is.	Local tsunami warning issued by the Alaskan Warning System for coastal areas from Attu to Adak. A tsunami watch was issued from Adak to Unalaska. No evidence of tsunami.

Several other earthquakes were investigated whose magnitudes were between 5 and 6. They are not listed because they did not pose a possible tsunami threat.

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