Surface temperature changes of the crater of Agung Volcano from Landsat-8 TIRS during 2017-2018 eruption

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Abstract. This paper described the application of Landsat-8 TIRS (Thermal Infra Red Sensor) to analyze the surface temperature changes of the crater region of Agung volcano during early of 2013 until late of 2019. Agung volcano is an active stratovolcano located in Bali island. We processed the brightness temperature from channel-10 of Landsat-8 TIRS during early of 2013 – late of 2019 and analyzed the changes. The results of this research showed that the eruptions that occurred during 2017 - 2018 have indicated highly increasing in the surface temperature of the crater region. The surface temperature changes of the crater region, which can be detected from Landsat-8 TIRS data, can be used as a precursor of an eruption.

1. Introduction
Agung Volcano is a composite stratovolcano that is conical in shape with an open crater[1]. The Agung volcano, located in Bali (Figure 1), erupted in late November 2017 after several years of quiescence. Hundreds of flights have been cancelled because of ash pollution, causing a major air traffic disturbance in Indonesia[2]. Previous eruptions in 1808, 1821, 1843 and 1963 showed similar types, including those that were explosive (eruption, by throwing incandescent rocks, lava fragments, pyroclastic rain and ash), and effusive in the form of hot cloud flow, and lava flow[3]. Bali is the most popular tourist destination in Indonesia, especially for foreign tourists. The eruption of Agung Volcano, which is located in the heart of the island of Bali, from the end of 2017 to the middle of early 2018, of course had an impact on the decreasing number of tourists coming, as a direct impact due to the disruption of transportation wheels, especially air transportation to and from I Gusti Airport Ngurah Rai. In addition, increased volcanic activity has caused evacuation of people living in disaster prone areas. Due to the large impact caused by volcanic eruption, disaster mitigation efforts are more oriented to the development of an early warning system for eruption. This study aims to identify the symptoms or precursors of volcanic eruptions using remote sensing image data, using thermal channels. Image data used in this study were a time series of Landsat-8 TIRS, during eruption and inter-eruption periods. Previous studies have shown that thermal image data is very useful for monitoring and mapping related to volcanic eruption disasters, namely by using Landsat data[4][5][6][7][8][9][10], AVHRR [11], MODIS [12][13][14][15], Himawari[2]and also ASTER[16][17]. The advantage of this study compared to previous studies is the use of medium
resolution TIRS data from Landsat-8, the latest generation of Landsat series, over a long period of
time in time series, which covers eruption and inter-eruption periods.

![Figure 1](https://www.google.co.id/maps) ![Figure 1](http://landsat-catalog.lapan.go.id/)

**Figure 1.** Agung Volcano, the research location (red rectangle), was lied in Bali island (a). The Agung Volcano seen from Landsat-8, 26 August 2017 (b). Map source: [https://www.google.co.id/maps](https://www.google.co.id/maps). Image source: [http://landsat-catalog.lapan.go.id/](http://landsat-catalog.lapan.go.id/).

2. Methods

2.1. Data

61 Landsat-8 TIRS imageries, from early of 2013 to late of 2019 were processed to obtain the band 10 brightness temperature (BT10) of the crater region of Agung volcano. Landsat-8 data were collected through the [http://landsat-catalog.lapan.go.id/](http://landsat-catalog.lapan.go.id/) from the Remote Sensing Technology and Data Center of the Indonesian National Institute of Aeronautics and Space (LAPAN) and from Google Earth Engine through [https://developers.google.com/earth-engine/datasets/catalog/LANDSAT_LC08_C01_T1_TOA](https://developers.google.com/earth-engine/datasets/catalog/LANDSAT_LC08_C01_T1_TOA).

