

Observing Deformation at Mt. Raung East Java Based on PALSAR-2 Imagery by Using Interferometric SAR

Arliandy P. Arbad¹, Takeuchi W.¹, Achmad Ardy², and Ridwan A. Ashari³

¹Institute of Industrial Science, The University of Tokyo, Tokyo 153-8505, Japan.

²Faculty of Agriculture, Dept. of Agronomic-Tech, Lampung University, Indonesia.

³Dept. of Geodesy and Geomatic, Universitas Gadjah Mada, Yogyakarta, Indonesia.

E-mail : arbad@iis.u-tokyo.ac.jp

Abstract. In August 2015, Indonesia Center of Volcanology and Geological Hazard Mitigation (CVGHM) recorded of tectonic activities at Mt. Raung with maximum amplitude 2-32 mm and continuing the tremor quakes until the beginning of the 2016 eruption period. Mt. Raung is located at East Java Province, one of most active stratovolcano in Indonesia, typically erupt with explosive eruptions and another deadly hazards such as pyroclastic flow, lahar and volcanic gases. Radar imagery consequently proposes of value device for mapping and assessing of volcano opportunities. By this study, we propose InSAR method to observe deformation in Mt. Raung. Interferometric SAR derives the phase difference based on two images of PALSAR-2 observations taken in January 2015 and January 2016. According to the processing of interferometric SAR, those images must be coregistered into a stack, and we selected 2015 imagery as master and the other imagery as slave. We estimate the interferogram result to know the line-of-sight then be flattened by removing the topographic phase an inflating volcano (or any other landform) produces a pattern of concentric fringes in a radar interferogram from which the effects of viewing geometry and topography have been removed. Finally, we expect the result of InSAR processing technique to investigate ground deformation of Mt. Raung. It would be a capable and cost-effective way of enhancing the techniques normally used in geodetic monitoring to assess the next eruptive events.

1. Introduction

As we know Indonesia is a part of ring of fire, some of hazard disasters caused tectonic activates and volcanic activities are frequently occurred. Most of interesting evidence, around 13 % of the world's active volcanoes are located in Indonesia. Tectonically, the active volcanoes are the result of a collision between Indian-Australian, Eurasian, and Philippine Plates [10] Large number of people living close to volcanoes site because these areas usually contain some of the most mineral rich soils, which provide perfect conditions for farming. Lava and material from pyroclastic flows are weathered to form nutrient rich soils which can be cultivated to produce healthy crops and prosperous harvests. Volcanic eruptions produce disaster materials such as the lava, pyroclastic fall, pyroclastic flows, pyroclastic surges, lateral blast, debris avalanche, volcanic tsunamis, mud, flooding and harmful gases [9]. A large number of volcanoes are situated in the (so-called) ring of fire area. Analysis from geographic and topographic data suggests that Indonesia is the most volcanically active in the world, with numerous eruptions each year and millions of people living on the flanks of the volcanoes [4].



The objective of this study is to observe the characteristics of mount Raung activities by using InSAR, the most commonly technique is used remote sensing methods, remote sensing has been largely implemented to characterize of volcano eruptions, both of optical remote sensing and SAR (Synthetic Aperture Radar)[5], SAR data involve the reflection and radiation of electromagnetic waves. In this research, we propose to use the InSAR analysis method to process SAR (Synthetic Aperture Radar) images taken from ALOS2/Palsar2 data. Characteristic of SAR image is an inherent characteristic of coherent imaging, including SAR imaging is the presence of speckle noise, which is random, deterministic, interference pattern in an image formed with coherent radiation of a medium containing many sub-resolution scatters. Mapping active volcano using SAR (e.g[7]) in mount Merapi to classify the pyroclastic deposits has applied to observe active volcano.

2. Methodology

Mount Raung is located in East Java Province, one of the most active volcanoes in Indonesia which short eruptions cycle among 1 year to 5 years. According to reported from Centre of Volcanology and Geological Hazard Mitigation Indonesia, of tectonic activities at Mt. Raung with maximum amplitude 2-32 mm and continuing the tremor quakes until the beginning of the 2016 eruption period.

