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Analysis of 2006 Merapi Eruption Data Based on Continous Wavelet Transform, Wavelet Decomposition and Correlation

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ABSTRACT: Seismic data analysis of the 2006 Merapi volcano eruption has been carried out using the Continuous Wavelet Transform (CWT) and the Wavelet-based Decomposition and Correlation (WAVEDECOR) combined with the Fast Fourier Transform (FFT). The CWT is used to show the frequency pattern of the event while the WAVEDECOR is used to denote the frequency band of the signal. The CWT and the WAVEDECOR are supported by the FFT to ensure the dominant frequency of the observed signals. The results shows that visual patterns and a dominant frequency distribution of certain events, including the VT-A, the Low Frequency (LF), the VT-B, tremor, multiphase and lava avalanche. The result from this analysis was then compared with related eruption signal of Merapi in 1996 to determine the pattern similarity. The comparison results shows almost identical results for dominant frequencies in VT-A events as well as MP events. *The findings in the VT-B event showed that the dominant frequency pattern was slightly different from the 1996 data which showed at medium to high-frequency while for the 2006 data showed only at medium frequency.*

KEYWORDS: Merapi, Volcano Eruption, Wavelet

1. INTRODUCTION

The research related to Wavelet Transform application for Merapi Volcano seismic, including Ohrnberger [1], Fadeli [2] and Dairoh and Suryanto [9] has been done. In addition, Putra [3] has also conducted research to find out the activities that occurred during the 1996 eruption. Thisresearch was conducted using the Wavelet Package Transform method followed by the Wavelet Decomposition and Correlation (WAVEDECOR) methods. The WAVEDECOR method aims to strengthen the findings of the Wavelet Package Transform in the form of the dominant frequency band of the related event. The results of the research indicate the existence of Volcano Tectonic or VT and Multiphase or MP events which appeared in the 1996 eruption.

Subsequent research conducted by Putra et al. [4] analyzed Merapi seismic signals in 1996 using the ADAPLET (Wavelet-Based Adaptive Filters) method. The purpose of this research was to determine certain patterns or characteristics of the eruption, namely VT-A, VT-B, and MP. The results were obtained is certain patterns in each event by taking into account the parameters of the signal coefficients.

The Putra's research is a part of the research roadmap which related to wavelet-based seismic wave analysis which is shown in Fig. 1. The final aim of this roadmap was to find the specificmother wavelets specifically for processing the eruption of Merapi Volcano.

The Putra's research still revolves around eruption seismic record data in 1996. Therefore, it is necessary to conduct research related to the 2006 of the subsequent eruption. The research purpose on 2006 eruption wants to know and understand the event pattern of the eruption compared to the findings of previous research in order to continue the stage of further research.

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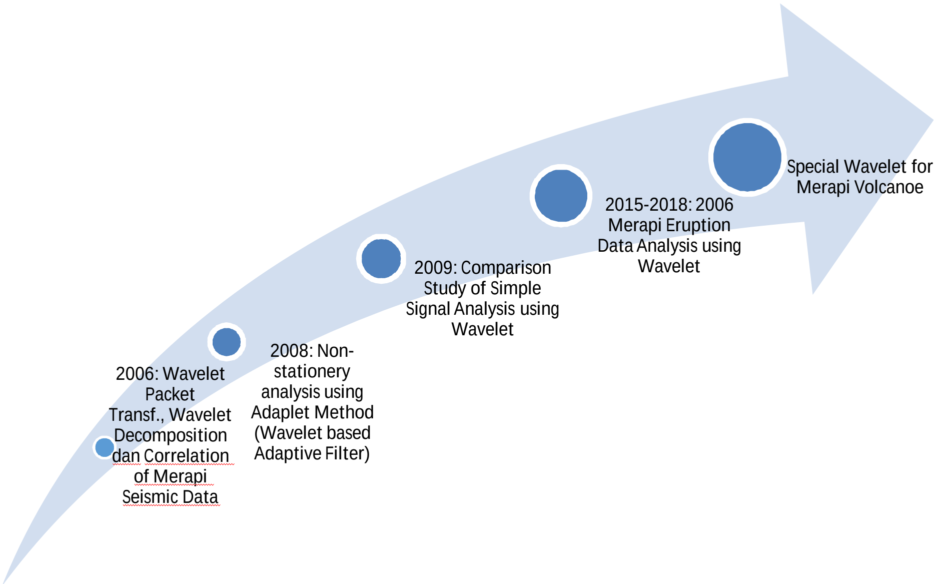

Figure 1: Roadmap of research on wavelet-based seismic wave analysis

II. RESEARCH METHOD

I. INTRODUCTION

This research uses three data recording of Merapi Volcano eruptions, which is the vertical components (SZ), the North-South component (SN), and the East-West component (SE). Seismic data processing is carried out separately using the Continuous Wavelet Transformations (CWT) and the WAVEDECOR (Wavelet-based Decomposition and Correlation). The CWT is used to process signal data in the time-frequency region to find out the frequency range during events, while the WAVEDECOR is used to decompose the signal into several frequency bands which are then correlated to determine the level of similarity in a particular frequency band range. The results of the two methods are used to analyze eruption events that occur and compared with the findings of Putra [3] before. The research method is shown in Fig. 2.The mother wavelet used in this method is Coiflet, which has been used in previous researches, this is because Coiflet is able to provide good results in seismic processing [6] [7].

II. WAVELET-BASED DECOMPOSITION AND CORRELATION (WAVEDECOR)

The WAVEDECOR is a method that combines full wavelet decomposition and cross-correlation to show the level of signal similarity at certain frequencies [3]. Full wavelet decomposition results in 2^n signal decomposition, the example for 3 levels full decomposition shown in Fig. 3.

