Hypocenter Relocation of Earthquake Swarm in West Halmahera, North Molucca Region, Indonesia by using Double-Difference Method and 3D Seismic Velocity Structure

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Abstract. The earthquake swarm events sequence occurred in west Halmahera, north Molucca, Indonesia for the period of October 2015 to February 2016 as reported by Meteorological, Climatological, and Geophysical Agency (BMKG) of Indonesia. There were tenths swarm events with Magnitude larger than four in the region during the period. In this study, we used the earthquake catalog data compiled by BMKG to improve the location of swarms event in west Halmahera, north Molucca, Indonesia. We relocated 86 swarm events by applying teleseismic double-difference method and 3D seismic velocity model. The focus depth of swarm events mainly concentrated at depth of 5 to 12 km at south-east of Jailolo volcano. Our preliminary interpretation the earthquake swarms may be related to the stress change around the deep magma region of the volcano.

1. Introduction

Earthquake swarms are generally defined as a sequence of events closely clustered in time and space without mainshock and these events can be used for forecasting eruptions [1]. It means swarms are sequence of the quakes of similar magnitude to the mainshock. Earthquake swarms are usually common in volcanic regions [2]. The previous study on AD 2000 Izu island earthquake swarm by Toda et al. [3] concluded that gradual and sustained increase in stressing rate caused by magma intrusions and eruptions, extrusion or creep event will lead to producing earthquake swarms. The phenomenon of earthquake swarms were also detected by BMKG network in west Halmahera, north Molucca, Indonesia in October 2015 to February 2016. During this time period, there were tenths swarm events with Magnitude larger than four in the region. The destructive swarm event has been reported occured on November 20, 2015 with Magnitude of 4.9 which caused houses and public facilities damaged in the region. The Molucca region has complex and unique tectonic and geological setting, high seismicity [4,

5, 6, 7] and volcano activities as shown in Figure 1. The previous tomographic inversion study by [8] showed the two opposing subducted slabs of the Molluca Sea plate beneath arc-arc collision zone between Sangihe and Halmahera. In this study, we attempted to determine an accurate earthquake swarms hypocenter by applying double-difference relocation method [9] and regional 3D seismic velocity model [8].