2.1. Data Processing

For analyzing the eruption events in June to July 2015 we used SAR data derived from ALOS2/Palsar-2 Images which L-band frequency characteristic onboard from Advanced Land Observing Satellite (ALOS2) with active microwave sensor. Table below show details data are used for this study.

Table 1. Data information

Date	Sensor	Processing Type	B _{perp} [m]	Stack	Polarization	Orbit
20Jan 2015	ALOS2/Palsar2	L.1.1	0.0	Master	HH	Ascending
19Jan2016	ALOS2/Palsar2	L.1.1	237.3	Slave	HH	Ascending

PALSAR-2 is L-band frequency (active microwave remote sensing) which characterize enable to penetrate cloud (cloud-free) and day-and-night observation. Images below are used for interferometric SAR Processing. The synthetic aperture radar signal processing could be implemented simply as follow below.



Figure 1. image (a) is show Master image which recorded in January 20, 2015 and image (b) is show slave image which recorded in January 19, 2016.

2.2. Flow Chart

In this research we proposed InSAR method in the conventional single-interferogram approach, derives from two radar images of the same area acquired at different times to measure ground displacement. The technique uses the phase difference of backscattered signals from the two acquisitions to measure differential motion in the Line Of Sight (LOS) direction include vertical and

horizontal components. The InSAR deformation image produced from two SAR images that associated to the eruption in the beginning of 2016.

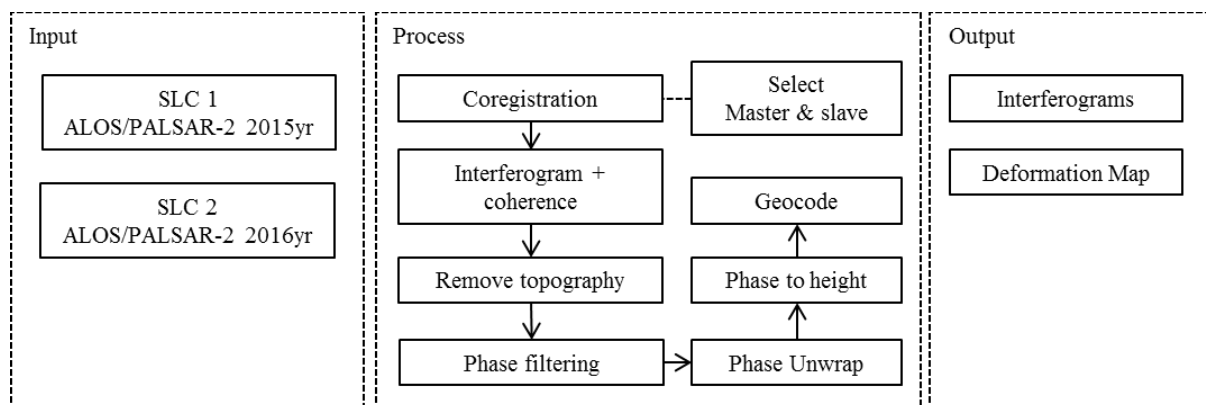


Figure 2. Flowchart study

We presented the interferometric analysis using snap software, a common architecture for all Sentinel Toolboxes is being jointly developed by Brockmann Consult, Array Systems computing and C-S called Sentinel Application Platform by ESA, (2016) to get interferogram and line of sight displacements, the interferometric phase was unwrapped with the SNAPHU program. To show ground deformation with high spatial resolution and accuracy on the large areas observation we used DInSAR (Differential Synthetic Aperture Radar Interferometry) explained by Massonnet(2008)[11]; Gabriel *et al*, (1989) [3] which phase can be subtracted from the SAR interferogram to remove topography. DInSAR used to analysis the line of sight displacement for monitoring and detecting change volcano in long-term and short-term [6] and also for studying fault mechanism [1].

3. Results and Discussion

Mount Raung is located in East Java Province, one of the most active volcanoes in Indonesia which short eruptions. We observed mount Raung based on activities since June 21st 2015 and continuing until July 4th 2015 which magma and volcanic materials. Figure below as shown the ALOS2/PALSAR images from different time. As basic study, some changes happened inside the calderas due to volcanic activities during the eruptions period.



