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Proceeding of the 2018 Internasional Conference on Research and Learning of Physics

(ICRLP 2018)

Theme
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PREFACE

On behalf of the Committee, I would like to thank you for your participation in the 2018 International Conference on Research and Learning of Physics (ICRLP2018) which has been held at the Auditorium Universitas Negeri Padang, West Sumatra, Indonesia, August 9 - 10, 2018.

This ICRLP2018 is organized by the Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang. The main purpose of these conferences and seminar is the dissemination of the best research results from academics, researchers, professors, practitioners, observers, teachers, and students in both Physics Research and Physics Learning Research. This conference is expected to become a forum to discuss strategic issues in related fields. The two-day conference is expected to build cooperation between academics, researchers and institutions at both national and international levels. The scope of ICRLP 2018 covers various fields in Physics Research and Physics Learning Research.

I would like to express my sincere appreciation to all the participants, financial sponsors, exhibitors, supporting organizations and all the committee members who has made ICRLP2018 successful. With these strong support, we are sure ICRLP will be beneficial to all the participants, and you enjoy in Padang.

We are looking forward to meeting you in the next ICRLP.

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Ground deformation measurement of Sinabung vulcano eruption using DInSAR technique

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Ground deformation measurement of Sinabung vulcano eruption using DInSAR technique

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Abstract. Mt Sinabung has been erupting and spewing fumes many times in the recent year after inactive for four centuries. This paper investigates the ground deformation due to the Mt Sinabung eruption in February 2018 using Differential Interferometry Synthetic Aperture Radar Technique (DInSAR). The deformation observed and extracted from Sentinel 1A satellite data in ascending orbit that provided by Europe Space Agency (ESA). The result shows eruption direction and depth vulcanic fumes in millimeters units. This study will improve our mitigating and understanding to predict future eruption effect.

1. Introduction

Sinabung has been active volcano after four centuries. The first eruption occurred in August 2010 and continue until now. From August 2010 to September 2010, Sinabung has five times eruption and flow the white plume. Two years later, in September 2013 the volcano continue eruption, emit the white plume and ash plume at least 12 times until December 2013. The volcano shows its activity be more active in 2014 that starting from First January 2014 until December 2014. However, in this term, February 1, 2014, was a fatal eruption, because the eruption devours many victims of the soul. Nevertheless, the tragedy was not stopped, continuing every year until 2018. Monitoring and analyzing the hazard is required to obtain the information that can use to predict and prevent the fatalities of tragedy coming in future.

For this aim, the Differential Interferometry Synthetic Aperture Radar (SAR) technique is used to process and analyze the tragedy. The technique has proven in monitoring volcano activity included its deformation and volume [1],[2]. Also, capable to measure land deformation in millimeter precision with high resolution [3]. In processing, the technique measure phase difference between two acquisition of SAR data. In this case, the data ware used before and after the volcano eruption event which observed by Sentinel-1A and 1B (C-Band) satellite that provided by the European Space Agency (ESA). The satellite was selected upon the availability of SAR data in disparate geometry and orbit. Therefore, analyzing from a different point of view can be obtained.

The objectives of the research are measure ground deformation on Sinabung area due to the eruption on February 19, 2018, and determine the volcano ash spread direction. Then the result from D-InSAR technique validates using in-situ observation, Himawari satellite, and Sentinel-2A satellite images. The measurement is important as scientific information to predict, early warning system and preventing the victim in future.

2. Study area and satellite data set

The area of study is in Sinabung volcano that located at 3 10' 5.51'' N 98 23' 15.78'' E North Sumatra, Indonesia. The volcano grows up after the super-eruption at Toba Caldera 74 thousand years ago with altitude is 2460 m above sea level and 1.200 m above the surface []. After the first eruption on August 2010 Sinabung volcano has been an active volcano, which has tens times eruption until July 2018.

