Citation: Silva, G., T. Hara (2021), Hypocenter determination of local earthquakes using data from local stations in and around Timor Leste, Synopsis of IISEE-GRIPS Master's Thesis.

HYPOCENTER DETERMINATION OF LOCAL EARTHQUAKES USING DATA FROM LOCAL STATIONS IN AND AROUND TIMOR LESTE

Geovanio Pedro da Silva Almeida[1,2] **Supervisor: Tatsuhiko HARA[3*]**

ABSTRACT

We conducted hypocenter determinations for 37 events that occurred in the period between March 2014 and March 2016 in Timor Leste and its surroundings. We used seismograms recorded at local temporal and permanent stations within the epicentral distance of 10 degrees. We picked P and S arrival times using the SEISAN software and determined the hypocenters. The errors in each direction of latitude, longitude, and depth are less than 20 km for most of the analyzed events. Due to the station distribution, the errors for latitudes are larger than those for longitudes. Most of the events occurred close to the plate boundary between the Australian continental and Banda plate. When we use data from only temporal stations deployed in Timor Leste, it is possible to locate all the events, and the errors of the events in the eastern part of the study region become larger due to the poor coverage. We compared the hypocenters of this study to those in the ISC bulletin. The average of distance is 25.4 km. Since the station distribution of the temporal network deployed in Timor Leste is similar to that of the planned new seismic network, these results are helpful to evaluate its capacity of earthquake monitoring and suggest that data from the new network will be useful to improve the accuracy of hypocenter determinations in and around Timor Leste.

Keywords: Hypocenter, Timor Leste, Local data.

1. INTRODUCTION

Timor island lies between the inner Banda arc and Australia Continental Plate in Southeast Asia. Timor Leste occupied the eastern part of the island. Timor island is part of the outer rim of the Banda arcs. Timor island uplifted during the intersection of the Banda Arc and the North Australian continent, and the collision time ranged from about ~8 to ~3 Ma (Audley-Charles, 2011; Keep and Haig, 2010). Consequently, this tectonic setting induces seismicity in Timor Region. There is no record of damaging earthquakes along the Timor trough. However, Coudurier-Curveur et al. (2021) suggested a possibility of large earthquakes along the Timor Trough based on their analyses of multibeam bathymetry and 2D seismic reflection data. Therefore, the improvement of earthquake observation capacity is important for Timor Leste. In this study, we determined the hypocenters of local events in the period between March 2014 and March 2016 in and around Timor Leste using data from local temporal and permanent stations to examine the earthquake monitoring capacity of the planned new network, since the configuration of the temporal stations is similar to the planned new network. We also determined the hypocenters using

[1] Institute of Petroleum and Geology (IPG) Under the Ministry of Petroleum and Mineral, Dili, Timor Leste.
[2] IISEE-GRIPS Master's course student.
[3] International Institute of Seismology and Earthquake Engineering, Building Research Institute.

data only from the temporal stations to evaluate their capacity for earthquake monitoring. We compared the hypocenters of this study to those in the ISC bulletin to see whether they are consistent or not.

2. METHODOLOGY

2.1 SEISAN

We used the SEISAN software (Havskov and Ottemöller, 1999; Havskov et al., 2020) to pick P- and S-waves arrival times. This software is a program for analyzing earthquake data at seismic observatories that is both interactive and efficient, and it consists of algorithms and a primary database for evaluating earthquakes based on analog and digital seismic data.

2.2 HYPOCENTER

HYPOCENTER is computer software that calculates earthquake hypocenters of local, regional, and global earthquakes (Lienert and Havskov, 1995). It is used as a default program for hypocenter determination in the SEISAN. Input data such as station locations and arrival times should be prepared before analyses. We used SEISAN to prepare P-wave and S-wave arrival time data and then ran the HYPOCENTER program to compute hypocenters

3. DATA

3.1. Data Retrieval

In this study, we analyzed data for 37 earthquakes between March 2014 and March 2016 in the Timor island area. We used Wilber 3 on the IRIS website to retrieve waveform data from local stations within the epicentral distance up to 10 degrees. We acquired the event information from the International Seismological Centre (2021) catalog.