Figure 3. ALOS2/PALSAR Images of Mt. Raung taken Pre-eruptive and Post-eruptive.

Regarding to Centre of Volcanology and Geological Hazard Mitigation one of the most active volcanoes in Indonesia, which short eruptions period, mount Raung activity currently, located at the bottom of the caldera. In February 1902, cone of central caldera appeared around 90 m. Character of mount Raung is explosive eruptions (Strombolian) as happened in 1586, 1597, 1638, 1890, 1953 and 1956, the resulting ash was thrown up into the air and never happens hot clouds glide blanketed much of the body in 1953. The main danger eruption of mount Raung is the danger of a direct result of the

eruption such as hot clouds glide and throw pyroclastics. The period of eruption. Based on the history of eruptive activity shortest period between two eruptions is 1 year and the longest 90 years.

3.1. Coregistration and Coherence Image

Following the SLC images, we can confirm by coregistered images into each eruption period, detail coregistration images as shown below.

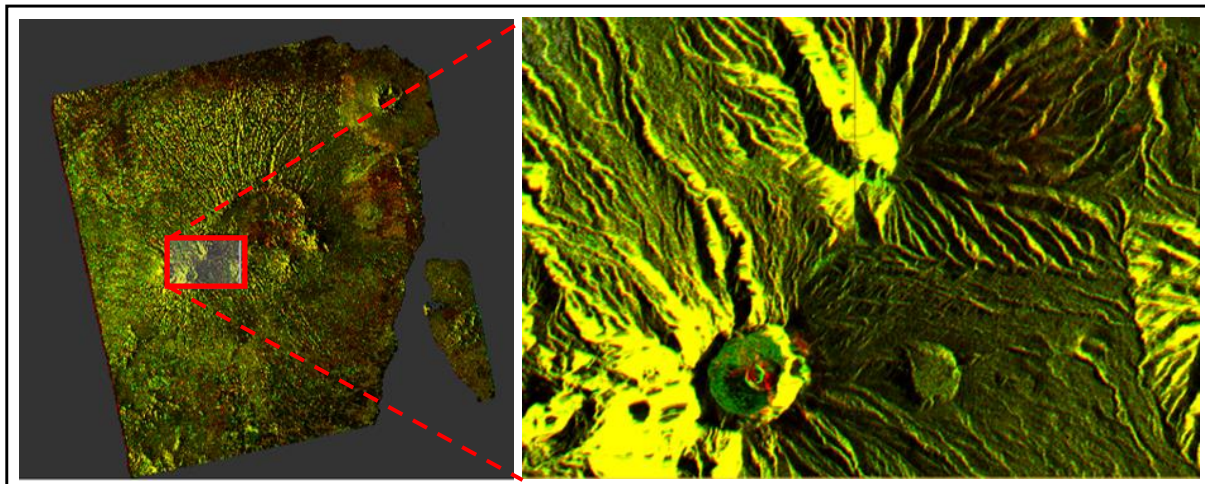


Figure 4. Images from the shape of area are made by coregistration of SLC images between slave and master images, taken in different time.

For The RGB View can be useful for amplitude change detection. Regarding to ESA SNAP (2016) those images, we will see things that have changed in red or green and things that have not changed in yellow. It is also a visual indication that the coregistration has properly aligned both images. The resulting of RGB view should look mostly yellow. Poor registrations will have badly lined up terrain. The first result of interferograms as RGB could be allowed us to study interferometric SAR in volcano disaster in particular landslide case.

