Citation: Rahman, Md., M., T. Hara (2019), Determination of Hypocenters of Earthquakes in and around Bangladesh, Synopsis of IISEE-GRIPS master report.

DETERMINATION OF HYPOCENTERS OF EARTHQUAKES IN AND AROUND BANGLADESH

Md. Mominur RAHMAN[1,2] **Supervisor:** **Tatsuhiko HARA**[3]

ABSTRACT

We analyzed 56 earthquakes that occurred in and around Bangladesh between June 2016 and February 2019. We picked arrival times from waveform data of the local network of Bangladesh Meteorological Department. Then we determined hypocenters of those events. We investigated the detectability of the local network. Some events that occurred in Bangladesh especially in the western part that are not registered in the ISC bulletin were detected by the local network. On the other hand, the local network did not detect some events which occurred in Bangladesh that were registered in the ISC bulletin. Then we compared the hypocenters determined by the local network data to those retrieved from the ISC bulletin and the USGS catalog. The differences between hypocenters are less than about 50 km in the epicentral distance from the centroid of the local network up to 300 km. The differences are larger at the greater epicentral distance for some events. We found the tendency that intermediate depths events were located as shallow earthquakes. We combined the arrival times from the local network and the arrival times recorded in the epicentral distance up to 10 degrees from the ISC bulletin and the USGS catalog. Then we determined the hypocenters using the combined data and compared the hypocenters with those retrieved from the ISC bulletin and the USGS catalog. The large differences between hypocenters found for the analysis using only local data are reduced.

Keywords: Hypocenter determination, Detectability, Comparison of hypocenters, Combination of arrival time data.

1. INTRODUCTION

Bangladesh is an earthquake-prone country, and it is very vulnerable to earthquake (e.g., Zaman and Monira, 2017). Bangladesh lies at the junction of three tectonic plates, the Eurasian plate, Indian plate, and Burma plate (e.g., Munima, et al., 2018). Bangladesh Meteorological Department (BMD) is the only organization in Bangladesh which is responsible for issuing the earthquake information and warning. In this study, we determined the hypocenters of earthquakes in and around Bangladesh using arrival times from the local seismic network of BMD. We investigated the detectability of the local network through comparison of the hypocenters determined by the local network and those from the ISC bulletin. Then we compared the hypocenters to those from the ISC bulletin and USGS catalog to examine the accuracy of hypocenters. We also determined hypocenters using the local and regional data to investigate whether it is possible to improve hypocenter determination. The systematic investigation on the detectability of earthquakes and accuracy of hypocenter determination in this study is the first attempt for analyses using the local network data of BMD.

[1] Bangladesh Meteorological Department, Dhaka, Bangladesh.
[2] IISEE-GRIPS master course student
[3] International Institute of Seismology and Earthquake Engineering, Building Research Institute.

2. DATA

2.1. Data from the local network of BMD

We analyzed 56 earthquakes that occurred in and around Bangladesh from June 2016 to February 2019. Waveform data from the 10 broadband seismic stations of BMD were used to determine hypocenters of these events. The magnitude range of these 56 earthquakes is from 2.5 M_L to 6.9 M_L determined by BMD.

2.2. Data from ISC bulletin

We used earthquake information from the ISC bulletin (http://www.isc.ac.uk/iscbulletin/search/bulletin/) in the period from June 2016 to February 2019 to investigate the detectability of the local network. We also used data from the ISC bulletin in the period from June 2016 to December 2016 for hypocenter comparison and determination. We retrieved origin times, hypocenters, P and S wave arrival times and magnitudes from the ISC bulletin.

2.3. Data from USGS catalog

We retrieved origin times, hypocenters, P and S wave arrival times and magnitudes from the USGS catalog (https://earthquake.usgs.gov/earthquakes/search) in the period from January 2017 and February 2019 for hypocenter comparison and determination.

