DETECTION OF THERMAL CHNAGES POSSIBLY ASSOCIATED WITH VOLCANIC ACTIVITY WITH LESS FAINT CHANGES FROM MODIS

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1. Introduction

There are many reports in natural disasters such as volcanic activity and earthquakes. To mitigate these disasters, monitoring of the crustal activity is important. But it is difficult to monitor all volcanoes on the ground. On the other hand, satellite remote sensing on temperature anomaly is one of the most effective methods to monitor volcanic activity, because it can monitor in a wide area at a time and with a high frequency on a day. We use the MODerate Resolution Imaging Spectroradiometer (MODIS) sensor on board AQUA satellite for volcanic activity monitoring in this paper. MODIS has 36 different bands. Band 20 of MODIS has a character of less influence from atmosphere but a tendency to give lower temperature for cloud surface. Bands 31 and 32 of MODIS are more sensitive to clouds. Therefore, these bands are considered the best tool for monitoring volcanic activity for MODIS. The previous studies focus on the variation of temperature around the targets such as a crater and there is a possibility to include spurious changes due to meteorological condition, seasonal factors, and so on. Since a brightness temperature observed by MODIS is affected by various factors. Therefore, in order to extract a brightness temperature by a specific cause, it is effective to consider a difference between adequate reference points. In this paper, differential brightness temperature is computed for extracting regional or global changes in an image. Then, the differential brightness temperature is evaluated in singularity over all the analyzed period in time and space. The purpose of this paper is to present the developed algorithm for detecting thermal temperature anomaly associated with a volcanic eruption by MODIS and demonstrate the effectiveness of practical application to eruptions of Mt. Merapi, Mt. Krakatau, Mt. Kerut and Mt. Semelu volcanoes in Indonesia and Mt. Asama volcano in Japan.

2. Data processing of MODIS data

In this paper, we analyze the band 20 for surface temperature investigation and bands 31 and 32 to remove cloud effects. The. data processing is as follows:

(1) MODIS binary data are converted into brightness temperature, and make the daily map of the brightness temperature which has an area of 1 square degree centered at target pixel of the summit or the crater.

(2) Computation of differential brightness temperature.

Differential brightness temperature is defined by the brightness temperature at the focused point (FP) and the four reference points (RP) with a certain distance in the north, east, south and west direction from the FP (Maeda and Takano, 2008).

$$\begin{cases} S_{FP} = BT_{FP} - BT_{RP} & (BT_{FP} > 0, BT_{RP} > 0, BT_{FP} - BT_{RP} > 0) \\ S_{FP} = 0 & (otherwise) \end{cases}$$

S_{FP}, BT_{FP}, and BT_{RP} are differential brightness temperature, brightness temperatures at the focused point and the reference point, respectively. S_{FP} is computed for all pixels in one scene. Then, the time variation of S_{FP} is investigated for all pixels from the start of the analysis and the time for which S_{FP} becomes a maximum value in the series is registered for each Fp. The distance between RP and FP is 0.05 degrees (5 km) in this paper. The procedure is illustrated in Figure1.

(3) Reduction of cloud effect.

If we subtract brightness temperature at the RP with cloud from that at the FP, an inaccurate S_{FP} value is obtained. Because the brightness temperature of the cloud pixel is lower than that of the surface pixels. Therefore cloud effects should be removed. For this aim, brightness temperature at bands 31 and 32 are analyzed (Pergola et al., 2004).

(5) Evaluation of singularity.

Then, in order to evaluate the singularity of the largest S_{FP} , S_{MAX}, δ is defined as follows;

$$\delta = \frac{S_{FP}}{\bar{S}},$$

where S_{FP} is the average of S_{FP}.

3. Results

The analyzed period for Indonesian volcanoes is from January, 2003 to December, 2008 and from January, 2003 to April, 2009 for Mt. Asama volcanoes. Here we show the results of Mt. Merapi volcano. Mt. Merapi volcano is located at the middle of Java Island (7.542°S, 110.442°E) in Indonesia (see Figure 2). Mt. Merapi volcano is one of the most active volcanoes in the world and gave some distractive eruptions and killed many people in history. The resent remarkable volcanic activity was recorded from May 13, 2006 to the middle of July, 2006 (Global Volcanism Program, Merapi). Figure 3 is an example of the daily brightness temperature map in May 10, 2006 which is three days before the start of the eruption. The center of the figure is the summit of the Mt. Merapi. The procedure is given in the previous section (1). Some pixels with higher brightness temperature are confirmed near the summit.

