Preliminary Results of Double Difference Tomography at Sunda-Banda Arc

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Abstract. The Sunda-Arc transition to the Banda Arc is located on the south of the Flores Island, Indonesia, where the Australian lithosphere is moving to the north direction. On-going subduction process dictates the tectonic setting though some studies also suggest a collision and obduction may occur in the past due to of plate buoyancy. This area has active seismicity with frequent large magnitude events. To better understand the tectonic system in this region, we performed double-difference tomography inversion using regional events. We obtained the data catalog from the Indonesian Agency of Meteorology, Climatology, and Geophysics ranging from 116° to 125° east longitude and -6.5° to 12.5° latitude. We collected 4312 events data, detected from 15 stations from January 2015 to December 2019. Final relocated hypocenters showed a reduced fixed-depth problem and a more clustered event, although some deep events disappear. Most events are related to the subducting Benioff zone with some clustered events in the northern area may be related to back-arc thrust. We also observed clustered events near active volcano region and reduced shallow seismicity region to the west of the Timor Island. Resolution test using the checkerboard and Derivative weigh Sum (DWS) shows that fair P wave resolution can be achieved until 300 km, although a smearing start to show at a deeper depth. However, due to lack of arrival S wave data, the resolution test suggest good resolution can only be seen until a depth of 100 km. Tomogram P and S wave models show a clear dipping subducting slab from south to North down to a 250 km. We also spot a fast velocity band near the Timor Island area that similar to the previous tomography study, interpreted as sliver forearm. We spotted a band of lower Vp, lower Vs and higher Vp/Vs at shallow depth close to the volcanic line and we interpreted this as a zone of higher temperature, that may relate to magmatic activity in this region. We also noticed a zone of low velocity and higher Vp/Vs that may relate with dehydration and partial melting. However, we feel this still uncertain due to low Vs resolution.
1. Introduction

Our study area is located at the Eastern part of Indonesia where the Indo-Australian plate is subducting underneath the Eurasian plate. We focused our study at south of the Flores Island where the Australian continental crust moves near the trough and a transition zone from the Sunda Arc to the Banda Arc. The transition area of the Sunda-Banda arc is characterized by changes in tectonic order from the subduction of the Indo-Australian oceanic plate along the Sunda Arc to the collision of the continental arc along the Banda Arc (Shulgin et al., 2009). The change has brought implications for the complexity of the geological and geodynamic arrangements in this transition area. This area shows a high magnitude events such as one that occurred in the south of Sumba Island known as the 1977 Sumba earthquake zone. Earthquakes with a magnitude above 6 with a thrust mechanism also occurred in the north of this region. These events were related to Flores and Wetar back-arc thrust. Both thrusts occurred due to the accommodation of forces from the subduction in the south of the Nusa Tenggara archipelago (Supendi et al, 2020). Supendi et al (2020) used local tomography method and found a positive anomaly model between slow velocity at a depth on 70 km that has 10-20 km thickness and interpreted as forearm sliver. This study tried to use regional events recorded on a permanent station near the area and simultaneous inversion to invert velocity perturbation. We are targeting a better imaging of subsurface structure in the region and seismicity pattern.

2. Data and Method

This study used the BMKG earthquake catalog limited from 116° to 125° east longitude and -6.5° to 12.5° latitude. We used the arrival time phase of P and S waves from 15 stations, with a data period of January 2015 to December 2019. In total, we obtained 3140 event data with most events occur in the western part of Sumba Island, south of Sumba Island, the eastern part of Alor, and the southern part of the eastern island (Figure 1). We observed that most events are shallower than 60 km and presumed these events are related with subduction process in this region. We also noticed a lower scattered number of events in the Savu Sea. We employed the double difference tomography method (Zhang et al, 2003) to determine the velocity structure and to relocate the hypocenter to the study area.