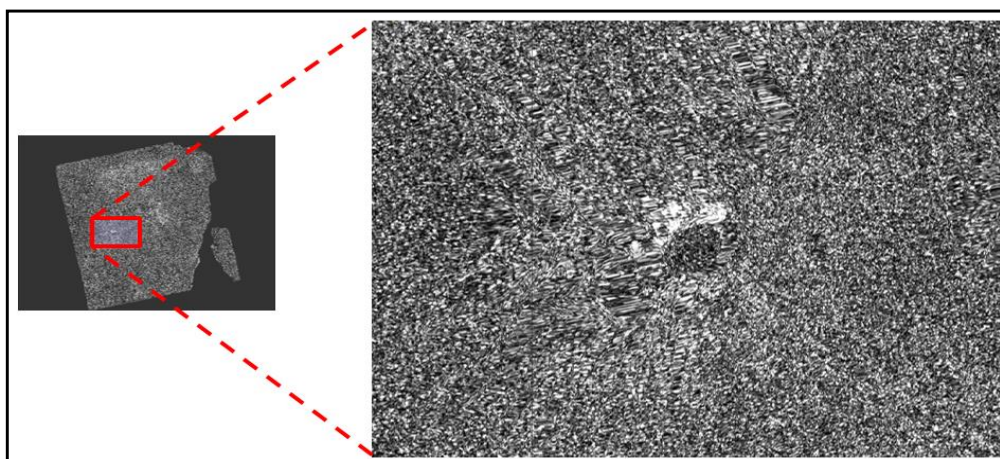


Figure 5. Images from the shape of coherence estimation of Mt. Raung obtained from interferogram between master and slave image.

The coherence band shows how similar each pixel is between the slave and master images in a scale from 0 to 1. Areas of high coherence will appear bright. Areas with poor coherence will be dark. In the image, vegetation is shown as having poor coherence and buildings have very high coherence.

3.2. Deformation Analysis

We processed SAR images from two different datasets from PALSAR2 (Table 1.) by using the SNAP procedure to generate LOS deformation rate maps of the mount Raung area for the following observation periods: 2015.01.20 (PALSAR-2 track 131-7020; Figure 1a), 2016.01.19 (PALSAR-2 track 131-7020; Figure 1b). All the tracks proceed into SNAPHU developed at Stanford university, processing after removed topographic phase, phase unwrapping is a key step during the signal processing of interferometric synthetic aperture radar (InSAR) data. The precision and efficiency are two key problems of phase unwrapping.

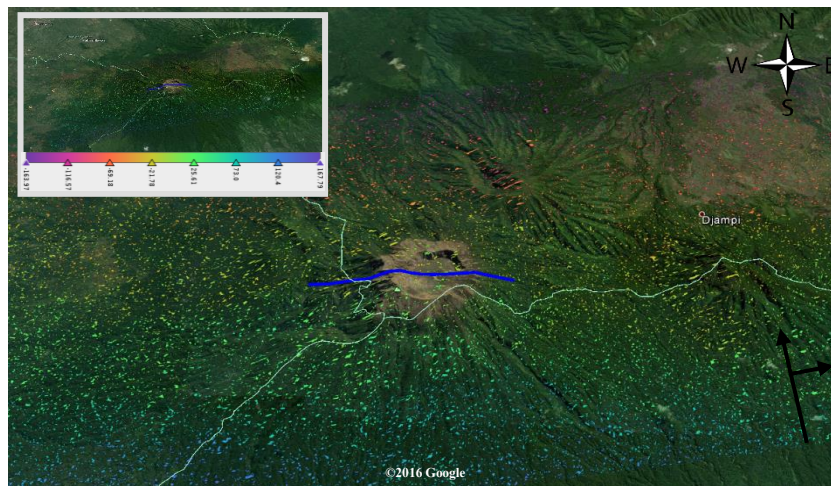


Figure 6. Land surface changes occurred in the Mt. Raung, which the result of geocoded processing overlaid with Google Earth.

Following the interferograms shown in **Figure 6**, from January 2015 to January 2016, a small amount of subsidence persisted near the caldera of mount Raung, but the northern of mount Raung began to rise slightly. Uplift spread throughout the central part of the caldera and southern part of mount Raung indicated subsidence. Northeast of mount Raung, is located mount Ijen in the same caldera, here mount Ijen activities also could be assessed in land surface changes. The color progression inside the caldera is reversed between uplift and either subsidence. The surface changes profile plot are outlined below.