The WAVEDECOR processing use Coiflet-5 as a mother wavelet with a 5 level full decomposition which will produce a decomposition signal of 32 frequency bands. This is due to the fact that the sampling frequency of the data is 100 Hz, so the maximum frequency that meets the Nyquist Theorem is 50 Hz. Therefore, the decomposition process will be carried out for each signal range with a frequency range of 50/32 Hz or about 1.56 Hz.

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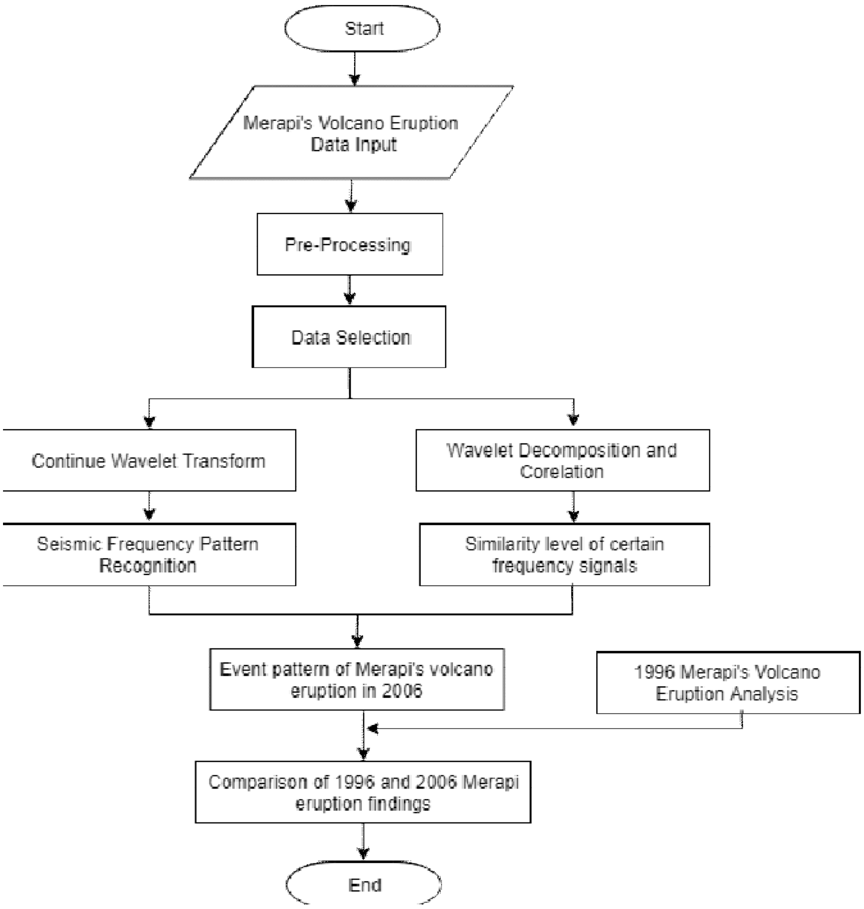

Figure 2: the Researchmethod

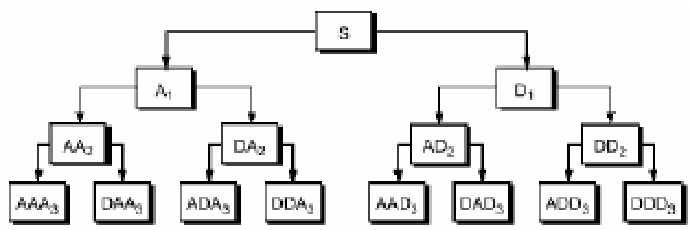

Figure 3: Full 3 levels wavelet decomposition tree [3]

III. RESULTS& DISCUSSION

I. Event Analysis

The research focuses on the analysis of certain events of Merapi eruption on June 4, 2006, which is based on visual characteristics according to Wassermann [8]. These visual characteristics obtained by a number of events, namely VT-A, LF, VT-B, Tremor, MP, and lava avalanche. The first findings shown in Fig. 4 (VT-A) for 44 seconds, began with the appearance of P waves in the 8th second with the appearance of a visual pattern that was not very clear with the appearance of low frequencies followed by the appearance of S waves in the 14th second with a visual pattern that clearly changes with a dominant frequency in the range of 3.5 - 7.5 Hz. The results of the WAVEDECOR are shown in Fig. 5 with the dominant frequency located in the high-frequency band between 4.69 to 7.81 Hz.

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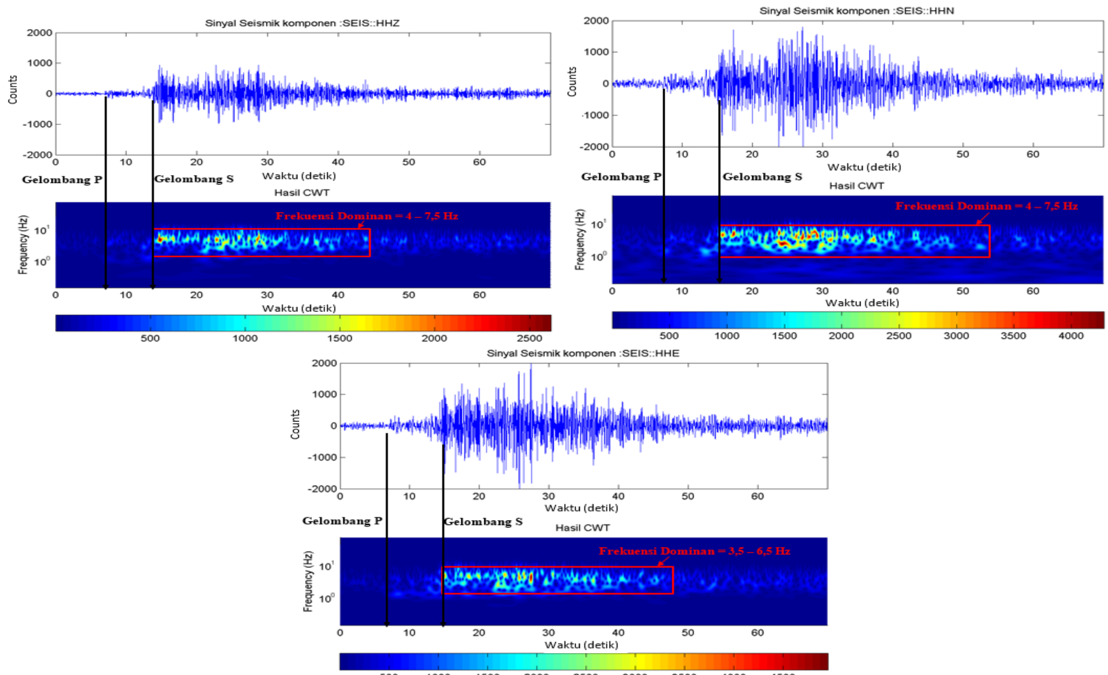

