ANALYSIS OF THE ACCURACY OF EARTHQUAKE PARAMETERS IN MINAHASSA PENINSULA, SULAWESI, WITH SEISMOGRAM WAVEFORM DATA PROCESSING

AM Triyan[1], Suharno[2], A Kurniawan[3], IBS Yogi[4] and RC Wibowo[5,*]

[1,2,3] *Geophysics Engineering, Engineering Faculty, University of Lampung, Sumantri Brojonegoro Street No.1 Bandar Lampung City, Indonesia*

[4] *Petroleum Geoscience, Universiti Teknologi Petronas, Malaysia*

[5] *Geological Engineering, Engineering Faculty, University of Lampung, Sumantri Brojonegoro Street No.1 Bandar Lampung City, Indonesia*

[*] *Email: rahmat.caturwibowo@eng.unila.ac.id*

Article Information:

Received:
28 October 2024

Received in revised form:
14 November 2024

Accepted:
18 November 2024

Volume 6, Issue 2, December 2024
pp. 59 – 68

http://dx.doi.org/10.23960/jesr.v6i2.200

Abstract

The Minahassa Peninsula is located in the northern part of Sulawesi, which is a meeting point for several major tectonic plates, namely the Sunda Plate, the Philippine Plate, and the Pacific Plate. The movement and interaction between these plates cause active seismic conditions. Around the Minahassa Peninsula, there are also local faults that can cause earthquakes. This study aims to analyze the accuracy of earthquake parameters published by BMKG by processing waveform data using the author's SeisComP software. This study uses two waveform data of earthquake events in the Minahassa Peninsula of Sulawesi obtained from WebDC3 and processed using SeisComP software with the results of the first earthquake event with an occurrence time of 2024-08-01 00:00:05 UTC, a depth of 146 km, a location point of latitude 0.07 ˚S, longitude 123.37 ˚E, a magnitude of 5.4 Mw with RMS Res. 1.6 s and Azimuth Gap 144 ˚ and the second earthquake event with an event time of 2024-08-22 04:43:05 UTC, a depth of 120 km, a location point of latitude 0.09 ˚S, longitude 123.50 ˚E, a magnitude of 4.7 Mw with RMS Res. 1.0 s and Azimuth Gap 144 ˚. From these results, it can be concluded that the search for earthquake parameters that occur using seismogram waveform data on SeisComP software with open-source limitations has quite a good accuracy.

Keywords: *Earthquake parameters, waveform data, WebDC3, SeisComP, accuracy.*

I. INTRODUCTION

Indonesia has high seismic and volcanic activity in the Pacific Ring of Fire. This geographical location makes it one of the countries with the highest earthquake risk in the world. The background of earthquakes in Indonesia is plate tectonics, subduction zones, fault lines, and volcanism. Complex tectonic and geological factors make Indonesia one of the most seismically active countries in the world [1].

Minahassa Peninsula is located in the northern part of Sulawesi, a meeting area between several major tectonic plates, namely the Sunda Plate, the Philippine Plate, and the Pacific Plate. The movement and interaction between these plates create active seismic conditions. Around Minahassa Peninsula, local faults can cause earthquakes if there is a significant shift in the earth's crust. Seismic activity in this region is often related to plate shifts and existing faults [2].

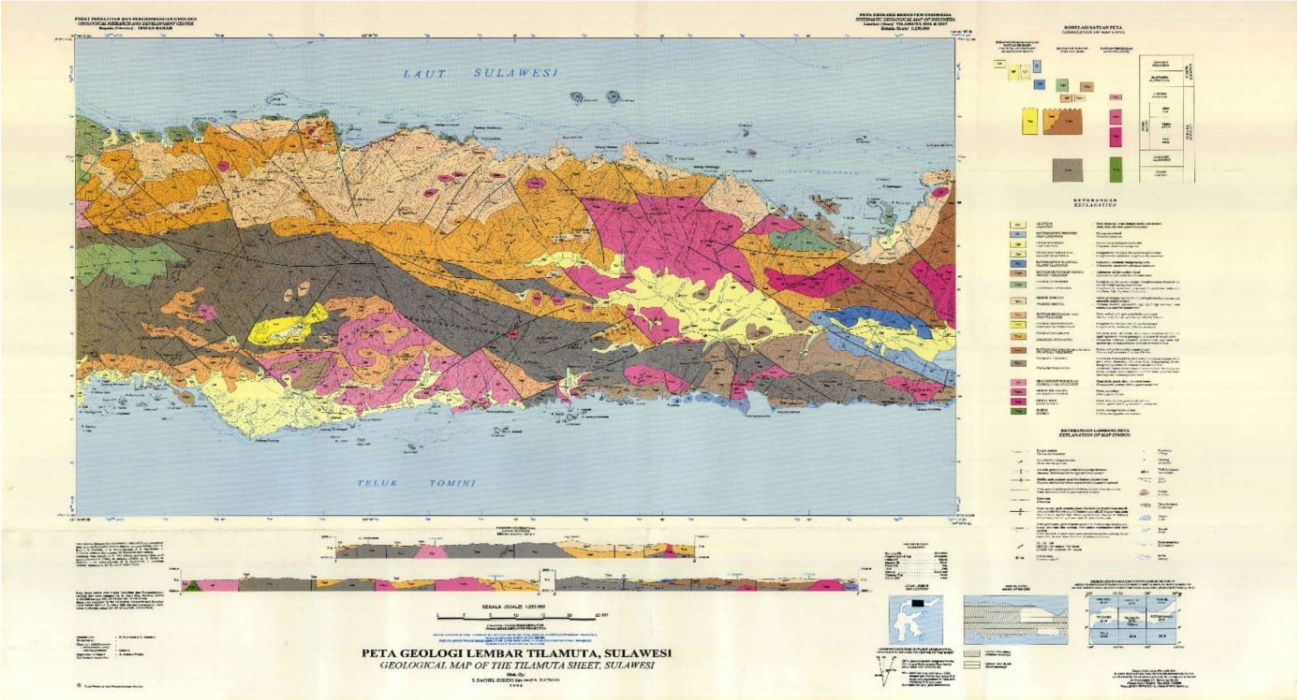

Figure 1. Geological sheet map of northern Sulawesi [3].

