Landscape Movement in Yogyakarta Mount Merapi Using D-InSAR Analysis

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Abstract: Mt. Merapi in Indonesia Yogyakarta is famous as active volcano. In October 2010, large-scale eruption and volcanic earthquakes affected the citizens of Yogyakarta. In addition, Yogyakarta is also famous as Sand mining place. Since Mt. Merapi is known as good quality sand place. The act of mining sand such as mountains, coasts, sandy beaches, and sedimentary debris flows is called Sand mining. Sand mining is the cause, coastal erosion, disasters such as floods and environmental problems such as landscape destruction and groundwater pollution are also generated.

The purpose of this paper is to detect Landscape movement in Yogyakarta Mt. Merapi using Differential Interferometry SAR analysis. In this study authors use ALOS-2/Sentinel-1 data for analysis. Consequently D-In-SAR image detect the change of landscape because of Sand mining and eruption. However, it is difficult to take a balance of coherence and variation amount. Ultimately, adapt the time series In-SAR analysis and explore the possibility of analysis using optical satellite images and UAV data. Time series Interferometry SAR analysis can reduces the error which contained in the Interferometry SAR image by statistically processing some of SAR images. Therefore, it is considered possible to accurately capture small variations such as sand mining, because Time series In-SAR can grasp the time transition of the variation, and highly accurate measurement. Moreover, it is thought that it is possible to grasp the signs and tendency of the eruption, and the change after the eruption by grasping the variation of the time series in the volcanic activity of Mt. Merapi. If it is possible to take the best use of the characteristics of the UAV, it is considered that it is possible to get the information such as end user (drillers, excavators, etc.) need which is about estimating the amount of sand mined by mining, and estimating the progress of the mining plan and the location at risk of landslide

１．INTRODUCTION

１.１　Background

Yogyakarta Special State is located on the south coast of central Java in the Republic of Indonesia, and its capital is Yogyakarta City. Cities are concentrated in the southern part of the state. Mt. Merapi which is active volcano, is located in the northern part of the state. Yogyakarta is one of the most prosperous agricultural areas due to the high-quality soil and water-keeping capacity of Mt. Merapi.

On the other hand, Mt. Merapi is also famous as an active volcano, and eruptions occur regularly. In October 2010, large-scale eruption and volcanic earthquakes affected the citizens of Yogyakarta. The most recently eruption occurred on February 13 and March 27, 2020. In Mt. Merapi, many volcanic debris are deposited at each eruption, resulting in topographic changes. In the rainy season, volcanic debris deposited by rainfall is eroded and flows out to the foot of the mountain as a debris flow. In addition, Yogyakarta is also famous as Sand mining place. Since Mt. Merapi is known as good quality sand place. Starting around 2010, sand has now been mined on a scale that greatly changes the terrain.

1 . 2 Sand mining

The act of mining sand such as mountains, coasts, sandy beaches, and sedimentary debris flows is called sand mining. Sand, which is one of the building materials, is increasing demand as the world's population increases. However, sand used in building materials such as concrete production is required to be of good quality, worldwide sand is said to be lack of supply.

Management of mining has become a major problem in this sand mining. Especially overseas, illegal sand mining, which is illegal to mines and get the sand, is carried out in many areas. In some area, sand mining is the cause, coastal erosion, disasters such as floods and environmental problems such as landscape destruction and groundwater pollution are also generated.

Figure 1 Sand mining in Mt. Merapi

1 . 3 The purpose of the research

Mt. Merapi in Yogyakarta is an area with significant topographic changes due to volcanic eruptions and sand mining. The purpose of this study is to detect land cover changes in Mt. Merapi over time using differential interferometry SAR analysis. In addition, considering about the application possibility of time series In-SAR analysis and the utilization of UAV in the field.

2 . ANALYSIS METHOD

2 . 1 D-In-SAR Analysis

The sensor used in the synthetic aperture radar (SAR) is a sensor that observes the reflected waves of microwaves irradiated on the ground surface. It is not like optical satellites. SAR is possible to obtain information of the reflection intensity and polarization of the ground. One of the application analysis using this data is interferometry SAR. Further difference Interferometry SAR, by interfering with the observation by two the same orbit, it is possible to capture the distance difference and variation between the satellite and the ground surface by taking a difference. Figure 2 shows an outline of crustal deformation extraction in a mountain by differential In-SAR. In general, the image obtained by the first SAR observation is called a Prime image, the image obtained by the second observation is called a Secondary image. To make interference images from the obtained data, it is necessary to calculate the complex conjugate product of Prime images and Secondary images, and to capture phase difference, it is necessary to remove orbital fringes, topographic stripes, errors caused by the atmosphere layer, errors caused by ionized layers, and other noises in order to capture variations.

