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## Analysis of Land Deformation on Slope Area using PS InSAR. Case Study: Malang Area

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**Abstract.** The geographical position of Indonesia located between two continents and oceans is strategic, but at large risk of experiencing various disasters. Climate change and vulnerable location (surrounded by plates and geological faults in the Earth's crust) creates an earthquake-prone region and causes land/mudslides. In this paper, PS InSAR method (Persistent Scatterer Interferometric Synthetic Aperture Radar) is implemented to Phased Array type L-band Synthetic Aperture Radar (PALSAR) data to study the potential damage caused by the earthquake or volcanic eruption in Malang vicinity. By comparing the amplitude images periodically, shifting soil can be determined using precise orbital information. The analysis showed a significant decrease of land deformation on slope area in Klojen district in Malang city, reached up to  $-7.128$  mm/year.

### 1. Introduction

Indonesia is one of countries which is prone to natural disasters. In some area, e.g. Bandung, Jakarta, Medan, Malang, Semarang and other cities, land deformations, land subsidence and landslide are main cause of building cracks, floods, changing land use, and other serious problems. Synthetic Aperture Radar (SAR) data processing using Differential Interferometric Synthetic Aperture Radar (DInSAR) has proven to be the effective solution to measure land deformation precisely in wide spatial coverage with high resolution data. Many applications are implemented using this method, such as land subsidence in Bandung [10], Jakarta [11], Sidoarjo mudslide [12], glacier movement [20], volcanic activities [9][19], Earth's crust movement [7][21], and underground mining activities [13][3][4].

However, DInSAR method has a weakness such as prone to temporal changes and atmospheric disturbance. In the paper, we propose Persistent/Permanent Scatterer Interferometry (PSI) or PS InSAR method which is a newer method developed from DInSAR to analyze land deformation on slope area in Malang vicinity, East Java, Indonesia. This method is based on multi-temporal SAR imagery data to enhance the detection sensitivity for land deformation [1]. The backscattered signal from a coherent object during data acquisition, which are known as permanent/persistent scatterer (PS)

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is analyzed. It is important to have these permanent pixels since using clear interferograms, these positions represent land movement. In SAR imageries, human made objects could be found clearly in cities or high slopes. The PS InSAR is developed by scientists to monitor land deformation in many applications, including land deformations in cities [10][18][6], infrastructure stability [14], seismic faults [15], volcano activities [2], and landslides in sloped area [17]. The advantages of this method are: (1) wide area coverage, (2) efficient for mapping and survey activities, and (3) high accuracy in measuring land deformation as well as conventional land survey. Moreover, the method offers high scalability, effective since there is no in-situ measurements, time and cost efficient, almost real-time for systematic monitoring system, although it has high dependency on data provided by ALOS satellite and high computation complexity.

PALSAR is a radar sensor carried by ALOS satellite. Since it works in microwave band, comparing to optical sensor, it becomes reliable sensor working in any weather conditions, day and night. During normal operation, PALSAR observes the Earth's surface with  $34.3^\circ$  off-nadir angle to produce 10 meter spatial resolution mode. Off-nadir angle could be changed from  $9.7^\circ$  to  $50.8^\circ$ . Wide observation mode could be achieved using ScanSAR which has 100 meter spatial resolution. Swath width mode of ScanSAR is from 250 to 350 km, while normal resolution has 70 km wide.

There are three level of PALSAR product data:

1. Level 1.0  
Data which is reconstructed from raw data, unprocessed signal with additional geometric and radiometric coefficients correction, but not used yet. Imageries are separated for each polarization (HH, VV, HV, VH).
2. Level 1.1  
In this level, data has been compressed using range compression and azimuth compression and stored as complex data for slant range. Each polarization separates each imagery.
3. Level 1.5  
Imageries are processed in multi-look and projected into a geographical position. Longitude and latitude in the product are calculated without considering elevation using systematic geocoding (G) or systematic georeference (R). Each imagery is separated based on the polarization and only one technique (G or R) is applied.

Basically, PALSAR data acquisition is the same as SAR acquisition mode. Based on configuration system, SAR sensor could retrieve the data in several modes: Stripmap, ScanSAR dan Spotlight.

