TIME-SERIES SAR INTERFEROMETRY ANALYSIS OF SURFACE DEFORMATION AT MT. BROMO INDONESIA

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ABSTRACT

One of the most active volcanoes in Indonesia is Mt. Bromo, volcanic activities at Mt. Bromo has been recorded in 1775. We observe the surface deformation of the Mt. Bromo which located at eastern Java Indonesia area that includes neighborhood volcanic system on TNBTS (Taman Nasional Bukit Tengger Semeru). Recently, remote sensing has played as an important role to observe volcano behavior. We apply the SAR Interferometry (InSAR) algorithm referred to as Small Baseline Subset (SBAS) approach that allows us to generate mean deformation velocity maps and displacement time series for the studied area. The common SBAS technique, the set of interferometric phase observations writes as a linear combination of individual SAR scene phase values for each pixel independently. Particularly, the proposed analysis is based on 22 SAR data acquired by the ALOS/PALSAR sensors during the 2007–2017 time interval. A fewer studies have been able to show capability of InSAR analysis for investigating cycle of volcano especially of Mt. Bromo which characterized eruption stratovolcano in ranging one to five years. The results expected in this work represent an advancement of previous InSAR studies of the area that are mostly focused on the deformation affecting the caldera. According to the result, we expected this study could implement on risk management or infrastructure management.

Keywords: SBAS, surface Deformation, volcano eruption, ALOS/PALSAR

ABSTRAK


Kata kunci: SBAS, deformasi permukaan, erupsi gunung api, ALOS/PALSAR
INTRODUCTION

Volcanic processes which produce a variety of geological and hydrological hazards (Tilling, R.I., 1989) are difficult to predict and capable of triggering natural disasters on regional to global scales (Chowdhury et al., 2016). Centre of Volcanology and Geological Hazard Mitigation (CVGHM, 2016) Indonesia recorded of tectonic activities of Mt. Bromo, their recorded tectonic activity dominated by continuing tremor vibration with maksimum amplitude which tend to fluctuate. Mount Bromo status is now siaga (level 3 of 4) with potential to evoke freatik eruptions and magmatic materials, distribution materials such as ash plumes and pyroclastis fall will occur around the volcano. 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.

The objective of this study is to implement Small Baseline Differential InSAR (SBAS D-InSAR) technique for estimating time-series surface deformation at Mt. Bromo regarding big eruptions in 2010 and 2015. (Ma, C., et al., 2016) has shown the potential SBAS to investigate mining subsidences. Remote sensing method is the most commonly rapid technique of assessment unrest volcano, remote sensing has been largely implemented to rapid assess assessment (e.g Voigt et al, 2011) after Haiti earthquake in 2010, also enables us to estimate ground deformation with high precision and with a temporal resolution constrained by the recurrence interval of the SAR satellite. In the past decade ago, (Abidin et al., 2004) has published report on surface deformation of Bromo volcano as detected by GPS.

METHOD

For analyzing the eruption events in 2010 we used SAR data derived from PALSAR sensor and Images which L-band frequency characteristic onboard from Advanced Land Observing Satellite (ALOS) with active microwave sensor to achieve cloud-free and day-and-night land observation. The dataset is composed of 22 SAR images, collected from 24 May 2007 to 4 November 2011 (Descending passes, HH polarization, Track 91, Frame 3780). We tried to see the correlation after 2010 eruption with the last 2015 eruption at Mt. Bromo by seeing the report from CVGHM 2016 and processing of ALOS/PALSAR2 obtained from 25 Mar 15 and 4 May 16. we used of L-band SAR data with a wavelength larger than the usual C-band and X-band, C-band is generally considered for ground motion measurements, reduces some of the limitations of differential SAR interferometry, in particular, signal decorrelation induced by vegetation cover and rapid displacements.