Minahassa Peninsula, Sulawesi, also has many active volcanoes that can potentially affect seismic activity in the surrounding area. Eruptions or volcanic activity near this area can trigger earthquakes. Overall, seismic activity in the Minahassa Peninsula results from the area's geological and tectonic complexity, which involves meeting several tectonic plates and the presence of local faults [4].

This study used waveform data from several earthquake sources recorded by seismographs installed at seismic receiving stations in the Minahassa Peninsula area, Sulawesi. Waveform data is a time-lapse record of seismic waves captured by a seismograph. This data describes the variation in ground motion as a function of time and includes important information about the characteristics of an earthquake, such as amplitude, frequency, and duration [5]. The waveform data produced, namely E, N, and Z waves, represent the east, north, and vertical components of each instrument that records ground motion. The results of picking P and S waves in the SeisComP software on E, N, and Z waves can produce earthquake parameters that occur. SeisComP is an open-source software system used for real-time monitoring and analysis of seismic data. Developed by the Helmholtz Centre Potsdam for Geosciences, SeisComP provides tools for collecting, processing, and distributing seismic data. SeisComP automatically collects data from multiple seismic stations and stores it in a format that can be processed [6]. If an earthquake occurs, the seismic waves recorded by the receiving station will automatically be processed by BMKG, producing earthquake parameters. This will then be published to BMKG social media for public information as an early warning. Therefore, this study was conducted to analyze the accuracy of earthquake parameters published by BMKG by processing waveform data using SeisComP software by the author.

II. Materials and Methods

The research data used by the author is secondary data in the form of waveform data from seismogram recordings installed at each BMKG seismic receiving station, which is classified as open source and entered into the SeisComP software on webDC3, which provides the data. In this case, the author obtained seismogram waveform data in (.MSEED) format. MiniSEED is a standard file format used to store and transfer seismic data. This format was developed by the International Federation of Digital Seismograph Networks (FDSN) to facilitate the exchange of seismic data between various institutions and systems [7].

The waveform data used and selected are two earthquake event data in the Minahassa Peninsula area, Sulawesi. The first step to obtaining the data is for the author to enter the page (http://eida.gfz-potsdam.de/webdc3/) to download the two selected events and the open-source station that reaches the earthquake event.

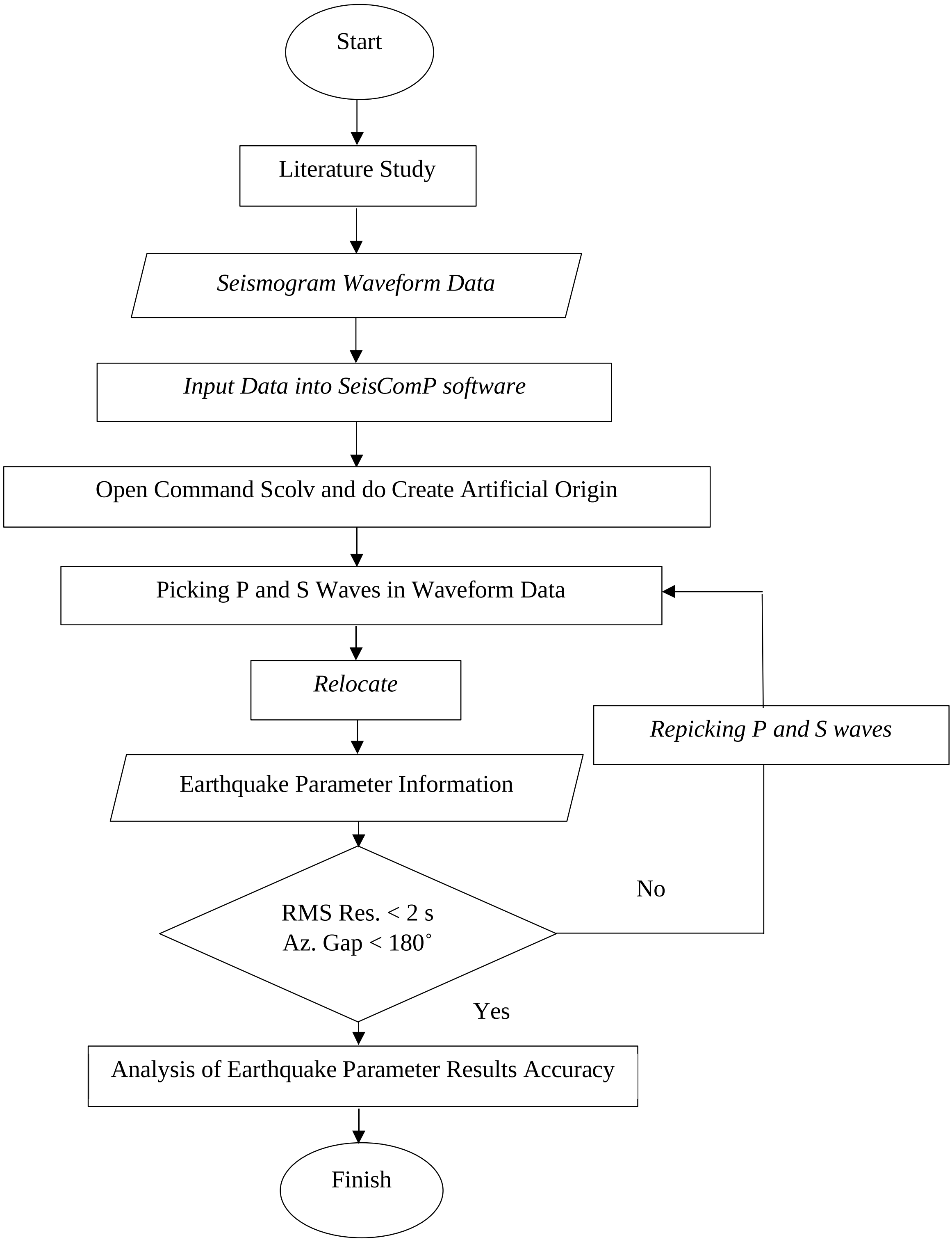

Figure 2. Data processing flow diagram.