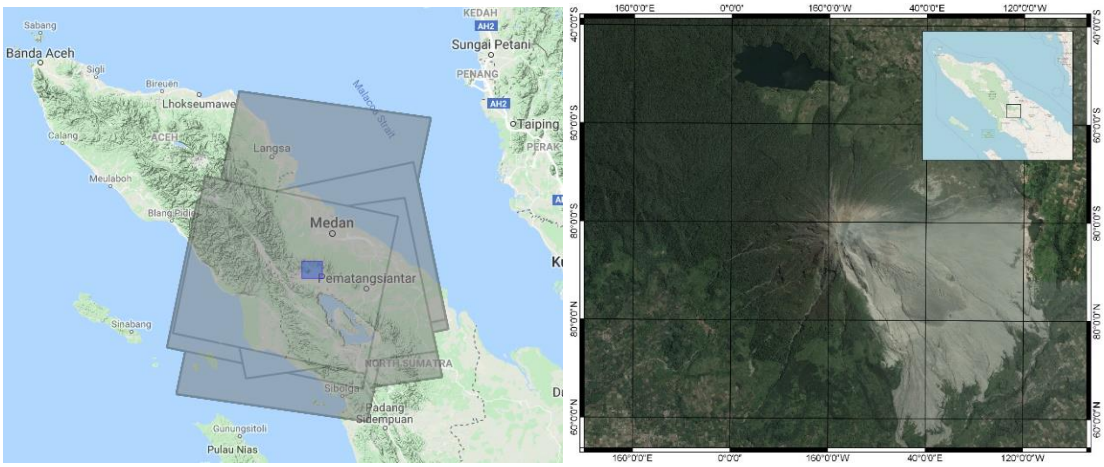


Figure 1. Map of Sinabung volcano at Karo regency, North Sumatra, Indonesia

The satellite data set used for this observation are Sentinel-1A and Sentinel-1B for both ascending and descending orbit. One pair SAR image before and after event used for each satellite orbit of Sentinel-1A and 1B. The type of SAR image is Interferometric Wide (IW) mode in Single Look Complex (SLC) format with has a spatial resolution of 5 m by 20 m [4]. The IW mode capture three sub-swaths using Terrain Observation with Progressive Scan SAR (TOPSAR). IW SLC format contains one image per sub-swath and one per polarization [5] with total there image for single polarization (SV) and six for dual polarization (DV)[4].

Table 1. Satellite dataset of Sentinel-1A and Sentinel-1B ascending orbit (part:143, frame: 1189) and descending orbit (part:62, frame:581).

Satellite mission	Acquisition time	λ (cm)	f_0 (GHz)	orbit	Beam mode	Pol.	Swath (km)	ΔT (days)
Sentinel-1A	08/02/2018	5.5	5.4	Ascending	IW2	VV+VH	250	12
	20/02/2018	5.5	5.4	Ascending	IW2	VV+VH	250	12
	14/02/2018	5.5	5.4	Descending	IW2	VV+VH	250	12
	26/02/2018	5.5	5.4	Descending	IW2	VV+VH	250	12
Sentinel-1B	14/02/2018	5.5	5.4	Ascending	IW2	VV+VH	250	12
	26/02/2018	5.5	5.4	Ascending	IW2	VV+VH	250	12
	08/02/2018	5.5	5.4	Descending	IW2	VV+VH	250	12
	20/02/2018	5.5	5.4	Descending	IW2	VV+VH	250	12

3. Methodology

Deformation measurement in Sinabung eruption is using Differential Interferometry Synthetic Aperture Radar (D-InSAR) technique. The technique calculates the phase difference between two SAR data [6] and removes its phase shift related to topography by generating a differential interferogram using Digital Elevation Model (DEM) [7].