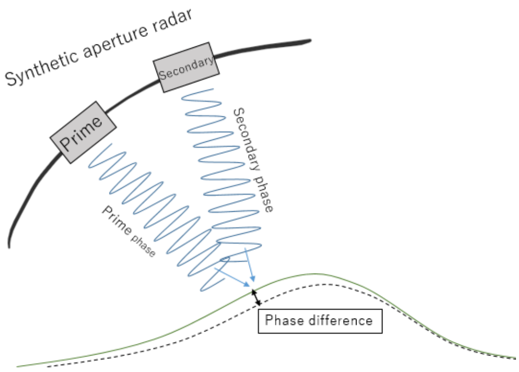

Figure 2 Outline of Differential-In-SAR

2 . 2 Satellite Data

In this study, ALOS-2/PALSAR-2 and Sentinel-1A are used to analyze the difference interference SAR at Mt. Merapi, Yogyakarta.

In ALOS-2, since operation started in 2014, this time the change extraction of sand mining is carried out by ALOS-2. As a combination considering the relationship between the amount of change in sand mining and coherence, we prepared data that the period difference between the two images of Prime image and Secondary image was one year, two months, and two weeks.

Sentinel-1A has also been in operation since 2014 and will detect land changes since 2014. Sentinel-1A is frequently observed and there is a lot of data available, so this time get the Sentinel-1A data by looking at the results of ALOS-2. The list of data used in the differential In-SAR analysis is shown in Table 1.

Table 1 Satellite data list

Satellite/Sensor	Direction	Sensing day (Prime-Secondary)
ALOS-2/ PALSAR-2	Ascending	2020/06/12-2020/08/07
	Descending	2015/04/13-2015/04/27
		2017/03/13-2017/05/22
		2018/05/21-2019/05/20
Sentinel-1A	Ascending	2020/03/16-2020/03/28

2 . 3 Reserch flow

The flowchart in this study is shown in Figure 3. In the differential Interferometry SAR analysis, we first pre-process the Prime image and the Secondary image of the prepared SAR. After registration, filtering process, phase unwrapping, geocoding, to obtain a differential In-SAR image.

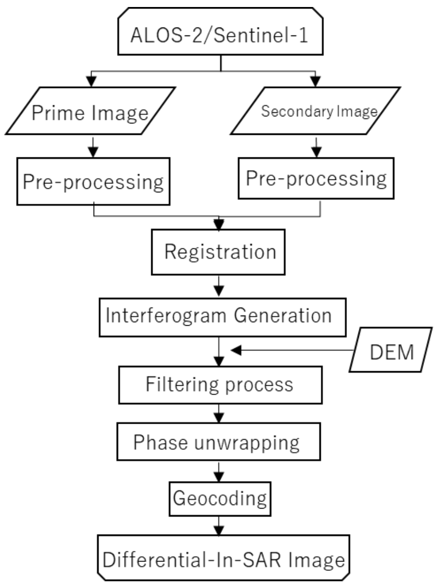

Figure 3 Differential-In-SAR Analysis flow

3 . Result of D-In-SAR

3 . 1 Analysis by ALOS-2

GMTSAR, an open software that can analyze interference, is used for differential Interferometry SAR analysis for ALOS-2 data. The color bar required to understand the analysis results are shown in Figure 4. The light blue portion of the center is the part where there is no result variation of phase 0. Since the wavelength of ALOS-2 is about 24 cm, the variation amount until the phase is 360 degrees. So,the next light blue is 12 cm. When the color line up like [light blue→red→blue→light blue], it can be said that it approaches the +12cm satellite. In addition, when the color line up like [light blue→blue→red→light blue], it can be said that it is 12cm away from the satellite, it's mean that the crust is sink.