Figure 4:The Continuous Wavelet Transform Results of the VT-A event eruption data in 2006

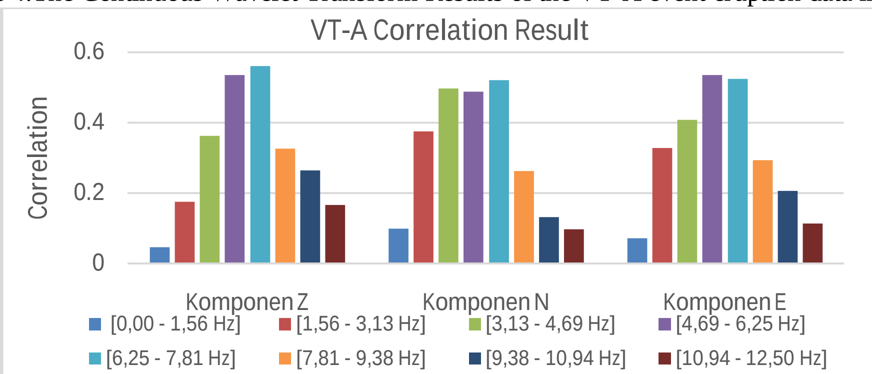

Figure 5:The WAVEDECOR results of VT-A event eruption data in 2006

The second finding is the Low Frequency or LF event, which is shown in Fig. 6. This signal has a small earthquake amplitude with a clear P wave appearance without showing the appearance of S waves. This event is short, only occurs for 15 seconds starting with the appearance of P waves at 7th to 23rd seconds. The CWT results in Fig. 6 shows the dominant frequency range of the LF event on the three signal components in the frequency range of 1 - 4 Hz. The result of the WAVEDECOR of the LF event is shown in Fig. 7, with the dominant frequency band located at the low frequency located between the frequency band 1.56 - 3.13 Hz.

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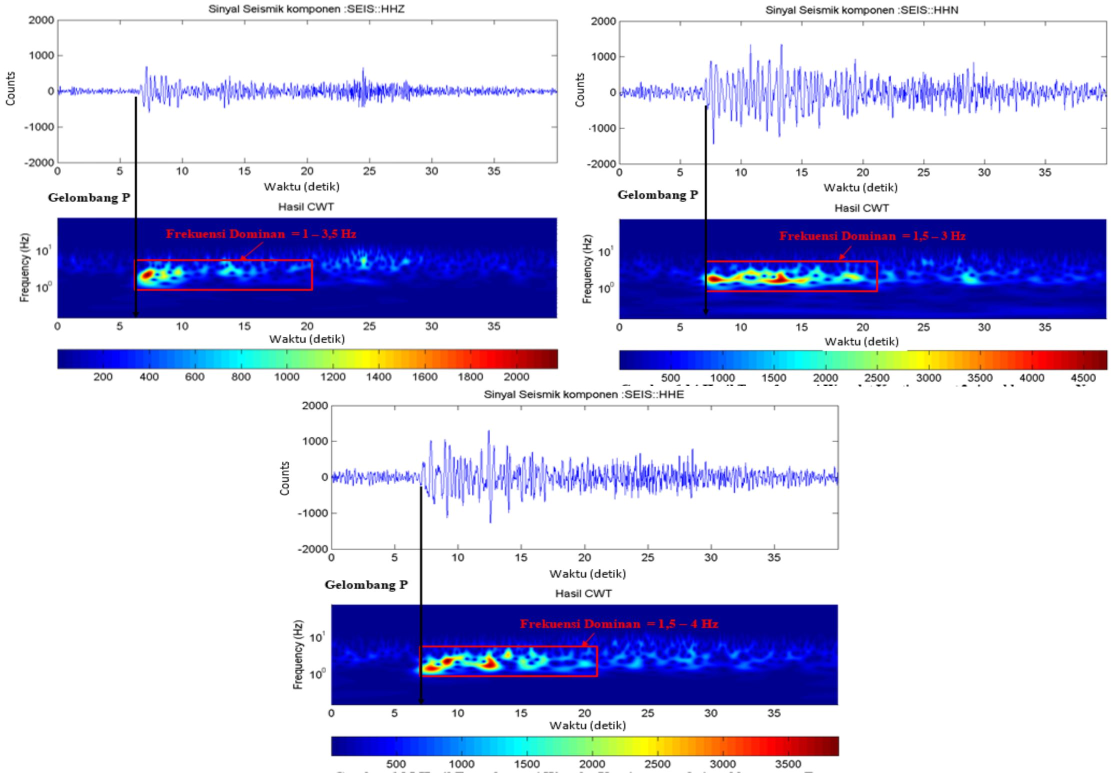

Figure 6:The Continuous Wavelet Transform Results of the LF event eruption data in 2006

The third finding is VT-B,which is shown in Fig. 8, this signal shows the arrival of the P wave, but it is difficult to detect the arrival of the S wave clearly. The dominant frequency value of VT-B is also lower than the VT-A event. The CWT results in Fig. 8 shows the appearance of P waves in the 12th second without the appearance of the S wave clearly with the frequency range of the VT-B event on the three signal components in the frequency range 2.5 - 6.5 Hz. The results of the WAVEDECOR shown in Fig. 9 with frequency bands in the intermediate frequency range of 3.13 - 6.25 Hz.