SBAS D-InSAR

SBAS approach that allows us to generate mean deformation velocity maps and displacement time series for the studied area. The common SBAS technique was proposed by (Berardino, P., et al., 2002), the set of interferometric phase observations writes as a linear combination of individual SAR scene phase values for each pixel independently. The basic of the SBAS approach is the inversion of the unwrapped interferograms for the deformation time series (Lanari, R., et al., 2007). This technique also allows us to detect possible orbital ramps caused by inaccuracies in the SAR sensors orbit information. We used GIAnT software to obtain time-series analysis at Mt. Bromo Indonesia. GIAnT is distributed with implementations of SBAS [Berardino et al., 2002, Doin et al., 2011] and MInTS [Hetland et al., 2011] techniques. The prepackaged implementations are meant to work with outputs from ROI PAC [Rosen et al., 2004b], DORIS [Kampes et al., 2003], GMTSAR [Sandwell et al.] or GAMMA [GAMMA Remote Sensing Research and Consulting AG, 2013]. Cumulative phase can be obtained by solving a linear least squares problem. Solves only for pixels with complete dataset, i.e. all interferograms and acquisitions are available. In a given pixel, the observation Equation 1 is:
\[ \phi_{ij} = \sum_{n=i}^{j-1} \delta \varphi_n \] ..........................(1)

\( \Phi_{ij} \) : Phase of the interferogram combining acquisitions i and j
\( \delta \varphi_n \) : Phase increment between acquisitions n and n+1.

RESULT AND DISCUSSION

Interferometry was performed on each image pair according to their connection relationship based on the aforementioned optimized baselines of SBAS, and 196 interferograms were obtained in Fig 1. A total of 22 time-series cumulative phase deformation diagrams were collected through orbit refining, relating, phase unwrapping, and geocoding.

Deformation characteristics at Mt. Bromo

![Interferogram of Time Series-DInSAR based on SBAS algorithm processing obtained from 24 Mar 2007 to 4 Apr 2011](image)

Subsequently, −10 cm subsidence map was acquired based on the further processing of these diagrams. Regarding the SBAS-DInSAR result, the time-series diagrams could give us some hints to investigate land surface changes around the volcano. Surrounding the caldera of Mt. Bromo we collected 6 sample points as shown in Fig 2. these diagrams clearly shows uplift was occurred in 2011 eruption. All the sample points relatively small changes at (post-eruptive to co-eruptive) the eruption occurred in 2010, those results related to the Centre of Volcanology and Geological Hazard Mitigation (CVGHM, 2011) Indonesia report, they recorded of tectonic activities of Mt. Bromo, activity dominated by continuing tremor vibration with maximum amplitude which tend to fluctuate with potential to evoke phreatic eruptions and magmatic materials. The evidences can be
taken to prevent buildings from being damaged or other measures taken to control potential geohazards, etc.) is possible to be obtained.

**D-InSAR in 2015 eruption at Mt. Bromo**

After the volcano eruption, the processes which produce a variety of geological and hydrological distribution materials such as ash plumes and pyroclastis fall will occur around the volcano. The 2010 eruption more destructive rather than 2015 eruption. In this study we proposed InSAR method in the conventional single-interferogram approach, exploits two radar images of the same area acquired at different times to measure ground displacement.

**Fig 2. D-InSAR interferogram during 2015 eruption at Mt. Bromo, the red line identified as a study area**
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.

In 2015 eruption, The map shows very fluctuating changes immediately after the eruption, subsidence cover a similar width of the southwest flank that moved during the slide more changes and some areas are given the uplift representative with yellow color. On the other hand, in the percentage of caldera areas much more subsidences in 2015 eruption rather than 2010 eruption, it will allow us to make a correlation study in 5 years cycle of Mt. Bromo for the further study.

CONCLUSION

In this study, InSAR and SBAS-InSAR techniques allow us understand the annual growing characteristics of subsidence disasters under high-intensity volcanic of Mt. Bromo Indonesia, and recognize the ground deformation features above a single working face. The time-series analysis of SBAS-InSAR achieves more reliable results (Tizzani, P., et al, 2007) and more accurately reflects the mining subsidence characteristics of a single working face in 2015 eruption (D-InSAR Processing). We find that some uplift up to (10 cm/yr : in the end 2010 continue in the beginning 2011) are occurred at the caldera of Mt. Bromo in the direction of advancing, which may be caused systematically by an inappropriate selection of the reference points or another volcanic activities phenomenon such as the ash-materials.

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REFERENCES


