Subsurface Structure Model of Mount Merapi Using Receiver Function

Rian Amukti[1], Wiwit Suryanto[2] and Suharno[1]

Mailing address: [1]Geophysic Engineering Lampung University, [2]Geophysic Gadjah Mada University

E-mail address: hatake.rian@gmail.com

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ABSTRACT

Modeling of MT. Merapi subsurface using receiver function method has been done. Receiver function is method to analyze subsurface structure using a seismic station that consists of three components. To obtain receiver function response, data were rotated from (ZNE) (Z=Vertical, N=North, E=East) to ZRT (Z=Vertical, R=Radial, T=Tangential) component, and deconvolution between Radial and Vertical component is used. The inversion technique of receiver function response is used to obtain subsurface structure. The result of modeling indicates that in the North of MT. Merapi there is low velocity anomaly at depth 5-15 km. This anomaly is known MLA (Merapi Lawu Anomaly).

1. INTRODUCTION

Receiver function analysis is a method to model crust and upper-mantle structure from teleseismic wave forms recorded at three-component seismic station (Langston, 1979). A receiver function is the time series that when convolved with the vertical-component seismogram reproduces the horizontal-component seismogram (Ligorria and Ammon, 1999), and the timing and amplitude of the arrival S in the receiver function are sensitive to the local earth structure. This method applies deconvolution of P wave from radial component to isolate receiver function response (Ammon, 1997). In many Countries, researches of crust and upper mantle were modeled by using receiver function analysis like Hainan Island NW South China Sea (Qiu, 2002), the crust and upper mantle from the North German Basin to the Archean Baltic Shield (Alinaghi2003), crust and upper mantle across the Dead Sea transform (Mohsen, 2004), northern Sumatra and the Malaysian peninsula (Kieling, 2010).

Research of the internal structure of the Earth by using shallow seismic tomography method in Central Java, Indonesia has been done by several researchers including Koulakov (2007) and Wagner (2007). Seismic tomography method utilizing essentially the earthquake which originated from tectonic activity that caused a wave that propagates towards the seismic monitoring stations. If there is an anomaly of the medium through which seismic waves, it can be seen the difference between the P-wave arrival time on seismograms recorded on P-wave arrival time in the form of theoretical time series. An easier understanding of the principles of tomography can be illustrated as work at CT scan is used in medicine to determine a person's internal organs. One issue that draws on the results of seismic tomography study in Central Java is the existence of a low velocity anomaly is located between Mount Merapi and Mount Lawu at depths of 5-15 km, known as MLA (Merapi Lawu Anomaly), however, assurances as to such anomalies should be tested using other methods that can be done to corroborate or refute it, thus conducted this study in the receiver function study area is the central part of Java Island.

2. RECEIVER FUNCTION

The recorded of earthquake event from seismometer three components has a lot of information of P, S and surface wave. The receiver function is method to model crustal beneath station by analyzing P wave teleseismic. The fundamental of this method is that the P waves signal from distant events incident to a discontinuity in the crust or upper mantle will be converted to S waves (Ps), that arrive at the station after the direct P wave (Figure.1). Basically, the S waves travel slower than the P waves, so, a direct measure of the depth of the discontinuity is calculated by the time difference in the arrival of the direct P wave and the converted phase (Ps), provided the velocity model is known. The important one is to isolate P-to-S converted phases that reverberate in the structure beneath the seismometer by using water-level deconvolution (Ammon, 1997).
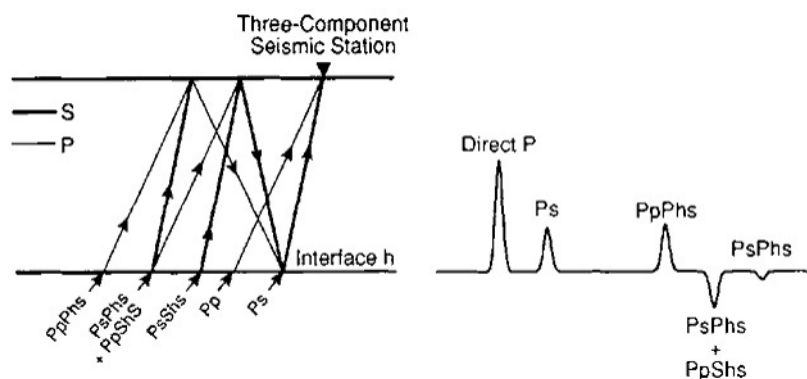

Figure 1: Signal of P-to-S converted phases from teleseismic event and their response on synthetic seismogram (Ammon, 1990).