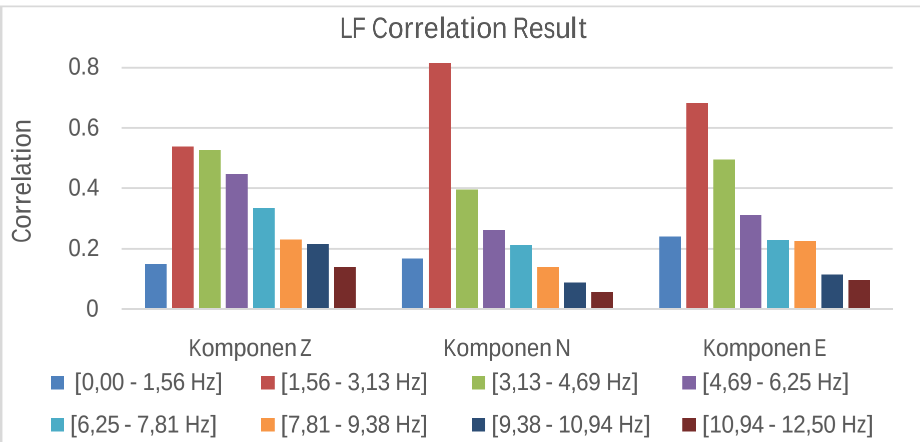

Figure 7: The WAVEDECOR results of LF event eruption data in 2006

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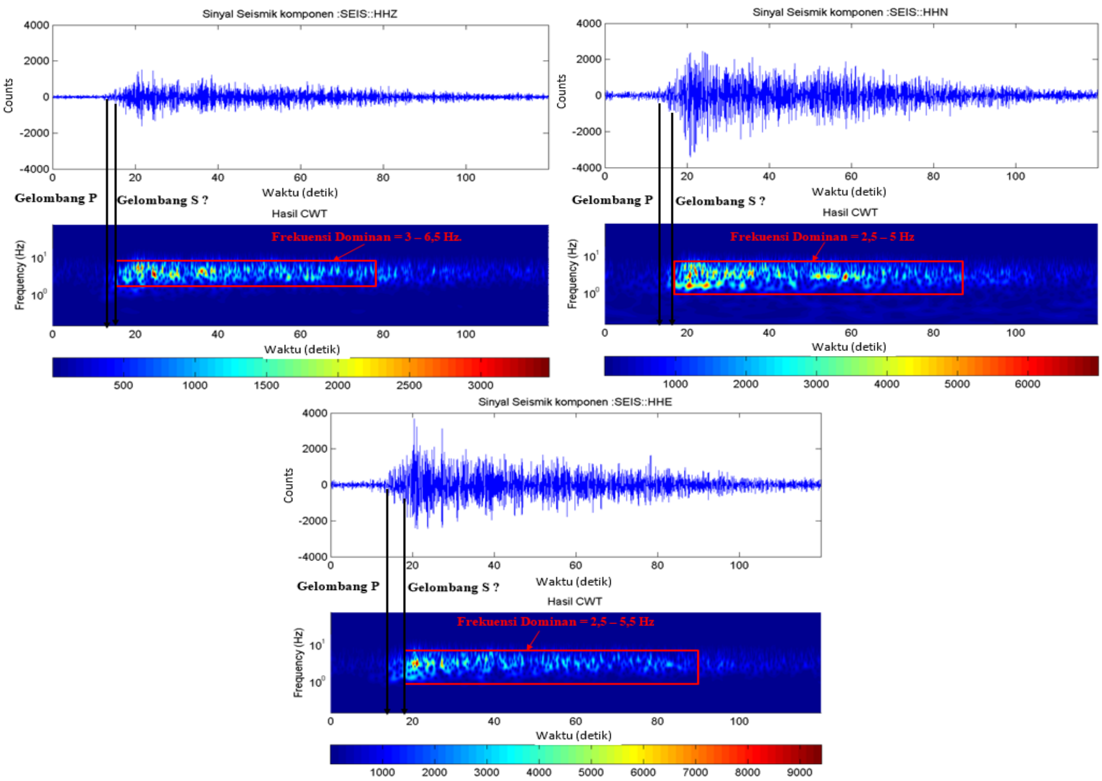

Figure 8: The Continuous Wavelet Transform Results of the VT-B event eruption data in 2006

