Precise Hypocenter Determination around Palu Koro Fault: a Preliminary Results

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Abstract. Sulawesi area is located in complex tectonic pattern. High seismicity activity in the middle of Sulawesi is related to Palu Koro fault (PKF). In this study, we determined precise hypocenter around PKF by applying double-difference method. We attempt to investigate of the seismicity rate, geometry of the fault and distribution of focus depth around PKF. We first re-pick P-and S-wave arrival time of the PKF events to determine the initial hypocenter location using Hypoellipse method through updated 1-D seismic velocity. Later on, we relocated the earthquake event using double-difference method. Our preliminary results show the distribution of relocated events are located around PKF and have smaller residual time than the initial location. We will enhance the hypocenter location through updating of arrival time by applying waveform cross correlation method as input for double-difference relocation.

1. Introduction

Sulawesi area is located in plate tectonic interaction like Eurasia, Indo-Australia, Pacific, Philippine Sea and Sundaland [1]. That condition made complex tectonic pattern which signed by seismicity and volcanoes activity. High seismicity activity in the middle of Sulawesi is related to Palu Koro fault (PKF).

The first step to study about seismicity and his relation to fault is hypocenter determination. Hypocenter required to study structure, tectonic regime and processes that trigger seismic activity. Hypocenter accuracy depend on factors, one of them is seismic wave velocity structure.

Many techniques had developed to determine hypocenter become precisely. One of them is double difference method [2]. This method based on fact that if the hypocenter separation between two hypocenter is small enough recorded at the same station compared to event – station distance then the ray path can be considered identical along their length. The double-difference methods have been successfully aplied to determine precise hypocenter around active fault and subduction zone in Indonesia region [3,4,5,6,7,8,9]

2. Methodology

In this research we used 226 PKF events waveform from BMKG's network during January 2011 – December 2016. We re-picked P- and S-phase arrival time from PKF events waveform to determine initial hypocenter. Initial hypocenter determined by Hypoellipse method [10]. Output from Hypoellipse consist of origin time, hypocenter, *RMS*, observed arrival time, calculated arrival time and residual time.

1-D velocity model used as initial model is iasp91 1-D velocity model [11]. That 1-D velocity model updated by coupled velocity – hypocenter method [12] on Velest [13]. Generally, updated 1-D velocity model higher than initial 1-D velocity model, see **Table 1**.

Table 1. Comparison between Initial and Updated 1-D Velocity Model.

Depth (Km)	Initial Velocity Model (Km/s)		Updated Velocity Model (Km/s)	
	P wave	S wave	P wave	S wave
20	5.8	3.36	5.99	3.46
30	6.5	3.75	6.17	3.58
35	8.04	4.47	8.08	4.55
71	8.044	4.48	8.08	4.55