Figure 1 describes a schematic ray diagram for P-wave teleseismic with its converted phases and their responses on synthetic seismograms. The amplitudes of the arrivals in a receiver function depend on the incidence of the impinging P-wave and the size of the velocity contrasts generating the conversions (Ps) and multiples (PsPhs, PpShs, PpPhs). The arrival times of the converted phase and multiples depend on the depth of the velocity contrast the P and S velocity between the contrast and the surface, and the P-wave incidence angle, or ray parameter. The relative amplitudes of the later arrivals and their frequency content depend on the nature of the velocity transition (Ammon, 1997).

3. ROTATION OF DATA

To analyze data from teleseismic events, firstly, we applied band pass filter at range 0.03-1 Hz for getting better P-onset arrival time. Then rotated coordinate from ZNE by using azimuth (back azimuth) information to ZRT system [1]. Equation 1 explain how to rotate from ZNE to ZRT system, the two horizontal components N and E are rotated into radial R and tangential T components.

$$\begin{pmatrix} R \\ T \\ Z \end{pmatrix} = \begin{pmatrix} cos\theta & sin\theta & 0 \\ -sin\theta & cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} E \\ N \\ Z \end{pmatrix} \tag{1}$$

Where $\theta=270-\varepsilon$ and ε is the back azimuth. The back azimuth describes the angle between the vector pointing from the seismic station to the north. Secondly, after rotation of ZRT system then we calculated receiver function by deconvolving the P coda from radial and vertical component. The resulting receiver function now has information of the near-receiver function structure which is modeled crust-mantle structure beneath seismometer.

4. DATA

The data used in this study consists of the data MERAMEX.