3.2. Seismic Velocity Structure Model

In determining a hypocenter of an earthquake using the HYPOCENTER program, velocity model parameters can be put in the input file for local earthquake analyses. We used model iasp91 (Kennett and Engdahl, 1991), and applied the earth flattening transformation (Müller, 1985) to it to use for the program HYPOCENTER.

3.3. Data Processing

We picked P- and S- arrival times from waveform data using SEISAN software manually. We determined a preliminary hypocenter using the HYPOCENTER program implemented in the SEISAN package program. We checked the obtained results and examined the residuals (differences between the arrival times and those theoretically calculated), the errors, etc., which are given in the file "print.out" made by HYPOCENTER.

4. RESULTS AND DISCUSSION

4.1. Determination of hypocenter by using local waveforms

First, we show the results of hypocenter determinations using the seismic data from all local stations (within the epicentral distance of 10 degrees). Figure 1 shows the hypocenters of 37 events, and Figure 2 shows the frequency distributions of the errors of the hypocenters. The latitude errors are larger than those for longitudes. The errors for longitude are less than 10 km for 32 events, while those for latitudes are less than 10 km for 20 events. Most of the errors are less than 20 km, 34 events for longitude, latitude, and depth, respectively.

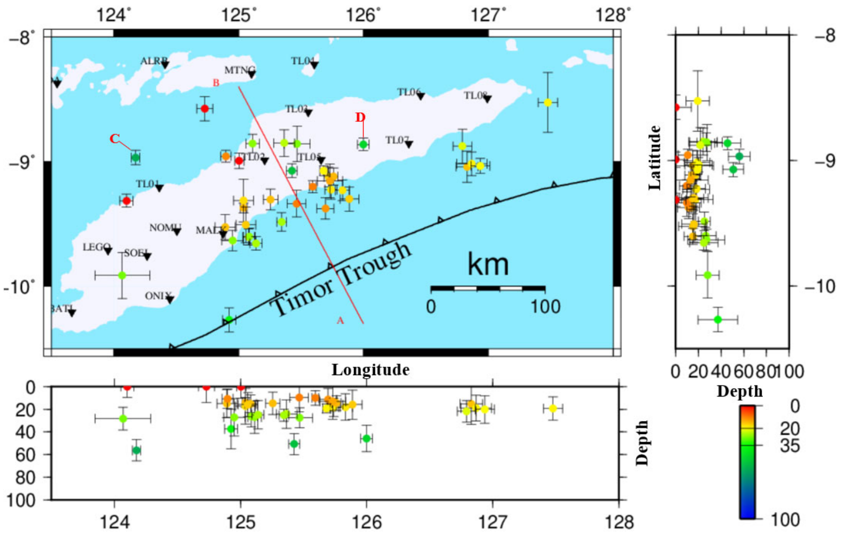

Figure 1. Hypocenters distribution in and around Timor Leste in the period March 2014 – March 2016. The cross-section along A-B is shown in Figure 3. The events denoted by C and D are discussed in the text.

Figure 3 shows the cross-section along the profile A-B shown in Figure 1. Among 37 events, 20 events are plotted with the slab geometry of model Slab 2.0 (Hayes et al., 2018). Taking into account the errors, most of the events occurred near the plate interface, while there are some shallow events in the Timor plate and two intra-slab events. The focal depth of event C in the western part of the study area is 56.2 km (±9.5 km), and the slab depth is 52 km. The focal depth of event D is 45.8 km (±11.5 km), and a slab depth of 17.5 km. Event C is likely to be an interplate earthquake, while event D is likely to be an intraslab earthquake.

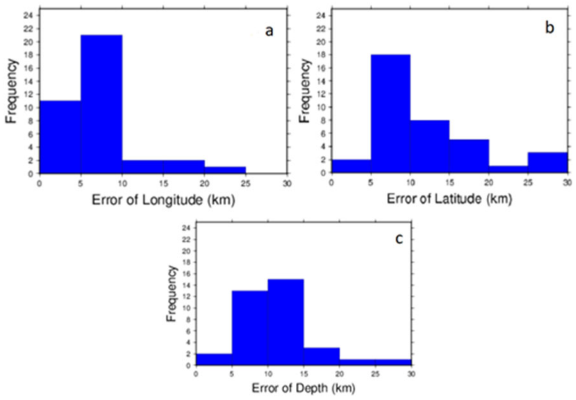

Figure 2. Frequency distributions of the errors of the hypocenters determined using all the waveforms data