The first stage of waveform data processing in the SeisComP software is to move the downloaded seismogram waveform data into the SeisComP software using the WSL tool. Next, enter the SeisComP software with the WSL tool, then enter the scroll command, create an artificial origin, and enter the time according to the selected seismogram waveform data one by one. Then, pick the P and S waves to produce the earthquake parameters.

After that, the author interprets the waveform data from the processing as the result of picking P and S waves, which produce earthquake parameter information. The parameter information obtained by the author after processing using the SeisComP software will then be analyzed for accuracy using the processing results published by BMKG.

III. Results and Discussions

A. Earthquake Event Waveform Data Used

The research data used by the author is seismogram waveform data obtained from the results of seismogram recordings installed at each BMKG seismic receiving station, especially in the area around the author's research location. This data is affordable, classified as open source, and included in the SeisComP software. The author used two earthquake event data in the Minahassa Peninsula area, Sulawesi.

The following is information on two pieces of seismogram waveform data that were selected and will be processed using SeisComP software; the two pieces of data are as follows:

Table 1. Data of the two selected earthquake events

Time of Event	Magnitude (Mb)	Lat. (˚S)	Long. (˚E)	Depth (km)
2024-08-01T00:00:08	5.2	-0.06	123.27	147.3
2024-08-22T04:43:13	4.7	0.09	123.81	120.5

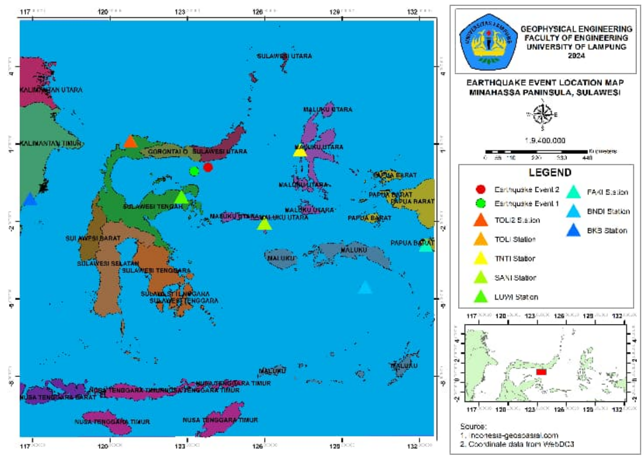

Figure 3. Map of the location of 2 earthquake points used for the study.

B. Data Processing in SeisComP Software

The first step in processing waveform data in SeisComP software is to enter the two waveform data that have been downloaded into the SeisComP software using the Windows Subsystem for Linux (WSL) tool using the command (Scart -I (file name .mseed) seiscomp/lib/var/archive/). Furthermore, when the waveform data has been entered into the SeisComP software, the next step is to enter the scolv command to pick P and S waves.seiscomp/lib/var/archive/). Furthermore, when the waveform data has been entered into the SeisComP software, the next step is to enter the scolv command to pick up P and S waves.

Then, in the scolv section, do Create Artificial Origin according to the location of the two selected earthquake events, then enter the time the earthquake event occurred; after that, click submit, and you will enter the scolv section, which displays the imperfect earthquake parameters and displays the Z, N, and E waves which are the results of waveform data recorded by the recording station. Next, click the picker to carry out the process of picking P and S waves at each station that reaches around the earthquake event that occurred.

The first earthquake event was processed on August 1, 2024, at 00:00:08 UTC. Its location point was latitude -0.06 ˚S and longitude 123.27 ˚E, with a magnitude of 5.2 Mb and a depth of 147.3 km. The results of picking P and S waves are obtained in Figure 4 by carrying out the processing stages as explained above.

In the first earthquake event, it can be seen in Figure 4 that an earthquake with a magnitude of 5.2 Mb can be read by six open-source stations surrounding the earthquake point. Although the distance from each station is different and the results of the recorded seismic waves also have differences, the picking of P and S waves will be adjusted to the reading results of the SeisComP software. In the image above, the stations have been sorted from the closest to the farthest, supported by the display of waveforms at each station.