## **2. Persistent Scatterer Interferometry SAR (PS InSAR)**

PS InSAR is developed from InSAR (Interferometric Synthetic Aperture Radar), which is used in 90s to measure land deformation. The objective of PS InSAR application in the beginning is to identify land deformation in single coherent pixels of several SAR imageries separated by large baseline in order to achieve high accuracy. The level of land deformation accuracy at least up to sub-meter fraction or even millimeters per year. Since DInSAR utilizes multitemporal radar imageries, temporal decorrelation and atmospheric inhomogeneous degrade the interferogram. Other disadvantages are: (1) geometric decorrelation related to the large baseline between two acquisition imageries, (2) the ambiguity that limits the operational power of this method. Permanent Scatterer (PS) could eliminate the effects and increase the land deformation accuracy. The PS InSAR process is started by identifying all PS points and analyze the 2D deformation in these points which could eliminate main weaknesses of DInSAR. This is based on the fact that the atmospheric phase contribution correlated spatially to single scene of SAR data, but tend to uncorrelated in daily or weekly data. Therefore, the atmospheric effect could be estimated and eliminated by combining long period data analysis and temporal fluctuation could be calculated [13]. The process of PS InSAR is briefly described in Fig. 1 [16][1]. Key steps of the process are: (1) interferogram computation, (2) differential interferogram computation using Digital Elevation Model (DEM), (3) preliminary estimation of the most possible coherent pixels, (4) improving step (3), where rough grid of PS candidates estimate the wavelength

which represents the atmospheric signal. After interpolate these estimations, differential interferogram is corrected and additional PS are recalculated [9].

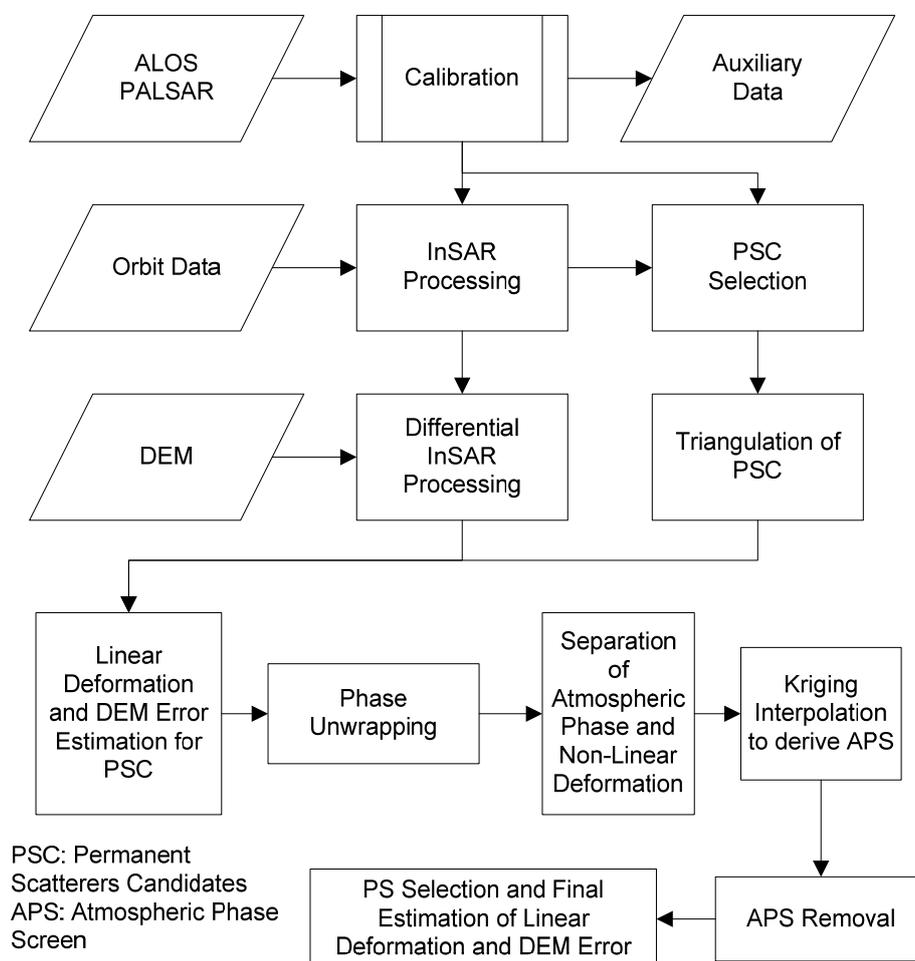


Figure 1. Block diagram of PS InSAR processing.