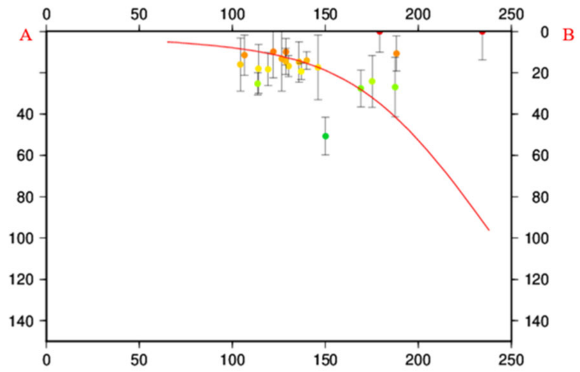

Figure 3. The cross-section along the profile A-B in Figure 1. The red curve denotes the slab geometry from model Slab 2.0 (Hayes et al., 2018).

4.2. Determination of hypocenters by using temporal network

We used data from a temporal network consisting of eight stations deployed in Timor Leste. Among 37 events, arrival time data from the other stations were not available for eight events, and then data used in this section are the same as those in section 4.1 for these eight events. This means that the data from the temporal stations are essential to locate them in this study. Even though all 37 events can be located using only data from the temporal stations. Figure 4 shows the hypocenters obtained using temporal stations. Comparing Figures 1 and 4, we can find that the errors of the events in the western region become larger.

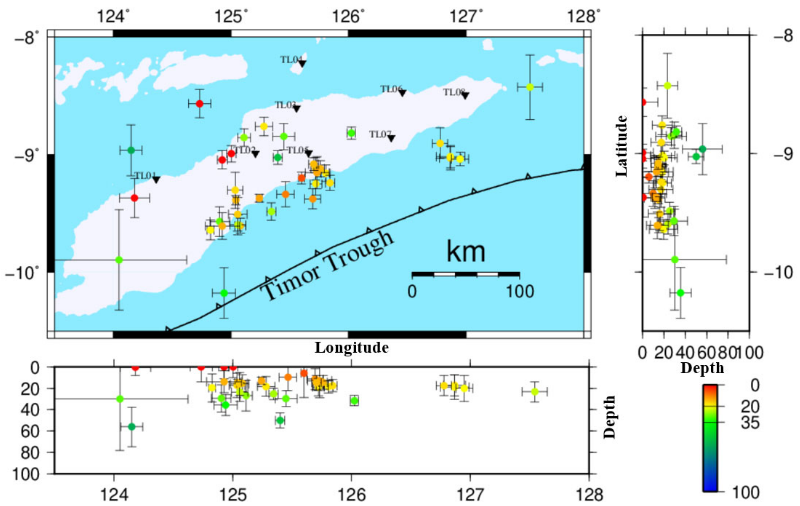

Figure 4. Hypocenter locations determined by using eight temporal stations

Figure 5 shows the frequency distributions of the errors of the hypocenters. Compared to those shown in Figure 2, the ranges with the largest frequencies are the same for longitude and latitude (the range from 5 to 10 km). The ranges with large frequencies for depth are those from 5 to 15 km both in Figures 2 and 5. These suggest that the errors do not change much for many events. The averages of the errors for longitude, latitude, and depth are 7.4, 10.6, and 10.6 km for longitude, latitude, and depth, respectively using all the local data. They are 8.4, 12.0, and 10,8 km respectively using data from eight temporal seismic stations. As for the longitude and latitude the latter is larger slightly. The errors for depth are comparable.

In Figure 6, the hypocenters for each pair of the events in Figures 1 and 4 are connected, and Figure 7 shows the histogram of the distances between the hypocenters for each event. As was stated above, among 37 events, data for 8 events are the same. That is why they are not included in this histogram. Except for one event, the differences are less than 20 km. The average of the distances is 7.2 km.