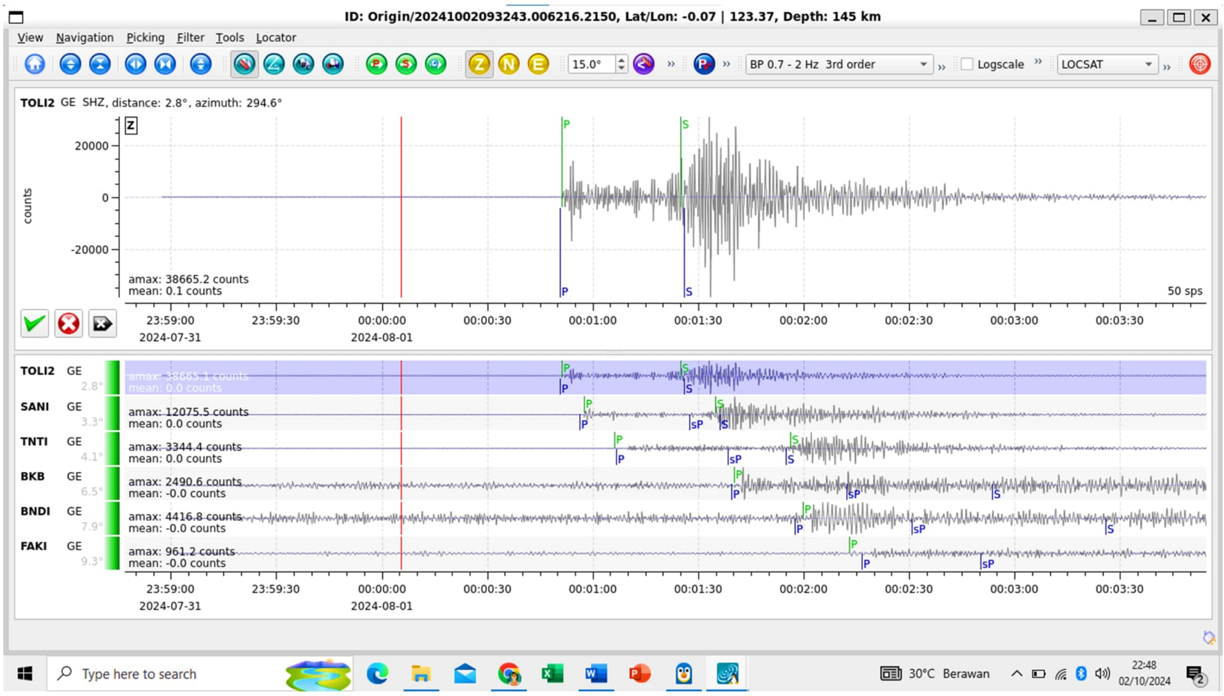

Figure 4. P and S wave picking in the first earthquake event.

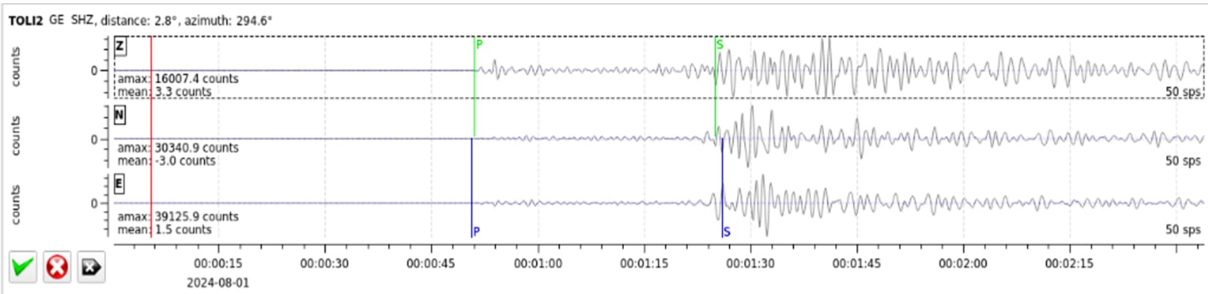

Figure 5. P and S wave picking at TOLI2 station.

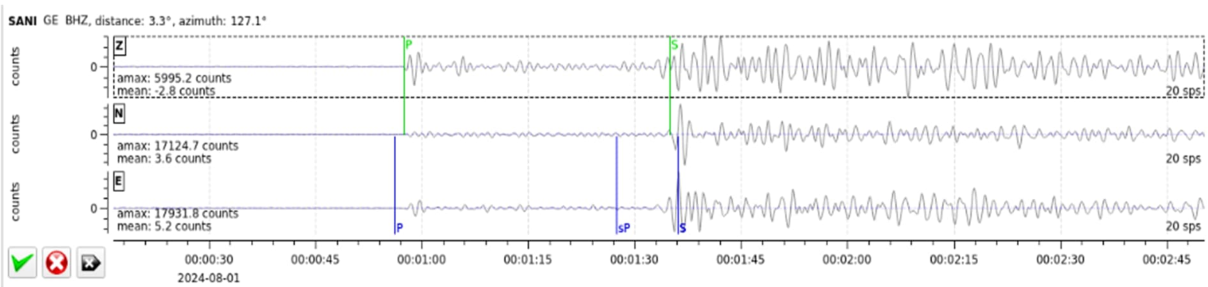

Figure 6. P and S wave picking at SANI station.

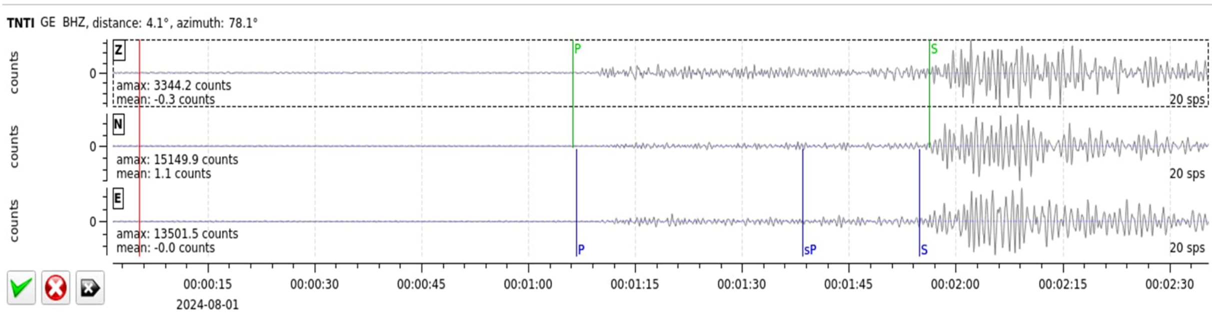

Figure 7. P and S wave picking at TNTI station.