![Figure 1](image-url). Map of the study area. Red to blue circles represent the initial hypocenter between January 2015 and December 2019. Magenta triangle are volcanoes and blue inverted triangles show the stations. Vertical lines are cross section line used in figure 3 and 4.
The initial and reference velocity model in this study is the 1-D velocity model AK135 (Kennett et al., 1995). For the parameterization, we considered several factors such as station location and event distribution. One challenging problem in our study is low numbers of receiver stations compared to the numbers of source events. Figure 2 shows the grid parameterization in this study. We set the inner grid to have 40 km space in all direction and larger distance (200 km) on the outer grid to include all data in our study.

The optimum damping value can be determined empirically by carrying out a series of inversion process that will generate different variance model value and variance data. The optimum damping value is associated with a reduction in data variance and at the same time does not significantly increase the variance of the model (Eberhart P, 1986). The determination of this attenuation value is obtained by plotting the trade off curve between the data variant and the model variant. We set the appropriate damping factor to be 230 for the Vp dan Vs inversion.

3. Results, Discussions and Conclusions

To investigate the recovered anomalies, we carried out the checkerboard recovery tests. We added 10% velocity anomaly relative to the 1-D reference velocity. Next, we used the same configuration of sources and receiver as our observation data and invert to see how well the checker-board model recovered. The results of checkerboard tests for horizontal slices and cross sections are presented in Figures 3. In general, all Vp anomalies are reproduced well both in horizontal and vertical directions. However, resolution in Vs anomalies is questionable due to less S wave arrivals. Depth resolution for Vp is quite reliable, down to a depth of 150 km.

Figures 4 shows inverted model both for Vp, Vs and Vp/Vs ratio in horizontal slices. Note that the Vp/Vs model are not joint inverted in this study, instead we calculated by dividing the number of Vp and Vs on the same grid. At a depth of 30 km, we noticed a low velocity area for both Vp and Vs at West Nusa Tenggara, Eastern part of East Nusa Tenggara, and the Timor Island. Interestingly, the location of low velocity is close to the Volcanic Line that extend horizontally from Bali between 8° to 9° south latitude, though not any volcano seen on the Timor Island. The low velocity at West Nusa Tenggara and East Nusa Tenggara seems to extend to a depth of 50 km and not any low velocity on the Timor Island at greater depth. We interpreted the low velocity below West and East Nusa Tenggara may be related with partial melting zone that feed current active volcano. We further observed the horizontal slices and found that below a depth of 70 km, most inverted velocities are dominated by higher velocity.
Figure 5 shows inverted velocity model cross section from West to East. We observed a band of dipping down high velocity (blue color) from south to north direction. The location of dipping high velocity is coincidence with the dipping down hypocenter trend from south to north. We interpreted this band of high velocity as the Indo-Australian plate that is subduction Eurasian plate, though the Eastern part of this study at Timor Island is known as the Sunda-Banda Arc transition, represents the subduction from Australian lithosphere that move to the North. The cross section in the East (cross section M in Figure 5) show two interesting features. The first is the band of horizontal low velocity that extends horizontally at a depth of 30-40 km. We are still not sure about this and will investigate further. The second is a zone of low velocity between fast velocity. This feature, although not so identical, resemble structures known as fore arc sliver as previously suggest by Supendi et al, (2020).

![Figure 3. The checkerboard inversion model. Blue color is positive anomaly and red color is negative velocity anomaly. Line for cross section is shown on Figure 1.](image-url)
Figure 4. Inverted Vp, Vs and Vp/Vs ratio horizontal slices. Note the color blue is positive anomaly in Vp, Vs and high Vp/Vs; Red Color is the opposite.

Figure 5. Vertical slices on Tomography model for Vp, Vs and Vp/Vs ratio. The map view for cross-section is located on Figure 1 as red vertical line. Note that the left direction represents North direction.
As for the conclusion, Our preliminary results showed promising subsurface structures beneath Sunda-Banda arc through delay time tomography model, especially in Vp model. However, due to lack of S wave arrival time, the quality of Vs and Vp/Vs ratio need to be improved by adding more stations and possibly longer duration data set. A combination of data that has more stations such as the one from Supendi et al, (2020) would give better image in the eastern part of the model. We would like to thank the the Indonesian Agency of Meteorology, Climatology, and Geophysics for providing data and discussion.

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