3. METHODOLOGY

3.1. Program HYPOCENTER

We used the program HYPOCENTER, which was developed by Lienert and Havskov (1995). This program can determine both local and distant events. It was written in FORTRAN77. The program HYPOCENTER first collects a set of parameters which control hypocenter determination procedure and stations information. Next, it conducts a travel time consistency test and starts to locate events by iteration processes. It calculates travel time and their derivatives, conducts residual weighting and calculates hypocenter corrections to be applied. The iteration is repeated until the solution is converged.

3.2. Hypocenter determination using waveform data from the local network

First, we converted local waveform data to SAC format data by using CSDP-IAS software. Then we used Seismic Analysis Code (SAC, Goldstein and Snoke 2005) to pick P and S arrivals. The picked arrival times are used for preparing the input file for the program HYPOCENTER. After preparing all the necessary data files, we run the program
HYPOCENTER to determine hypocenters. We used iasp91 (Kennett and Engdahl, 1991) as a velocity model for hypocenter determination. We obtained all the location information with hypocentral errors.

4. RESULTS AND DISCUSSION

4.1. Hypocenter determination using local waveform data

We determined hypocenters of 56 earthquakes that occurred in and around Bangladesh in the period from June 2016 to February 2019 by HYPOCENTER using arrival time data from the local network.

Figure 1 shows the hypocenters of these events. Based on the distribution shown in Figure 1, we set the region defined by the latitude range from 19° N to 28° N and the longitude range 87° E to 95° E to examine the detectability of the local network, which is shown by the rectangle in Figure 1. There are 51 events in this region among the 56 events that we analyzed.

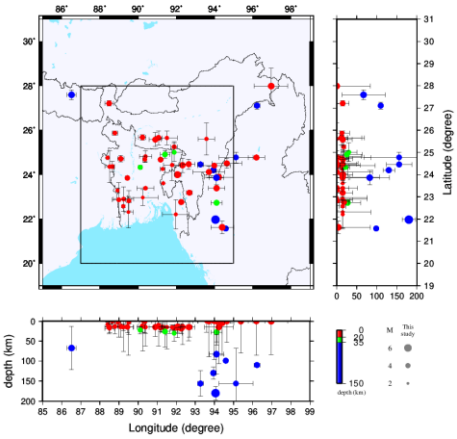

Figure1. Hypocenters of 56 events determined by HYPOCENTER (Lienert and Havskov, 1995) using data from the local network of BMD.

4.2. Detectability of local network of BMD

In order to investigate the detectability of the local network, we compared the hypocenters determined by the local network to those of the events registered in the ISC bulletin. 510 events are registered in the area shown by the rectangle of Figure 1 in the period from June 2016 to February 2019 in the ISC bulletin. Among the 510 events, 28 events were detected by the local network of BMD (Figure 2) and 482 events were not detected by the local network of BMD (Figure 3).

The agencies that reported the locally undetected events in Bangladesh are International Data Center (IDC, Comprehensive Nuclear-Test-Ban Treaty Organization, CTBTO, Viena), National Center for Seismology (NDI, India), National Seismological Center (DMN, Nepal). The minimum of the body wave magnitudes of the common 28 events is around 4, which suggests the lower bound of the detectability of the network.

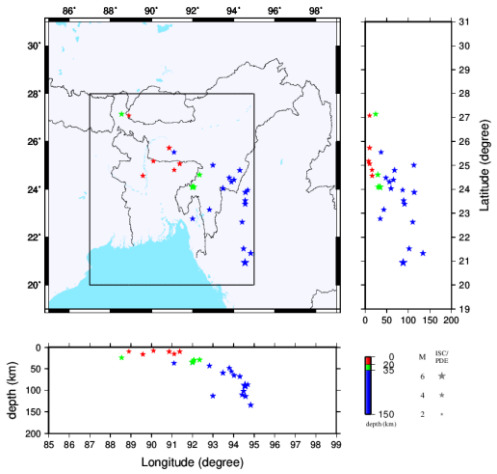

Figure 2. Hypocenters of 28 events detected by the local network of BMD among 510 events in the area shown by the rectangle.