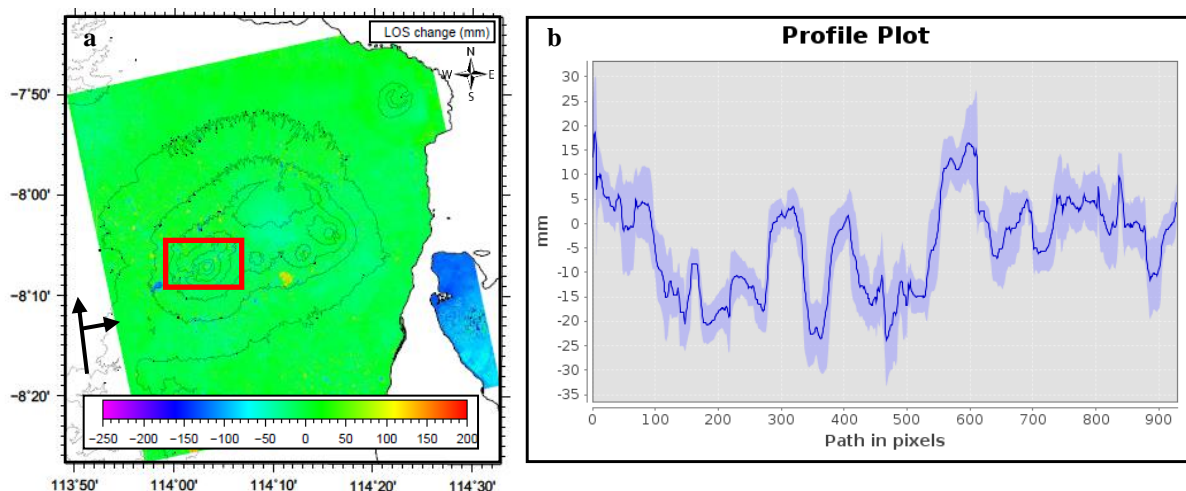


Figure 7. Image (a) is a complete scene processing of ALOS2/PalSAR-2 and image (b) is a profile plot of land surface changes related to **Figure 6**. the blue line is representative of path in pixel value.

Moreover, the result indicates that mount Raung started inflating soon after the end of June to the beginning of July (**Figure 6**). Related to CVGHM report, during the period August 2015 - January 19, 2016 earthquake recorded in the Post PGA Raung. The path-following phase unwrapping algorithm usually has high computational efficiency, but low coherence areas are prone to have accumulated errors. The result indicate that mount Raung started inflating soon after the end of June to the beginning of July (**Figure 7b**). Related to CVGHM report, during the period August 2015 - January 19, 2016 earthquake recorded in the Post PGA Raung, consisting of: Earthquake Tremor, volcanic earthquake, Tectonic earthquake and Blowing (which began recorded on August 15, 2015). Since August 5, 2015 RSAM value is fluctuating decline and relatively stable. Interferograms color shown in (**Figure 7a**) it could allowed us to interpret a wider area, including mount Ijen located in northeast of mount Raung.

As the results of InSAR processing, some volcanic eruptions have been preceded or accompanied by extremely large water level variations that were observed without special equipment. The simplicity of these observations is appealing and unequivocally demonstrates that groundwater levels change in response to volcanic deformation. Much more can be learned, however, from high-resolution water level measurements in well-characterized aquifers (Dzurisin, D., 2006). As an example; we could do assessment at Songgon districts position on the slopes of the mount Raung cause these districts traversed by several rivers that disgorge in the mount Raung. Binauand Badeng rivers with a length of 12 km, the Manggaran river 10 km and 8 km flow at Kumbo River [14].

For the human life assessments (risky and vulnerability) the results of these processing is allowed us to assess from geographic and topographic data suggests that Indonesia is the most volcanically active in the world, with numerous eruptions each year and millions of people living close to the volcanoes. Located in 3 regions mount Raung activities have been spreading threat for human life.

3.3. Future Study

The result given the new sight of volcanic activities monitoring and implementing of InSAR to observe volcano. Based on our study, we plan to check ground truth (field survey) analysis by surveying surrounding the volcano to understand of volcanic activities associated to the fault and vegetation surrounding the mount Raung. And find the relationship between land surface changes through the ground water level changes also we can find correlation ground water flow effect associated to deformations in mount Raung.

