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USE OF THE JOKO TINGKIR SOFTWARE FOR RAPID DETERMINATION OF TSUNAMI FAULTING PARAMETERS RESULTING FROM THE Mw-7.8 EARTHQUAKE OF MARCH 2, 2016, IN SOUTHERN SUMATRA

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ABSTRACT

The purpose of this research was to use the Joko Tingkir software, to measure rapidly tsunami-faulting parameters of the March 2, 2016, earthquake (Mw = 7.8) off the coast of Southern Sumatra. The five parameters that needed measurement were the quake's rupture duration (Tdur), the dominant period Td), the exceedance duration of 50 seconds (T50Ex), the multiplication between rupture duration and the dominant period (Tdur x Td), and the multiplication exceedance duration and dominant period (T50Ex x Td). The methodology of measuring these parameters is based on the direct analysis of the locally measured seismic broadband vertical components, without inversion. The seismographic data used for this study was obtained from 18 seismic stations of the BMKG network. The tsunami parameters thresholds used by the Joko Tingkir software were: Tdur = 65 s, Td = 10 s, T50Ex = 1, Tdur x Td =650 s^2 and T50Ex x Td = 10 s. Earthquakes that have three or more parameters that are equal or bigger than these threshold values, are known to be associated with tsunami generation. Rapid measurements of parameters - in less than 4 minutes after the quake's origin time - that have values of Tdur = 65.70, Td = 3.60, T50Ex = 0.13, Tdur x T50Ex = 234.00 and T50Ex x Td = 0.48, do not typically generate tsunamis.

1. INTRODUCTION

The March 2, 2016, M=7.8 earthquake occurred 800 km off the west coast of southern Sumatra. It resulted from strike-slip faulting within the oceanic lithosphere of the Indo-Australian plate. This event was located about 600 km to the southwest of the major subduction zone that defines the boundary between the India/Australia and Sunda plates, offshore from Sumatra. At this location, the India/Australia tectonic plates move in a north-northeast relative to the Sunda sliver subplate. The deformation zone is along the defuse boundary between the India and Australia plates (USGS, 2016, Pararas-Carayannis, 2005; 2007). More specifically, off the west coast of Sumatra, the India plate is moving in a northeastward direction at about 5 to 5.5 cm per year (50 to 55 mm/yr) relative to the Sunda plate. It is assumed that the Australian plate is also moving toward the northeast direction and at the same rate against the Sunda plate to take the slack of the Indian plate's movement. However, it may be also rotating - at an unknown rate - in a counterclockwise direction (Pararas-Carayannis, 2007).

Large strike-slip earthquakes are not unprecedented in the diffuse boundary region separating the India and Australia plates off the Sumatra subduction zone (Pararas-Carayannis, 2005; 2007). In 2012, two events of M 8.6 and M 8.2 on the same day (04/12/2012) ruptured a series of oceanic strike-slip structures 650-850 km to the north of the March 3, 2016, event. On June 18, 2000, an M 7.9 earthquake ruptured an oceanic strike-slip structure about 1000 km southeast of the March 3, 2016, earthquake. The focal mechanisms of the all of these earthquakes are consistent in implying that each event could have occurred as the result of left-lateral slip on an approximately north striking fault or right-lateral slip on an approximately west striking fault. The two different orientations of strike-slip faulting are both possible under the same tectonic stress field; perpendicular strike-slip faults that are both compatible with the same stress field are called "conjugate faults" (Pararas-Carayannis, 2005; 2007).

Joko Tingkir software is a tsunami application method used to measure tsunami parameters and detect real time, in order to decide rapidly which earthquakes generate a tsunami or not (Madlazim et al., 2015; Madlazim and Prastowo, 2016). Using the Joko Tingkir software we measure five parameters. These parameters are the duration of the rupture (Tdur), the dominant period Td), the exceed duration of 50 seconds (T50Ex), the multiplication result between rupture duration and dominant period (Tdur x Td), and the multiplication result that exceeds duration and dominant period (T50Ex x Td). The tsunami parameters threshold used by the Joko Tingkir software are: Tdur = 65 s, Td = 10 s, T50Ex = 1, Tdur x Td =650 s^2 and T50Ex x Td = 10 s. If there are three or more tsunami parameters that have magnitude that are the same or bigger than the threshold, it is expected tbat the earthquake will be tunamigenic (Madlazim and Hariyono, 2014; Madlazim and Supriyono, 2014). In brief, the purpose of this research is to measure and detect tsunami parameters rapidly by using the Joko Tingkir software.