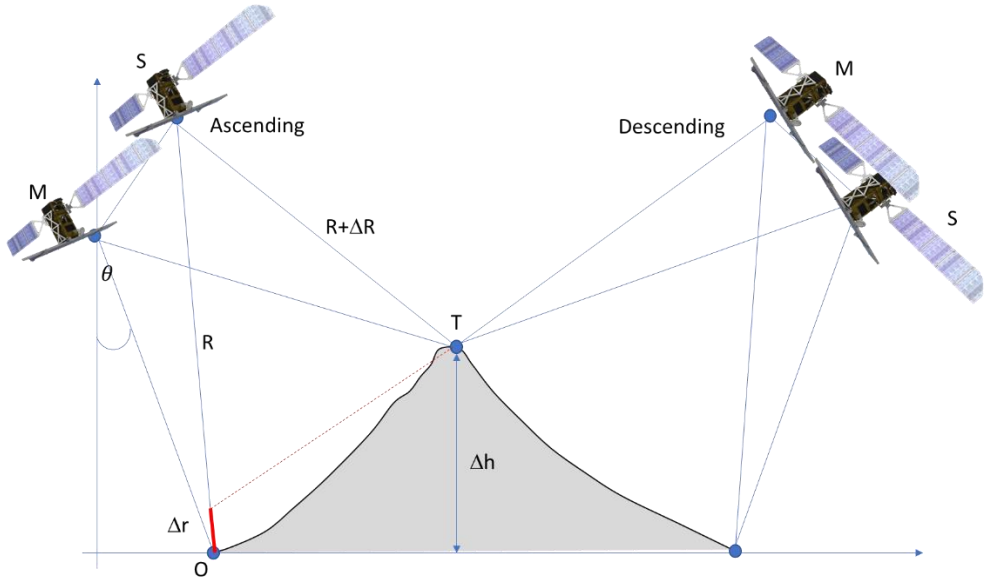


Figure 2. Geometry interferometry SAR image of Sinabung volcano observed by Sentinel-1A and 1B in both ascending and descending orbit

The phase variation of master and slave SAR images is expressed as

$$\phi_1 = 4\pi R/\lambda \quad (1)$$

$$\phi_2 = 4\pi(R + \Delta R)/\lambda \quad (2)$$

$$\Delta\phi = \phi_2 - \phi_2 = 4\pi\Delta R/\lambda \quad (3)$$

Where $\phi_1$and ϕ_2 is a phase of master and slave SAR image respectively, R is slant range and λ is wavelength radar transmitting.

The parameter that contributes to the phase difference is sourced from earth curvature, topographic, surface deformation, atmospheric condition and noise [8]. Mathematically can express as

$$\Delta\varphi = \Delta\varphi_{flat} + \Delta\varphi_{height} + \Delta\varphi_{disp.} + \Delta\varphi_{atm.} + \Delta\varphi_{noise} \quad (4)$$

$\Delta\varphi_{flat}$ is the flat earth phase that presents in the interferometric phase due to the curvature of the reference surface. The value is estimated from the orbit and metadata of SAR images. $\Delta\varphi_{height}$ is the contribution of topographic in interferometric phase due to the inaccuracy of reference DEM [9]. $\Delta\varphi_{disp.}$ is relative displacement of the target T to reference point. $\Delta\varphi_{atm.}$ is an interferometric phase that introduced by an atmospheric condition such as humidity, temperature, and pressure. $\Delta\varphi_{noise}$ is the noise that introduced by temporal condition, different look angle of both satellite and volume scattering [10].