Figure 4 (a) shows the variation of brightness temperature at the summit, and there are very high brightness temperatures in the volcanically active period colored by red. On the other hand, there is no increase of brightness temperature in the same period at the point far from the summit, as shown in Figure 4 (b). Figure 4 also provides a clear seasonal variation, that is, decrease of brightness temperature in the rainy season, which starts from September and ends February in Indonesia. Figures 5 (a) and 5 (b) explain the extraction of cloud effects clearly. Figure 5 (a) is a scene with cloudy area marked by C observed on March 7, 2007. The brightness temperature difference between band 31 and band 32 along the vertical line in Figure 5 (a), is illustrated in Figure 5 (b). A black line shows the brightness temperature difference on the observed day and a red means the monthly average of brightness temperature difference during the analyzed period from 2003 to 2008. Green and blue lines correspond to the average ±1σ, and the average ±2σ of the brightness temperature difference, respectively. It is found that there are two areas with values lower than the average -1σ, and these correspond to cloud pixels in Figure 5 (a). We examine many cases and the similar results are obtained. Therefore, it is defined that the value of the average -1σ is a criterion for eliminating the cloud effects for the case of Mt. Merapi volcano. Figures 6 (a) and 6 (b) are the distribution map of the singularity of the brightness temperature difference on March 7, 2007. Figure 5 (a) gives the corresponding original brightness temperature. Figure 7 indicates the time variation of the singularity at the summit. Vertical axis is the singularity, and horizontal axis is time. Red lines indicate the top 1% of the singularity values and these anomalous values are concentrated in the volcanically active period colored by red. Actually the top 5 values are detected in this period.

References

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Pergola, N., Marchese, F., Tramutoli, V., 2004. Automated detection if thermal features of active volcanoes by means of infrared AVHRR records. Remote Sensing of Environment, 93, 311-327.

Global Volcanism Program, Merapi, SI / USGS Weekly Volcanic Activity Reports, http://www.volcano.si.edu/world/volcano.cfm?vnum=0603-25=&volpage=weekly

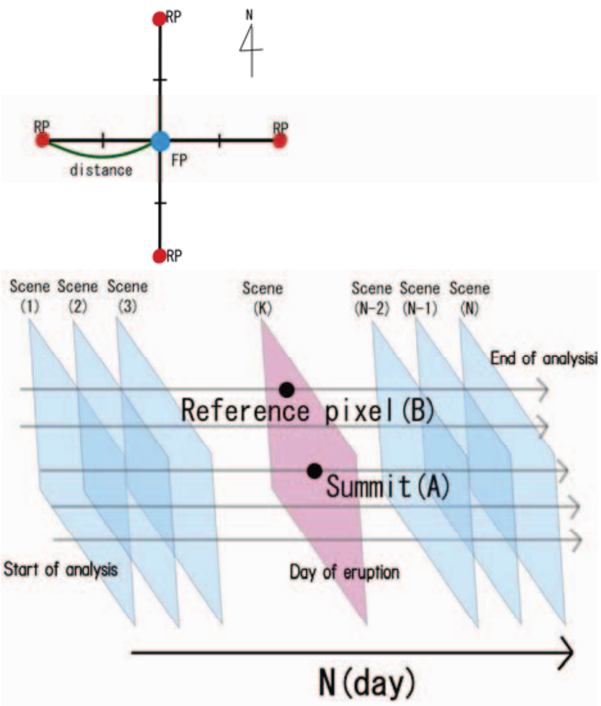

Fig. 1 Scheme of data processing

Fig. 2 Mt. Merapi volano

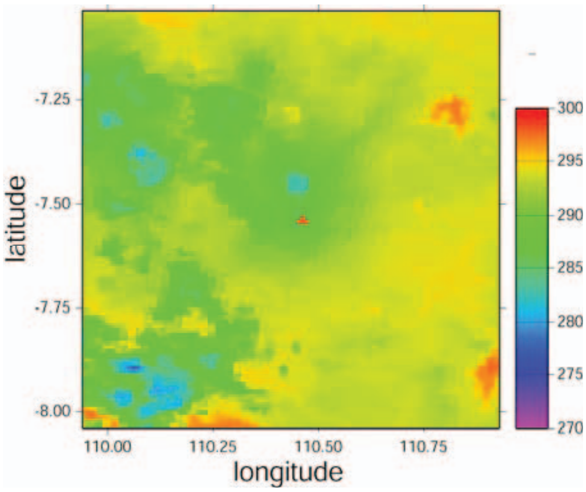

Fig. 3 An example of brightness temperature

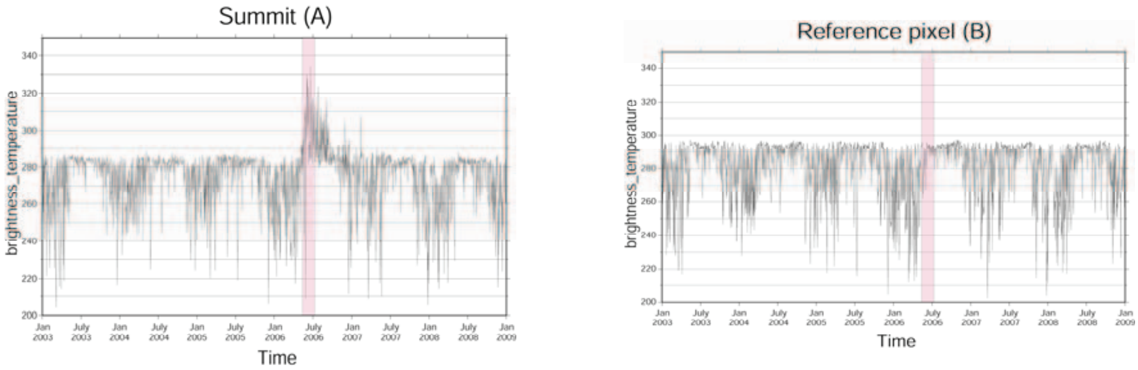

Fig. 4 Brightness temperature variation (a) Summit pixel and (b) pixel far away from the summit

