Preliminary Result of Earthquake Source Parameters the Mw 3.4 at 23:22:47 IWST, August 21, 2004, Centre Java, Indonesia Based on MERAMEX Project

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Abstract. In order to study the structure subsurface at Merapi Lawu anomaly (MLA) using forward modelling or full waveform inversion, it needs a good earthquake source parameters. The best result source parameter comes from seismogram with high signal to noise ratio (SNR). Beside that the source must be near the MLA location and the stations that used as parameters must be outside from MLA in order to avoid anomaly. At first the seismograms are processed by software SEISAN v10 using a few stations from MERAMEX project. After we found the hypocentre that match the criterion we fine-tuned the source parameters using more stations. Based on seismogram from 21 stations, it is obtained the source parameters as follows: the event is at August, 21 2004, on 23:22:47 Indonesia western standard time (IWST), epicentre coordinate -7.80°S, 101.34°E, hypocentre 47.3 km, dominant frequency f0 = 3.0 Hz, the earthquake magnitude Mw = 3.4.

1. Introduction
Merapi Lawu anomaly (MLA) is the location having an anomaly Vp/Vs = 1.9 found by [1, 2, 3, 4, 5] from seismograms from MERAMEX (MERapi AMphibious EXperiment) project. In order to study the structure of MLA using waveform forward modeling or full waveform inversion it needs high precision source parameters. The result from catalog searching at the time where MERAMEX project conducted, it is found only one event at near MLA which has hypocenter in 160 km depth located at -7.540°S, 110.7046°E with Mb=3.6 on August 24, 2014 on 07:08:31 IWT from [6].

The magnitude of the event is weak so the quality of the seismogram must be checked which the good seismogram is if it has SNR value higher and equal to 5 dB [7].

The hypocenter of this event is far from MLA that could reduce the accuracy. The faraway location makes the wave propagation time longer, the spatial coordinates get bigger, and the waves will pass through various unknown subsurface structure. These combinations increase the accumulation of errors and lead to incorrect results. To improve the accuracy, the station location is chosen where the seismic wave travel from the source does not pass through the MLA.
For the weak event in which the magnitude < 4 the focal mechanism is difficult to calculate, which the error is higher and not reliable [8]. For weak event, the seismic source wave modelling is approached by the point source [9] so that focal mechanism on this research is not computed.

The next parameter needed is the source frequency where the frequency is obtained from the dominant frequency from the P-wave phase because the value of this frequency is the highest compared to the others phases.

Based on these arguments, this research looks for an event that occurs as close as possible to the MLA location, has high SNR value, and the station location chosen is out of the MLA region so that forward modeling or full waveform inversion produce accurate results.

2. Seismogram and Location of Investigation
Seismogram is taken from the MERAMEX project from GFZ German Research Centre for Geosciences. The seismogram are obtained from the 130 seismographic stations which were installed and operated from May to September 2004. The installed station were scattered on both onshore and offshore in the Central Java, and Yogyakarta region. For this research the station that are onshore are chosen.

MLA is located between (-7.01°E, 110.52°S) to (-7.67°E, 111.19°S) at Centre Java, Indonesia. figure 1 shows MLA location and the contour based on [1]. From figure 1 it can be seen that MLA is irregularly shaped. The black shape has the highest $V_p/V_s = 1.9$. The grey colour indicates decreased gradation of $V_p/V_s < 1.9$.

3. Method
There are two steps to find the event; i.e. find the event roughly from a few stations, and fine-tuned the selected event that matched the criterion using many more stations. The purpose of the 1st step is finding the event location nearest of MLA quickly, and the 2nd step is fine-tuned the event location and source frequency. Many stations are used on the second steps with the hope the result will be more accurate.

SEISAN [10] is used to find the location of event. This software consists of various softwares to process seismograms for many purposes. To compute the hypocentre, SEISAN uses many alternatives ways using HYPOCENTER [11], HYPO71 [12], or HYPOINVERSE [13].

To calculate the SNR value the $SNR = 20 \log_{10} (A_s/A_n)$ formula is applied, where $A_s$ is a root mean square (rms) signal value and $A_n$ is rms noise. The signal to be used to compute SNR is P-wave phase as $A_s$ and the background signal (the signal before the P-wave phase comes) which considered as noise as $A_n$.

Spectrum analyser function from SEISAN is used to find the dominant frequency of P-wave phase. The P-wave phase is choose because this wave phase has the highest frequency in seismogram. This frequency is very important in waveform forward modelling or full waveform inversion because the size of grid or mesh depends to this frequency. Not all the seismogram are used to calculate the dominant frequency. The choice of seismogram is based on the representative of the farthest, medium and the closest distance toward the epicentre.

4. Result and Discussion
The hypocentre at 1st step is searched using five stations from July to the end of September 2004 from the MERAMEX project seismogram data. There are more or less 500 events are found both onshore and offshore. One of the events occurred which fulfil the requirement is on 21 August 2004, at 23:22:49 IWT, $M_w = 3.2$, epicentre coordinate is (-7.668°S, 110.967°E), and hypocentre is 37.5 km. This result is obtained from five stations namely A11, A13, AK1, BK3, and CK6 as shown in figure 2. In this figure the triangle is the station, the red dot is epicentre, and the black ellipsoid is the epicentre error. The epicentre error is about 20 km.
The SNR of the P-wave phases of all stations has a value of more than 20 dB which means it qualifies as a good signal. Table 1 shows the value of SNR for five stations.

| Station | SNR (dB) |
|---------|---------|
| AI1     | 35.0    |
| AI3     | 29.7    |
| AK1     | 45.8    |
| BK3     | 25.3    |
| CK6     | 24.0    |

21 stations is used to fine-tune this event namely BJ2, BK1, BKB, BK2, BK3, AK1, AK2, AK4, AK5, AJ1, AJ2, AI1, AI2, AI3, AH4, AH5, BI2, BI4, CK1, CK3 and CK6. The result of fine-tuned are follow. The origin time on 23:22:47 IWT, epicentre coordinate becomes (-7.808°S, 111.134°E), hypocentre is 47.3 km, dominant frequency f0=5.04 Hz, and Mw=3.4. Figure 3 shows the fine-tuned epicentre and stations location. The different colour at all of the stations in figure 3 shows the error which the green colour is the lowest error, yellow colour is moderate error, and the red colour is
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r: Replot  f: Forward or next trace
q: Quit s: Make spectral modeling

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Displacement

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Push any key to continue, R to replot

General parameters: F-spectrum
Vel  8.1 Dens 3.40 Dist 5 Depth 47
Co  500 Qalp 0.7 k 0.01 q1Hz 1.0 Spec model
Spectral frequency band 0.010 20.000

Filter: 1.000 5.000 4 1

(a)
the highest error. The epicentre error is about 12 km nearly halves from result the 1st step which is means the accuracy in the 2nd step is improve.

The dominant frequency of source is fine-tuned using spectrum analysis as shown in figure 4. In this figure we shows P-wave phase spectrum which give \( f_0 = 2.364 \) Hz. By using the same processing method, we process another selected stations, i.e. BK3, AK1, and AH5 stations, where the final dominant frequency is 3.0 Hz.

5. Conclusion
We have found an event that can be used for forward modelling or full waveform inversion to investigate the structure of MLA. This event is located near the MLA region derived from seismograms located outside the MLA.
Future Work
The source parameters obtained will be validated by performing forward modelling of the stations that have been used to find the hypocenter.

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