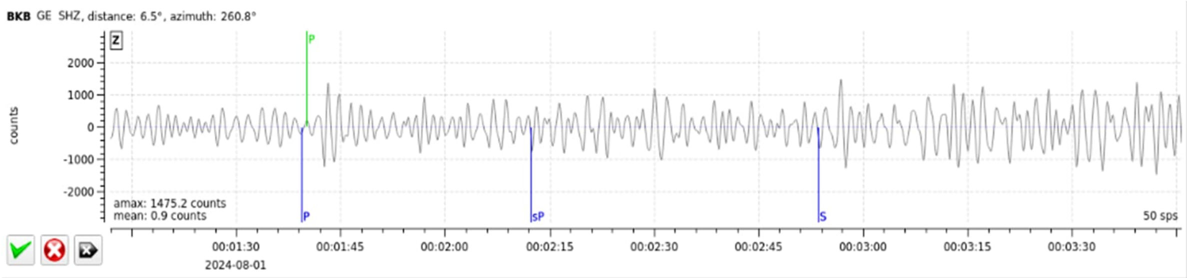

Figure 8. P wave picking at BKB station.

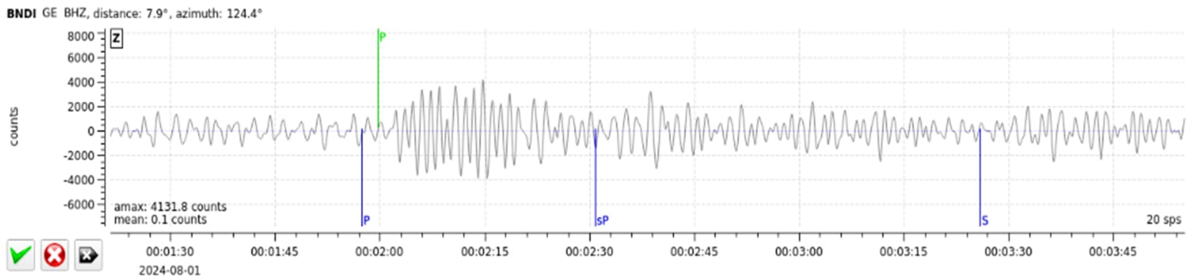

Figure 9. P wave picking at BNDI station.

Figure 10. P wave picking at FAKI station.

In Figure 5, the first picking is done at the closest station, TOLI2 station, by picking P and S waves because the waveforms are very clearly visible, and the location of the P and S waves is visible. Furthermore, in Figure 6, picking at the second station, SANI, the waveforms can still clearly see the location of the P and S waves. Furthermore, in Figure 7 at the TNTI station, the position of the P and S waves is still slightly visible.

In Figure 8, at the fourth station, BKB, the S wave cannot be picked because it is difficult to see the position of the S wave due to the distance of the station being far from the earthquake point, so the seismograph records it is less detectable. Likewise, with the fifth station BNDI in Figure 9 and the sixth station FAKI in Figure 10, the further the distance of the recording station from the earthquake point, the more difficult it will be to read and see the seismic waves of the earthquake that will be picked for the S and even P waves. For the record, when an earthquake event with its recording station reaches the earthquake and has ten stations, if the 9th and 10th stations have difficulty in picking P and S waves, then the two stations do not need to be picked. It can affect the results of the earthquake parameter information obtained even though it is less accurate in determining the position of the earthquake point because fewer stations surround the earthquake.

Then, when you have done the P and S wave picking at each station, click relocate to see the results of the earthquake parameters produced during the first earthquake event.

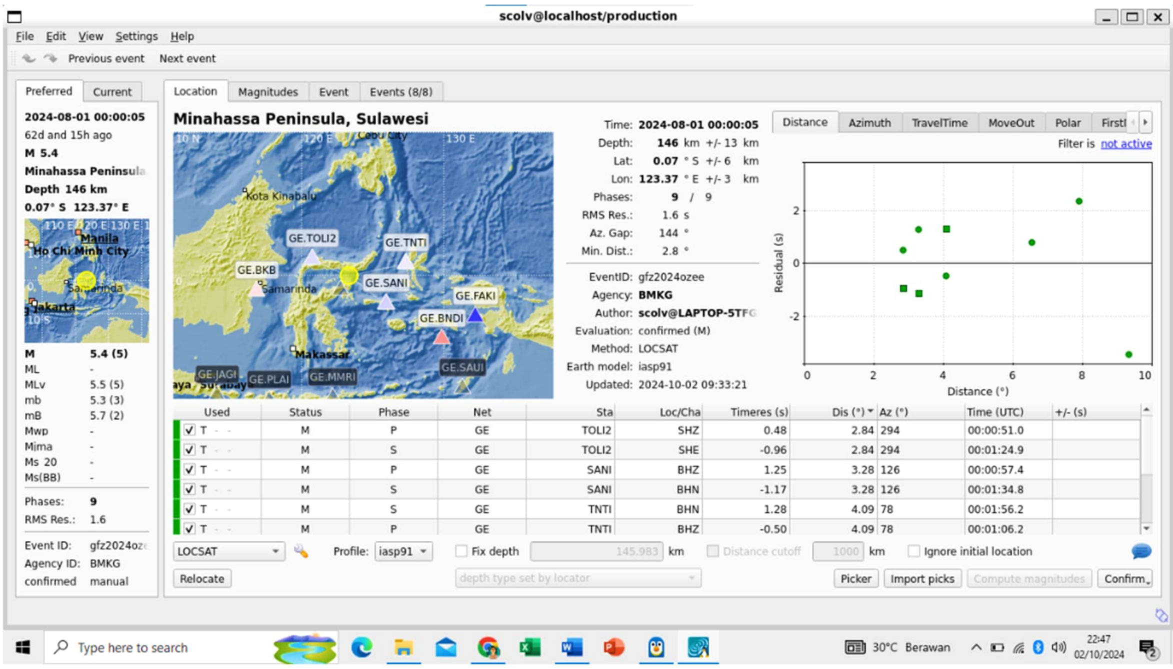

Figure 11. Results of earthquake parameter information in the first earthquake event.