2. THE TSUNAMI FAULTING MODEL

The tsunami parameters used with the tsunami-faulting model (Lomax and Michelini, 2012) are illustrated by Figure 1.

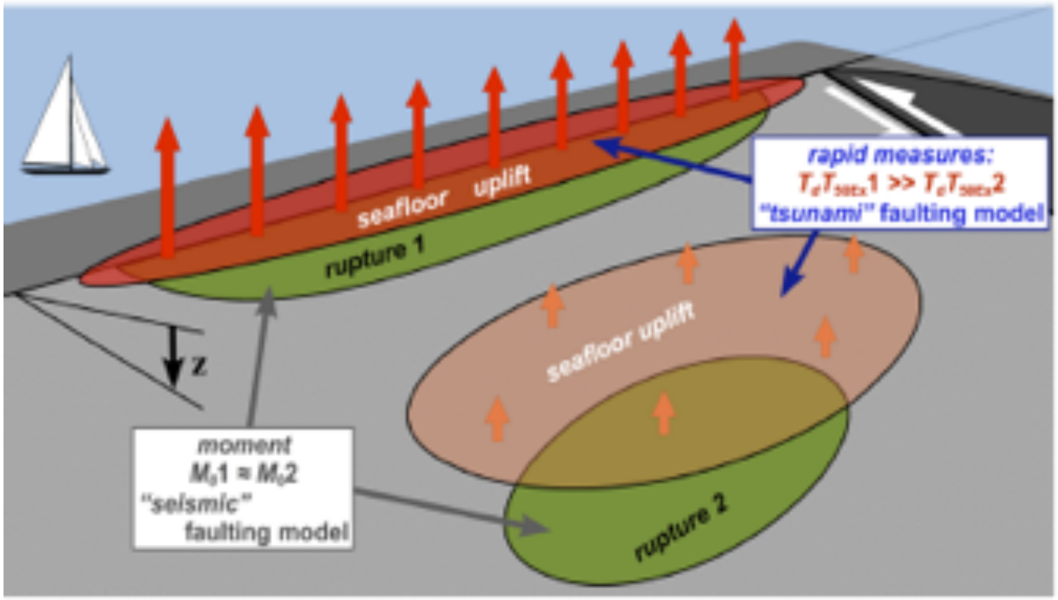

Figure 1. Tsunami faulting model (Lomax and Michelini, 2012a)

According to this model a direct procedure for the rapid measurement of an earthquake's tsunami generation potential involves the simple measurement on the seismograms of two P-wave values - specifically the predominant period on velocity records Td, and the likelihood that T50Ex, the high-frequency, rupture-duration (Tdur),exceeds 50-55 sec. We have shown previously of that Td and Tdur are related to the length of rupture parameter L, width W, slip D and depth z, and that either of the dominant period - rupture duration products Td*Tdur or Td*T50Ex give more information on tsunami impact and size than MwCMT, Mwp and other currently used discriminants (Lomax and Michelini, 2012b). These results imply that potential for tsunami generation is not directly related to the moment M_0 from the "seismic" faulting model of an earthquake, as assumed with the use of the MwCMT discriminant. Instead, information on L and z, as provided by Td*T0 or Td*T50Ex, represent the "tsunami faulting model" and can constrain well the tsunami potential of an earthquake.

