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

Dodi Sudiana †, Rokhmatuloh ‡, Mia Rizkinia †, Ardi ‡, Rahmat Arief †, Bambang Setiadi*, Luhur Bayuaji*, Josaphat Tetuko Sri Sumantyo*

† Department of Electrical Engineering, Faculty of Enginering, Universitas Indonesia, Kampus Baru UI, Depok 16424, Indonesia.

‡ Department Geography, Faculty of Mathematics & Natural Sciences, Universitas Indonesia, Kampus Baru UI, Depok 16424, Indonesia.

*Josaphat Microwave Remote Sensing Laboratory, Center for Environmental Remote Sensing, Chiba University, 1-33 Yayoi-cho, Inage-ku, Chiba 263-8522, Japan.

E-mail: † dodi.sudiana@ui.ac.id

Abstract The geographical position of Indonesia located between 2 continents and oceans is strategic, but at large risk of experiencing various disasters. Climate change and vulnerability location is surrounded by plates and geological faults in the Earth's crust resulted in Indonesia's earthquake-prone region deforms the Earth and 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 Bandung vicinity. By analyzing the amplitude image from 2009 to 2011, shifting soil can be determined using precise orbital information. The result showed a significant decrease in the slope in Bandung vicinity at -149.589 mm along two years observations.

Key words **PS-InSAR, PALSAR, Bandung, shifting soil**

1. Introduction

Indonesia is one of countries which is prone to natural disasters. In some area, e.g. Bandung, Jakarta, Medan, 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 [1], Jakarta [2], Sidoarjo mudslide, glacier movement [3], volcanic activities [4] [5], earth's crust movement [6][7], and underground mining activities [8][9][10].

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) method which is developed from DInSAR. The method is based on multi-temporal SAR imagery data to enhance the detection sensitivity for land deformation [11]. PSI analyze the backscattered signal from a coherent object during data acquisition, which are known as permanent/persistent scatterer (PS). 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 PSI is developed by scientists to monitor land deformation in many applications, including land deformations in cities [12][13], infrastructure stability [14], seismic faults [15], volcano activities [16], and landslides in sloped area. 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.

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° off-nadir angle to produce 10 meter spatial resolution mode. Off-nadir angle could be changed from 9.7° to 50.8°. 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 [7]. The process of PS-InSAR is briefly described in Fig. 1 [17]. 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 [18a].

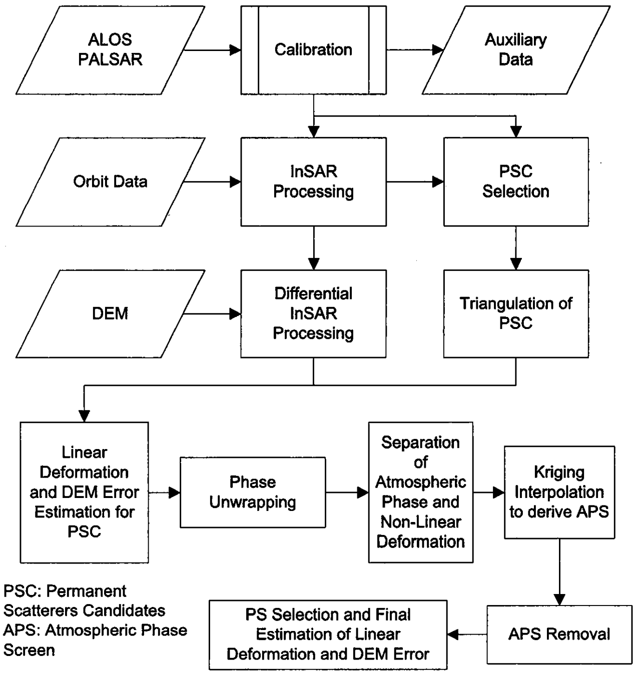

Figure 1. Block diagram of PS-InSAR processing

3. Area and Data Description

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The city of Bandung is sorrounded by mountains so that the morphology of the area is like a giant bowl [18a]. Geographically, the location of the city is in the middle of West Java Province, with elevation about 768 above sea level. Geologically, the city has alluvial sediments after Tangkuban Parahu Mount eruptions. In northern, western and central part, the sediments are generally dominated by andosol, while greyish alluvial with clay sediment dominates the southern and eastern part. The area which is prone to earthquake in the city has organic facies lacustrine, fluvial and aluvial fan sediments, such as in eastern and southern part. Since the land character of these area is softer, low level earthquake could be disastrous to the city. Now, the densed population of Bandung, especially in the city center has moved the physical development to the rural area. Based on Statistic Center Bureau in 2011, the widest area of landuse in the city is for settlement, which covers 8,739.983 Hectares.

