S-velocity structure in Cimandiri fault zone derived from neighbourhood inversion of teleseismic receiver functions

To cite this article: Syuhada et al 2018 J. Phys.: Conf. Ser. 985 012013

View the article online for updates and enhancements.
S-velocity structure in Cimandiri fault zone derived from neighbourhood inversion of teleseismic receiver functions

Syuhada¹, T Anggono¹, F Febriani¹ and M Ramdhan²

¹Research Centre for Physics - Indonesian Institute of Sciences (LIPI), Tangerang, Indonesia
²Indonesian Agency for Meteorology Climatology and Geophysics (BMKG), Jakarta, Indonesia

E-mail: hadda9@gmail.com

Abstract. The availability information about realistic velocity earth model in the fault zone is crucial in order to quantify seismic hazard analysis, such as ground motion modelling, determination of earthquake locations and focal mechanism. In this report, we use teleseismic receiver function to invert the S-velocity model beneath a seismic station located in the Cimandiri fault zone using neighbourhood algorithm inversion method. The result suggests the crustal thickness beneath the station is about 32-38 km. Furthermore, low velocity layers with high Vp/Vs exists in the lower crust, which may indicate the presence of hot material ascending from the subducted slab.

1. Introduction

The study area is located in the Cimandiri fault zone. The fault is located in the area where there is high population cities and infrastructure exposed to the seismic hazard (figure 1). The Cimandiri fault has produced some moderate and shallow earthquakes causing serious damage on the surrounding area such as the Rajamandala earthquake in 1910, the Tanjungsari earthquake in 1972 and the Sukabumi earthquake in 2001 [1, 2]. Thus, knowing realistic earth models in the area located near this fault zone is an essential tool for assessing the seismic hazards in this area. However, the information about velocity crustal structure in this region is limited and mostly focused on the shallow structure derived from surface geological surveys (see e.g. [1, 2]) and geophysical investigations using audio-frequency magnetotelluric and gravity method (see e.g. [3, 4]). In recent years extensive receiver functions studies [5, 6] have been conducted to identify the structure and the geometry of the fault. In addition to these studies and to give better constraint about crustal structure information around this area, we investigate the detailed S-wave velocity structure by applying further analysis on receiver functions of teleseismic events recorded at a single three-component seismic station near the Cimandiri fault zone.
2. Data and method
In this study, we investigate S-wave velocity structure using earthquake data recorded in the period from 2008 to 2015 by single station located near the Cimandiri fault zone \([5, 6]\). This seismic station is part of the IA-Network operated by BMKG and GFZ-Postdam. For computing receiver functions, we use over 49 seismograms with clear P-arrivals from earthquakes having magnitude larger than 6 and epicentre distance between 30° and 90°. This selection provides seismic records that may have good signal to noise ratios \([7]\). It is important to note that some of these records may have low signal to noise ratios and thus, are removed from the analysis if the computed receiver functions do not meet the misfit criteria. Before computing receiver functions, the seismograms are inspected manually to choose the best quality records as well as to discard traces without clear P arrivals. The seismograms are initially baseline-corrected by removing the linear trend and eliminating the effect of instrument response. The horizontal components of the seismogram are then rotated into radial and transverse components. The time windows of the seismogram are finally chosen 10 s before and 50 s after the P-wave arrival.

We applied the time domain iterative deconvolution technique \([8]\) to compute the receiver functions. To control the high frequency noise of the receiver function, we perform the Gaussian filter with bandwidths of 1.5. The selected Gaussian width eliminates the frequency contents greater than approximately 0.75 Hz. This value is chosen by trial and error, considering the balance between the detailed waveform of receiver function and the effect of the high frequency noise to the receiver function. The quality of computed receiver function are then evaluated using a least-square misfit
criterion, which calculates the difference between the observed radial component and the convolution of the calculated receiver function with the observed vertical component. In this study, we only use radial receiver functions that achieve at least a 90% fit for further analysis. Once determined, the selected receiver functions are then stacked according to distance and back azimuth of the events and the waveform similarities to increase the signal to noise ratio, as well as to assure that the individual receiver function are passing through similar structure [7]. The staking process resulted in four receiver function stacks for this seismic station as shown by figure 2.

![Figure 2](image_url)

**Figure 2.** Plot of radial receiver functions at station SKJI arranged by group: (a) Group 1, (b) Group 2, (c) Group 3 and (d) Group 4. The top trace in each panel displays the stacked radial receiver functions.

To derive an S wave velocity profile beneath the seismic station, we apply the non-linear neighbourhood algorithm (NA) [9, 10] based on random choice of model samples to find the best model using the misfits of the previous models. We divide the crustal structure into 6 layers (sediment, basement, upper crust, middle crust, lower crust and upper mantle) consisting of 4
parameters in each layer. These parameters describe the layer thickness, Vp/Vs, the S wave velocity at the top and bottom of each layer. After a number of trials, the tuneable parameters are set for each inversion involving 5000 iterations, producing 250050 velocity models.

3. Result and discussion

All four stacks for this station (figure 2) are characterized by relatively complicated waveform in the first arrivals indicating the presence of shallow complex structure [5, 6], then followed by P-s conversion wave arrival at around 5.5-6 seconds. A large amplitude reflection is also identified at around 10 s indicating the presence of deep reflector. As the study area located in the southern edge of the Eurasian continent, characterized by the subduction process of Indo-Australian plane beneath Eurasian plate at rate 67 mm/yr [11, 12], thus we speculate that this strong amplitude is possibly related to the reflection in the subducted slab.

