ISSN 8755-6839

SCIENCE OF TSUNAMI HAZARDS

Journal of Tsunami Society International

Volume 37 Number 1 2018

FILTER-M APPLICATION FOR AUTOMATIC COMPUTATION OF P WAVE DOMINANT PERIODS FOR TSUNAMI EARLY WARNING

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ABSTRACT

The purposes of this research is to improve Indonesia Tsunami Early Warning System (InaTews), especially to improve result of automatic computation of P wave dominant period by applying filter-M to ignore noises signal. To reduce the effect of noise and signal defect on the calculation of the P wave dominant period automatically, this study used M-filter. The M-filter used the concept that the dominant period for small and moderate earthquakes is unlikely to exceed twice the maximum dominant period of the great earthquake. The automatic computation of P wave dominant period uses direct method, where the calculation uses time equation (τc) directly applied to seismogram, without inversion so that calculation process becomes faster. M-filter has been developed and used to filter out defective and high-null seismogram signals, so the seismogram is not used for the average computation of the P wave dominant period.

Keywords: *filter-M, dominant period, automatic computation, tsunami early warning*

1. INTRODUCTION

The concept of an earthquake and tsunami early warning system or the one that is called as Earthquake and Tsunami Early Warning System (EETWS) is currently popular, and the potential for EETWS to reduce the destructive effects of earthquake and tsunami has been well recognized. EETWS is a real-time seismic monitoring system that can detect ongoing earthquake and tsunami and alert the target area, before the arrival of the most damaging waves. Madlazim since 2011 (Madlazim, 2011; 2013) has developed a Jokotingkir computer program for tsunami early warning in Indonesia by applying regional and teleseismic (global) methods from Lomax and Michelini (2011; 2013) to measure duration of rupture (Tdur), dominant period (Td) and the 50 seconds exceed duration (T50Ex) earthquakes with greater magnitude that is more than 6 SR which was occurred in Indonesia. The Jokotingkir application has been validated (Madlazim et al., 2015). Madlazim et al in 2016 have also evaluated the parameters of earthquake sources announced by Indonesia tsunami early warning (Madlazim&Prastowo, 2016). While Colombelli&Zollo (2015) have found an early warning method of an earthquake with on-site P wave basis (Colombelli&Zollo, 2015). Tsunami early warning is critically dependent on the speed of determining the tsunami hazard potential in real-time before the wave floods the shoreline. Tsunami energy can quickly characterize the destructive potential of the resulting wave. The traditional seismic analysis is inadequate for predicting the tsunami energy accurately (Titov et al., 2016).

The development and implementation of other faster and more accurate tsunami parameters are needed. Since 2007, Lomax and Michelini have developed methods of measuring tsunami parameters (Tdur, Td, and T50Ex) by using teleseismic data, was implemented in the earliest software, and have been implemented since 2011 for tsunami early warning in France. Then since 2011, Madlazim has developed Jokotingkir software for tsunami early warning for local earthquakes in Indonesia by using algorithms from Lomax and Michelini. Since 2013, the software has been tested on a limited basis in BMKG Jakarta PUSLITBANG and the results were more accurate than tsunami early warning, Ina-Tews (TEMPO Magazine, 2013). However, the application of teleseismic methods for measuring Tdur, Td, and T50Ex from Lomax and Michel was in the trial until 2017 it found some inaccuracies for local earthquakes. Based on the evaluation of BMKG PUSLITBANG 2012 until May 2013, there have been 27 false warning events for the ones with magnitude less than 5,5 SR (Masturyono et al. (2013) and BMKG PUSLITBANG evaluation result from March 2017 until March 2018 has found 15 false warning events for magnitude less than 6.5 SR in this study. We have improved the Jokotingkir software algorithm to calculate the dominant period by applying the M-filter to avoid noise-dominated signal in order to improve the performance of the tsunami early warning system further.

In this study, we have improved the Jokotingkir software algorithm by using M-filtering in calculating the dominant period of P wave by ignoring the noise-dominated signal of the earthquake in order to improve the performance of the tsunami early warning system further. Therefore, the purpose of this study is to develope a tsunami early warning system through the application of M-filters for calculating the dominant period of earthquakes automatically from waveform data recorded by local seismic stations managed by BMKG.

