S-velocity structure in the southern Simeulue Island from inversion of teleseismic receiver functions

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Abstract. We invert receiver functions to determine the velocity structure beneath two seismic stations in the southern Simeulue Island. We compute receiver functions from teleseismic events using the time domain deconvolution technique. The S-velocity profiles are obtained by inverting receiver functions using a linearized-iterative inversion with an AK-135 for the initial model. The result shows that the island is covered by sediment layer at the near surface. The inversion results also indicate that the crustal thickness beneath the Island is around 22-24 km depth, agreeing well with the crustal model obtained from the previous studies.

1. Introduction
The study area is located in Simeulue Island an interesting place for studying crustal structure with respect to active deformation, in which the region has experienced complex geological processes including plate rift-drift and amalgamation, collision and subduction since Cretaceous [1]. Simeulue Island is situated west of Sumatran Island near the convergence margin, in which the Indo-Australian plate subducts obliquely beneath the Eurasian plate. This obliquely subduction contribute to the development of the strike-slip fault zone on the Sumatran mainland accommodating most of the right lateral strain from the relative plate motion, which is well known as the Sumatran Fault Zone [2]. Thus, the process of this slip partitioning may also affect to the crustal deformation of the study area. Furthermore, this subduction zone has produced large earthquakes, including the recent 2004 Sumatra-Andaman and Nias earthquakes with magnitudes larger than Mw 8 located around 100 km from Simeulue Island. The Sumatra-Andaman event caused deformation on the Island in which the northern part of island elevated up to 1.5 m and the southern part subsided around 0.5 m [3, 4]. To quantify seismic hazard in this area, the velocity profile of the crust is needed as input. Therefore, we investigate crustal structure using receiver functions derived from teleseismic events in this work.

The deployment of temporary network in 2005 as part of the SEACAUSE experiment [5] has provided valuable data for crustal velocity studies underneath this island. This network recorded the teleseismic events that can be employed for receiver function analysis. The analysis of teleseismic receiver function has been widely used in characterizing the earth’s velocity structure [6, 7]. This method uses the fact that the teleseismic P wave propagates through seismic discontinuity layers will produce PS converted wave. Thus, it is possible to obtain the S wave velocity profile underneath a seismic station by inverting receiver functions.
2. Data Observation and Methods

We use teleseismic data recorded by two seismic stations belonging to the Simeulue ZB temporary network operated from December 2005 to March 2006 as part of the seismological network of the SEACAUSE project [5]. This temporary network was initially part of a geophysical data acquisition in order to characterize the segment boundaries of the upper plate around the Sumatran forearc. In our study, we use seismic stations located in the southern part of Simeulue Island. In computing receiver functions, we select the teleseismic event with the distance between 30°-90° and magnitude greater than 5.5. This distance range is used to minimize waveform complexity due to contamination from regional and core phases. Receiver functions are produced by deconvolving the vertical component from the horizontal components of the seismogram. This method effectively removes the source and path factors and retains the P-S converted phases due to the presence of layer discontinuities underneath the stations. Prior to deconvolution process, we inspect manually to ensure the quality data as well as to pick the P arrivals. The selected seismograms are then removed from the instrument response and rotated to radial and transverse components. Next, the waveforms are cut 10 s before the onset of P arrivals and 50 s after it. Finally, we apply the time domain iterative deconvolution procedure developed by Ligirroia and Ammon [8] with 500 iterations to compute the receiver functions. In this method, the frequency content of the receiver functions is controlled through a Gaussian filter. Here, we use the Gaussian bandwidths of 1.5, which removes the frequency content above approximately 0.75 Hz. To assess the quality of the receiver functions, we perform the misfit value computed from the difference between the observed radial seismogram and the synthetic receiver function convolved back with the vertical seismogram. Only receiver functions with a 90% fit or above are used for the inversion process. This step rejects many waveforms for the inversion process. Overall, each station used in this analysis has more than 2 good receiver functions.

For the inversion process, we use rfin96 code developed by Herrmann and Ammon [9] to invert the receiver function. This code is based on a linearized-iterative inversion by minimizing the misfit between the observed and modeled receiver functions [10]. In this process, we use the initial model AK-135 [11] consisting of 21 layers and fix the Vp/Vs ratio in each layer.
3. Results and Discussion

We invert the receiver functions to get the S-wave velocity profiles underneath two seismic stations (LABU and BATU) located in the southern part of Simeulue Island. Figure 2 shows the computed receiver functions on radial and transverse components at both seismic stations. Large amplitude signals appear on the transverse component at the two stations suggesting the presence of complex structure at shallow depth [12]. For radial component of receiver functions, the Moho P-S arrival is not clearly seen at both stations, perhaps due to the presence of strong reverberation from the sediment layer [13]. This seismically slow layer might obfuscate the Moho P-S phase. We also observe that the stronger effect of sediment layer is found at station BATU indicated by larger time delay of the direct P phase. This station is located near the Coast of Simeulue Island covered dominantly by alluvium deposit [4]. Whereas the station LABU is located in the formation composed mainly of arenite sandstone. Thus at shallow layer, the seismic wave is expected to propagate slower on station BATU providing the stronger effect on the receiver functions.

![Figure 2. Receiver functions calculated at station BATU and LABU plotted as a function of back azimuth.](image_url)

![Figure 3. (a) S wave velocity profiles for station BATU and LABU and (b) The waveform fitting between the calculated and the observed receiver functions marked by the red and blue lines, respectively.](image_url)
The inversion results from the two stations are depicted in figure 3. For both stations, the output models provide waveform fits more than 70%. At shallow depth, the inversion results show that BATU station is covered by a near-surface sediment layer with S velocity slower than that at LABU station. This result is consistent with the station’s location as discussed previously. The velocity profiles for the two stations then generally have common characteristics for deeper part. The velocity increases to around 3.6 km/s at 10-12 km depth which might attribute to the continental crust. Some geological and geophysical studies conducted around this island and Nias Island, south of the study area [14, 15] suggest the continental crust, part of Sunda block, underplate beneath the forearc basins around the study area. The slight increase of Vs is observed at 22-24 km depth on station BATU, indicating the transition into the oceanic subducting slab as suggested by other previous studies. The high velocity S wave of 5 km/s found around 38-40 km depth might represent mantle S wave velocities. This result is also similar with the wide angle reflection profile conducted around Simeulue Island [15].

4. Conclusions
We estimate teleseismic receiver functions from 2005 temporary deployment stations in the southern Simeulue Island. The resulted receiver functions are then inverted to generate the S-velocity structure. In general, the models show that the sediment layer is observed in the shallow depth, the transition of the continental crust to the subducting slab observed at 22-24 km depth and mantle velocities at 38-40 km. The results are consistent with other crustal studies conducted around this island.

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