Preliminary Result of Hypocenter Relocation Using Double Difference Method along Sumatran Fault, Indonesia

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Abstract. The Sumatran fault zone has a high seismicity and seismic hazard threat levels due to this fracture through densely populated areas. The fault zone of Sumatera has 19 main segments which each segment has the possibility to generate a strong earthquake. Therefore, in this study we attempt to improve the accuracy of hypocenter locations which is needed as basic analysis in advance seismology and in seismic hazard analysis. The final objective of this study is to analyze the subsurface seismic velocity structure of the Sumatran fault by applying seismic tomography method. For the preliminary result, we have been conducting double-difference method to relocate 967 events recorded by 49 stations compiled by Meteorological, Climatological, and Geophysical Agency of Indonesia (MCGA) from 2009 to 2017 along Sumatran fault. Our preliminary results from the relocation process indicate prominent features of event cluster around Sumatra fault system. The next step, we will improve the onset of P- and S-wave arrival time by using waveform cross-correlation in order to get more reliable hypocenter location.

1. Introduction

The Sumatran fault is a trench parallel strike-slip fault caused by oblique subduction between Indo-Australian plate and the overriding Eurasian plates [1]. Total length of the right-lateral strike-slip Sumatran fault is 1900 km, which Sieh and Natawidjaja (2007) [2] divided into 19 major fault segments. In addition to reverse-faulting subduction earthquakes near the Sunda trench [3], in the Sumatran fault usually occurs many shallow strike slip fault earthquakes too [4,5].
Seismicity along the Sumatran fault zone is high, and many large earthquakes have occurred along the fault. For example, one of the largest earthquakes occurred in June 1943, earthquake doublets have occurred repeatedly. Estimated magnitudes on the second event magnitude $M_s 7.6$, following the first event of $M_s 7.3$. The rupture of this event produce failure of Sumani segment of the Sumatran fault [6].

Among the 19 segments of the Sumatran fault, with its high seismicity level and historical seismicity of the Sumatran fault. It is very important to have better information of geometrical structure to analyze the subsurface seismic velocity of the Sumatran fault. For example by applying seismic tomography method, and to achieve it is required an accurate earthquake hypocenters as input [7,8,9].

2. Data and Method
We used waveform data obtained from broadband seismograph network that was operated by Meteorological, Climatological, and Geophysical Agency of Indonesia (MCGA). Earthquake data from 2009 to 2017. We used 49 stations along Sumatra to Java (Figure 1) and events were chosen with several criteria which are magnitude $\geq 3$ MLv, depth $\leq 30$ km. Initial velocity model used in this research is AK135 global velocity model [10] with modified layer depth. We applied double-difference method using HypoDD [11] to relocate hypocenter location with minimum of 6 phases of P and S arrival time, or only P wave [12]. The process of relocation divided into 19 clusters based on fault segment that using on this research.

3. Result and Discussion
We sort 7218 events from 2009 to 2017 becoming 767 events that just focused earthquake event on 19 fault segments (Figure 2). Relocation hypocenter location result using HypoDD shows a significant improvement, and relating with the geological structure. We relocated of 666 events from 767 events. Rose diagram show shifting direction is to Northeast, with highest shifting angle is $5.6^\circ$, and the average
shifting angle is 0.55º (Figure 3, right). Histogram after relocation also show better fit data, it showed from distribution frequency on minimum travel time residual (Figure 3, left).

Figure 2. All earthquakes before sorting data (2a) and all data used after sorting before relocation (2b).

Figure 3. Histogram of residual times after relocation (left) and Rose diagram (right).
Figure 4. Seismicity map after relocation & Cross Section of fault segments from A to D. Blue line is Slab 2.0 that showed Sumatra Subduction [11].

To determine the characteristic of subsurface on every fault segment, we analysis the cross sections of few fault segment that have many data and show significant improvement of the fault pattern. Cross section data show difference between pattern before relocation and after relocation. Before relocated, a lot of data has a depth of 10 km. It is fitted as a fix depth. Automated processing systems that can determine the depth. When one or more of these elements is missing, then depth resolution is often poor,
a fixed depth will be assigned and a spurious or misleading depth avoided. Seismic activity on all of this shallow earthquake indicate the possibility of impulse in the fault field leading to the northeast direction. We also observed some interesting earthquake clusters (Figure 4 & Figure 5). For instance: an earthquake cluster in the “Cross Section A, B, D, E, F”. The amount of seismic activity that occurs in the area causing the fracture pattern to become clearer.

Figure 5. Cross Section of fault segments from E to J.
Segments that have many earthquakes form clusters and have a clear fracture pattern in the Aceh and Seulimeum segments, both of which are in northern Sumatra. Whereas in the central part of Sumatra, the fairl active segment is Toru segment. In the southern part of Sumatra, there are not many large seismic activities, so there is a suspicion of a seismic gap in this southern Sumatra region. Based on the cross section, we also observed few fault segments like “Cross Section G and H” which in southern Sumatra region, have historical earthquake like “1994 Liwa earthquake” (Mw 6.9), 1926 and 1943 earthquake around Lake Singkarak (Mw ~7.4), they does not have major activity, this is interesting because considering the energy that is still stored in the fault on this area can be very dangerous if we have seen from the history of events in the past.

4. Conclusions
We have conducted relocating hypocenter of the earthquake using the double difference method in Sumatran Fault. The result showed that shallow earthquake event after relocation made pattern of the fault to become clearer, however few segment of the fault do not have many data to describe the pattern, but it become more serious because it can be the sign that the fault storing a big energy in that area. Therefore, the result will be improved to make better result, like combining cross correlation data with the catalog data. And it may be used for such further research as seismic tomography study.

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