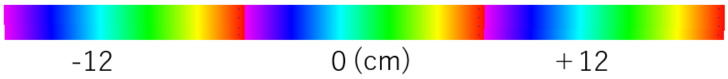

Figure 4 Displacement color bar of ALOS-2

Figure 5 shows the Differential Interferometry SAR analysis results of the period difference of May 21, 2018 and May 20, 2019 is about one year, the period difference between March 13, 2017 and May 22, 2017 in Figure 6 shows the Differential Interferometry SAR analysis results of about 2 months. As can be seen by comparing Figures 5 and 6, the period difference in Figure 5 is low coherence in the analysis results of one year, it is not possible to detect the correct information. As a result of the analysis results, the appropriate period difference in this study is considered to be two months.

It is displayed in Figure 6 as a representative of the analysis results of two months. The area enclosed in black is the Mt. Merapi which is this research purpose, and SAR data is based on the right-hand observation of the descending. This time result show some blue lines from the center of Mt. Merapi to the bottom right. Since the line is in the order of light blue to blue to red to light blue from the vicinity of the center, this line is away from the satellite, this mean that the Mt. Merapi crust is sink. Therefore it can be read that the ground surface from the top of Mt. Merapi to a little south from Figure 6 is subsidence of about 2cm. The variation in Mt. Merapi from March to May 2017 was only due to sand mining, and this can thought that the Differential Interferometry SAR analysis of the analysis was able to capture the change by sand mining.

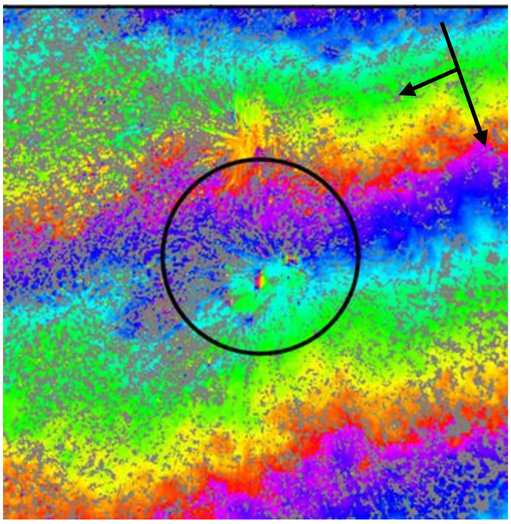

Figure 5 Result 1(2018/05/21-2019/05/20)

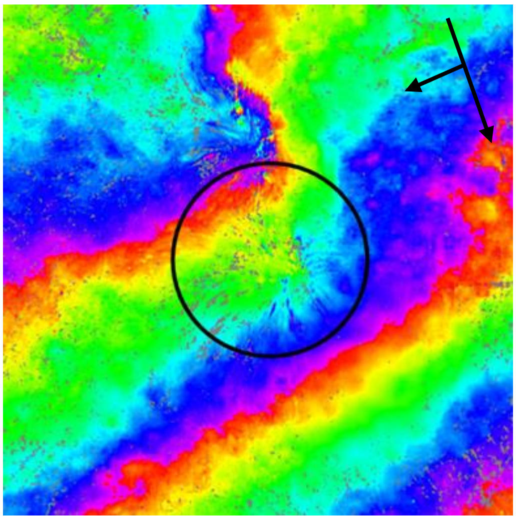

Figure 6 Result 2(2017/03/13-2017/05/22)

3 . 2 Analysis by Sentinel-1

The differential In-SAR analysis of Sentinel-1 uses SNAP from European Space Agency. The color bar required for the analysis result of Sentinel-1 as well as the analysis result of ALOS-2 is shown in the figure 7. Since the wavelength of Sentinel-1 is about 5.6 cm, the variation up to the next same color is 2.8 cm.

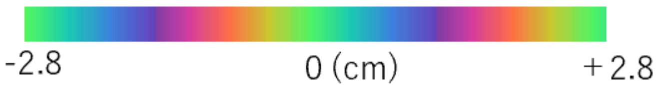

Figure 7 Displacement color bar of Sentinel-1

Figure 8 shows the analysis results of March 16, 2020 and March 28, 2020. During this period, Mt. Merapi had a small eruption on March 27. According to Figure 8, the color is changing from the vicinity of the top of the mountain to the foot. Because it is green to blue, it can be seen that the crust is bulged about a few cm from this analysis result. In other words, it can be said that it is possible to detect volcanic eludes ejected by volcanic.