4. Conclusion

PALSAR-2 data can be used to assess subsidence and volumetric changes in the areas of volcanoes. By this study we claimed that using InSAR method it is possible to calculate large mass movements in the two observations during the different time observations to get clues for further study we can use same technique to quantify volumetric changes in the summit areas of volcanoes dome and the utility of InSAR for measuring the complex geophysical signals at mount Raung is evident given the variety of deformation measurements revealing both eruptive and non-eruptive behaviour, following the interseismic deformation over the Java fault, our study could supports to understand the surface movements along the fault, which agrees well with previous geological studies. For future study we will do risk and vulnerability assessment including this study to create disaster prone-areas due to volcanic activities and InSAR time-series analysis for monitoring sense of motion in East Java volcanic system and fault along the South Semarang to East Java about 300 km.

Acknowledgments

Thank you for LPDP (Indonesia Endowment Fund for Education) Scholarship funding, Indonesia Ministry of Finance. JAXA (Japan Aerospace Exploration Agency) to provide ALOS22/PALSAR-2 images. Remote Sensing of Environment and Disaster Laboratory, Industrial Institute of Technology University of Tokyo and also Earthquake Research Institute for sharing knowledge on volcano sense.

References

- [1] Currenti, G., Bonaccorso, A., Del Negro, C., Guglielmino, F., Scandura, D. and Boschi, E 2010 FEM-based inversion for heterogeneous fault mechanisms: application at Etna volcano by DInSAR data *Geophysical Journal International* **183**(2) pp.765-773.
- [2] Dzurisin, D 2006 *Volcano deformation: new geodetic monitoring techniques* (Springer Science & Business Media)
- [3] Gabriel, A.K., Goldstein, R.M. and Zebker, H.A 1989 Mapping small elevation changes over large areas: differential radar interferometry *Journal of Geophysical Research: Solid Earth* **94**(B7), pp.9183-9191.
- [4] Loughlin, S., Sparks, S., Brown, S., Jenkins, S. and Vye-Brown, C. eds 2015 *Global Volcanic Hazards and Risk* (Cambridge University Press)
- [5] Lu, Z., Kwoun, O. and Rykhus, R 2007 Interferometric synthetic aperture radar (InSAR): its past, present and future *Photogrammetric engineering and remote sensing* **73**(3), p.217.
- [6] Papageorgiou, E., Fomelis, M. and Parcharidis, I 2012 Long- and short-term deformation monitoring of Santorini Volcano: unrest evidence by DInSAR analysis *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* **5**(5), pp.1531-1537.
- [7] Solikhin, A., Pinel, V., Vandemeulebrouck, J., Thouret, J.C. and Hendrasto, M 2015 Mapping the 2010 Merapi pyroclastic deposits using dual-polarization Synthetic Aperture Radar (SAR) data *Remote Sensing of Environment* **158** pp.180-192.
- [8] Solikhin, A., Thouret, J. C., Gupta, A., Harris, A. J., and Liew, S. C 2012 Geology, tectonics, and the 2002–2003 eruption of the Semeru volcano, Indonesia: Interpreted from high-spatial resolution satellite imagery *Geomorphology* **138**(1), 364-379.
- [9] Tilling, R.I 1989 Volcanic hazards and their mitigation: progress and problems *Reviews of Geophysics* **27**(2), pp.237-269.
- [10] Zaennudin, A 2010 The characteristic of eruption of Indonesian active volcanoes in the last four decades *J. Lingkungan dan Bencana Geologi* **1** pp.113-129.
- [11] Massonnet, D. and Souyris, J.C 2008 *Imaging with synthetic aperture radar* (CRC Press)
- [12] Snap Processing and Tutorials 2016 from <http://step.esa.int/main/doc/tutorials/>
- [13] Mt. Raung Report taken from <http://www.vsi.esdm.go.id/>
- [14] BPS Report taken from https://bondowosokab.bps.go.id/website/pdf_publicasi/Statistik-Daerah-Kecamatan-Sumber-Wringin-2015.pdf