Figure 11 shows the result of the first earthquake event processing. The earthquake parameters were obtained with the earthquake occurrence time of 2024-08-01 00:00:05 UTC, a depth of 146 km, a location point of latitude 0.07 ˚S, longitude 123.37 ˚E, a magnitude of 5.4 Mw with RMS Res. of 1.6 s, and an Azimuth Gap of 144 ˚.

Next, the processing of the second earthquake event on August 22, 2024, at 04:43:31 UTC with a location point of latitude 0.09 ˚S and longitude 123.81 ˚E, a magnitude of 4.7 Mb and a depth of 120.5 km. In the second earthquake event, it can be seen in Figure 12 that the earthquake event with a magnitude of less than 5 Mb, namely 4.2 Mb, can only be read by four open source stations surrounding the earthquake point.

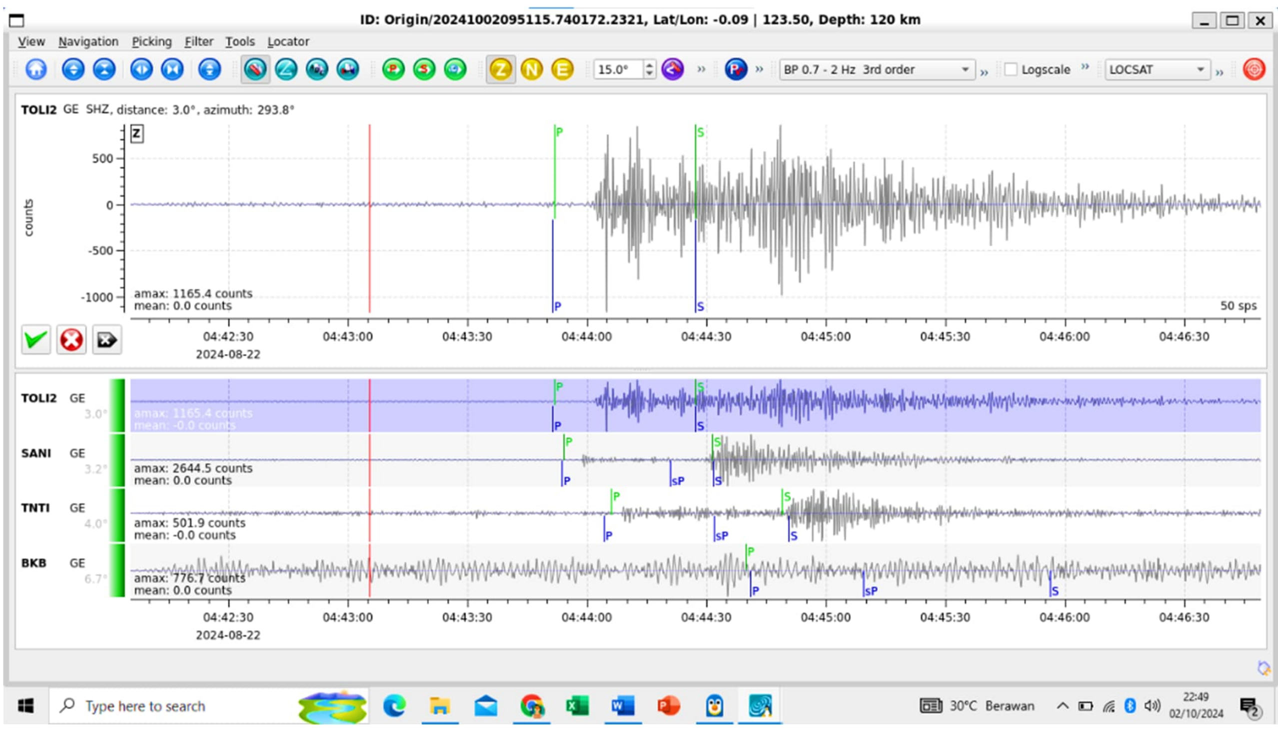

Figure 12. Picking P and S waves in the second earthquake event.

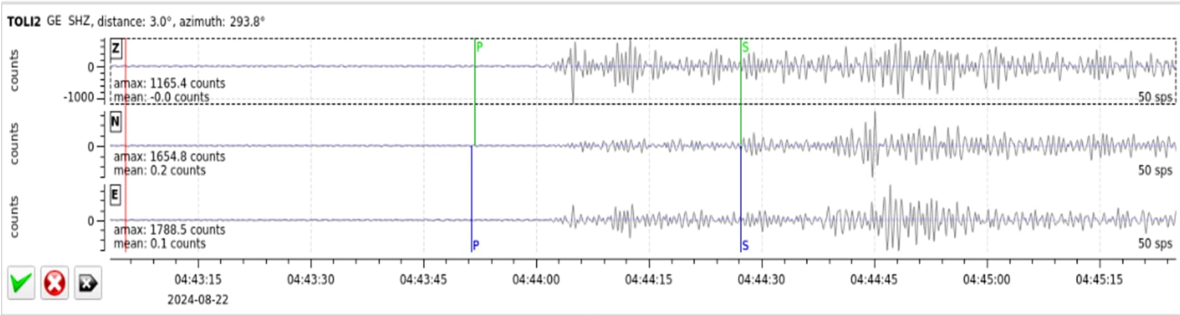

Figure 13. P and S wave picking at TOLI2 station.