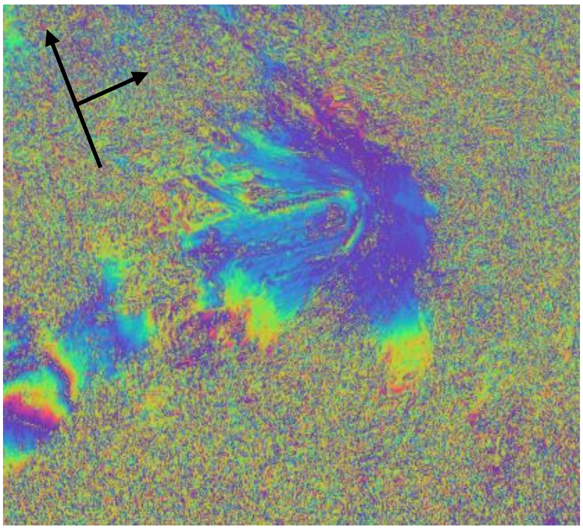

Figure 8 Result3 (2020/03/16-2020/03/26)

4 . Future study

4 . 1 Apply for Time Series In-SAR Analysis

In the method of D-In-SAR analysis, it is difficult to detect the change because of coherence and period of two images. When the period difference was increased, and the change could not be extracted. In addition, it was difficult to extract the change from the relationship between the low resolution and the amount of variation when the period difference is lowered. Therefore, in the current Interferometry SAR analysis technique, there is a time series interferometry SAR analysis can use. It is an application of Differential Interferometry SAR analysis. Time series interferometry SAR analysis reduces the error contained in the interferometry SAR image by statistically processing a large number of SAR images. Thus, in order to be able to grasp the time transition of the variation, in order to allow highly accurate measurement, it is considered possible to accurately capture small variations such as sand mining. Moreover, it is thought that it is possible to grasp the signs and tendency of the eruption, and the change after the eruption by grasping the variation of the time series in the volcanic activity of Mt. Merapi.

4 . 2 Utilization of UAV

Satellite data can observe widely. On the other hand, it is also effective to obtain high-resolution images using UAV locally. Figure 9 shows ortho image of the data taken in UAV at Mt. Merapi, Yogyakarta in January 2020. The UAV is Parrot's ANAFI, and the loaded camera can observe 4K and thermal infrared. The filming was done by the video from a height of 30 m, and the correction was done to the ortho image after returning to Japan. The resolution is about 10 cm, and it can be seen that the accuracy is considerably better than that of satellites. The position of the truck, the position of the excavator, and the active of mining can see in Figure 7.
As described above, it can be seen that it is also possible to observe very fine parts of the UAV. If it is possible to take the best use of the characteristics of this UAV, it is considered that it is possible to obtain information such as the end user (drillers, excavators, etc.) such as estimating the amount of sand mined by mining and estimating the progress of the mining plan and the location at risk of landslides.

Figure 9 Sand mining filmed by ANAFI

5 . Conclusoins

From the Differential Interferometry SAR of the period difference of two months, it was detected that there is a possibility of variation by Sand mining. In addition, from Sentinel-1, the state of the change due to the eruption was also extracted. However, it is necessary to verify this result. As a method, it is possible to capture the change in Mt. Merapi and its cause by utilizing optical satellite data. In addition, there is also a method of comparing the actual amount of variation in the field by numerically the amount of variation.

AlOS-2 and Sentinel-1 were mainly used in this study, but since the current method only captures changes, it is necessary to test the analysis method and the data used. As the next analysis method, it seems that time series interference SAR analysis is suitable. In addition, the use of ALOS-4 data which scheduled for launch in 2022 will expand the range of analysis. On the field study, the use of UAV is very effective and end users can get the information which they need.

6. Acknowledgment

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7. References

References from Journals:

Masaharu,FUJITA. 2012 Sediment Disaster due to Mt.MERAPI Eruption 2010. Annals of Disas Prev Res Inst, Kyoto Uni, No.55 A, 2012

Yousuke,NISIO. 2018. Sand mining in Mt.Merapi. JSECE No.83

Timokazu KOBAYASHI.2018. A Prototype System for InSAR time series analysis. Geographical Survey Inst 2018 No.130

References from websites:

Geographical Survey Inst-How to create a SAR interferometry imege from https://www.gsi.go.jp/uchusokuchi/sar_procedure.html

GMTSAR-An InSAR processing system based in GMT from https://topex.ucsd.edu/gmtsar/