2.2. Data Pre-processing

The Landsat-8 TIRS Imageries were transformed to Spectral Radiance Top of Atmosphere (TOA) (Equation 1) and then converted to TOA brightness temperature(Equation 2)[17]. Then, DOS1 (Dark Object Subtraction 1) was implemented[18].

\[ L_\lambda = M_\lambda Q_{cal} + A_\lambda \]  

\[ T = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)} \]

where \( L_\lambda \) is TOA spectral radiance (Watts/(m\(^2\)*sr*μm)), \( M_\lambda \) is a Band-specific multiplicative rescaling factor, \( A_\lambda \) is a Band-specific additive rescaling factor, and \( Q_{cal} \) is the Quantized and calibrated standard product pixel values (DN). \( T \) is the at-satellite brightness temperature (K), \( L_\lambda \) is TOA spectral radiance, and \( K_1 \) and \( K_2 \) are Band-specific thermal conversion constants.

2.3. Data Analyzing

Time series and spatial analyzing of brightness temperature data of crater region was conducted to understand the dynamics of volcanic eruption activity. In this study, the basic concept underlying it is that the increasing of temperature on the crater is one of the precursors of volcano eruption[19].
3. Results

3.1. The temporal dynamic of brightness temperature

Figure 2 showed the dynamic of brightness temperature of Agung Volcano’s crater region from early of 2013 until late of 2019. Based on the graph, it can be seen that generally the increase in eruption activity from 2017 - 2018 shows an highly increasing in the brightness temperature value. Also, it can be identified that from early of 2013 until late of 2019, there were at least seven times periods of marked increase in volcanic activity (marked by dotted black rectangles).

Based on these graph can also be known the condition of volcanic activity of Agung volcano based on the brightness temperature values recorded from Landsat-8 TIRS imagery, namely normal active conditions (the temperature region between the green and red dotted lines, with the average on the blue dotted line). The red dotted line is the threshold of the Agung volcano being in an eruption condition.

3.2. The spatial distribution of the brightness temperature

Figure 3 showed the spatial distribution of the brightness temperature around the crater region during eruption and inter-eruption periods. The images showed the spatial distribution of the brightness temperature around the crater region during eruption and inter-eruption periods, in 2017-2018. From the images (10 June 2018 and 28 July 2018), they appear the increasing of brightness temperature of Agung Volcano’s crater region during eruption periods. Also, it can be identified that, the eruption center of Agung volcano is in the crater region.

3.3. The results of observations at the Post of Merapi Volcano Observation, as confirmation of the results of image analysis

Information on the eruption of Agung volcano on 13 June 2018 and 25 July 2018, confirmed the results of the analysis of the images. It was stated that there was an eruption of Agung volcano on 13 June 2018 at 03:05 GMT with the height of the ash column observed ± 2,000 m above the crater (± 5,142 m above sea level). The gray column was observed with a thick intensity leaning towards the
Southwest and West. This eruption was recorded on a seismogram with a maximum amplitude of 25 mm and a duration of ± 2 minutes 12 seconds[20]. Also, there has been an eruption on 24 July 2018 at 16:41 GMT with the height of the ash column observed ± 700 m above the crater (± 3,842 m above sea level). The ash column was observed to be white to gray with thick intensity leaning East and Southeast. This eruption was recorded on a seismogram with a maximum amplitude of 7 mm and a duration of ± 2 minutes 15 seconds[21].

4. Conclusion
Eruption phase shows an increase in brightness temperature, both temporally and spatially. The eruptions that occurred during 2017 - 2018 have indicated highly increasing in the surface temperature of the crater region. The surface temperature changes of the crater region, by which can be detected from time series Landsat-8 TIRS data, can be used as a precursor during an eruption event. More research needs to be done on the use of TIRS Landsat-8 TIRS data to analyze the precursor of other types volcanoes in Indonesia.

![Figure 3. Spatial distribution of the brightness temperature around the crater region (black rectangles) during eruption (e,f) and inter-eruption periods (a, b, c, d).](image)

**Figure 3.** Spatial distribution of the brightness temperature around the crater region (black rectangles) during eruption (e,f) and inter-eruption periods (a, b, c, d).

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