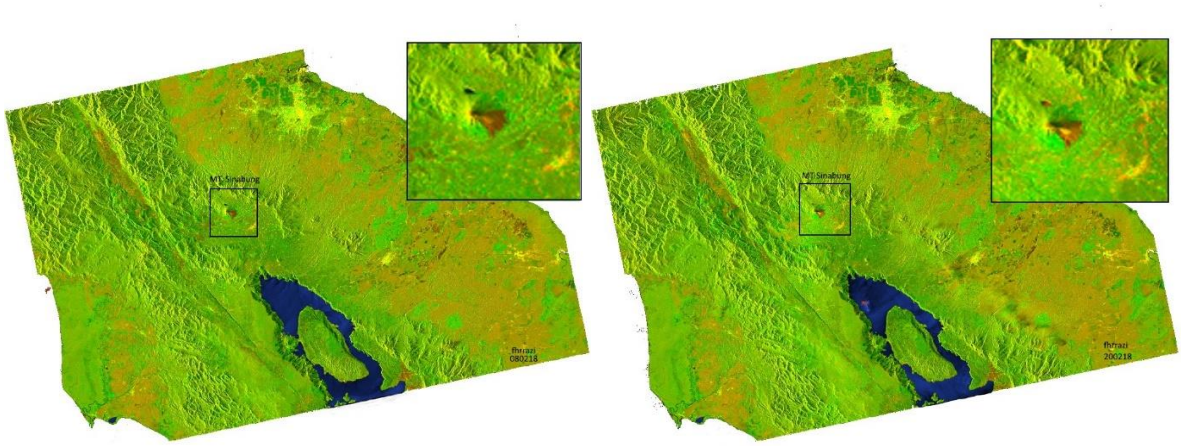
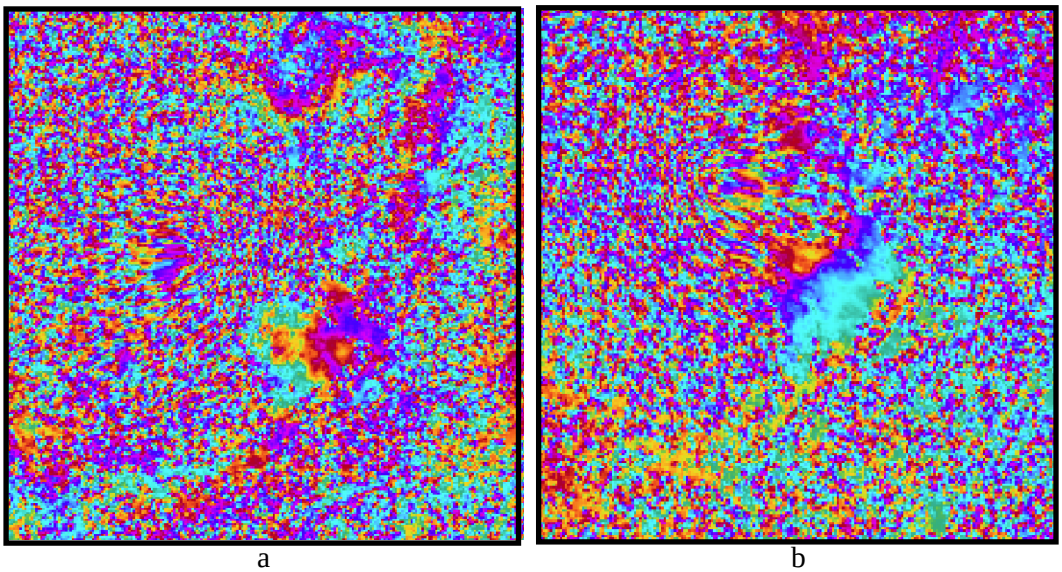


Figure 3. SAR image of Sentinel 1A Sinabung volcano area before eruption (08/02/2018) and after the eruption (20/02/2018).