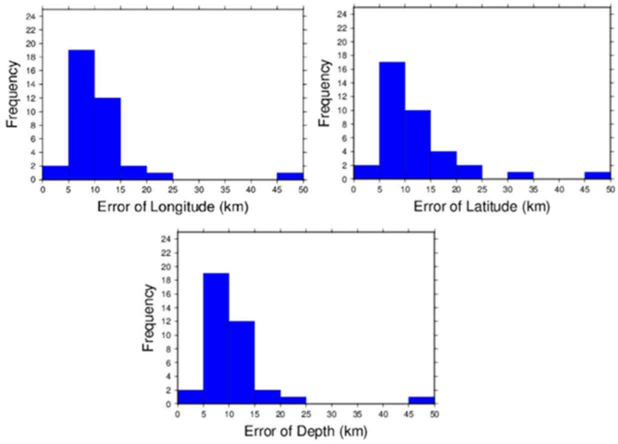

Figure 5. Frequency distributions of the errors of longitudes, latitudes, and depths of the hypocenter determined using temporal seismic stations are shown in (a), (b) and (c), respectively

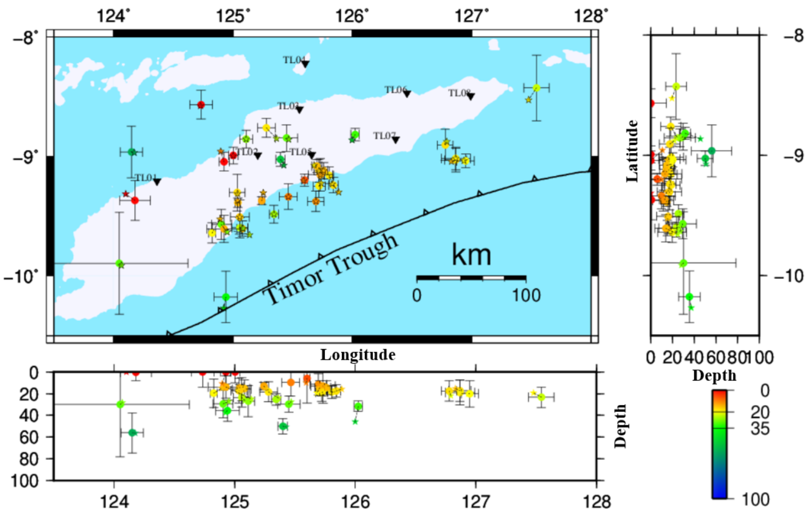

Figure 6. Hypocenter comparison between data from the local network and eight temporal seismic stations.

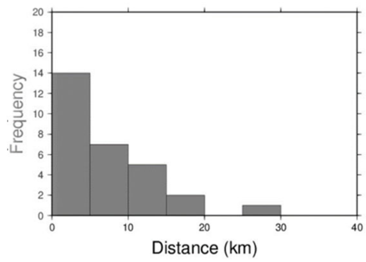

Figure 7. The histogram of hypocenter distances between local data and temporal seismic stations

4.3. Hypocenter comparison between the results determined by using local seismic data and ISC information

We compared the hypocenters obtained in 4.1 to those from the ISC bulletin (ISC, 2021). We selected 12 events from which the ISC determined their hypocenters whose semi-major errors are less than 10 km. Figure 8 shows the graphical comparison, and Figure 9 shows the histogram of the distances between the corresponding hypocenters.

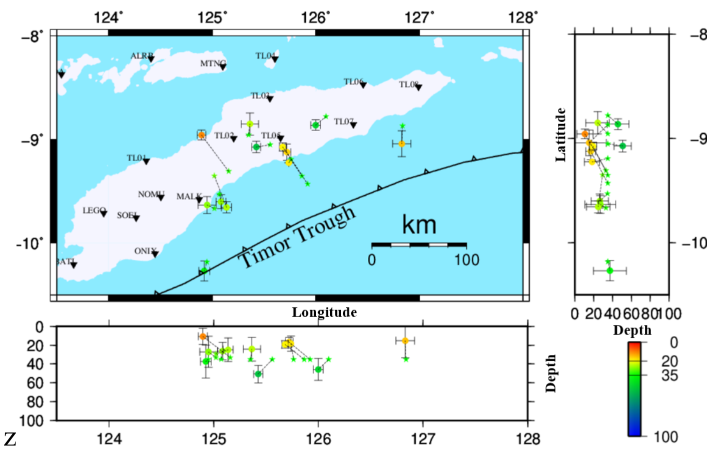

Figure 8. Hypocenter comparison using data from the local network and ISC information