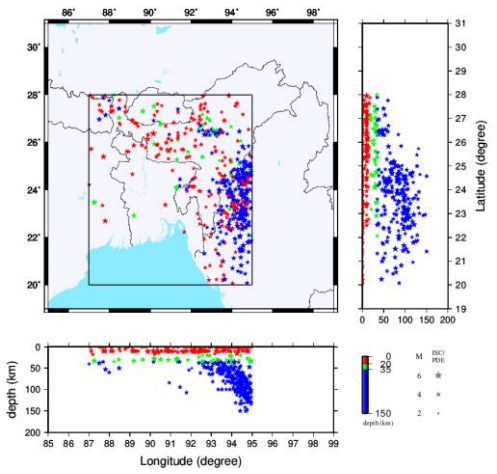

Figure 3. Hypocenters of the 482 locally undetected events that are registered in the ISC bulletin.

Among 51 events, 23 events are detected by the local network of Bangladesh Meteorological Department (BMD) but not registered in the ISC bulletin, the magnitude range of these 23 events is from 2.3 to 4.1 M_L obtained from the local network of BMD. Figure 4 shows the hypocenters of these 23 earthquakes. The focal depths of most of them are in between 0 to 20 km. Several earthquakes are located in the west and south parts of Bangladesh while a few events in these regions are registered in the ISC bulletin.

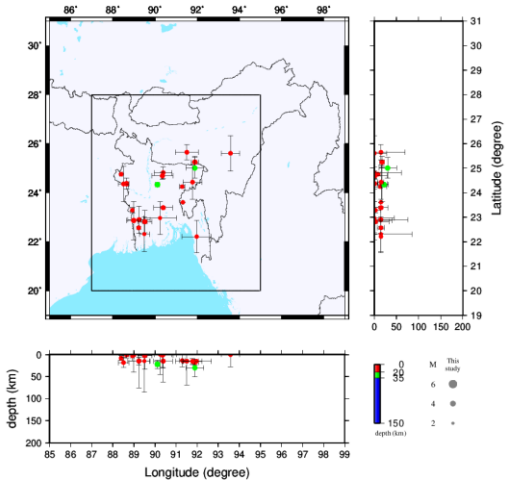

Figure 4. Hypocenters of 23 events that are not registered in ISC bulletin but were detected by the local network in the area shown by the rectangle.

4.3. Comparison of hypocenters of local events with that of the ISC/USGS catalog

We investigated the accuracy of the hypocenters determined by the local data. Among the 56 events, we analyzed 33 events that are registered in the ISC bulletin and USGS catalog. Figure 5 shows the comparison of these hypocenters. There is a tendency that intermediate-depth events that occurred beneath of Myanmar and Myanmar-India border region are located as shallow events. Choudhury (2008) determined hypocenters for 3 events that occurred in and around Bangladesh using data from the Bangladesh seismic network deployed at that time. Among them for the 1 event, which occurred on December 7, 2007 beneath Myanmar, the difference between the focal depth determined using the local data and that of the USGS catalog was large. This result is consistent with the result of the present study.

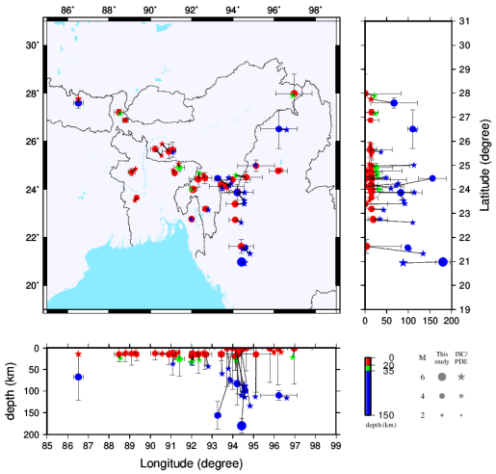

Figure 5. Comparison of hypocenters of 33 events determined using the local data and those from the ISC/USGS catalog which are denoted by the circles and the solid stars, respectively.