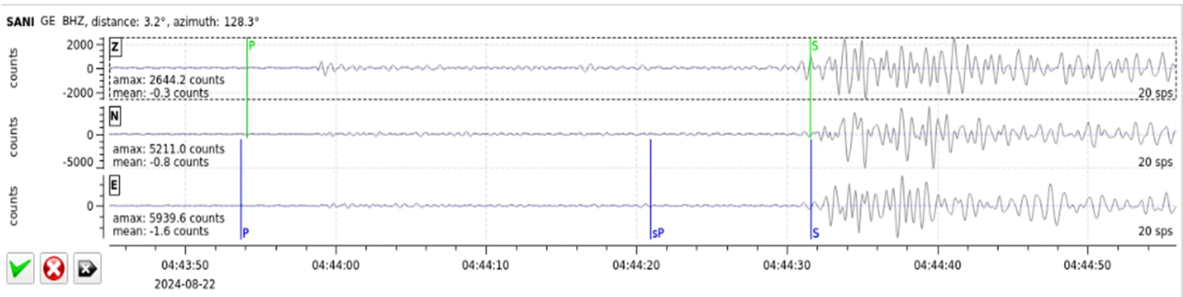

Figure 14. P and S wave picking at SANI station.

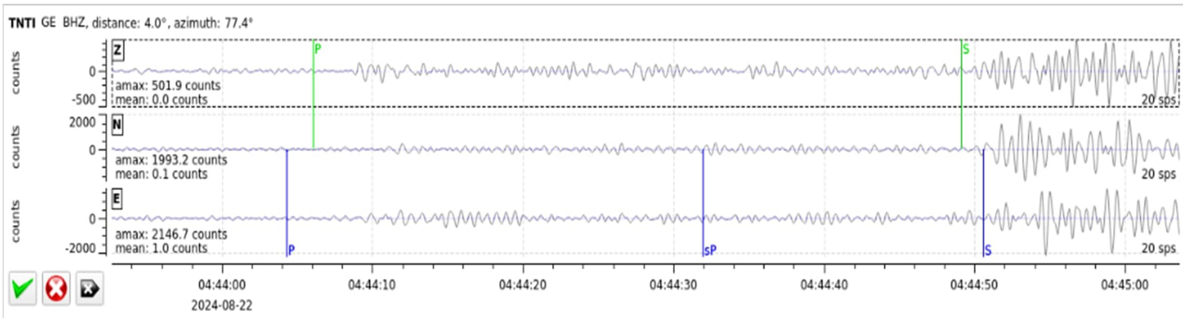

Figure 15. P and S wave picking at TNTI station.

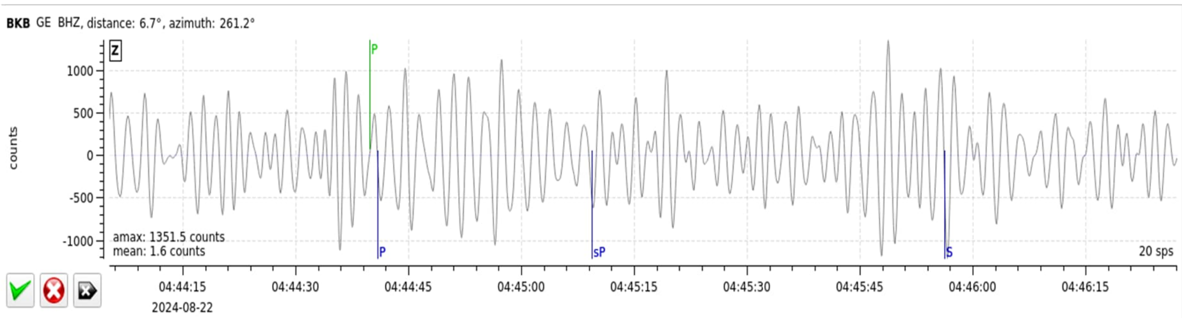

Figure 16. P wave picking at BKB station.

In Figure 13, the second earthquake event data processing, with the first picking done at the closest station, namely the TOLI2 station, with P and S wave picking because the seismic waves at this station are very clearly visible from the position of the P and S waves. Furthermore, in Figure 14, the second station wave picking is SANI, with its seismic waves that can still clearly show the position of the P and S waves. Furthermore, in Figure 15, the wave picking at the TNTI station is still slightly visible for the position of the P and S waves. Meanwhile, in Figure 16 at the fourth station, namely BKB station, the S wave cannot be picked because the seismic wave shape makes it difficult to see the position of the S wave due to the distance of the station far from the earthquake point. Hence, the recording device is less detectable. Then, click relocate to see the results of the earthquake parameters produced.