4.1 MERAMEX Data

MERAMEX, the data used in this study are recorded at seismic stations, the locations of which are shown in Figure 2, recording Data for 150 days in 2004. Seismograph station spacing is 10-20 km.
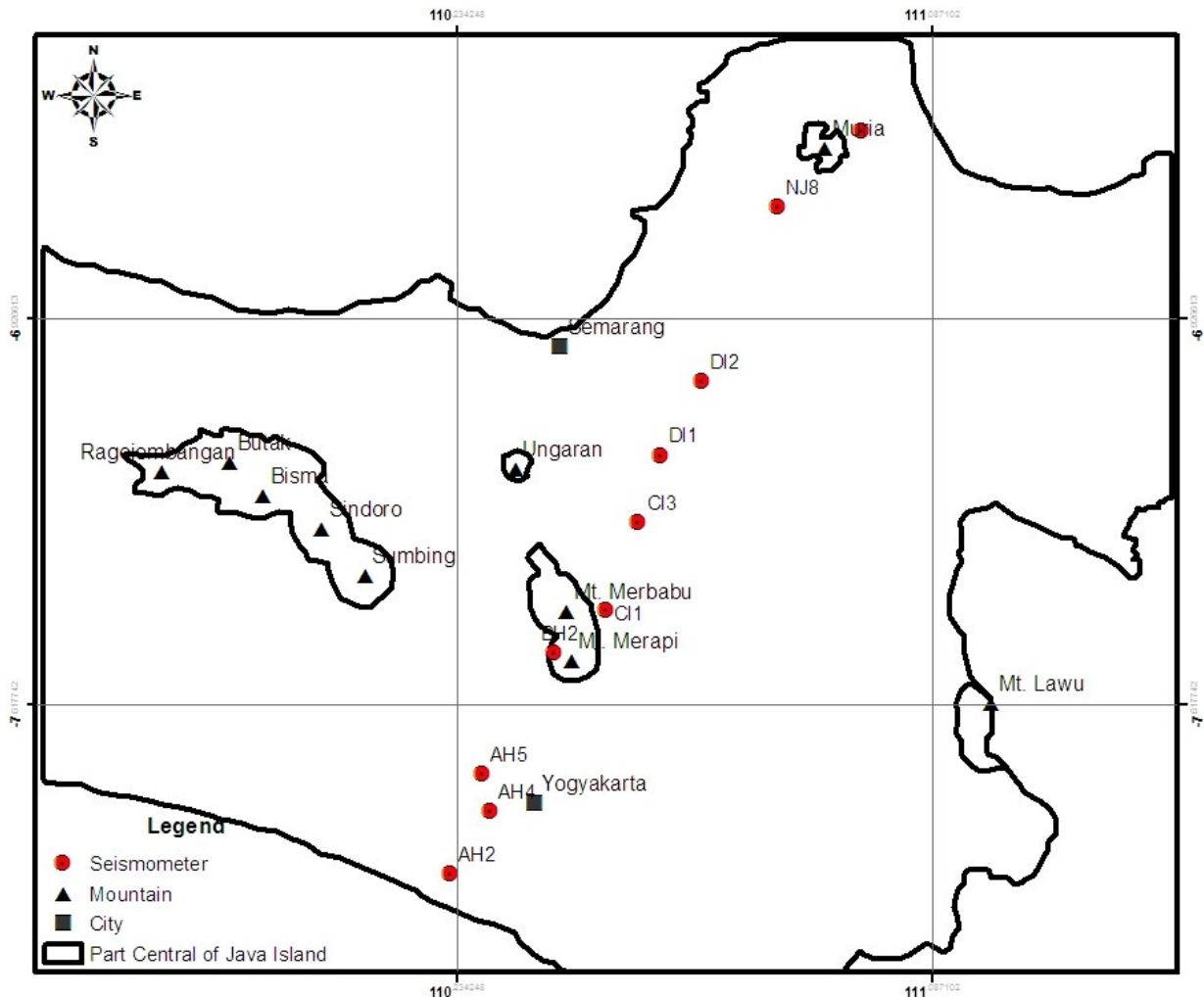

Figure 2: Seismograph station network in the research area of data MERAMEX.