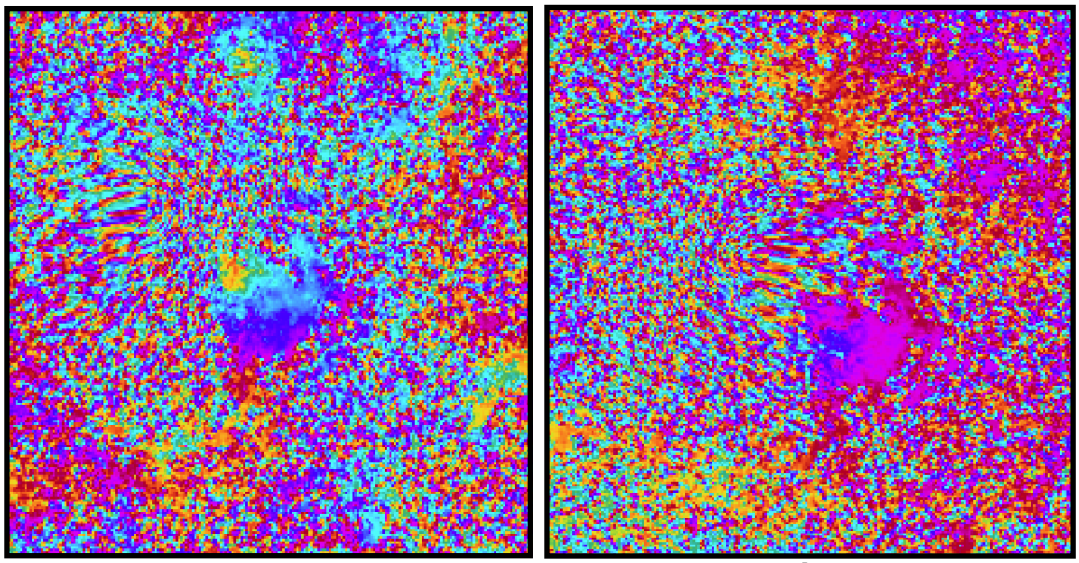
4. Result and Discussion

The deformation value of Sinabung eruption extracted from SAR satellite of Sentinel-1A and 1B by applied the D-InSAR technique. The technique compares the phase difference two complex radar SAR observation before and after the event with the same area [11]. The data before incident observed from ascending and descending orbit is on February 8, 2018, and February 14, 2018, respectively. For after eruption event is on February 20, 2018, and on February 26, 2018, for ascending and descending orbit respectively while the real event is on February 19, 2018, at 8:54:30 AM.

Fig. 4 shows the interferogram of the Sinabung volcano and its surrounding. The interferogram formation is generated by cross multiplying the master image with the complex conjugate of slave[12]. For reducing the noise on the interferogram was carried out by averaging adjacent pixel in complex interferogram (multi-looking) and applied active filtering (Goldstein filter). Multi-looking is effective for removing the uncontrolled noise was introduced by temporal, baseline and volume scattering [12]. The variation of interferometric phase $\Delta\phi$ is proportional to Δr from each resolution cell of two SARs divided by transmitted wavelength λ. The interferometric fringes represent in 2π a cycle of arbitrary color whit each cycle represent the half wavelength which is for Sentinel 1A and 1B the wavelength λ is 5.4 cm [13].



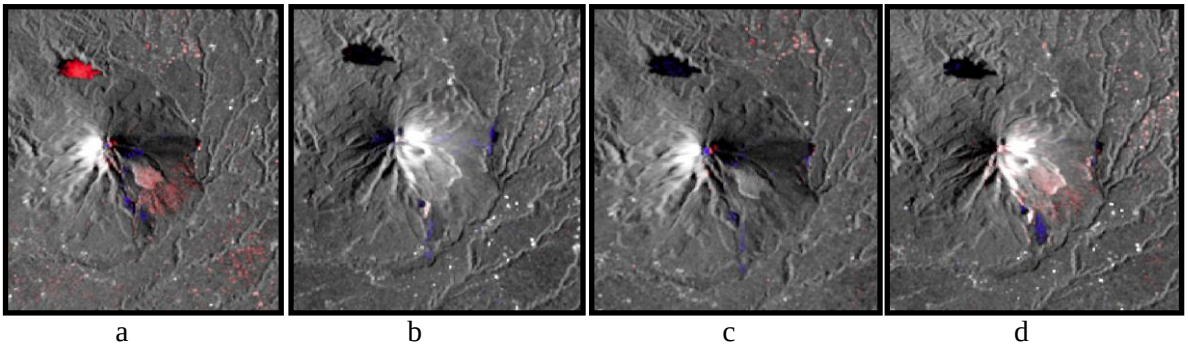
a b



c d

Figure 4. The interferometric phase of Sinabung volcano. a. Interferometric phase (IP) observed by Sentinel-1A with ascending orbit (080218-200218). b. IP sentinel-1A descending orbit (140218-260218). c. IP sentinel-1B Ascending orbit (140218-260218). d. IP sentinel-1B descending orbit (080218-200218).