2. METHODOLOGY

The calculation of P wave dominant period uses direct method, where the calculation uses time equation (τc) directly applied to seismogram, without inversion so that calculation process becomes faster. The dominant period of the earthquake is estimated from the dominant period of the P wave because the P wave arrives at the fastest seismic station compared to the S wave and the surface wave. To determine the dominant period (Td), first it is calculated by using time domain (τc) to the following equation:

$$\tau_c = 2\pi \int_{T_1}^{T_2} v^2(t)\mathrm{d}t \Big/ \int_{T_1}^{T_2} \dot{v}^2(t)\mathrm{d}t,$$

(Nakamura, 1988; Wu and Kanamori, 2005; Lomax and Michelini, 2013)

With T_1 = 0 second (P onset) and T_2 = 55 seconds for seismogram of the teleseismic earthquake (Lomax and Michelini, 2009).

The accuracy of the dominant period calculation automatically uses that formula is influenced by the quality of the seismogram. While the quality of seismogram is determined by; 1. Disturbing noise. 2. Seismogram or earthquake signals. 3. Seismic station quality. Overcoming the influence of the seismic stations quality that records the earthquake wave can be done by using the good quality seismic station management system. Meanwhile, to overcome noise and seismogram defects, especially for earthquakes recorded by local seismic stations whose magnitude ranges from small (magnitude 3) to 8.6, it is required a special method for filtering order not to affect the accuracy of the automatic dominant period calculation.

The flowchart for the calculation from the dominant period automatically that applies the M-filter is shown in figure 1 as shown:

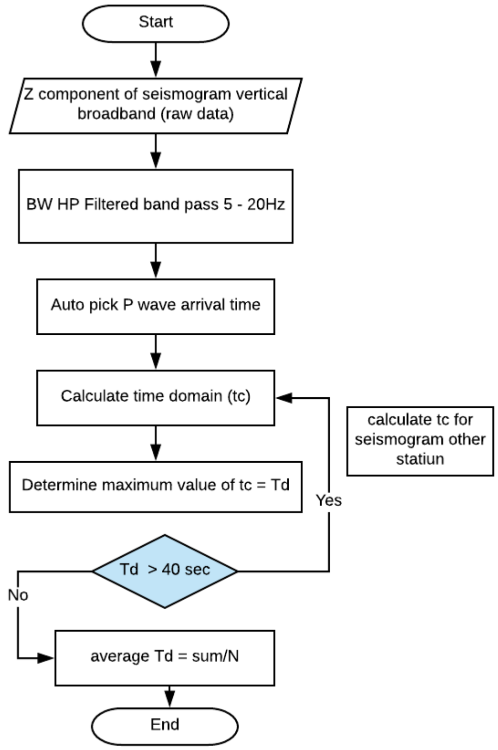
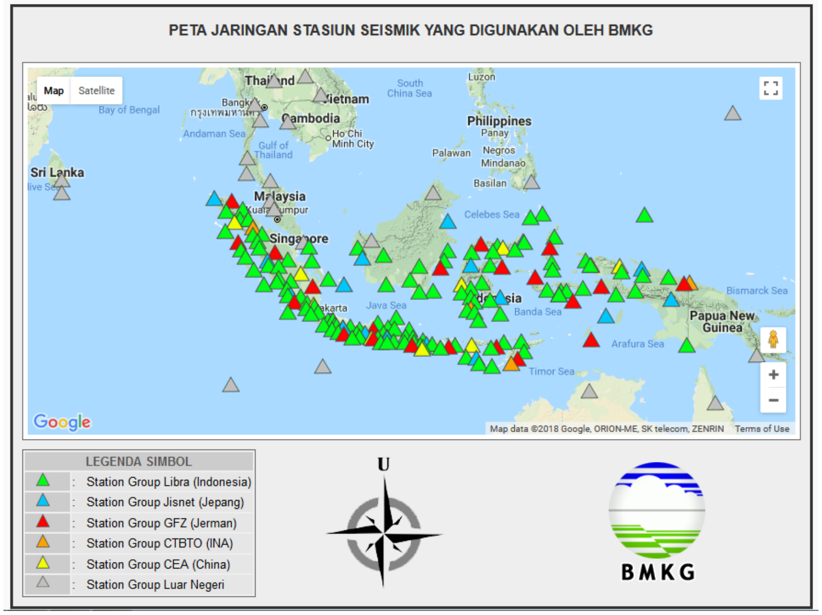


Figure 1. Dominant period computing flowchart that applies the M-filter (blue condition).