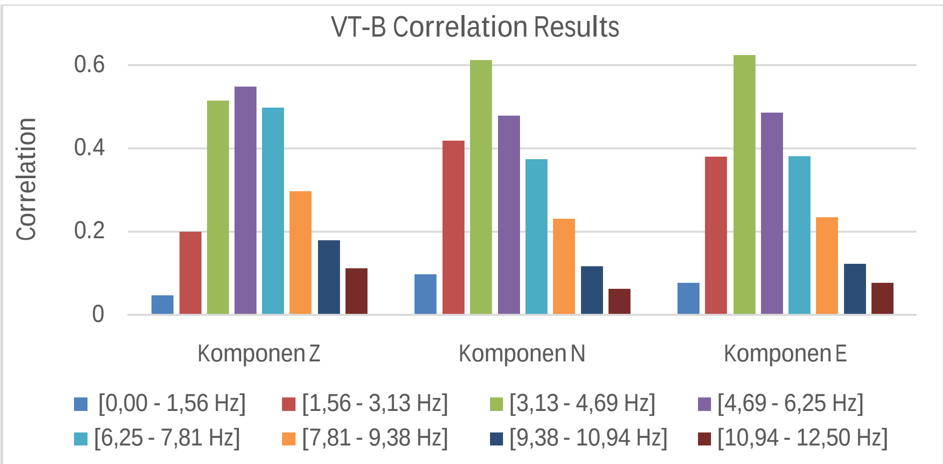

Figure 9: The WAVEDECOR results of VT-B event eruption data in 2006

The fourth finding is the Tremor event, which is shown in Fig. 10, shows earthquake activity Tremor starts from 15th to 180th seconds or occurs about 2 minutes 45 seconds with low-frequency emergence in the 90th to 110th seconds with the frequency range is dominant in all three signal components in the frequency range 1.5 - 8 Hz. The results of the WAVEDECOR are shown in Fig. 11 with three signal components located in the medium frequency with the dominant frequency band in the frequency range of 3.13 to 4.69 Hz, followed by a frequency band with a range of 1.56 - 3.13 Hz, and 4.69 - 6.25 Hz.

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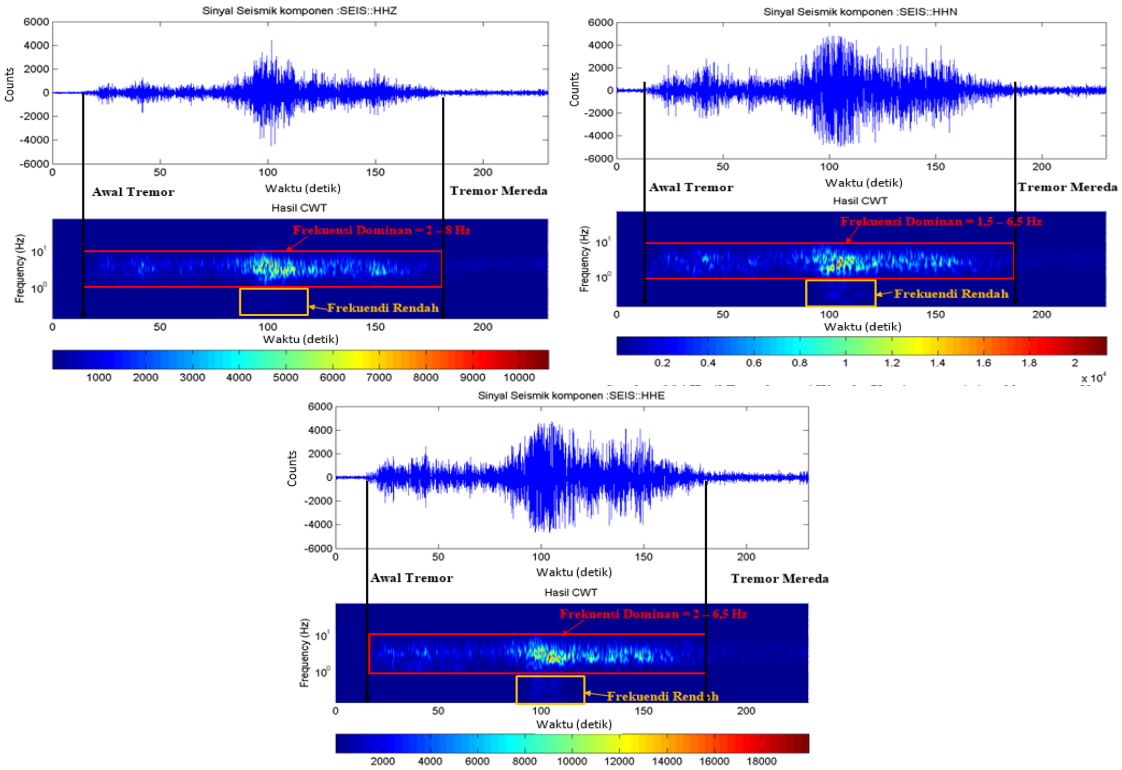

Figure 10:The Continuous Wavelet Transform Results of the Tremor event eruption data in 2006

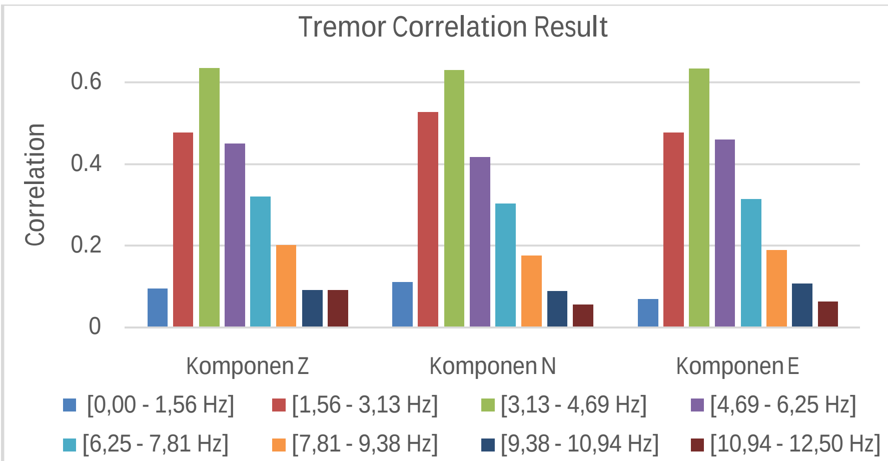

Figure 11: The WAVEDECOR results of tremor event eruption data in 2006

The fifth finding is a multiphase or MP event, this type of earthquake is characterized by the appearance of the initial wave that is not very clear compared to VT-A and VT-B. The CWT results in Fig. 12 shows the appearance of the initial wave with the amplitude spike occurres from the 23rd-second range to the peak of the wave gradually. Fig. 12 also shows the dominant frequency range of MP in all three signal components in the range of 2 - 6 Hz. The result of the WAVEDECOR is shown in Fig. 13, where the dominant frequency is the intermediate frequency with the location of the frequency band in the range of 3.13 - 6.25 Hz.