4.2 Earthquake data

Seismic events were selected for analysis teleseismic receiver function is the event of an earthquake with a magnitude above 6, the epicenters of selected 11 seismic events are shown in Figure 3. Data used for research of receiver function has several criteria: Only with earthquake, epicenter distance of 30° to 90° ($1^o = 111:11$ km) is selected, an earthquake with a magnitude of over 5:5 and have recorded a clear P-wave with S / N is high.
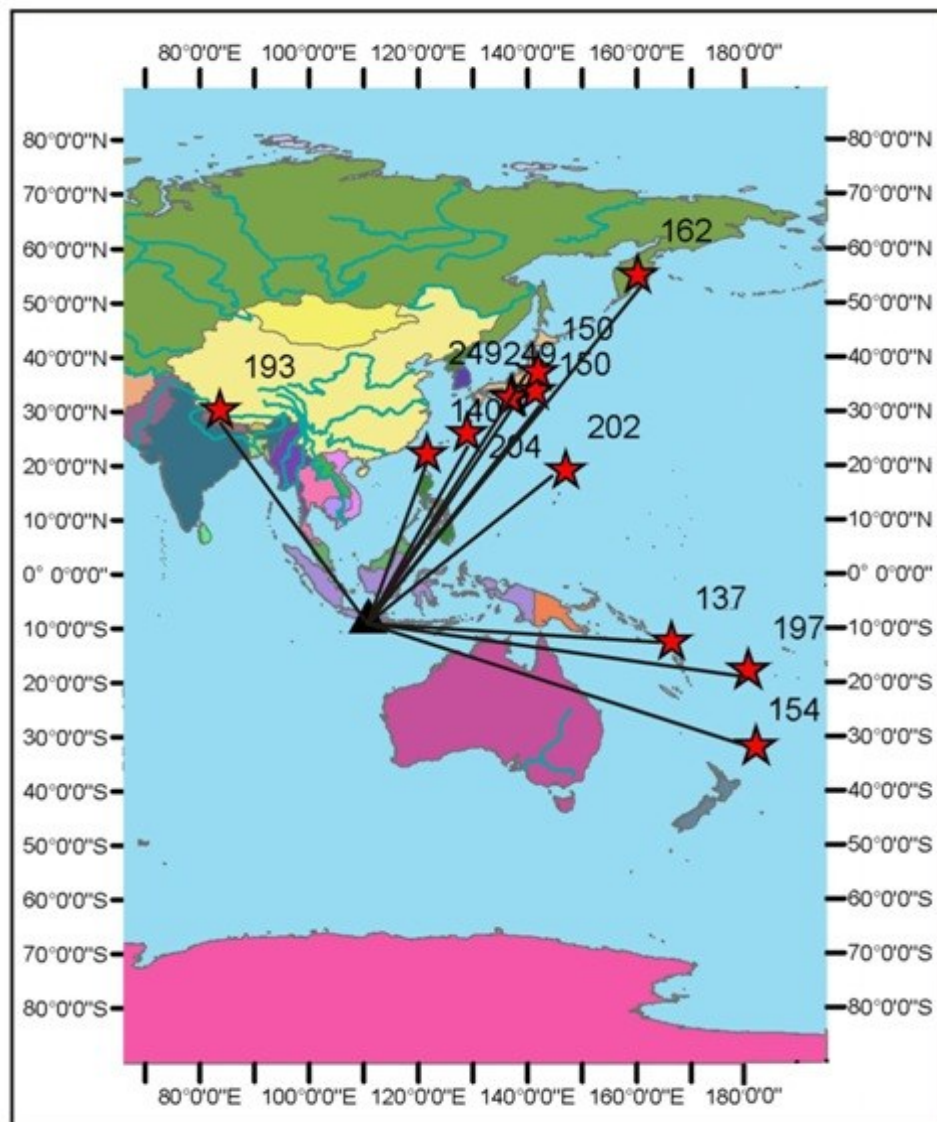

Figure 3: Earthquake event map used for receiver function studies.

5. RESULT AND DISCUSSION

The response of the receiver function for each station had a good response, because it has the same character of each event. AH2 stations have the same response from different events, as well as stations AH4, AH5, BH2, CI1, CI3, DI1, DI2, NJ3 and NJ8. In a seismic monitoring stations, recorded some events from different earthquakes. After doing the filter and select the signal with the same characteristics.