3. METHODOLOGY

The method used to measure the above mentionned parameters involves the direct analysis of the vertical component of the local broadband velocity seismogram, without applying the inversion method. For the present invwstigation we used the seismograms of the March 2, 2016 event, which were recorded by 18 seismic stations of the BMKG net work (Figure 2). The tsunami parameters threshold used by the Joko Tingkir software were the Tdur = 65 s, Td = 10 s, T50Ex = 1, Tdur x Td =650 s^2 and T50Ex x Td = 10 s. As previously mentioned, if there are three or more tsunami parameters that have magnitude same or bigger than the threshold values, the earthquake is tsunamigenic.

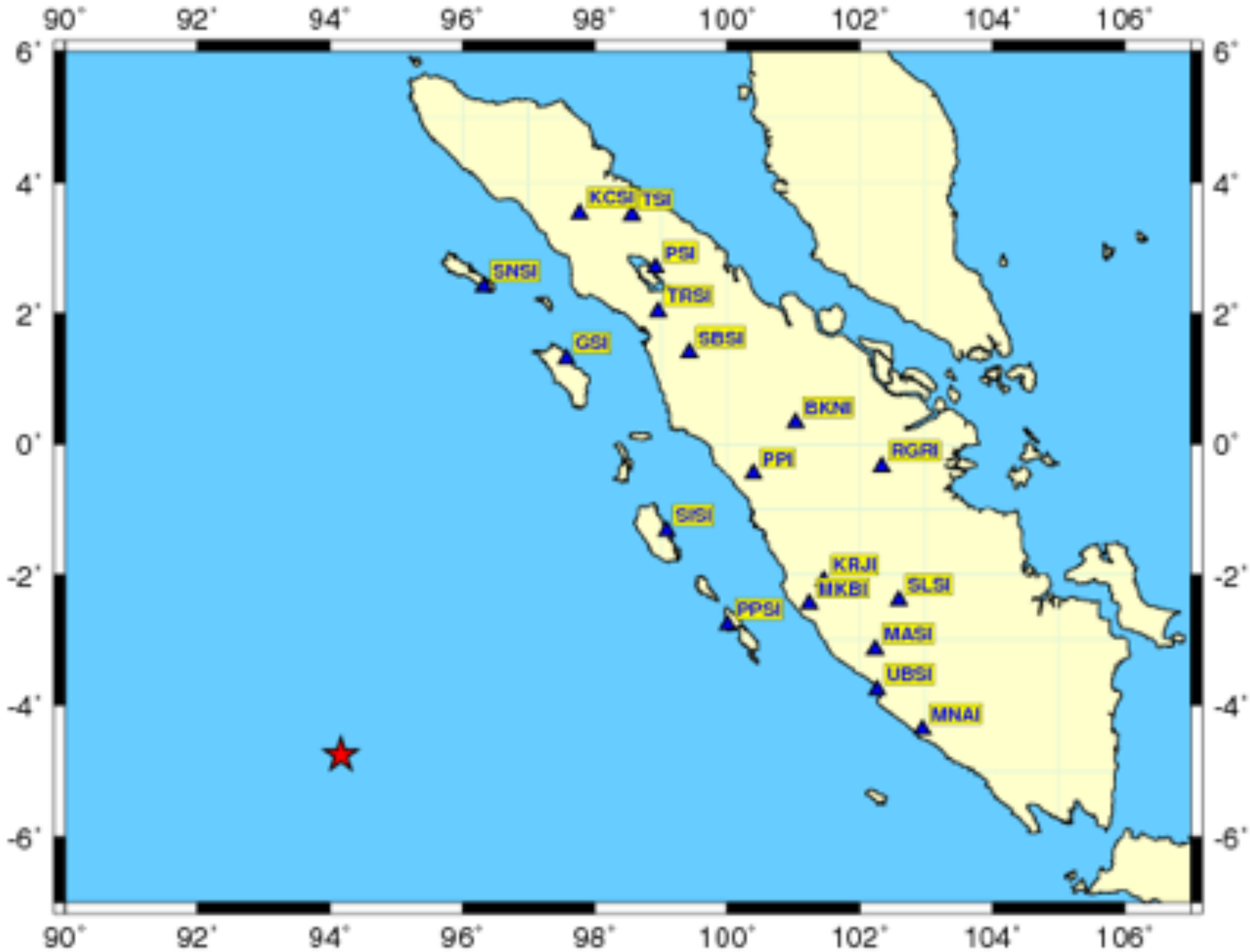

Figure 2. Map of 18 seismic stations and of the epicenter (red star) of the March 2, 2016, earthquake.