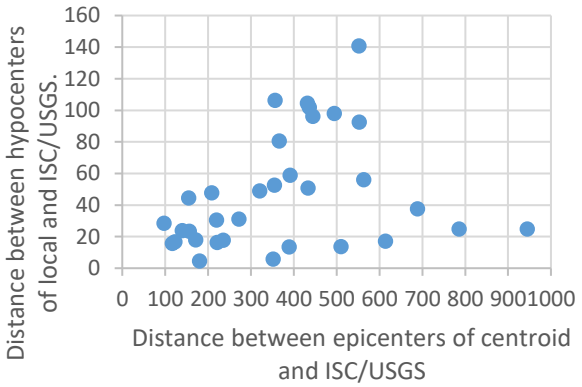

Figure 6. The distances between the hypocenters obtained from the local network data and those from the ISC/USGS catalog as a function of the distance of epicenters from the centroid of the local network.

Figure 6 shows the distances between the hypocenters obtained from the local network data and those from the ISC/USGS catalog with respect to the distance of an epicenter from the centroid of the local network. The differences between hypocenters are less than 50 km in the epicentral distance range up to 300 km. The differences are larger up to about 140 km at the greater epicentral distance for some events. The average distance between hypocenters is 46.9 km.

4.4. Comparison of hypocenters determined using the combined data to those of the ISC/USGS

As a preliminary attempt to improve hypocenter determination, we combined arrival time data from the local network and those from ISC bulletin and USGS catalog recorded in the epicentral distance up to 10 degrees. This analysis corresponds to hypocenter determination using local and regional data in the study area.

For the combined data, we found the location errors of 3 events among 33 events are greater than 100 km (i.e., the error of at least one of the three coordinates exceeds 100 km). We exclude these 3 events for comparison because the hypocenters are not well determined.

Figure 7 shows the comparison of hypocenters of 30 events determined using the combined data with those of the ISC/USGS catalog. Figure 8 shows the hypocentral distances for the local data analysis and those for the analyses of the combined data.

The large distances between the hypocenters determined using the local data and those from the ISC/USGS catalogs are reduced, as is shown in Figure 8, while for some events the distances between the hypocenters increased for the combined data. The average of the distances between the hypocenters of 30 events is 34.0 km in case of the combined data, and that is 48.6 km in case of the local data, respectively. The average of the differences is reduced in the case of the combined data for these 30 events.

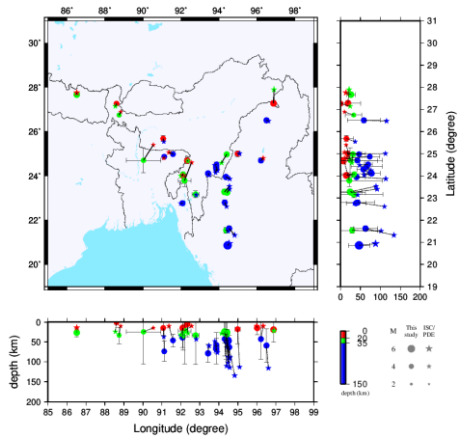

Figure 7. Comparison of hypocenters of 30 events determined using the combined data and those from the ISC/USGS catalog which are denoted by the circles and the solid stars, respectively.

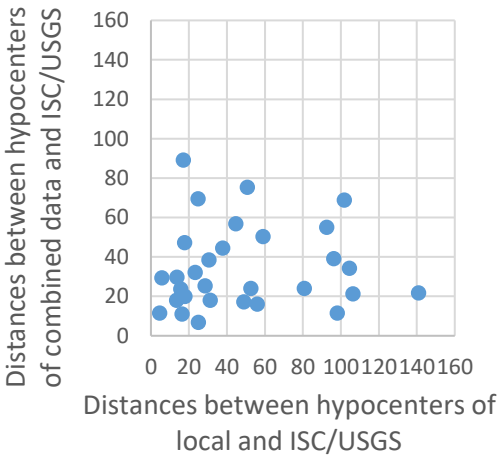

Figure 8. Comparison of the hypocentral distances of 30 events between the local data and the ISC/USGS data with those of the combined data and ISC/USGS data.