Furthermore, to obtain a good signal quality required stacking all signals. Stacking is done at each station signals. (Figure 4) seismic events were selected for analysis teleseismic receiver function is the event of an earthquake with a magnitude above 6, the chosen 11 seismic events (Figure 3). Data used for research of receiver function has several criteria: Only with earthquake, epicenter distance of 30° to 90° ($1^o = 111:11$ km) is selected, an earthquake with a magnitude of over 5,5 and have recorded a clear P-wave with S / N is high.
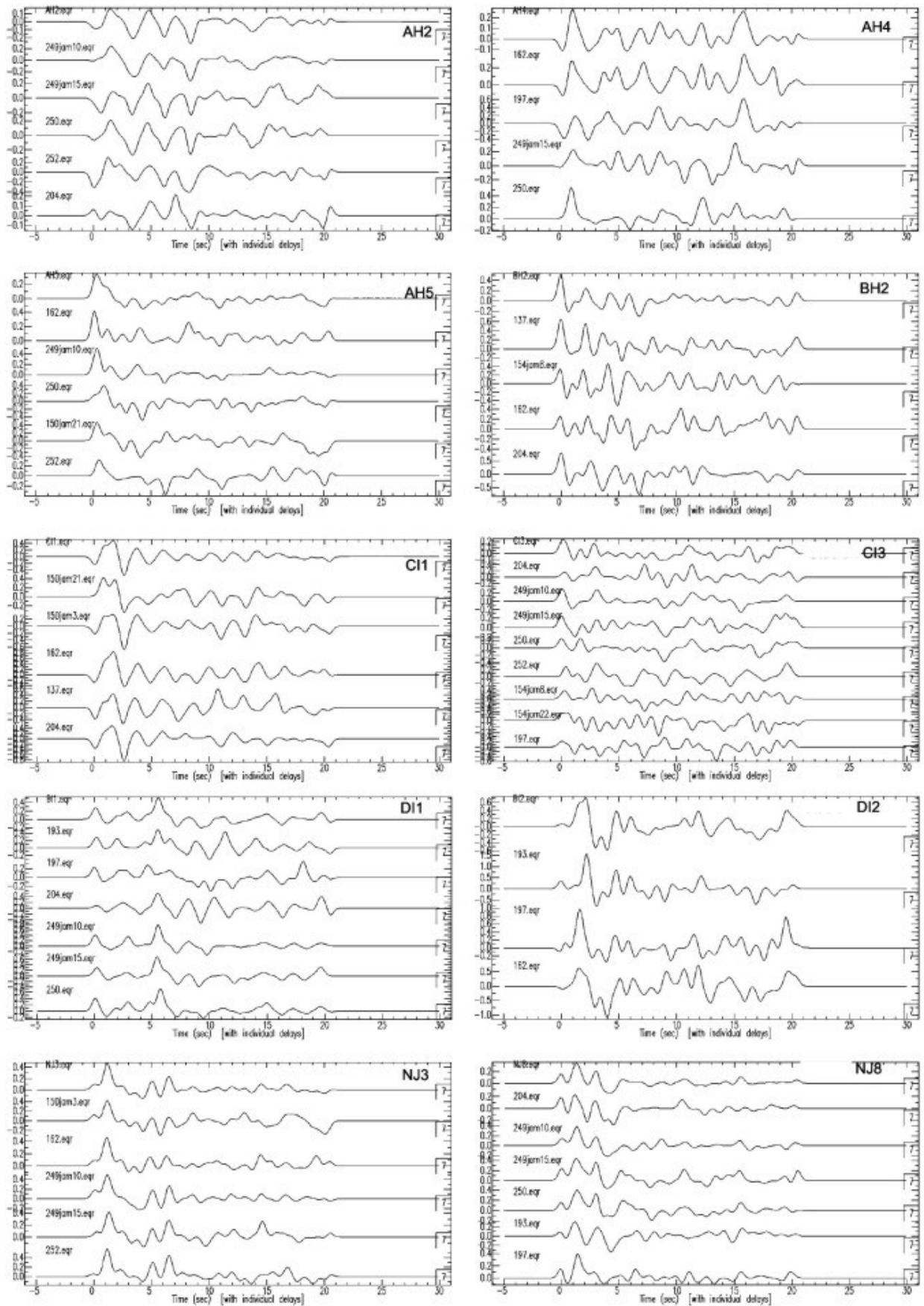
Figure 4: Stacking data of receiver function response