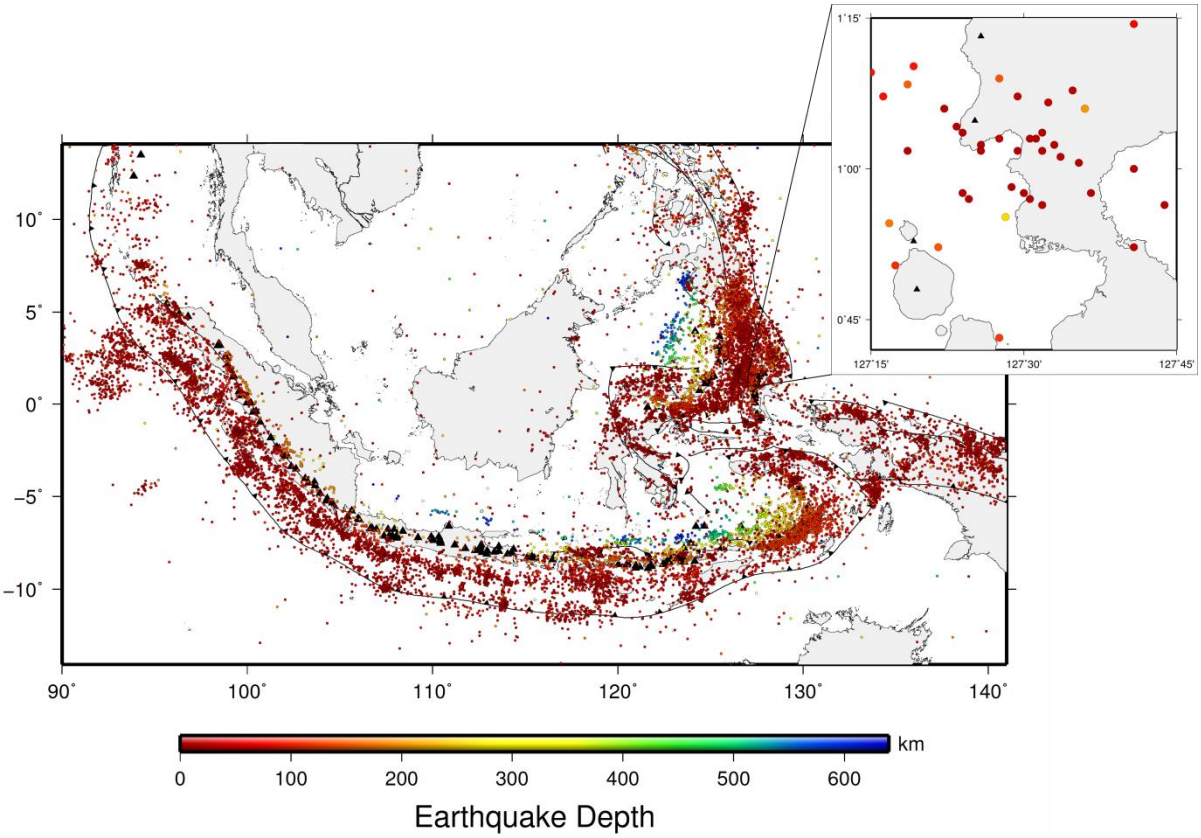

Figure 1. Distribution of earthquake epicenter with Magnitude > 4 (dot circle) around Indonesia region compiled by BMKG for the time period of April 2009 to January 2017. Top right is zoom in of the earthquake swarms location in west Halmahera, north Molucca, Indonesia.

2. Data & Method

We relocated 86 swarm events in west Halmahera region which occurred on November 2015. These events have magnitude range from 2.5 to 4.8. We used teleseismic double-difference (DD) relocation method [9] by using 3D velocity model from Widiyantoro and van der Hilst [8]. The arrival time data were obtained from Indonesian Meteorology, Climatology, and Geophysics (BMKG). We used around 30 stations at local and regional distances to relocate the swarm events.

3. Results and Discussions

We have been successfully determined 86 earthquake swarms event in west Halmahera, north Molucca, Indonesia by applying DD method. Our preliminary results show the relocated swarm events were distributed more clustered at south east of Jailolo volcano (Figure 2). The focus depth of swarm events and the fixed depth at depth of 10 km from BMKG data catalogue were improved significantly. The relocated swarm events have a focus depth from about 5 km to 30 km and commonly focused at depths

of 5 to 12 km (Figure 3). The location of these events in region of active tectonic and volcano are a key to interpret the source mechanism of events, whether its related to stress changed in magma region or creep processes around the fault. Our preliminary results show the relocated swarm events are located close to Jailolo volcano. So our interpretation these events may be related to stress change of deep magma activity around the volcano. However, our results need to compare with others geological, geodetic and geophysical methods. The dense local networks are also needed to determine more precise hypocenter determination and advance seismological study. Statistically, the travel time residual of phase pairs for relocated swarms event using DD method in this study show much better values than the initial swarms event location (Figure 4).

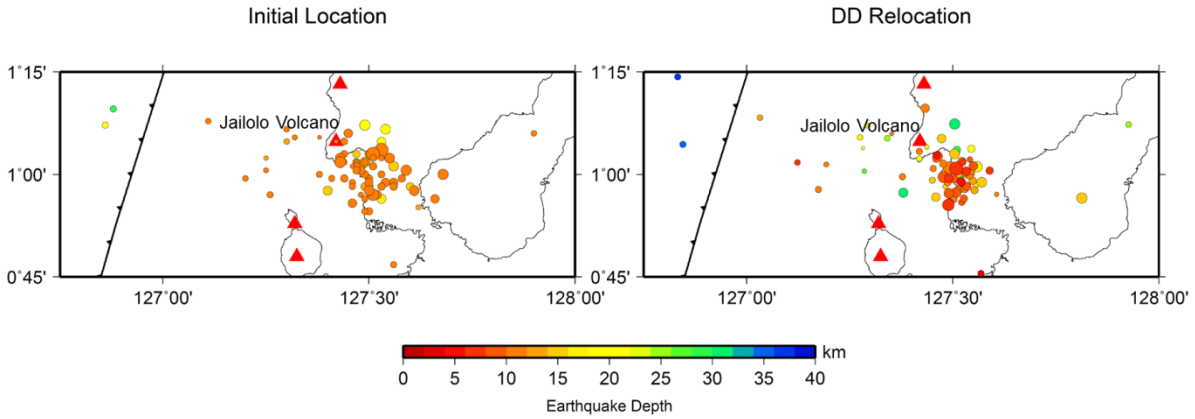

Figure 2. Earthquake swarms epicenter location before relocation (left panel) and after relocation using DD method and 3D seismic velocity model in this study (right panel).

