Comparison tomography relocation hypocenter grid search and guided grid search method in Java island

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Abstract. The main data in this research is earthquake data recorded from 1952 to 2012 with 9162 P wave and 2426 events are recorded by 30 stations located around Java island. Relocation hypocenter processed using grid search and guided grid search method. Then the result of relocation hypocenter become input for tomography pseudo bending inversion process. It can be used to identification the velocity distribution in subsurface. The result of relocation hypocenter by grid search and guided grid search method after tomography process shown in locally and globally. In locally area grid search method result is better than guided grid search according to geological reseach area. But in globally area the result of guided grid search method is better for a broad area because the velocity variation is more diverse than the other one and in accordance with local geological research conditions.

1. Introduction

Indonesia is formed by the interaction of three plates, Eurasia, Indo-Australian and Pacific plate, as a result there are many volcanoes and earthquakes in Indonesia. Indonesia has 129 active volcanoes, or about 15% of volcanoes in the world, one of the island where there are many volcanoes and earthquakes is Java island, it is formed by subduction between the indo-Australia that subducting under the Eurasia, so the research on seismicity of the volcano tectonic earthquakes in Java is needed. One of the method to obtain the seismicity is seismological analysis to determine the location of the hypocenter. But actually the location of hypocenter is often shifted from the actual position because of the velocity model used is less precise. This problem can be solved by relocating the hypocenter using velocity model that accordance with the state of the field, so the hypocenter could represent actual geological conditions. Hypocenter relocation methods are vary with the advantages and disadvantages of each, in this research used two method that are Grid Search and Grid Guided search. In this research conducted relocation hypocenter of the earthquake on the island of Java, the data recorded from 1952 to 2012 with 9162 P wave and 2426 events recorded by 30 stations. To determine the velocity of dispersion, tomography pseudo bending is carried out centered on the midpoint of the island of Java, Mt Slamet.
2. Data and Methodology

2.1 Data
Earthquake data recorded since 1952 until 2012 with a 9162 P waves, 2683 S waves, 2426 events were recorded by 30 stations. Tomography process only used the P wave phase.

2.2 Relocation Methods
Grid search relocation method is done by calculating the wave propagation time between the station and the "new hypocenter location" calculated by adding or subtracting a certain distance from the hypocenter positions early and use the 1D velocity table (in this study used AK 135 velocity table). This method can reduce the duration of computational calculations [1]. If the new hypocenter location has wave propagation time between it and the stations are closer or smaller than the wave propagation time of initial hypocenter location, it is considered as the solution.

Guided grid search method is used to relocate the hypocenter because global search technique can describe objective surface function more thorough by improving efficiency with giving higher probability value on the model that close to the solution than the model that far from the solution (Grandis, 2009 op cit [2]).

Travel time tomography is one way to describe velocity in subsurface. The procedure can describe in three stages: 1. Parameterization of the velocity in the subsurface; 2. Forward modeling by ray tracing from the hypocenter location to the station; 3. Optimization of the parameters obtained in the first stage (Figure 2) [3].

This study uses USGS earthquake data since 1952 to 2012 around Central Java, with 2783 numbers of S wave arrival time data. The data subsequently relocated using the Grid Search to get a better velocity model to get the description of S wave velocity model and it’s characteristic in subsurface by tomography technique.

With a simply velocity model that be used, the focus point location can be randomly spread over the subsurface area. The differences between modeled travel times and the travel times of the initial hypocenter is the input for the optimization. If the differences is equal to zero, theoretically an accurate velocity model is obtained [3].

Travel time from hypocenter to the station calculated with the equation (1):
where $V$ is the velocity in the model parameterization and $ds$ is the ray segment length. The inversion purpose is to minimize between modeled travel time and real travel time with ray tracing pseudo bending by Um & Thurber (1987) of cit [4].

\[
T = \int_{\text{ray path}} \frac{1}{V} ds \tag{1}
\]

Seismic wave propagation length can be calculated by equation (2)

\[
P_i = \sum_{j=1}^{N} M_j S_j \tag{2}
\]

with $P_i$ is seismic wave travel time matrix, $M_j$ is seismic wave propagation length in each cell matrix , and $S_j$ is slowness in each cell matrix. The cell that not passed by seismic wave will has zero seismic wave propagation length’s value.