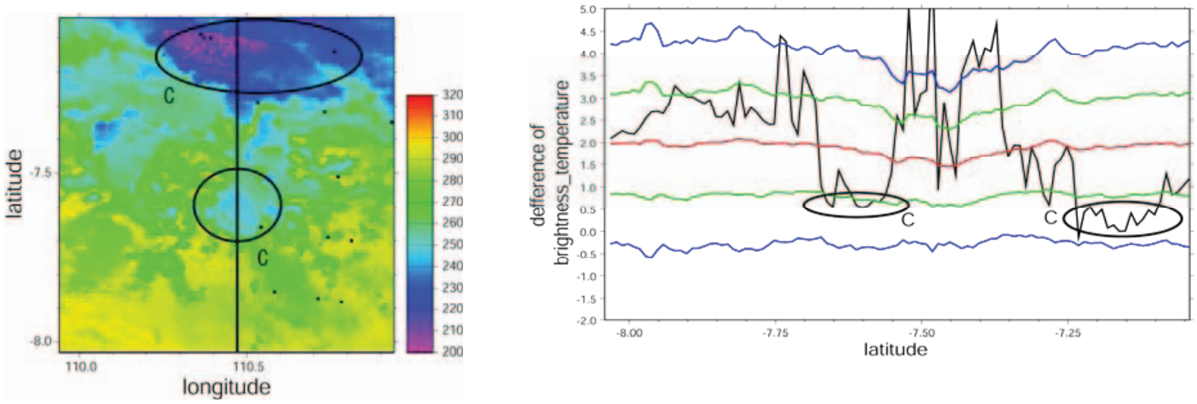

Fig. 5 Cloud effect reduction procedure (a) brightness temperature and (b) brightness temperature variation along the line in Fig.5 (a).

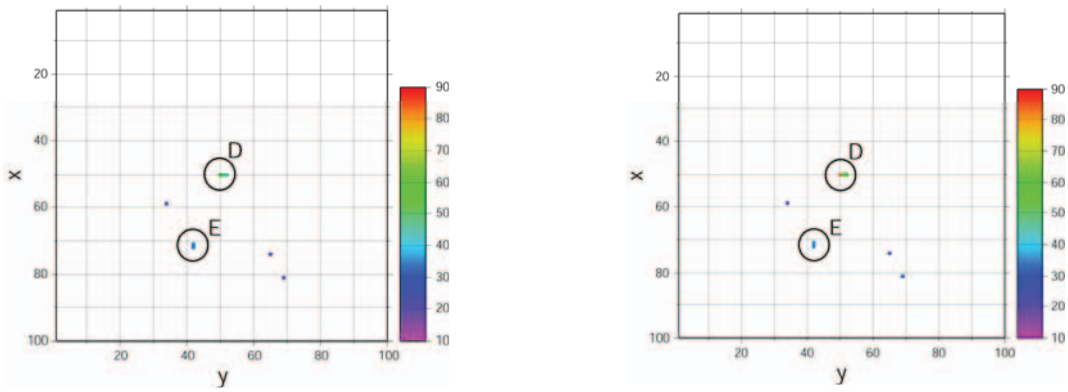

Fig. 6 (a) The distribution of the singularity on March 7, 2007, before the cloud effect reduction and (b) that after removing the cloud effect.

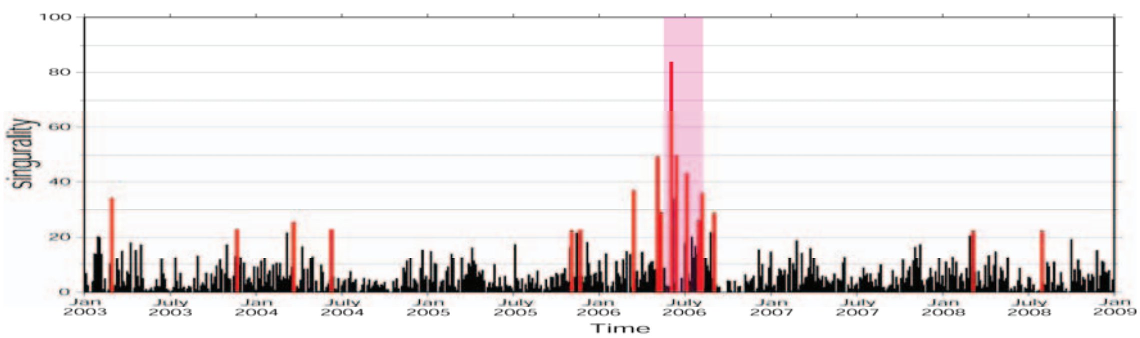

Fig.7 The variation of the singularity δ at the summit of Mt. Merapi volcano