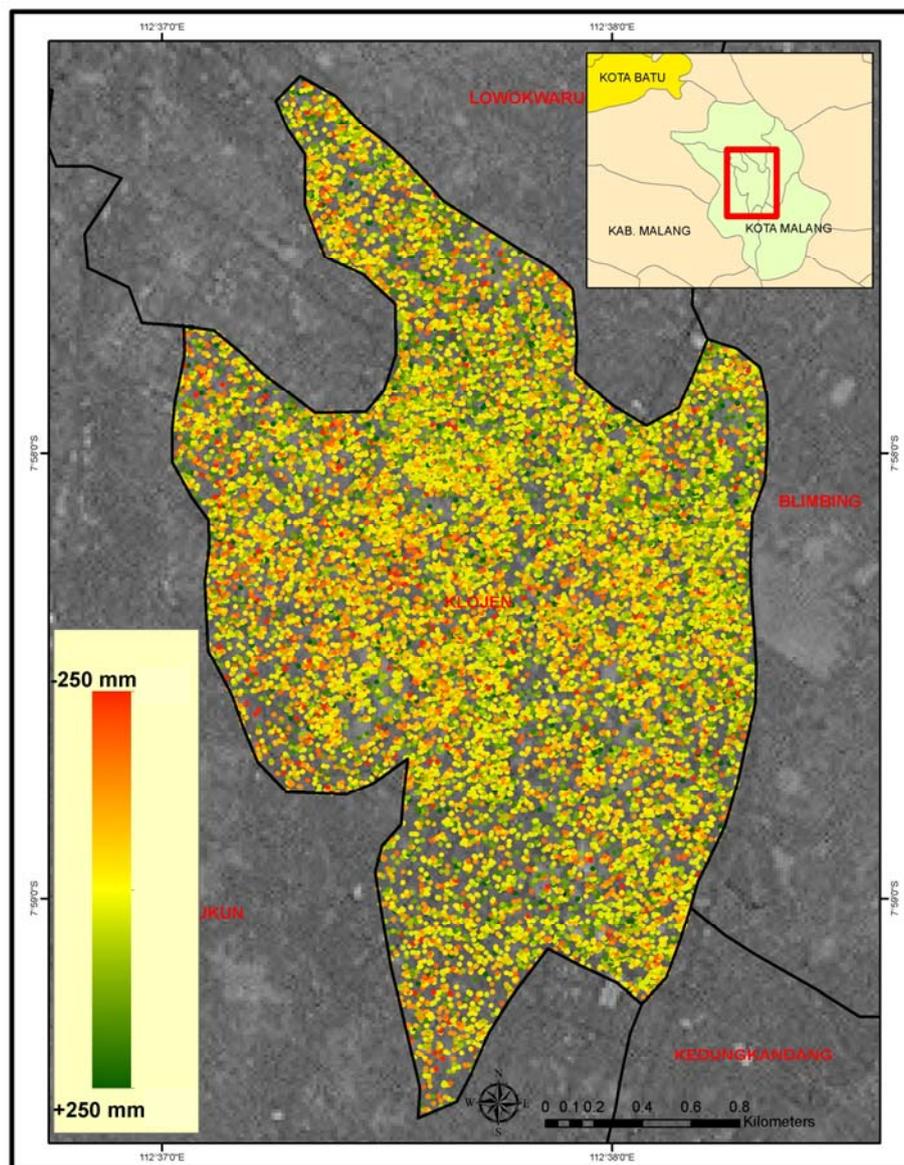
### 3. Area and Data Description

Malang is a city which is located at an altitude between 440-667 meters above sea level, and one of tourist destinations in East Java because of its natural and climatic beauty. It is located in the midst of Malang regency from 7.06°-8.02°S latitude to 112.06°-112.07°E longitude. The regency is surrounded by mountains: Mt. Arjuno in the North, Mt. Semeru in the East, Mt. Kelud in the south, Mt. Kawi and Panderman in the West. Land condition in Malang, among others: the southern part includes a wide plateau (suitable for industry), the northern part of the plateau is fertile (suitable for agriculture), eastern part is plateau with less state less fertile, the western part is a vast plateau (area suitable for education).

To analyze the land deformation in Malang and its vicinity, 6 (six) ALOS/PALSAR data in SLC format are used. To eliminate the topographical phase, low resolution DEM data from Shuttle Radar Topography Mission (SRTM) in 90×90m resolution is used as external DEM. PALSAR data are retrieved from February 2010 to February 2011 period and among those data, the oldest is selected as master image to calculate the temporal interferogram. Interferometric combination is derived to assure uniform spatial and temporal baseline distribution.

#### 4. Experiment Results

The study area is limited to the district of Klojen, Malang city. The geographical location is 7.953-7.991°S and 112.617-112.639° E. The analysis result is land deformation of the district and presented as vector file for the boundary of 107.552°E to 107.732°E, -6.9749°S to -6.8787°S. The deformation is overlaid on basic map derived from Google Map as shown in Fig. 2.



**Figure 2.** Velocity map of land deformation in Klojen District, Malang city

The district is divided into 11 villages, namely Bareng, Gadingkasri, Kasin, Kauman, Kidul Dalem, Klojen, Oro-oro Dowo, Penangungan, Rampal, Samaan, and Sukoharjo. The oldest PALSAR data retrieved on February 2010 is selected as master file. The highest averaged displacement occurs in Bareng village from 2010-2011, reaches -7.128 mm/year. And the lowest is Penangungan village which has 0.501 mm/year. Deformation velocity of these villages is presented in Table 1.