The example of the ray tracing in 3D can be seen in Figure 3:

Figure 2. Inversion of focusing operators by means of travel time tomography [3]

Figure 3. Tracks wave rays. Vector $T$ is the tangential unit vector, the vector $N$ is a normal vector [5]
Normal vector in the direction of the wave always leads to the center of curvature. Both vectors, vector T and N can be expressed in the following equation [5]:

\[
\frac{dr}{|dr|} = \frac{dr}{ds} = T \quad (3)
\]

\[
\frac{d^2r}{ds^2} = N \quad (4)
\]

3. Results and Discussion

The Result of this research can be seen in figures 4.

![Figure 4. Location Map slicing](image)

To perform a more detailed observations of the study area is observed vertically by making two slicing map in the Slamet mountain. The incision in the form of A - A 'with X = 106.503707 and Y = -6.751412 until X = 111.697802 and Y = -7.650037. These slicing represent the research area and its surroundings. The incision A-A 'cut subduction zones and parallel to the line of volcanoes in Java,

A. The Local (Central Java Area Mt. Slamet)

![Figure 5. Profile slicing A-A' Locally (Mt. Slamet)](image)

Tomographic inversion results using pseudo bending in slice A-A' describes the state of the subsurface based on the velocity of the P wave,figure 5 shown anomaly with a low velocity at the bottom of each subsurface mount on the relocation of the grid search method. This is caused by found fluid under every mountain pass slice A-A'. However, the value of the P wave velocity in the eastern part of the
Java island was a little high as a state under the surface of the Dieng plateau, Sumbing, Sindoro, Merapi, Merbabu, and Lawu mountain with a standard deviation values ranging from -1% to -8% compared to western part of the island of Java as Slamet and Cereme mountain with a standard deviation values ranging from -8% to -10 km / s. But there are a differences in guided grid search method, in this method, there is a high velocity anomaly with values standard deviation ranged from 7% to 10% in subsurface Cereme mountain and Dieng plateau, it shows that the area is composed by rocks more compact.

Merapi, Merbabu, and Lawu mountain with a standard deviation values ranging from -1% to -8% compared to western part of the island of Java as Mount Slamet and mountain Cereme with a standard deviation values ranged from -8% to -10 km / s. But there is a difference in guided grid search method, in this method, there is a high velocity anomaly with values standard deviation ranged from 7% to 10% below the mountain surface cereme and plato Dieng, it shows that the area is composed by rocks more compact.

B. Globally (the entire java island)

When viewed globally at the cross slice A-A’ grid search method are be found high velocity values at depths of 0-20 km with a standard deviation of 8%-10% rate, while more than 20 km there is a low velocity with value of standard deviation -8% to -10%, the region has a low velocity because it is an area of subduction of the Indo-Australian plate with the Eurasian, so the rocks making up the area in the form of molten rock that melted into magma due to strong impact.

But if we look at the cross slice A-A’ guided grid search method there are similarities with the method of grid search pattern, but in this method, the results have a more varied velocity. In the method of guided grid search Low-velocity are values with a pattern of spots on the grid search method, while high-velocity search entirely.

4. Conclusion

The conclusion of this research is result from the comparison of the two methods relocation grid search with the guided search grid as follows:

1. Locally cross-section grid search has a dominant low velocity (-8% to -10%), while the guided grid search method has a low velocity anomaly (-8% to -10%) and high (7% to 10%), geological research area is a cluster of volcanoes, so that the resulting velocity should predominantly low velocity in accordance with the grid search method. This indicated that the relocation of the grid search method is better used in areas that have a narrow area (local).

2. Global cross-section grid search method does not have good velocity variation, while at the cross-guided method variasi grid search has good velocity result, there is a low velocity anomaly (-8% to -10%) in areas which are volcanic while the grid method search does not show any anomalies. This proves that the guided search grid method is better used for a broad area of research area.
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