4. RESULTS AND DISCUSSION

The results of measuring the tsunami faulting parameters of the March 2, 2016, earthquake were rupture duration (Tdur), dominant period (Td), exceedance duration of 50 seconds (T50Ex), multiplication value of the rupture duration and dominant period (Tdur x Td), and the multiplication value between exceedance duration of 50 seconds and of the dominant period (T50Ex x Td). The three tsunami faulting parameters for each station are presented in Table 1 and the average of all tsunami faulting parameters are presented in Figure 3.

Table 1. Results of measurements of tsunami faulting parameters at each recording station.

No.	Name of stations	Tdur (s)	Td (s)	T50Ex	Tdur x Td (s^2)	Td x T50Ex (s)
1	SISI	12.35	3.97	0.03	49.03	0.12
2	PPSI	12.95	2.09	0.03	27.07	0.06
3	GSI	186.45	4.76	0.10	887.50	0.48
4	MKBI	105.20	2.36	0.09	248.27	0.21
5	PPI	12.44	2.43	0.03	30.23	0.07
6	SNSI	123.50	2.85	0.21	351.98	0.60
7	KRJI	25.56	1.90	0.13	48.56	0.25
8	UBSI	119.70	0.37	0.17	44.29	0.06
9	MASI	116.70	2.05	0.25	239.24	0.51
10	SBSI	18.24	1.45	0.05	26.45	0.07
11	TRSI	15.50	1.62	0.03	25.11	0.05
12	BKNI	35.30	3.60	0.24	127.08	0.86
13	MNAI	125.90	0.92	0.73	115.83	0.67
14	SLSI	21.48	2.93	0.08	62.94	0.23
15	PSI	132.42	13.30	0.07	1761.19	0.93
16	KCSI	12.05	3.38	0.05	40.73	0.17
17	RGRI	19.61	0.89	0.08	17.45	0.07
18	TSI	20.70	4.41	0.04	91.29	0.18
Average		**62.00**	**3.07**	**0.13**	**234.00**	**0.48**

The result of measurement of rupture duration using the Joko Tingkir software for the 18 stations (Table 1) varied for each station. The local seismic stations provided in Sumatra do not cover all azimuths. Minimum and maximum measurements of rupture duration (Tdut) was 12.44 s. at PPI station and 186 s at GSI station, respectively. The measurement result of earthquake rupture duration depends on the distance and azimuth of each seismic station location from the earthquake's epicenter, (Frankel and Kanamori, 1983; Catherine D. de Groot-Hedlin, 2005; Jaime Andres Convers1

Although the rupture duration average is more than the threshold value, the rupture duration magnitude was almost the same as the threshold value. Minimum and maximum measurements of the dominant period (Td) were 0.37s at the UBSI station and 13.30 s at the PSI station, respectively. The measurement result of earthquake dominant period indicates kinetic energy of the earthquake at the stations (Lomax and Michelini, 2011). The greater the dominant period, the greater is the kinetic energy of the earthquakes recorded at the seismic stations. Minimum and maximum measurements of exceedance durations of 50 seconds (T50Ex) was 0.03s at SISI, PPSI, PPI, TRSI stations and 0.73 s at MNAI station, respectively. If the exceedance duration of 50 seconds (T50 Ex) was less than one, this indicate that the earthquake energy was smaller at more 50 seconds. However, if the exceedsnce duration of 50 second (T50 Ex) was greater than one, this indicates that the earthquake energy is greater at more than 50 seconds (Lomax and Michelini, 2011; Madlazim, 2013; Madlazim et al., 2015).