Initial hypocenter and updated 1-D velocity model were used to relocate PKF event. RKF event relocated using double different method. Double different method based on fact that if the hypocenter separation between two hypocenter is small enough recorded at the same station compared to event – station distance then the ray path can be considered identical along their length. It means that the difference of travel time between two events recorded at the same station may be attributed to the differences in spatial separation. Double different applied on HypoDD software [14]. HypoDD required catalog travel time data, waveform cross correlation data and both of them. We used catalog travel time data to our preliminary results.
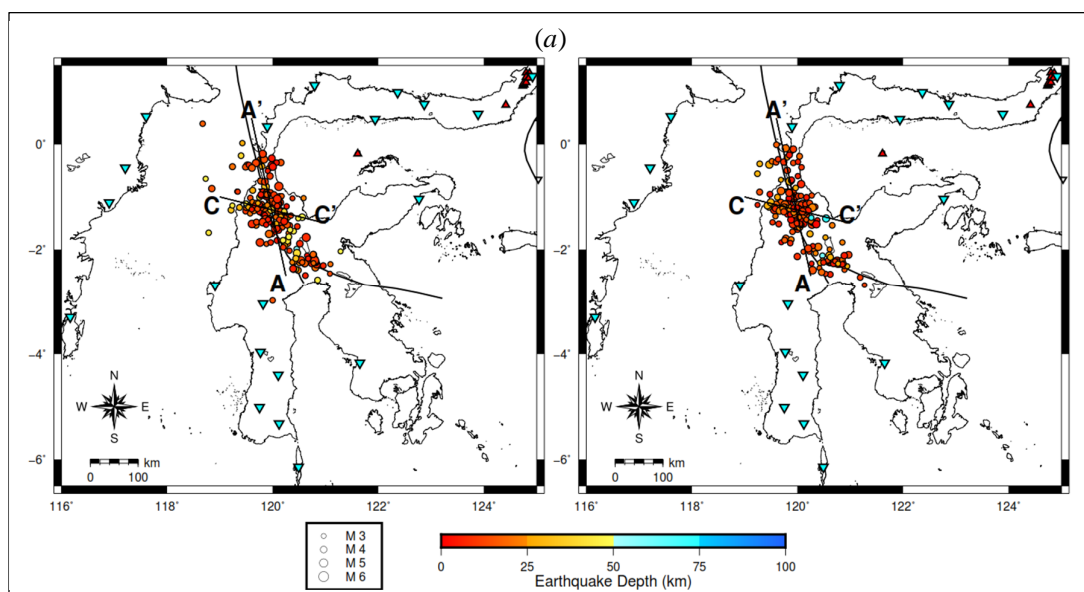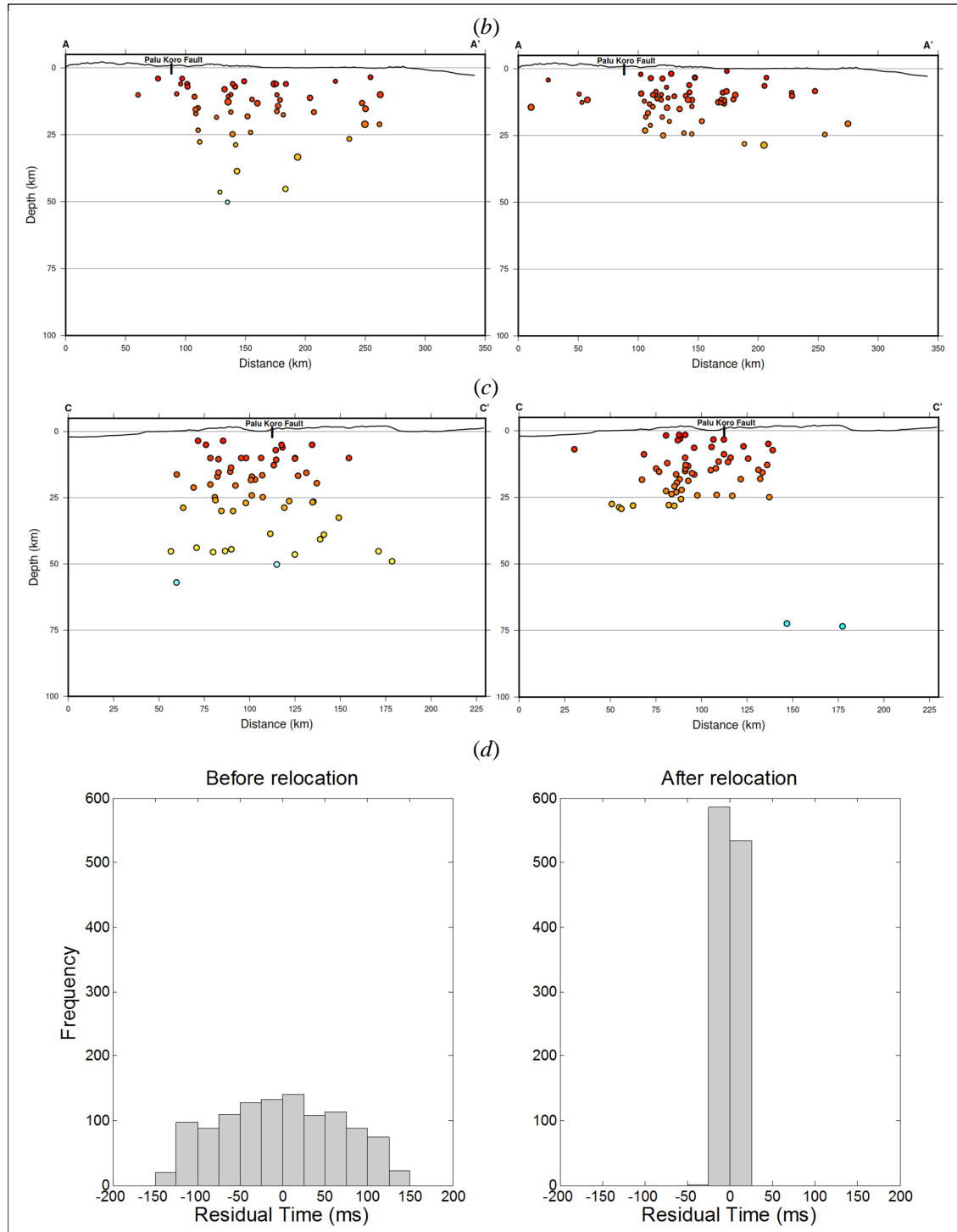

Figure 1. (be continued in next page)

Figure 1. Comparison results from Hypoellipse method (left) and double difference method (right). Part (*a*) show epicenter location. Circle dot is epicenter, blue inverted triangle is stations, red triangle is volcanoes, black line is fault and black line with triangle is subduction. Part (*b*) and (*c*) shows hypocenter location on A-A' and C-C' section from part (*a*). Part (*d*) show comparison double difference residual time.

3. Results

We relocated 226 PKF events from initial hypocenter by HypoDD. We evaluated the relocated hypocenter according to visual and statistic. Visually based on hypocenter distribution and statistically based on comparison their double difference residual time.

In Fig. 1, we can look that the relocated epicenter is closer and agree with PKF than the initial epicenter. The outliers on the relocated epicenter is less than the initial epicenter. Average movement from the initial epicenter is 88.714 Km. In section, average movement of hypocenter is up to 3.79 Km. Average depth from relocated hypocenter is 14.37 Km, more shallow than 18.17 Km from initial hypocenter. Generally, relocated hypocenter is more shallow than initial hypocenter, but not for all event.

Double difference residual time comparison between before and after relocation showed also in Fig. 1. Residual time is a difference between observed and calculated travel time. The quality of model can determine by residual time. The good quality signed by residual time value collected around 0 (zero) and on the contrary. The double difference residual time form initial hypocenter's around -134.249 until 134.491 ms with his average is -2.3568 ms. The maximum frequency of residual time around 0 (zero). The double difference residual time from relocated hypocenter is smaller than the initial hypocenter. The average double difference residual time of relocated hypocenter is 0.1929 ms and around -25.91 until 22.568 ms.

4. Conclusions

Our preliminary result that the hypocenter determination used double difference method showed hypocenter location more precisely. That is signed by the distribution of relocated hypocenter are located around PKF and have smaller residual time than the initial relocation. We don't interpret our preliminary result about seismicity and tectonic regime because there are next step to get hypocenter precisely. After used the catalog travel time data, we are going to use waveform cross correlation data and both of them to improve hypocenter determination. We consider, the relocation hypocenter obtained in this study will be usefull as input for advance seismological, seismic hazard mitigation in PKF and surround it.

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