Double difference relocation of earthquakes in Sunda-Banda transition zone, Indonesia

To cite this article: F R T Saputra et al 2019 J. Phys.: Conf. Ser. 1191 012012

View the article online for updates and enhancements.
Double difference relocation of earthquakes in Sunda-Banda transition zone, Indonesia

F R T Saputra¹,*, S Syuhada², T Anggono²

¹Center for Deep-Sea Research, Indonesian Institute of Science, Jl. Syaranamual Guru-Guru Poka Ambon 97233
²Research Center for Physics, Indonesian Institute of Science, Kawasan Puspiptek, Serpong, Tangerang Selatan 15314

*Email: fril001@lipi.go.id

Abstract. Accurate earthquake hypocenter location is very important for seismicity analysis. In this study we used 593 earthquakes information from International Seismological Center (ISC) catalogue from January 2009 to December 2016 for hypocenter relocation in Sunda-Banda transition zone. We applied double difference method and one dimensional AK135 for the velocity model. The result shows that position and orientation of earthquakes are changed significantly. Distribution of earthquakes are narrower in the subducting slab, which is associated to the geological setting in this region. A prominent feature found in this study is a lack of seismicity between 240 and 400 km depth that could be related to stress transition from extensional to compressional regime. Another feature is aseismic zone within 100 -120 km depth around 120°E in the subducting slab which suggest a presence of a slab window.

1. Introduction

Seismicity in the Sunda-Banda arc has attracted interest for seismologists since the early 1970s [1-3]. The boundary of the transition zone is marked by the presence of Sumba Island. Sumba Island is located to the south of the continuous volcanic arc of the Sunda-Banda system[4] and lies obliquely between two fore-arc basins, which are Lombok Basin to the west and triangular Savu Basin to the east [5,6]. Sumba Island does not fit in the Sunda-Banda Arc System and forms a strange continental fragment. Several studies suggested that Sumba may come from Australia [7-9], Asia [10-13], and it could be also formed as a part of an island arc built on ocean floor [14].

Seismicity surrounding Sumba islands from International Seismological Center (ISC) catalogue for time period of January 2009 to December 2016 is shown in Figure 1. Sunda zone, extending from Bali to western Sumba, features a wide zone of shallow earthquakes. Majority of shallow earthquakes in west Sumba are located in outer rise, on the subduction interface underneath the forearc, and on the back arc region. Most intermediate and deep earthquakes are located in the island arc north Sumba Island. Magnitude and frequency of earthquakes in the Sunda outer rise region increase eastward toward Sumba Island and terminates when entering the transition zone at ~119.5°E. West of Sumba Island is seismically active, meanwhile East of Sumba Island has experienced very little earthquake activity.

Location and earthquake source mechanism may provide one of the most direct insights into the distribution of deformation. If earthquake mechanisms are understood, deformation and associated
state of stress in the subduction environment can be characterized. This is of particular importance at sublithospheric depths where GPS measurements are not applicable. While it is important to recognize that aseismic slip may account for a large percentage of the strain field in subduction or collision zones [15], the seismic record may provide a robust comparison of deformation style and intensity between adjacent regions.

In order to study seismicity characteristics in Sunda-Banda transition zone, we applied double difference technique to relocate the hypocenter in this region. We expect the result will give us a more precise hypocenter location and a better illustration of subduction process in Sunda-Banda transition zone.

2. Data Observation and Methods
Double-difference algorithm is an efficient method to precisely determine relative hypocenter locations. It minimizes residuals between observed and theoretical travel-time differences for earthquake pairs observed at a common station. When arrival time data from nearby stations are available, the algorithm gives accurate relative locations of earthquakes, which is quite different from other relative location methods such as modified joint hypocenter determination (MJHD) [6, 16-17]. Double difference uses an assumption if the distance between the two earthquake hypocenters is smaller than the distance between the earthquake pair and a station, both earthquakes will have similar ray paths. With this assumption, the difference in travel time between two earthquakes recorded at the same station can be considered as a function of the separation geometry between hypocenters. Hence, errors in the velocity model can be minimized without station corrections.

We used P- and S-wave arrival time data from the International Seismological Center (ISC) for the time period of January 2009 - December 2016. The number of initial earthquakes was 593 with magnitude higher than 3 and depth of less than 600 km. Arrival time data were from 25 seismic stations located in Bali Island through Timor Island (114° – 126° E) (figure 1). For hypoDD inversion procedure, we used one dimensional AK135 for the velocity model [5].

3. Results and discussion
We successfully relocated 585 events using DD method, 8 earthquakes were removed because of airquakes (hypocenter location above the surface) and or out of the input parameter limits. Statistically,
the root mean square residual (Rrms) of relocated earthquakes shows better values than the initial Rrms (figure 2).

After relocation, earthquake distribution was denser and narrower. The seismicity in this region is unique related to the transition from subducting in western Sumba to collision in eastern Sumba. Western Sumba is seismically active whereas eastern Sumba is lack of seismicity activities. High intensity of intermediate and deep earthquakes that may represent the subduction slabs is shown in figure 3. Dip of the subducting slab in Sunda Arc is observed to be increasing from west to east. Beneath Sumatra, the seismic zone dips about 30 to 45°, but there is no earthquakes deeper than 300 km, which has been attributed to the relatively young age of subduction lithosphere [18]. Whereas, beneath the Java arc, the seismic zone dips about 60° and there were earthquakes with focal depths up to 670 km [18, 19].