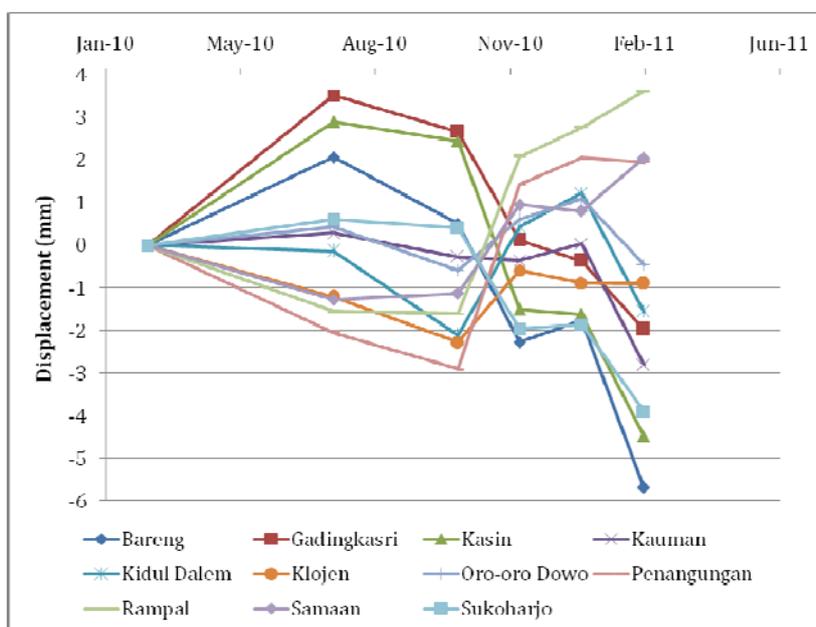
**Table 1.** Deformation time series for 11 villages in Klojen district, Malang city

Village	Master		Slave				Averaged Displacement (mm/year)
	Feb-10	Jul-10	Oct-10	Nov-10	Jan-11	Feb-11	
Bareng	0.000	2.070	0.507	-2.268	-1.750	-5.688	-7.128
Gadingkasri	0.000	3.518	2.675	0.124	-0.360	-1.965	3.992
Kasin	0.000	2.902	2.443	-1.499	-1.615	-4.483	-2.253
Kauman	0.000	0.292	-0.265	-0.356	0.037	-2.795	-3.086
Kidul Dalem	0.000	-0.130	-2.107	0.425	1.230	-1.553	-2.135
Klojen	0.000	-1.205	-2.270	-0.588	-0.883	-0.888	-5.834
Oro-oro Dowo	0.000	0.435	-0.585	0.618	1.092	-0.453	1.107
Penangungan	0.000	-2.045	-2.898	1.428	2.051	1.964	0.501
Rampal	0.000	-1.551	-1.603	2.082	2.771	3.622	5.322
Samaan	0.000	-1.270	-1.128	0.954	0.808	2.050	1.414
Sukoharjo	0.000	0.605	0.413	-1.957	-1.857	-3.892	-6.688

**5. Analysis**

Displacement located at Bareng village, has a significant character which has gradually increasing displacement, starting from 2.070 mm/year up to -7.128 mm/year, as shown in Fig. 3. Bareng is one of main village in Klojen district in Malang city, where trade area, tourist area and buildings are located. Eight other villages have fluctuating displacement values as shown in the figure. But it could be concluded that the displacement trend between October 2010 to February 2011 is positive for Kasin, Penangungan, Samaan villages, and negative trends for the rest of villages.

Malang consists of alluvial sediment material at 59% of the total area [5]. It becomes one factor of displacement in this area which alluvial sediment gives contribution of the displacement because of its characteristic. In addition, 10% area of Malang consists of Mediterranean lands which classified as erosion-high sensitivity, 15% of Andosol which classified as erosion-very high sensitivity, and 16% of Latosol as erosion-medium sensitivity.



**Figure 3.** Displacement of 11 villages in Klojen district, Malang city using PS InSAR method

## 6. Conclusions

It has been demonstrated that PS InSAR technique is applicable for mm scale surface deformation monitoring in Malang. By analyzing data set of ALOS/PALSAR images covering the city of Malang, significant subsidence of up to  $-7.128$  mm/year has been detected between year 2010-2011. To analyze longer deformation phenomena, longer period of PALSAR data is needed. The deformation estimates relate well with results from an independent study and geodetic measurements.

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