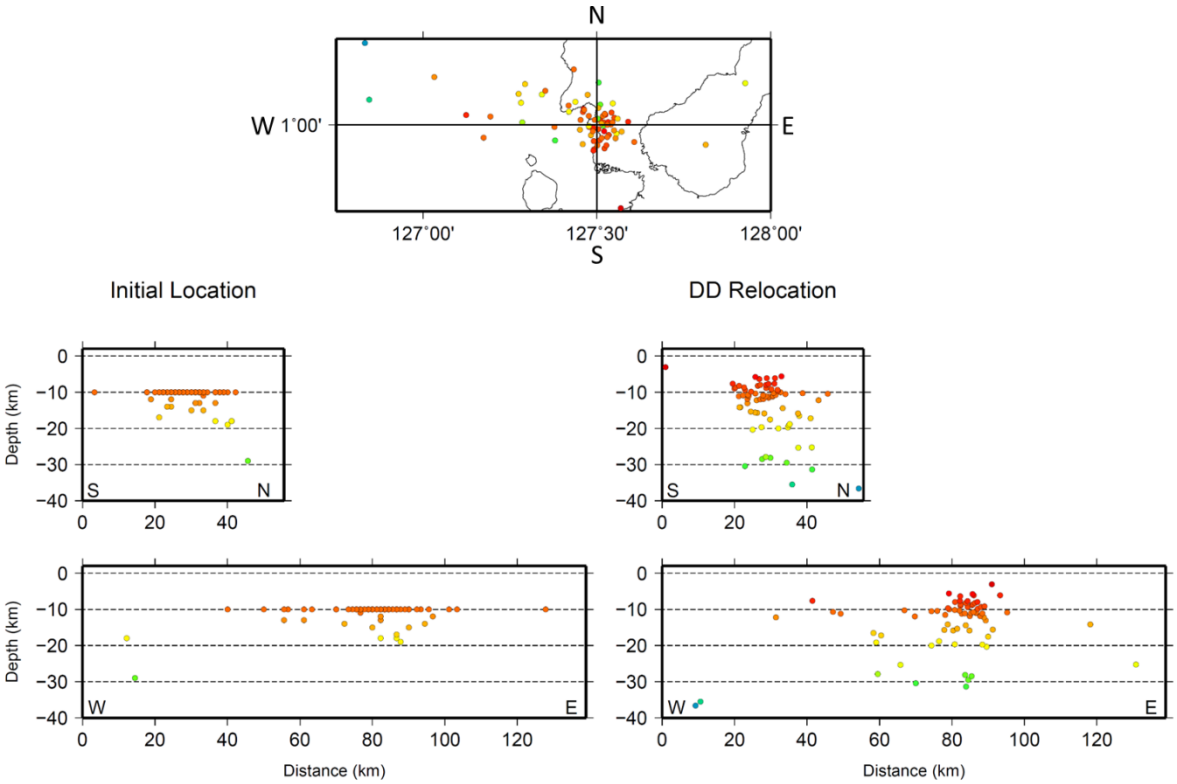

Figure 3. Vertical section of N-S and W-E before (left panel) and after relocation of earthquake swarms hypocenter distribution in this study (right panel), respectively.

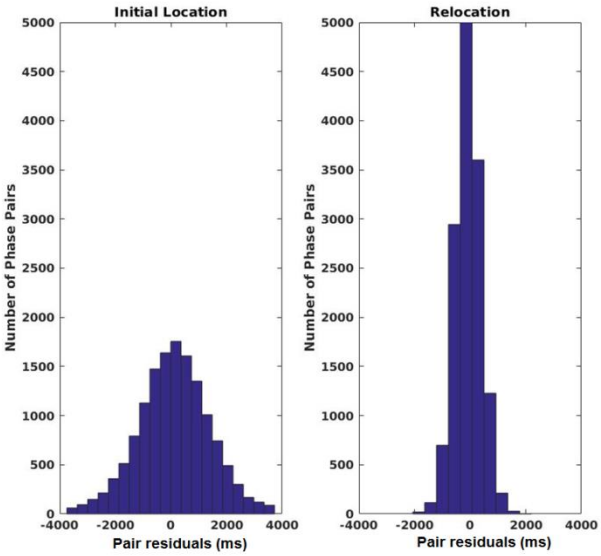

Figure 4. Histogram travel time residuals of phase pairs for initial locations (left) and relocations (right) of swarms events in this study.

4. Conclusions

We used the earthquake catalog data compiled by BMKG to improve the location of swarm events in west Halmahera, north Molucca region, Indonesia. We determined 86 swarm events by applying DD method and 3D seismic velocity model. The swarm events mainly distributed at depth of 5 to 12 km at south-east of Jailolo volcano. Our preliminary interpretation these swarm events may be related to stress change around the deep magma region of the volcano.

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