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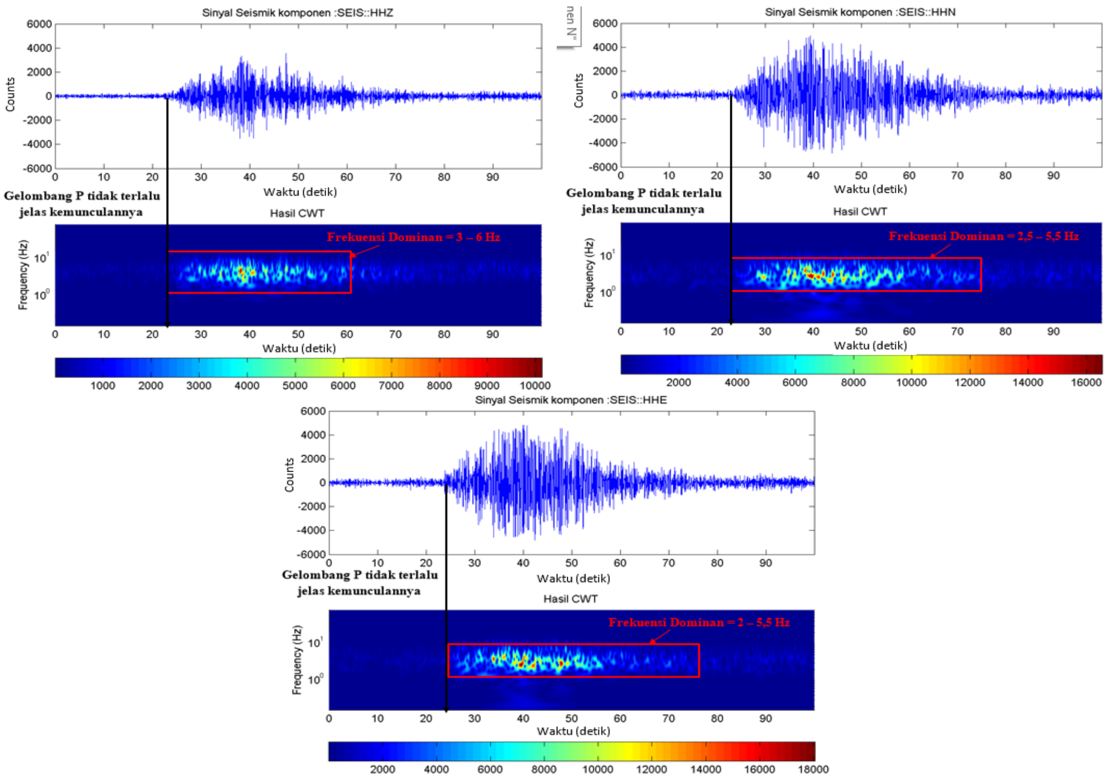

Figure 12:The Continuous Wavelet Transform Results of the MP event eruption data in 2006

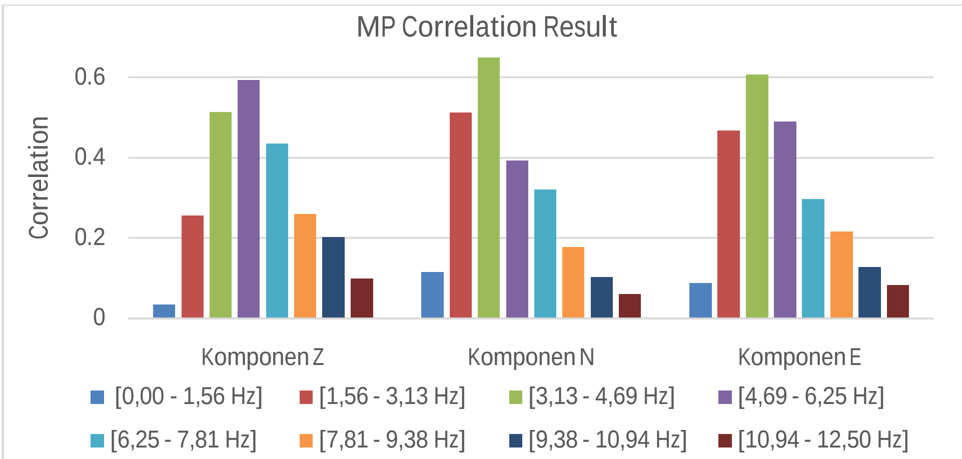

Figure 13: The WAVEDECOR results of MP event eruption data in 2006

The latest finding is a lava avalanche event accompanied by Tremor. The CWTresults in Fig. 14 shows the frequency distribution of the avalanches accompanied by tremors with the dominant frequency of earthquake avalanches on the three signal components in the range of 1 - 8 Hz accompanied by the appearance of low frequencies. The result of the WAVEDECOR is shown in Fig. 15, with the dominant frequency band being in the range of 3.13 Hz - 4.69 Hz.