To reduce the effect of noise and signal defect on the calculation of the earthquake dominant period automatically, this study used M-filter. The M-filter used the concept that the dominant period for small and moderate earthquakes is unlikely to exceed twice the maximum dominant period of the great earthquake. The maximum dominant period measurement results for large earthquakes (Mw = 6.5 to 8.1) that occur worldwide can be accessed at http://www.earth-prints.org/bitstream/2122/6546/2/Table_S1_TauC_To_v2.1.pdf for 23.8 sec (Lomax and Michelini, 2011). The maximum dominant measurements for maxillary earthquakes are then used for the dominant period measurement filters for earthquakes recorded by local seismic stations in Indonesia, when the dominant measurements of the local earthquake period are about two (2) times the maximum dominant period (about 40 seconds), the researchers ensure that the signal used to measure the dominant period is defective or the noise is dominant compared to the signal of the earthquake, so the signal is not feasible to be used for decision making.

The data used to test the new methods for calculating the local dominant period of earthquakes is automatically accessible online data provided by the Jakarta - Indonesia Meteorological, Climatology and Geophysics Agency (BMKG): http://202.90.198.100/webdc3/ and using seismic stations as shown in figure 1.



https://inatews.bmkg.go.id/new/meta_eq.php

Figure 1: Seismic stations distribution that used in this research.

The data used is the seismogram data of Z component velocity of earthquakes that occur in 2010 until 2018. We used 15 earthquakes that show a false warning (FW) and 13 earthquakes that show a true warning (TW).

3. RESULTS AND DISCUSSION

The automatic computation results of the P wave dominant period of 28 earthquakes data stored in BMKG Jakarta, Indonesia are presented in table 1 below. By using the waveforms data recorded by local seismic stations available in Indonesia, we have estimated the P wave dominant period of earthquakes automatically by using Jokotingkir 2018 version software. It is for earthquake references in OT + 4 minutes to simulate the information available within 4 minutes after the earthquake occurred. Table 1 shows a comparison between dominant period by using Jokotingkir old version and dominant period by using Jokotingkir 2018 version.

Table 1. Result of P wave dominant period calculation from 28 data of the earthquakes used

No.	Origin time (OT)	Mw	Lattitude	Longitude	Tdi	Tdi*T50Ex	Decision	Tdf	Tdf*T50Ex	Decision
1	2018.02.03 12:25:55	4.8	-7.62	128.73	35.34	33.93	FW	1.31	1.11	TW
2	2017.12.22 12:32:28	4.5	-0.81	124.56	30.83	10.48	FW	1.00	0.11	TW
3	2017.11.07 01:14:22	2.9	-4.02	127.73	341.20	51.18	FW	2.22	2.46	TW
4	2017.11.04 23:32:21	4.9	-1.89	139.20	18.87	10.38	FW	10.9	9.80	TW
5	2017.10.11 04:20:11	4.3	4.32	125.45	16.10	14.97	FW	0.95	0.45	TW
6	2017.09.30 16:45:52	4.8	-2.99	136.94	15.34	13.50	FW	1.11	1.15	TW
7	2017.07.17 08:17:15	3.4	-1.99	102.08	51.49	16.47	FW	1.00	0.91	TW
8	2017.06.27 04:55:30	5.1	1.50	126.80	71.76	38.03	FW	0.99	1.04	TW
9	2017.06.05 01:50:59	4.9	-2.24	134.60	7.53	19.89	FW	6.15	3.56	TW
10	2017.04.16 01:08:39	3.1	-2.85	129.18	67.23	78.66	FW	1.08	1.26	TW
11	2017.03.22 24:25:59	3.8	1.16	126.54	43.64	15.27	FW	2/89	2.78	TW
12	2017.12.08 23:51:09	6.3	9.98	140.12	4.86	39.92	FW	5.08	5.28	TW
13	2017.07.06 22:03:57	6.4	11.13	124.96	8.53	10.24	FW	8.37	6.69	TW
14	2017.06.03 12:24:57	6.3	54.16	171.02	2.64	11.39	FW	3.76	1.65	TW
15	2017.10.31 14:42:14	6.5	-21.7	168.9	24.56	23.09	FW	3.16	1.76	TW
16	2017.01.10 06:13:47	7.2	4.44	122.57	10.76	2.26	TW	1.85	1.66	TW
17	2016-03-02 12:49:47	7.7	-4.90	94.23	23.03	12.89	TW	4.69	9.66	TW
18	2014-11-15 02:31:43	7.0	1.98	126.48	12.60	26.85	TW	4.50	7.92	TW
19	2013-04-06 04:42:35	7.0	-3.54	138.46	68.85	277.49	TW	4.37	0.30	TW
20	2012-12-10 16:53:10	7.0	-6.64	129.83	4.99	25.51	TW	5.46	8.08	TW
21	2012-04-11 10:43:09	8.2	0.76	92.43	43.65	1233586.37	FW	3.04	5.38	TW
22	2012-04-11 08:38:35	8.6	2.27	93.14	17.22	641.05	FW	4.69	5.53	TW
23	2012-01-10 18:36:58	7.1	2.43	93.07	155.70	21835.55	TW	2.08	2.30	TW
24	2010-10-25 14:42:21	7.8	-3.46	100.20	43.43	415.27	TW	5.08	11.73	TW
25	2010-09-29 17:11:24	7.2	-5.01	133.73	17.59	188.11	TW	1.30	0.24	TW
26	2010-05-09 05:59:44	7.2	3.67	96.10	3.70	8.74	TW	3.80	6.72	TW
27	2010-04-06 22:15:03	7.6	2.32	97.17	40.05	1236.76	TW	3.83	5.97	TW
28	2009-09-30 10:16:09	7.7	-0.70	99.80	10.53	284.39	TW	3.33	4.39	TW