5. CONCLUSIONS

We analyzed 56 earthquakes that occurred in and around Bangladesh between June 2016 and February 2019. We used CSDP-IAS software to convert waveform data from the local network to waveform data in SAC format. We picked P and S arrival times from these local waveform data. Then we executed HYPOCENTER to determine hypocenters of earthquakes using local data.

We investigated the detectability of the local network. 510 events are registered in the ISC bulletin in the area defined by the latitude range 19°N-28°N and the longitude range 87°E-95°E. Among them, 28 events were detected by the local network, and 482 events were not detected by the local network. The minimum of the body wave magnitudes of the common events is around 4, and this is likely to correspond to the lower bound of the detectability of the local network. Among 56 events that were analyzed, 23 events are detected by the local seismic network but are not registered in the ISC bulletin. The magnitude ranges of these 23 events are 2.9 to 3.9 M_L.

Then we compared the hypocenters determined by the local network data to those of retrieved from the ISC bulletin and USGS catalog. We found the tendency that intermediate-depth events that occurred beneath Myanmar and Myanmar-India border region are located as shallow earthquakes. The differences between hypocenters are less than 50 km within the epicentral distance from the centroid of the local network up to 300 km, while the differences become large up to 140 km at the greater epicentral distance for some events.

We combined the local data and the ISC/USGS data whose epicentral distances were ≤ 10 degrees. We executed HYPOCENTER to determine hypocenters using the combined data. In the case of the combined data, the location errors for 3 events are greater than 100 km. We excluded these events from 33 common events and compared the hypocenters of the 30 events determined by the combined data with those retrieved from the ISC/USGS catalog.

This comparison shows that the large differences between the hypocenters at the distance range between 300 and 600 km obtained for the analysis using the local data are reduced in the analysis using the combined data, while the differences between hypocenters increased for some events. The average of the differences between the hypocenters is smaller for the analyses using the combined data.

ACKNOWLEDGEMENTS

This research was conducted during the individual study period of the training course "Seismology, Earthquake Engineering and Tsunami Disaster Mitigation" by the Building Research Institute, JICA, and GRIPS.I would like to express my sincere gratitude to the supervisors Dr. Tatsuhiko Hara, Chief research scientist, IISEE, BRI for his continuous support, valuable suggestion, and instruction during my study. I would like to thank Dr. T. Yokoi (Director of IISEE, BRI) and all others sensei of IISEE, BRI for their valuable lectures and support. I also would like to thank all the other staff members at IISEE/BRI and my colleagues for their support and encouragement during this training program. We used data from ISC (2019) bulletin for this study. We used Generic Mapping Tools (Wessel and Smith, 1998) for preparing some of the figures in this study.

REFERENCES

Choudhury, S. A., 2008, Bulletin of IISEE, 43, 7-12.
Goldstein, P., and Snoke, A., 2005, Seismology Data Management Center Electronic Newsletter.
International Seismological Center, 2019, On-line bulletin, http:// doi.org/10.31905/D808B830.
Kennett, B.L.N., and Engdahl, E.R., 1991, Geophys. J. Int. 105, 429-465.
Lienert B. R., and Havskov, J., 1995, Seismological Research Letters, 66, 5.
Munima, T., Salman, M.A., and Akhter, S.H., 2018, International Journal of Science, 3, 939 – 949.
Wessel, P., and Smith, W.H.F., 1998, EOS Trans. AGU, 79, 579.
Zaman, M.A., and Monira, N., 2017, J Geol Geophys 6, 300.
Website: https://earthquake.usgs.gov/earthquakes/search.
Website: http://www.isc.ac.uk/iscbulletin/search/bulletin.