The results of receiver function stack response of different events each station inverted to obtain subsurface structure. The complexity of geological conditions makes it difficult to get a good inversion results. The result of receiver function inversion response is red, while the observational data is black (Figure 5).
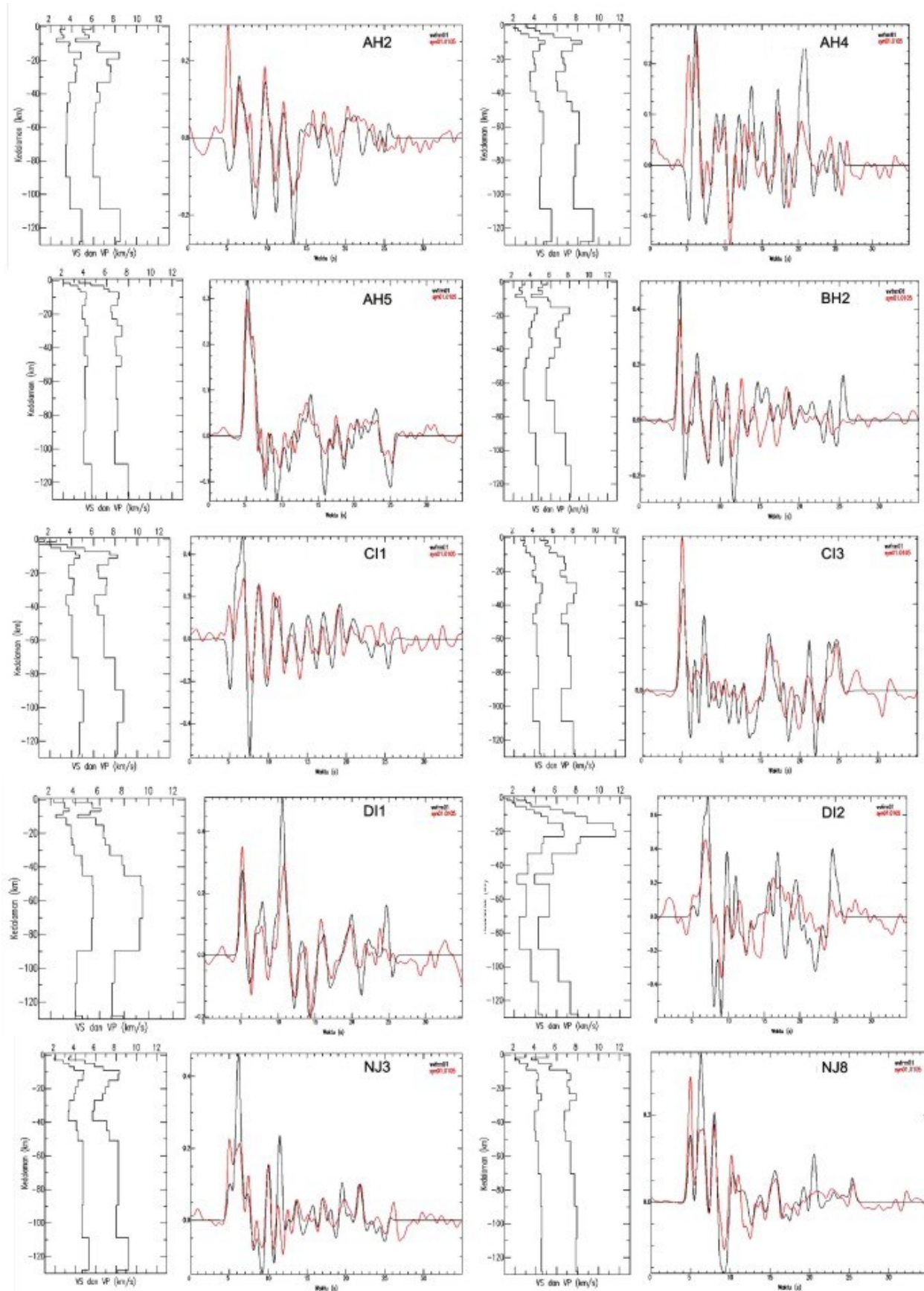
Figure 5: inverse response receiver function

Receiver function inversion results show a low velocity zone at a depth of 40 km at station AH2, AH4 station at a depth of 35 km, the station AH5 at a depth of 20 km, the station at a depth of 10 miles BH2, CI1 station at a depth of 20 km, the low velocity indicates the presence of partial melting, but still there is a low velocity at CI3 depth of 20 km, at a depth of 10 km DI station, the station at a depth of 45-90 km DI2, NJ3 station at a depth of 40 km. The presence of low velocity at this station indicate that partial

melting flowing toward Merapi Volcano, it still continues to flow to the north of Mount Merapi, thus making this happen in the low velocity region (Figure 5)

To obtain the accuracy of the resulting velocity model, then tested the model by comparing the velocity model that has been generated in this study with previous research models, i.e. models Koulakov (2007), and the model of Wagner (2007).