Seismologists refer to the direction of slip in an earthquake and the orientation of the fault on which it occurs as the focal mechanism. Focal mechanism solution from the Harvard Centroid-Moment-Tensor (CMT) catalogue in Sunda-Banda transition region suggests that intermediate depth earthquakes are dominated by reverse mechanisms, while deep earthquakes are exclusively normal mechanisms [20]. Focal mechanism solutions for shallow earthquake beneath Sumba and the back arc region are indicated as thrust faulting, strike slip beneath the arc and forearc, and normal faulting beneath Java trench [21-23].

![Figure 2. Histogram of Rrms before and after relocation.](image)

![Figure 3. Map of earthquake epicenters in Sunda-Banda transition zone (a) before relocation process and (b) after relocation process using double difference algorithm.](image)
Figure 4. Seven seismicity cross section lines in Sunda-Banda transition zone from longitude 118.5° to 121.5° with increment every 0.5°.

Figure 5. Distribution of seismicity cross section line A-A’, B-B’, and C-C’.

Lack of seismicity in the subduction slab between 240 and 400 km depth is a prominent feature observed along the study area and it is well known in many subduction zone worldwide [24, 25] (figures 5 and 6). Isacks and Molnar suggested that this is due to stress transition from extensional to compressional in the subducting slab [19]. Kirby et al. also noted the absence of earthquakes between
350 and 500 km depths from 107 to 115°E in the ISC hypocenters, further west of our study region [25]. There is also a seismicity gap in the 100 – 300 km depth range on the subduction slab from 120 to 121.5°E. McCaffrey et al. proposed that the seismic quiescence at intermediate depth at 123.5 – 124°E, beneath the Savu Sea, is due to detachment or slab tear of the lower part which therefore represents a slab window [26]. An implication of this model is that the deep parts of the slab are no longer connected to the surface, thus the response of each part to stress is independent. Apart from a mostly aseismic, the subducting slab is seismically active to depths over 600 km [20]. However we still need further investigation through focal mechanism to explain the lack of seismicity at this depth.

Figure 6. Distribution of seismicity cross section line D-D’, E-E’, and F-F’.
4. Conclusions
We used earthquakes information from ISC catalog to relocate hypocenter in the Sunda-Banda transition zone using double difference method. The relocated hypocenter distribution represented the subducting slab in this location. There was a lack of seismicity between 240 and 400 km depth which was suggested due to stress transition from extensional to compressional in the subducting slab and also a seismicity gap in the 100 – 300 km depth range on the subduction slab from 120 to 121.5°E which suggested due to detachment or slab tear of the lower part which therefore represents a slab window.

Acknowledgments
This study has been supported by INSINAS through grant No. 060/P/RPL-LIPI/INSINAS-1/III/2018.

References
[1] Thomas J F, Peter M 1970 J. Geophys. Res. 75 1431
[2] Thomas J F 1970 Bull. Seismol. Soc. Am. 60 565
[3] Thomas J F 1972 J. Geophys. Res. 77 4432
[4] Hans W 1994 J. of Southeast Asian Earth Science 9 51
[5] John A K 1975 Techtonophysics 26 165
[6] Warren H 1979 Geol. Survey Prof. Paper 1078. U.S. Government Printing Office, Washington D.C 345
[7] Audley-Charles M G 1975 Techtonophysics 26 213
[8] Rutherford E, Burke K and Lytwyn J 2001 J. Asian Earth Sci. 19 453
[9] Abdullah C I, Rampnoux J P, Bellon H, Maury R C and Soeria-Atmadja R 2000 J. Asian Earth Sci. 18 533
[10] Borch C C V D, Alex E G, Hardjoprawiro S, Hardi P, H. and Sapri H 1983 Sediment. Geol. 37 113
[11] Rangin C, Pubellier M, Az6ma J, and the Tethys Pacific Working Group 1990 Bull. Soc. gbol. France 8 VI 907
[12] Michael G A C 1985 Tectonophysics 119 435
[13] McCaffrey R 1988. J. Geophys. Res. 93 15163
[14] Hans J S and Shamita D 1999 J. Geophys. Res. 104 13101
[15] Christopher H S 2002 The Mechanics of Earthquakes and Faulting, Cambridge University Press. 471
[16] Hurukawa N and M Imoto 1992 Geophys. J. Int. 109 639
[17] Hurukawa N 1995 Geophys. Res. Lett. 22 3159
[18] Wortel M J R and Vlaar N J 1988 Pure Appl. Geophys 128 625
[19] Bryan I, Peter M 1971 Rev. Geophys. Space Phys. 9 103
[20] Kim S E, Mike S 2010 Tectonophysics 483 112
[21] Cardwell R K and Bryan L I 1978 J. Geophys. Res. 83 2825
[22] Fitch T J 1972 J. Geophys. Res. 77 4432
[23] McCaffrey R and John N 1984 J. Geophys. Res. 89 6171
[24] Stephen H K., Eric R E, and Roger D 1996 Geophys. Monogr. Ser. 96 195
[25] Stephen H K, Seth S, Emile A O, and David C R 1996 Rev. Geophys. 34 261
[26] McCaffrey R, Peter M, Steven W R, Yoko S J 1985 J. Geophys. Res. 90 4511