Note: Tdf is the P wave dominant period value calculated by Jokotingkir software that has been applied the filter-M (Jokotingkir 2018 version). Tdi is the P wave dominant period value calculated by the Jokotingkir software that has not been applied the M-filter (Jokotingkir old version). FW = False Warning. TW = True Warning.

The result of P wave dominant period automatic computation by using Jokotingkir 2018 version software showed higher accuracy compared to the automatic computation of P wave dominant period by using the Jokotingkir old version software. The automatic computation of dominant period by using Jokotingkir 2018 version software can reduce errors (false warning) up to 60.7% to 0% or from accuracy 39.3% to 100%. This is because the Jokotingkir version 2018 software already equipped with an M-filter that has the ability to filter the calculation of the dominant period of a particular station that is likely to be affected by a seismogram defected or dominated by noise. The discriminant use of Td*T50Ex in this study as shown in Table 1 refers to the results of Lomax and Michelini (2009) studies that the discriminant has been shown to be highly correlated with the tsunami's importance (It). In addition, there is an indication of the linear relationship between (Td*T50Ex) and It. Threshold of Td*T50Ex is 10 sec. It means that if Td*T50Ex ≥ 10 sec, so the earthquake has tsunami potential (Madlazim, 2013; Lomax and Michelini, 2009).

The earthquakes used in this study include small earthquakes to large earthquakes, both false warning, and true warning. For major non-tsunamigenic earthquakes and tsunamigenic earthquakes registered in the NOAA/WDC Historical Tsunami database (http://www.ngdc.noaa.gov/hazard/tsu_db.shtml), most of the earthquakes with magnitude Mw ≥ 7 occur within recent years. As a tsunami impact measurement, we defined the estimation of the size decision whether it is a tsunami or not (tsunami importance, It). This is for tsunamigenic earthquakes based on 0 - 4 descriptive index of tsunami effects and maximum water heights h (in meters) of the NOAA/WDC database, see Madlazim (2013) for more detail It info. It is approximate because it depends heavily on available seismic instrumentation, coastal bathymetry and population density in the incident area. This corresponds to the JMA threshold for issuing "Tsunami Early Warning"; the largest or most powerful tsunami usually has It ≥ 10.

4. CONCLUSIONS

A M-filter has been developed and used to filter out defective and high-null seismogram signals, so the seismogram is not used for the average calculation of the dominant period. The calculation results of the dominant period by using Jokotingkir software 2018 version shows a higher accuracy than the calculation of the dominant period by using the old version of Jokotingkir software.

ACKNOWLEDGEMENTS

We thank the reviewers for the critical comments that greatly enhance the clarity of the manuscript. This work is supported by the Ministries of Research, Technology, and Higher Education Republic of Indonesia (Ristek-Dikti) and WebDC3 at BMKG data archive and: http://202.90.198.100/webdc3/, which provides access to data of earthquake waves that are used in this study.

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