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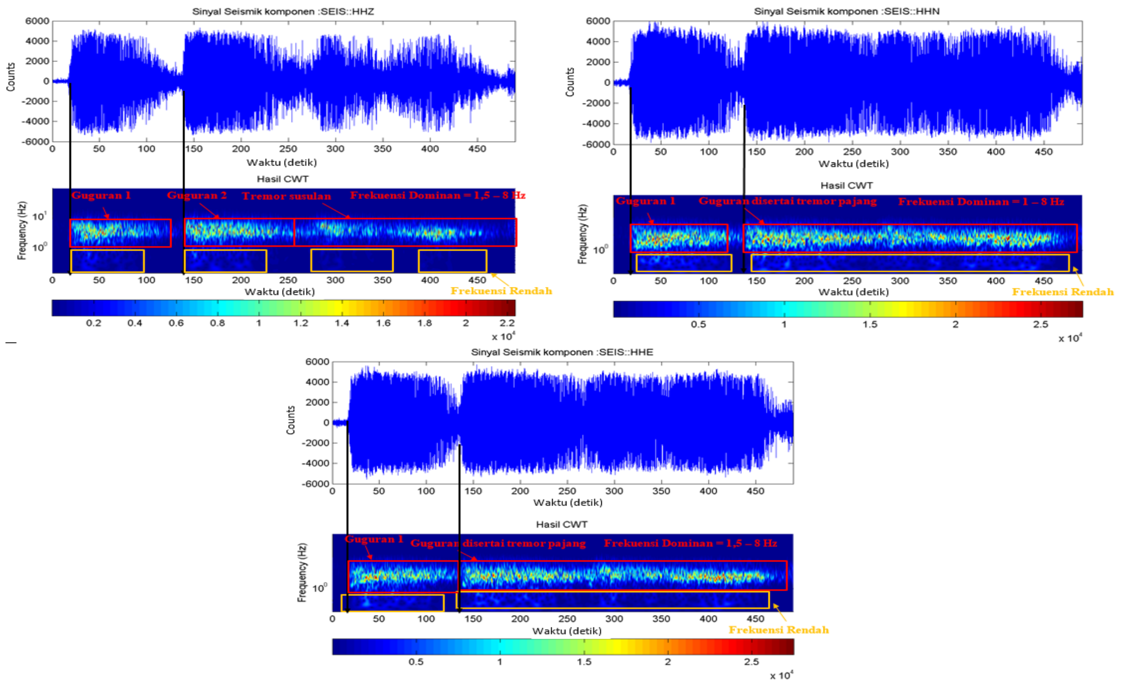

Figure 14:The Continuous Wavelet Transform Results of the Lava Avalanche event eruption data in 2006

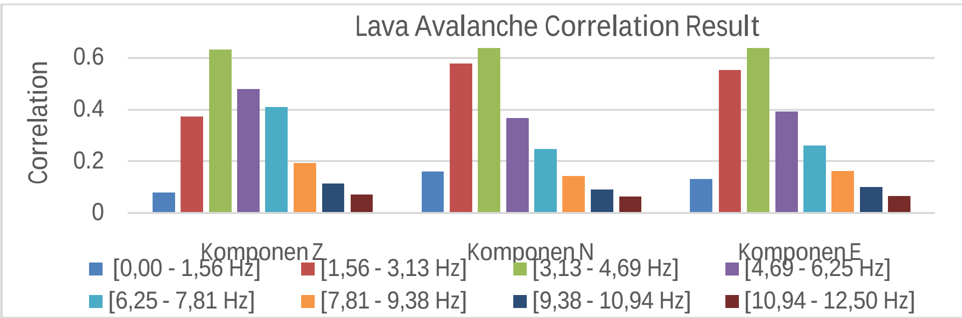

Figure 15: The WAVEDECOR results of Lava Avalanche event eruption data in 2006

II. COMPARISON OF 2006 AND 1996 ERUPTION EVENTS

The comparison of the results of the Merapi eruption event using the WAVEDECOR method is based on the three dominant frequency bands of the three events, namely VT-A, VT-B, and MP.Table 1 shows the first dominant results at low frequencies, this is due to the presence of microseismic waves which is recorded in the event, so that the first dominant will be ignored, while the second and third dominants become the main dominant frequency band for reference in this event, the same applies to VT-B and MP. The dominant frequency band in this event is dominated by medium and high frequencies, where the main dominant is 4.69 - 6.25 Hz followed by a high frequency of 6.25 - 7.81 Hz.

The results of the WAVEDECOR method with 2006 data, shown in Table 4, has the same results, with frequency dominant at medium to high frequencies. The dominance of the main frequency band in the 2006 data lies in the high frequency, ie. 6.25 - 7.81 Hz and followed by the intermediate frequency (4.69 - 6.25 Hz). This shows the similarity of the dominant frequency distribution in medium up to high frequencies although the dominance of the first and second frequency bands is different.

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Table 2 shows the dominantat the intermediate frequency band, which is 4.69 - 6.25 Hz and the high-frequency band 6.25 - 7.81 Hz. The findings in the 2006 data, which are shown in Table 5, show the dominance of the intermediate frequency band, namely 3.13 - 4.69 Hz and 4.69 - 6.25 Hz followed by the high-frequency band 6.25 - 7.81 Hz at third frequency dominant. This shows a slightly different matter where the VT-B event in the 1996 data was dominated by medium to high-frequency bands, whereas in the 2006 data it was more likely to be intermediate frequency even though it was followed by a high-frequency band afterward.