The next test of the model is comparison of the subsurface structure of Merapi Volcano in the south to north direction with the previous research models (Figure 6). Figure 6 shows (a) the result of P-wave velocity model of the subsurface structure generated by Wagner (2007), (b) the result of subsurface anomalous S-wave velocity disturbance generated by Koulakov (2007), and the present results generated by receiver function analysis: (c) subsurface P-wave velocity structure and (d) S-wave velocity disturbance.
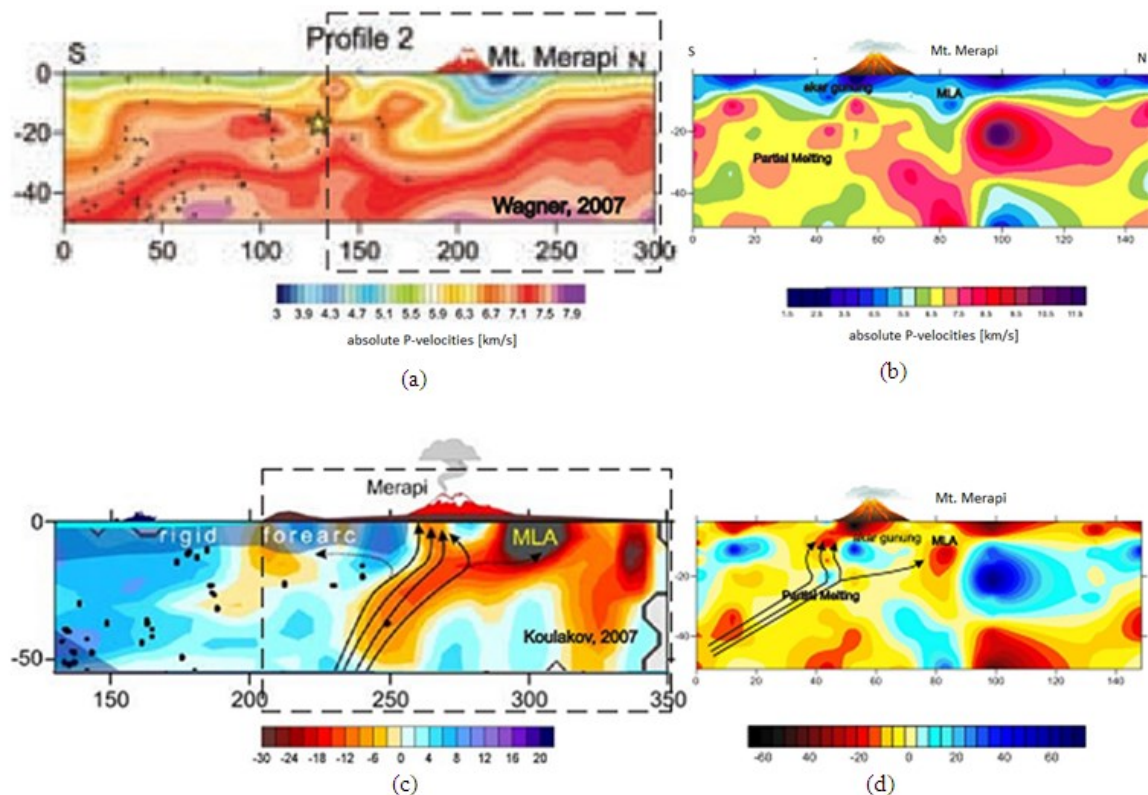

Figure 6: Comparison of the model structure of Merapi Volcano slices and area MLA between (a) P-wave velocity model (Wagner, 2007), (b) our result of P-wave velocity model, (c) model of anomalous interference-S wave velocity (Koulakov et al, 2007), (d) our result of model of anomalous interference-S wave velocity.

6. CONCLUSION

Results of research and receiver function modeling some conclusions that can be drawn:

1. Receiver response function analysis results showed that the distribution of earthquake data recorded in the station network MERAMEX apparently worth receiver function studies.

2. Low velocity anomaly is detected at a depth of 5-15 km is between Mount Merapi and Mount Lawu known MLA. MLA area (Merapi Lawu Anomaly) occurs due to partial melting of the stream that branched below Merapi Volcano.

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