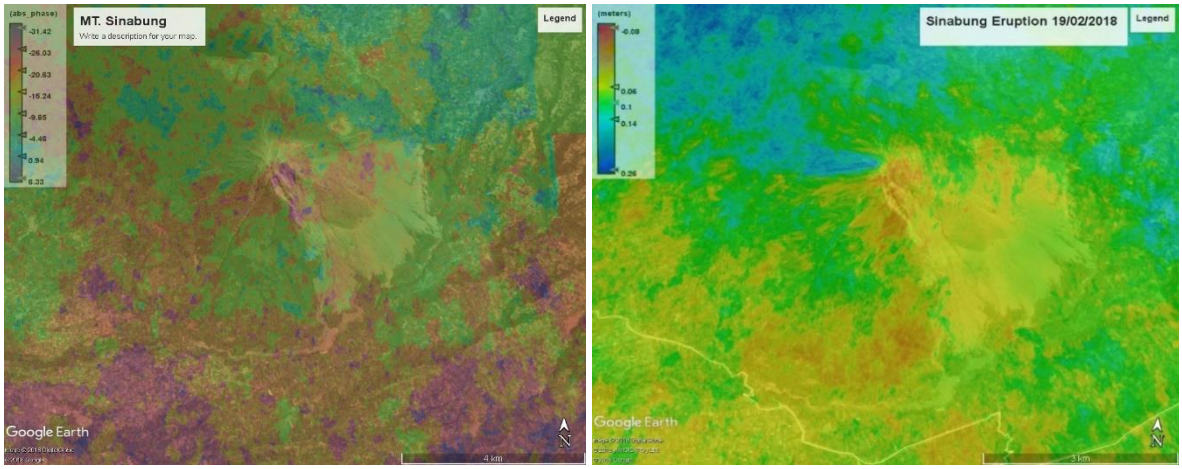
Fig. 5 show the amplitude changing for each pair of SAR images with acquisition time 080218-200218, 140218-260218 observed by Sentinel-1A and 1B with ascending and descending orbit respectively. Pair acquisition 080218-200218 observation by Sentinel-1A with ascending orbit has significantly changed than others satellite pair (Fig.5a) because the SAR data captured one day after Sinabung eruption (February 19, 2018). For pair acquisition 140218-260218 observed by Sentinel-1A and 1B with descending and ascending orbit, the amplitude change was not weighty because some volcano ash has spread and eroded by wind and rain.



a b c d

Figure 5. Amplitude changing of Sinabung volcano. a. observed by Sentinel-1A with ascending orbit (080218-200218). b. Sentinel-1A descending orbit (140218-260218). c. Observed by sentinel-1B ascending orbit (140218-260218). d. Sentinel-1B descending orbit (080218-200218).

The flattened interferogram contains ambiguity measurement of terrain altitude then unwrapping is required to obtain the elevation map in SAR coordinate which referred to ellipsoid Fig. 6a.



a b

Figure 6. Sinabung eruption map. a. Unwrapped phase map, b. Ground deformation map.

For obtained the ground deformation value carried out by conversion of unwrapped phase in a line of sight (LOS) direction of the satellite. Fig. 6b shows the ground deformation map in the millimeter unit. The volcano ash spread to all direction with different levels. The maximum is 260 mm on some area in the north-west (blue) and 30-100 mm in another area (yellow-green) of Sinabung volcano.

Figure 7. The spread of Sinabung volcano ash observed by Himawari satellite image on 19-02-2018.

Conclusion

The research shows the capabilities of interferometry SAR satellite data processed by D-InSAR technique measuring the ground deformation due to the Sinabung eruption. The technique successfully calculates the deformation in millimeter unit. Also, detected the volcanic ash spreads direction around the volcano. The most significant volcano ash was direct to the north-west of Sinabung with maximum deformation is about 26 mm and the result confirmed by Himawari satellite observation.

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