Table 1The WAVEDECOR result of VT-Aevent of 1996 data[3]

Dominant	**Frequency Range (Hz)**		
	SE	**SN**	**SZ**
I	0 – 1,56	0 – 1,56	0 – 1,56
II	4,69 – 6,25	4,69 – 6,25	4,69 – 6,25
III	6,25 – 7,81	6,25 – 7,81	6,25 – 7,81

Table2The WAVEDECOR result of VT-Bevent of 1996 data[3]

Dominant	**Frequency Range (Hz)**		
	SE	**SN**	**SZ**
I	0 – 1,56	0 – 1,56	0 – 1,56
II	4,69 – 6,25	4,69 – 6,25	4,69 – 6,25
III	6,25 – 7,81	3,13 – 4,69	6,25 – 7,81

Table3The WAVEDECOR result of MPevent of 1996 data[3]

Dominant	**Frequency Range (Hz)**		
	SE	**SN**	**SZ**
I	1,56 – 3,13	1,56 – 3,13	3,13 – 4,69
II	3,13 – 4,69	3,13 – 4,69	4,69 – 6,25
III	4,69 – 6,25	4,69 – 6,25	1,56 – 3,13

The results of Putra's finding [3], Table 3, shows a low-frequency dominant, namely 1.56 - 3.13 Hz followed by the intermediate frequency, namely 3.13 - 4.69 Hz and 4.69 - 6.25 Hz. The findings for the 2006 data, Table 6, show the dominance of intermediate frequencies, namely 3.13 - 4.69 followed by 4.69 - 6.25 Hz, and followed by a low frequency of 1.56 - 3.13 Hz. These findings indicate that the frequency distribution of MP events in 1996 and 2006 shows the distribution results of similar frequency bands.

Table4The WAVEDECOR result of VT-Aevent of 2006 data

Dominant	**Frequency Range (Hz)**		
	SE	**SN**	**SZ**
I	4,69 – 6,25	6,25 – 7,81	6,25 – 7,81
II	6,25 – 7,81	3,13 – 4,69	4,69 – 6,25
III	3,13 – 4,69	4,69 – 6,25	3,13 – 4,69

Table5The WAVEDECOR result of VT-Bevent of 1996 data

Dominant	**Frequency Range (Hz)**		
	SE	**SN**	**SZ**
I	3,13 – 4,69	3,13 – 4,69	4,69 – 6,25
II	4,69 – 6,25	4,69 – 6,25	3,13 – 4,69
III	6,25 – 7,81	1,56 - 3,13	6,25 – 7,81

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Table6The WAVEDECOR result of MPevent of 1996 data

Dominant	Frequency Range (Hz)		
	SE	SN	SZ
I	3,13 – 4,69	3,13 – 4,69	4,69 – 6,25
II	4,69 – 6,25	1,56 - 3,13	3,13 – 4,69
III	1,56 - 3,13	4,69 – 6,25	6,25 – 7,81

IV. CONCLUSION

The CWT shows the pattern of events that occurred on the eruption on June 4, 2006, with the emergence of the earthquake VT-A, LF, VT-B, MP, and Lava avalanche (Tremor Earthquake).

The WAVEDECOR method shows that the dominant frequency band in the VT-A event tends to be in the high-frequency band, LF event in the low-frequency band, VT-B event in the medium frequency band, Tremor in the intermediate frequency band, and MP event in the medium frequency band.

Comparison of data analysis from 1996 and 2006 eruptions showed similar findings for dominant frequencies in VT-A event with dominanttfrequency in medium to high-frequency bands and MP event with dominanttfrequency in the mid to medium frequency bands. The findings in the VT-B event showed that the dominant frequency pattern was slightly different from the 1996 data which showed at medium to high-frequency while for the 2006 data showed only at medium frequency.

V. SUGGESTION

Further processing should be carried out with the 2006 eruption data on another date and also with the 2010 eruption data for comparison.

ACKNOWLEDGMENT

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REFERENCES

[1] M. Ohrnberger, “Continuous Automatic Classification of Seismic Signals of Volcanic Origin at Mt.Merapi,Java, Indonesia,” Potsdam University, 2001.
[2] A. Fadeli, “Location of Seismic Source of Merapi (Central Java) with Impulsive character,” *Sci. Ser. International Bur.*, vol. 4, pp. 137–148, 1990.
[3] A. E. Putra, “Transformasi Paket Wavelet, Dekomposisi Wavelet Dan Korelasi Pada Data Seismik Gunung Merapi, Jawa - Indonesia,” *Semin. Nas. Teknol. Inf.*, pp. 1–7, 2006.
[4] A. E. Putra, A. Susanto, K. S. Brotopuspito, and J. E. Istiyanto, “Analisis Sinyal Non-Stasioner Menggunakan Metode Adaplet(Penapis Adaptif Berbasis Wavelet),” *Semin. Nas. Inform.*, vol. 1, pp. 1–11, 2008.
[5] A. Graps, “Introduction to wavelets,” *IEEE Comput. Sci. Eng.*, vol. 2, no. 2, pp. 50–61, 1995.
[6] E. Shokrollahi, G. Zargar, and M. A. Riahi, “Using Continuous Wavelet Transform and Short Time Fourier Transform as Spectral Decomposition Methods to Detect of Stratigraphic Channel in One of the Iranian South-West Oil Fields,” pp. 291–299, 2013.
[7] S. Chopra and K. J. Marfurt, “Choice of mother wavelets in CWT spectral decomposition,” in *SEG New Orleans Annual Meeting*, 2015, pp. 2957–2961.
[8] J. Wassermann, “Volcano Seismology,” in *New Manual of Seismological Observatory Practice 2 (NMSOP-2)*, no. August 2011, pp. 1–80.
[9] Dairoh and W. Suryanto, “Dekomposisi Wavelet Data Seismic Broadband dari Stasiun Wanagama Yogyakarta pada saat Letusan Gunung Merapi 2010” , Jurnal Fisika dan Aplikasinya, *Vol. 13*, no. 2, pp. 49–55, 2017.