In order to estimate the S-wave velocity model beneath the station, we invert the receiver function stack in each group using the non-linear neighbourhood algorithm described by Sambridge [9] and Shibutani [10]. The inversion models for the four groups are shown by figure 3. In general, the model solutions of the inversion for the four stacked receiver functions have some common characteristics. For example, the solutions indicate a low S-wave velocity layer at the surface corresponding to the soft sediments lying directly above the basement rocks. The model solutions also identify the crust-mantle transition layer at a depth of around 32-38 km. This result is in a good agreement with the previous receiver study using H-k stacking method [5]. Syuhada and Anggono [5] found that the crustal thickness beneath this station is around 33.6 km. Other studies also suggest that West Java generally have crustal thickness around 30 km derived from modelling of local and global crustal structure data [13, 14], reflecting the Eurasian continental character [15]. Furthermore, we also note that some stacking groups (group 1, 2 and 4) show slightly negative velocity gradient with high Vp/Vs in the lower crust. As discussed earlier that the seismic station located just above the subduction zone, thus, this feature may be a result of hot materials ascending from the slab during subduction process.

It is important to note that in the case of the raypaths sampling the same structure, some stacked receiver functions on the same seismic station might produce similar velocity structure in the final models (see e.g. [7]). Conversely, some variation in the output inversion models might be obtained if there is a prominent variation in crustal structure with azimuth (see e.g. [6]). This can only be detected by using receiver function with good enough azimuthal distribution. In all cases, the inversion results of this study produced reasonable fitting between observed and synthetic model, although the amplitude of the first arrivals is not fully matched. We have tried to improve this waveform fit by running inversion using various range of incident angles and model parameters, but we still have unsatisfied results. We suggest that this poor waveform fit is due to the presence of complex shallow structures such as dipping and anisotropic structures related to Cimandiri fault as inferred by previous studies [5, 6]. Therefore, further inversion process incorporating the parameters of complex structure (e.g. percent anisotropy, dip and strike of dipping and anisotropic structures) is necessary in order to provide a better crustal velocity structure beneath this station.
Figure 3. Plot of NA-inversion results obtained for station SKJI arranged by group: (a) Group 1, (b) Group 2, (c) Group 3 and (d) Group 4. The solid red and white lines represent the best and the average fitting model, respectively. The grey shaded area are all models (250050 models) searched to find the best model. The red line in the left panel is the best fitting Vp/Vs ratio model. The bottom trace in each panel displays the predicted and observed staked receiver functions indicated by blue and black lines, respectively.
4. Conclusions
We investigate the velocity structure beneath a single seismic station located near the Cimandiri fault zone by inverting the receiver function using the non-linear neighbourhood algorithm. The obtained velocity profiles indicate a crust-mantle transition at 32-38 km depth. Another main feature in these crustal velocity models is the presence of low velocity layer in the lower crust with high Vp/Vs which can be interpreted as ascending hot materials from the subducted slab.

Acknowledgments
The authors are grateful to Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) and GFZ Potsdam for their seismogram data.

References
[1] Dardji N, Villemni T and Rampnoux J P 1994 J. Southeast Asian Earth Sci. **9** 3
[2] Martodjojo S 2003 *The evolution of Bogor, West Java basin* Doctoral Thesis (Bandung: ITB Bandung Publishing)
[3] Febriani F 2014 *Subsurface structure of the Cimandiri fault zone, West Java, Indonesia* Doctoral Thesis (Chiba: Chiba University)
[4] Handayani L, Maryati M, Kamtono K, Mukti M M and Sudrajat Y 2017 Indonesian Journal on Geoscience **4** 39
[5] Syuhada and Anggono T 2016 *Proc. Int. Sym. on Frontier of Applied Physics* (Bandung) vol 1711 (New York: AIP Publishing) p 070001
[6] Syuhada and Titi Anggono 2017 *Proc. Int. Sym. on Frontier of Applied Physics* (Serpong) Series 817 (Bristol: IOP Conf. Series: Journal of Physics) 012074-1
[7] Macpherson K A, Hidayat D and Goh S H 2012 *J. Asian Earth Sci.* **46** 161
[8] Ligorría J P and Ammon C J 1999 *Bull. Seism. Soc. Am.* **89** 1395
[9] Sambridge M 1999 *Geophysical Journal International* **138** 479
[10] Shibutani T, Sambridge M and Kennett B 1996 *Geophysical Research Letter* **23** 1829
[11] Hamilton W 1988 *Geological Society of America Bulletin* **100** 1503
[12] Kopp H, Klaeschen D, Flueh E R and Bialas J 2002 *Journal of Geophysical Research* **107** 2034
[13] Nishimura S and Harjono H 1992 *Geojournal* **28** 87
[14] Heine C 2007 *Formation and evolution of intracontinental basins* Doctoral Thesis (Sydney: The University of Sydney)
[15] Hamilton W B 1979 *Tectonics of Indonesian Region* (Virginia: US Geological Survey)
[16] Midzi V and Ottemöller L 2001 *Tectonophysics* **339** 443