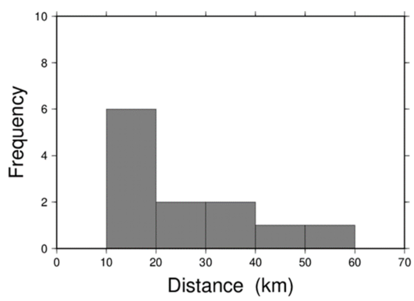

Figure 9. The histogram of the distances between the hypocenters of this study and those from ISC

The frequency is the largest in the range from 10 to 20 km, and six events (50 per cent) are in this range. The average distance is 25.4 km. Among the 12 events, the focal depths of the two events are determined, while they are fixed for others in the ISC bulletin. We determined the focal depth for all the 37 events using data from local stations. This suggests the possibility to improve the accuracy of hypocenters in the study region by using local data.

5. CONCLUSIONS

We determined hypocenters of the earthquakes in and around Timor Leste that occurred in the period between March 2014 and March 2016. A total of 37 earthquakes were located. We picked the arrival time of the P and S waves using waveform data recorded at the local stations (within the epicentral distance of 10 degrees) using the SEISAN software. Then we used the HYPOCENTER to carry out hypocenter determinations.

First, we used data from all the local stations. For most events, the errors for each special coordinate are less than 20 km. We compared the locations of the events to the slab geometry of the Slab 2.0 model. Taking the errors into account, many events occurred near the plate boundary. Some events were shallow crustal events and the intraplate earthquakes. Then, we conducted hypocenters determination using data from only temporal stations deployed in Timor Leste. The errors of the event in the western part of the study area become larger due to poorer station coverage. We compared the hypocenters from the two datasets. The larges distance between the corresponding hypocenters is 26.1 km among 37 events. The average of the differences is 7.2 km. We compared the hypocenters obtained in this study to those in the ISC bulletin. The average distance is 25.4 km. We analyzed 37 events using data from local stations, and showed that the focal depths were determined for all the 37 events. Among the 12 events selected in comparison to the information given by the ISC bulletin, there were two events whose focal depths were determined. Therefore, the local stations are useful for determining the hypocenters of a local earthquake in seismic monitoring activity in the study area.

ACKNOWLEDGEMENTS

This research was conducted as the individual study of the training course “Seismology, Earthquake Engineering and Tsunami Disaster Mitigation” by IISEE/BRI, JICA, and GRIPS. I would like to express my sincere gratitude to my supervisor Dr. Tatsuhiko Hara for his valuable support and experience, which helped me to complete my research successfully. I would also like to thank Dr. Takumi Hayashida and Dr. Toshiaki Yokoi for their valuable comments and suggestions to improve this research. We used the Generic Mapping Tools (Wessel and Smith, 1998) to draw the figures.

REFERENCES

Audley-Charles, M.G., 2011, Geological Society Special Publication, 355, 241-266.
Coudurier-Curveur, A., Singh, S., and Deighton, I., 2021, Frontier in Earth Science, 9, doi:3389/feart.2021.640928.
Havskov, J., and Ottemoller, L., 1999, Seis. Res. Lett., 70, 532-534.
Havskov, J., Voss, P.H., and Ottemöller, L., 2020, Seis. Res. Lett., 91, 1846-1852.
Hayes, G.P., Moore, G. L., Portner, D. E., Hearne, M., Flamme, H., Furtney, M., and Smoczyk, G. M. 2018, Science, 362, 58-61
International Seismological Centre, 2021, https://doi.org/10.31905/D808B830.
Keep, M., and Haig, D.W,. 2010, Tectonophysics, 483, 93–111.
Kennett, B.L.N., and Engdahl, E.R., 1991, Geophys. J. Int., 105, 429-465.
Lienert, B.R., and Havskov, J., 1995, Seis. Res. Lett., 66, 26-36.
Müller, G., 1985, The reflectivity method: A tutorial, J. Geophys., 58, 153-174.
Wessel, P., and Smith, W.H.F., 1998, Eos, Trans. Am. geophys. Un., 79, 579.