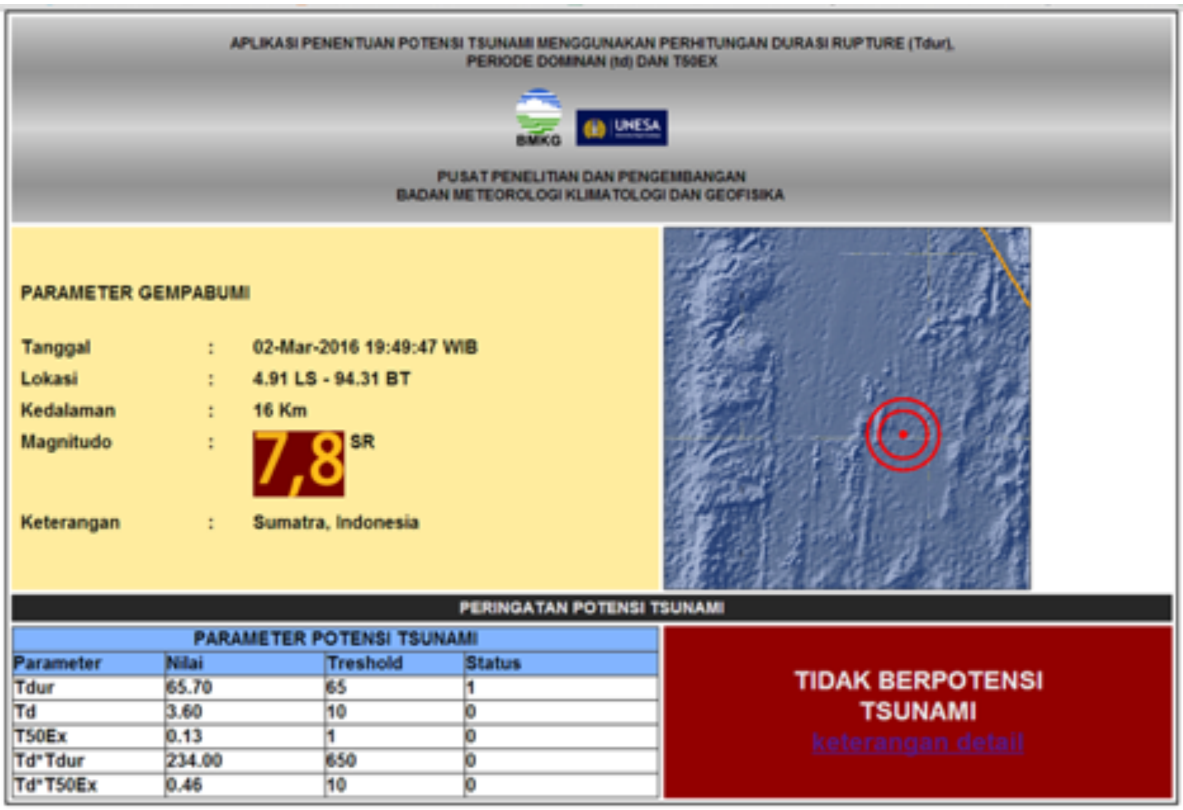

Figure 3. Tsunami application using the Joko Tingkir software. The earthquake did not generate tsunami because the tsunami faulting parameters status that has a magnitude greater than the threshold is Tdur only.

Figure 3 shows that all of the tsunami faulting parameters were less than the threshold, the only exception beibg that the rupture duration was greater than the threshold. However, the difference is only 0.70 second and it is insignificant - thus the earthquake was not tsunamigenic.

These results agree with a tsunami importance indicator less than 2 (Madlazim, 2013; Madlazim et al., 2015; Madlazim and Tjipto Prastowo, 2016) that published by NOAA at:

http://www.ngdc.noaa.gov/nndc/struts/results?bt_0=&st_0=&type_8=EXACT&query_8=60&op_14=eq&v_14=&st_1=&bt_2=&st_2=&bt_1=&bt_10=&st_10=&ge_9=&le_9=&bt_3=&st_3=&type_19=EXACT&query_19=None+Selected&op_17=eq&v_17=&bt_20=&st_20=&bt_13=&st_13=&bt_16=&st_16=&bt_6=&st_6=&bt_11=&st_11=&d=7&t=101650&s=70.