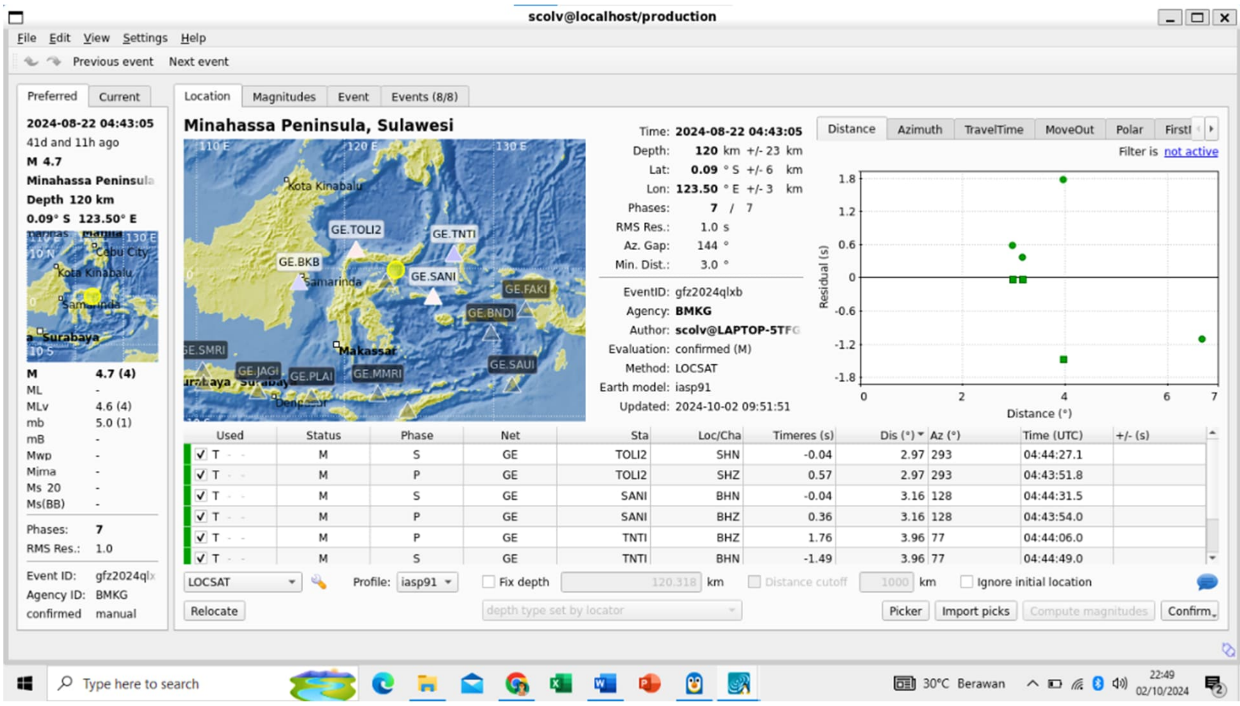

Figure 17. Results of earthquake parameter information on the second earthquake event.

Figure 17 is the result of the second process. The results of the earthquake parameters were obtained with the time of the earthquake occurrence 2024-08-22 04:43:05 UTC, a depth of 120 km, a location point of latitude 0.09 ˚S, longitude 123.50 ˚E, a magnitude of 4.7 Mw with RMS Res. of 1.0 s and an Azimuth Gap of 144 ˚.

C. Discussion

Based on the results of waveform data processing from the two earthquake events in the Minahassa Peninsula area, Sulawesi, using SeisComP software, which has open-source limitations, the results of parameter information from the two selected earthquake events are as follows:

Table 2. Results of parameter information for two earthquake events from processing

Time of Event	Magnitude (Mw)	Lat. (˚S)	Long. (˚E)	Depth (km)
2024-08-01T00:00:05	5.4	-0.07	123.37	146
2024-08-22T04:43:05	4.7	0.09	123.50	120

From Table 1, it can be seen that the earthquake data information published by BMKG on the same earthquake event has a difference that is not too far from the processing results presented in Table 2 above, so the author can conclude that with processing with SeisComP software by the author who has open source limitations compared to processing by BMKG which uses SeisComP software which is complete with data and stations used, has quite good accuracy for learning to find an earthquake parameter that occurs using seismogram waveform data obtained from WebDC3.

IV. CONCLUSIONS

Based on the processing results of 2 earthquake events in the Minahassa Peninsula area, Sulawesi, the first earthquake event was on 2024-08-01 00:00:05 UTC with a depth of 146 km, latitude 0.07 ˚S, longitude 123.37 ˚E, magnitude 5.4 M with RMS Res. 1.6 s and Azimuth Gap 144 ˚ and the second earthquake event was on 2024-08-22 04:43:05 UTC with a depth of 120 km, latitude 0.09 ˚S, longitude 123.50 ˚E, magnitude 4.7 M with RMS Res. 1.0 s and Azimuth Gap 144 ˚.

The author processed two earthquake events in Minahassa Peninsula, Sulawesi, with SeisComP software, which has open-source limitations. This is in contrast to the processing by BMKG, which uses SeisComP software that is complete with the data and stations used. The latter is accurate for learning to find an earthquake parameter using seismogram waveform data.

V. ACKNOWLEDGMENT

The author would like to thank Dr. Karyanto, S.Si., M.T., who has provided input and suggestions and contributed to improving the original version of the manuscript.

VI. References

[1] T. Frank, "*What is Geology? - Definition, History, Facts & Topics*," Study.com, November 21, 2023. [Online]. Available: https://studt.com/academy/lesson/what-is-geology-definition-facts-topics.html. Accessed October 10, 2024.

[2] N. Hidayati, and D. Sumintadireja, "Active Faults in the North Sulawesi: Characteristics and Implication for Earthquake Hazards", *Journal of Seismology*, 9(3), 204-215, 2015.

[3] S. Bachri, Sukido, and N. Ratman, *Geological Map of the Tilamuta Sheet of Northern Sulawesi*, Center for Geological Research and Development, 1993.

[4] S. P. Rahayu, and S. Santosa, "Characteristics of Earthquakes in the Minahasa Peninsula Region and Their Implications for Society", *Journal of Geophysics*, 15(2), 120-134, 2021.

[5] K. Aki, and P. G. Richards, *Quantitative Seismology: Theory and Methods*, W. H. Freeman, 1980.

[6] P. Bormann, K. Klinge, and S. Wendt, *Seismology: A Comprehensive Handbook*, Springer, 2013.

[7] H. Igel, A. D. Bailey, J. Talkish, H. Ding, A. Duran, S. Mantripraganda, B. Paten, and M. Ares, *Data Management for Seismology. In: Seismology: A Comprehensive Handbook*, Springer, 2009.