RSEM Modelling for Eruption Precursors Investigation on Lokon Volcano

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Abstract. Acceleration of volcanic activity can be detected from changes in the amplitude and energy of the seismic signals recorded around the volcano. The acceleration can be described from RSEM modelling. RSEM is useful for determining eruption precursors on volcanoes. In this study, the calculation of the cumulative RSEM value on Lokon Volcano used a very powerful software, namely ObsPy. Based on the RSEM model, the eruption of Mount Lokon on 12 September 2014 was different in character from the eruption on 20 May 2015. One was dominated by hybrid earthquakes and the other was triggered by volcanic earthquakes. These result showed that RSEM modelling can be used to investigate precursor of eruption.

1. Introduction

Seismic signals emitted by sources of volcanic activity contain a number of energies which can be important indicators in studying the behavior of volcanic eruptions. The real-time seismic energy measurement (RSEM) is a parameter that can describe the rate of seismic energy release during periods of intense volcanic activity [1]. RSEM is the standard deviation of the squared amplitude of the seismic signal over a certain time interval divided by the number of measurements [2]. Based on the cumulative RSEM model, investigations of the dominant seismic precursor triggered an eruption were carried out. RSEM modeling of seismic signal data can be done effectively using the ObsPy device which is designed to access and process seismic waveform data and metadata based on the Python programming language [2] [3] [4].

RSEM analysis using ObsPy will be useful to identify kind of frequencies associated with earthquakes on volcano. Thus, type of earthquake related with acceleration of volcanic activity can be determined. In this study, modelling of RSEM implemented on seismic data of Lokon Volcano and connected to eruption at September 12th, 2014 and May 20th, 2015.
2. Material and Method

The data used in this research are seismic recording data in Seisan format of Empung Station during June 2014 until September 2014 dan during January until May 2015. These data obtained from KKVO at Tomohon. Data were converted into MSEED format and stored in stream of the ObsPy. In the calculation of RSEM and their cumulative, seismic signals were divided into 5 frequency categories, namely 1-16 Hz, 1-3 Hz, 3-5 Hz, 5-10 Hz and 10-16 Hz. Then, cumulative RSEM were plotted using matplotlib modul in Python 2. Based on the graph of cumulative RSEM, eruption precursor were investigated.

3. Results and Discussion

RSEM modeling in this study were applied to seismic signal data related to the Mount Lokon eruption on September 12nd, 2014 at 19:00 UTC (see Figure 1) and May 20th 2015 at 07:20 UTC (Figure 2). The cumulative RSEM model in Figure 1 shows that a seismic signal with a frequency between 1-3 Hz has the same pattern as an overall seismic signal with a frequency of 1-16 Hz. The accelerated RSEM increase of the 1-3 Hz seismic signal indicated by the red dashed elliptical curve in Figure 1 was observed on 18-22 June 2014 and about 3 days before the eruption. Seismic signals with a frequency of 1-3 Hz were very dominant prior to the eruption. The seismic signal correlates with long period (LP) earthquakes and hybrid earthquakes [5]. Hybrid earthquakes are a combination of signal and frequency characteristics between LP earthquakes and shallow volcanic earthquakes (VB), while LP earthquakes are gusts of high energy gas which are locally called gusts of earthquake [6]. The increase in LP earthquakes correlates with an increase in degassing or the release of water vapor due to high pressure around the crater [6]. Increasing of hybrid earthquakes is in line with the increased flow of fluids or gases that break through rock fractures, causing vibrations [7].

Figure 1. Graph of Cumulative RSEM June until September, 2014 (Vertical red line state eruption at September 12nd, 2014 19:00 UTC).
The cumulative RSEM model in Figure 2 shows that the eruption that occurred on 20 May 2015 at 07:20 UTC was marked by a significant increase in seismic signals with a frequency of 1-3 Hz (dotted ellipse light blue) followed by an acceleration of 10-16 Hz seismic signals. (marked with a dashed ellipse in red). Seismic signals with a frequency of 10-16 Hz are associated with shallow volcanic-tectonic earthquakes (VB) and an increase in VB earthquakes is a marker for explosive eruptions of the volcanic type [8]. The volcanic type eruption was also confirmed through the microstructure analysis of the andesite and vesicular ash [9]. The acceleration of the number of VB earthquakes is related to the increase in scouring of the magma plug due to increased gas pressure [8]. The presence of a magma plug can be confirmed by the eruption product in the form of a volcanic bomb [10].

![Figure 2. Graph of Cumulative RSEM January until May, 2015 (Vertical red line state eruption at May 20th, 2015).](image)

The Geological Agency confirmed that the eruption on September 12, 2014 at 19:00 UTC was a small, phreatic type eruption with an eruption column height of about 500 m [5]. Phreatic eruptions are associated with an ash emission process that begins with the migration of low frequency seismic signals from 0.3 to 3 Hz [11]. The eruption on May 20 2015 at 07:20 UTC was an eruption accompanied by a bang with a black eruption column and was a small volcanic type. The two eruptions were clearly of different character and these could be inferred from the RSEM model.

4. Conclusion

The significance of the differences between the two eruption types is indicated by differences in the cumulative RSEM model as well as differences in the types of precursors and differences in energy intensity. The precursors associated with the eruption of Mount Lokon on 12 September 2014 were hybrid earthquakes, while the precursors for the eruption on 20 May 2020 were volcanic earthquakes. The results of this research indicate that seismic precursors can be detected from the cumulative RSEM model.
Acknowledgment

We gratefully acknowledge the support of LPPM Unsrat for funding this research through PDUPT 2019 Grant.

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