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REFERENCES

ARTHUR FRANKEL AND HIROO KANAMORI, 1983. DETERMINATION OF RUPTURE DURATION AND STRESS DROP FOR EARTHQUAKES IN SOUTHERN CALIFORNIA. Bulletin of the Seismological Society of America, Vol 73, No.6, pp 1527-1551.

Catherine D. de Groot-Hedlin, 2005. Estimation of the rupture length and velocity of the Great Sumatra earthquake of Dec 26, 2004, using hydroacoustic signals. GEOPHYSICAL RESEARCH LETTERS, VOL. 32, L11303, doi:10.1029/2005GL022695.

Jaime Andres Convers1 and Andrew V. Newman1, 2013. Rapid earthquake rupture duration estimates from teleseismic energy rates, with application to the real-time warning. GEOPHYSICAL RESEARCH LETTERS, VOL. 40, 1–5, doi:10.1002/2013GL057664.

Lomax, A. and Michelini, A. 2009. Mwpd: a duration-amplitude procedure for rapid determination of earthquake magnitude and tsunamigenic potential from *P* waveforms. *Geophysical Journal International*, Vol. 176, No. 1, pp. 200-214.

Lomax, A. and A. Michelini (2012a), Novel Algorithms Enabling Rapid, Real-Time Earthquake Monitoring and Tsunami Early Warning Worldwide, A*GU*, December 2012, San Francisco, *Eos Trans. AGU, NN(NN)*, Fall Meet. Suppl., Abstract *S53B-2495.*

Lomax, A. and A. Michelini (2012b), Tsunami early warning within 5 minutes, Pure and Applied Geophysics, 169.

Lomax, A. and A. Michelini (2011), Tsunami early warning using earthquake rupture duration and P-wave dominant period: the importance of length and depth of faulting, Geophys. J. Int., 185, 283–291.

Madlazim, 2011. Towards an Indonesian tsunami early warning system by using rapid rupture duration calculation. *Science of Tsunami Hazards*, Vol. 30, No. 4.

Madlazim, 2013. Assessment of tsunami generation potential through rapid analysis of seismic parameters a case study: comparison of earthquakes of 6 April and of 25 October 2010 of Sumatra. *The science of Tsunami Hazards*, Vol. 32, No. 1.

Madlazim, *Tjipto Prastowo* and *Thomas Hardy*, 2015. Validation of Joko Tingkir Software Using Tsunami Importance. *Science of Tsunami Hazards*, Vol. 34, No. 3.

Madlazim and Prastowo, T., 2016. Evaluation of earthquake parameters used in the Indonesian Tsunami Early Warning System. *Earthquake Science,* Vol. 29, No. 1.

Madlazim, Hariyono, E., 2014. Joko Tingkir program for estimating tsunami potential rapidly. AIP Conference Proceedings.

Madlazim and Supriyono, 2014. Improving experiment design skills: Using the Joko Tingkir program as a learning tool of Tsunami topic. *Science of Tsunami Hazards,* Vol. 33, No. 2.

Pararas-Carayannis, G., 2004. The Great Earthquake and Tsunami of 26 December 2004 in Southeast Asia and the Indian Ocean
http://www.drgeorgepc.com/Tsunami2004Indonesia.html

Pararas-Carayannis, G., 2005. Great Earthquake and Tsunami of 28 March 2005 in Sumatra, Indonesia.
http://www.drgeorgepc.com/Tsunami2005ndonesia.html

Pararas-Carayannis, G., 2007. Earthquakes and Tsunami of September 12, 2007 in Indonesia.
http://www.drgeorgepc.com/Tsunami2007Indonesia.html

USGS, 2016.
http://earthquake.usgs.gov/earthquakes/eqarchives/poster/2016/20160302.php