To analyze the land deformation in Bandung and its vicinity, 20 ALOS/PALSAR data in SLC format are used. To eliminate the topographical phase, the low resolution DEM from Shuttle Radar Topography Mission (SRTM) in 90×90m resolution is utilized as external DEM. The PALSAR data are retrieved from 2007 to 2011 and a special imagery is selected as master image to calculate the temporal interferogram. Interferometric combination is derived to assure uniform spatial and temporal baseline distribution.

4. Experimental Results

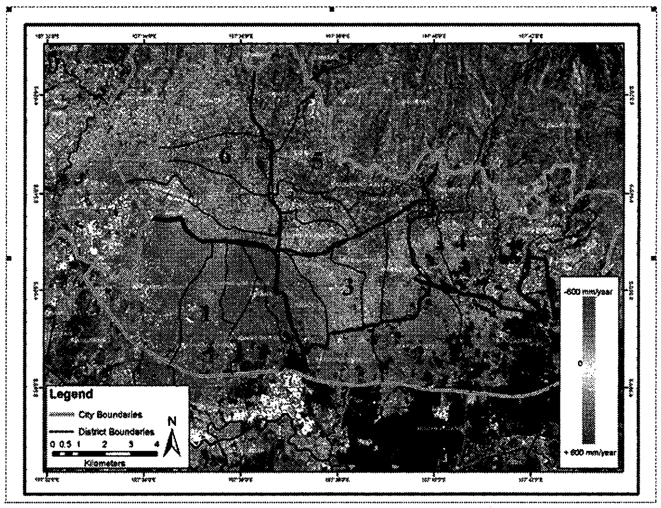

Figure 2. Total displacement map of Bandung Area using PS-InSAR method.

After conducting PS-InSAR processing, a displacement map is derived from the persistent scatterers analysis. The total displacement map of Bandung Area is depicted in Fig.2. It could be seen that the north area of Bandung experienced positive displacement, and on the other hand, the middle and south area of Bandung experienced negative displacement. It is identified that Ujung Berung,

Table 1. Deformation time series for nine slave data.

Area	Slave (mm)								
	Jan 09	**Jul 09**	**Des 09**	**Mar 10**	**May 10**	**Jun 10**	**Nov 10**	**Des 10**	**Mar 11**
(1) Tegallega	-2.01741	-6.08739	-8.08021	-9.02968	-12.2547	-11.1754	-12.866	-12.8321	-13.9091
(2) Gede Bage	1.40459	-1.38044	-7.71983	-18.6394	-21.2411	-22.2416	-19.6584	-24.8804	-35.2327
(3) Karees	-3.1665	-8.72084	-10.6894	-12.0486	-14.7097	-17.1693	-18.8644	-19.9489	-19.4589
(4) Ujung Berung	0.59055	3.38002	12.4655	17.6598	19.7869	20.2339	20.94655	23.4216	28.50751
(5) Cibeunying	-4.4036	-5.29544	10.5954	21.046	20.6065	21.3929	16.67045	23.94521	22.88247
(6) Bojonagara	-2.26084	-4.24873	1.24931	4.85523	3.78299	3.30254	0.850244	3.028675	7.896948

Bojonagara and Cibeunying area experienced positive displacement, and that Tegallega, Gede Bage and Karees area experienced negative displacement.

Table 1 shows the deformation in 6 area in Bandung. It depicts that the north area of Bandung has negative displacement, with the highest value experienced in Gede Baga reached -35.2327 mm. And the middle and south area has positive displacement, with the highest value experienced in Ujung Berung. The total displacement for negative displacement areas are -88.252 mm for Tegallega, -149.589 mm for Gede Baga and -124.777 mm for Karees. As for the total for positive displacement areas are 146.992 mm for Ujung Berung, 18.456 for Bojonagara and 127.439 for Cibeunying.

5. Analysis

It could be analyzed from the scattered points of displacement that area which experienced deformation is in the middle, south and some parts of west Bandung. This could be happened because of the land use. From RUTR Kota Bandung (General Plan of Bandung City Layout), pattern of land use in Bandung which was after 1990 expansion is dominated by residential and vacant land. Proportion of settlements is recorded 52.11% and vacant land (dry land and paddy) reached 31.26%. Other portion of land use is social facilities reached 3.30%, the military region reached 2.07% and 4.99% recorded for the other uses. Land use dominated in west and south area.

As for the trend of the displacement, could be seen in Fig.3. The three north areas; Bojonagara, Cibeunying and Ujung Berung, have increasing trend of displacement. And the three middle-south areas; Tegallega, Karees and Gede Bage, have decreasing trend of displacement.

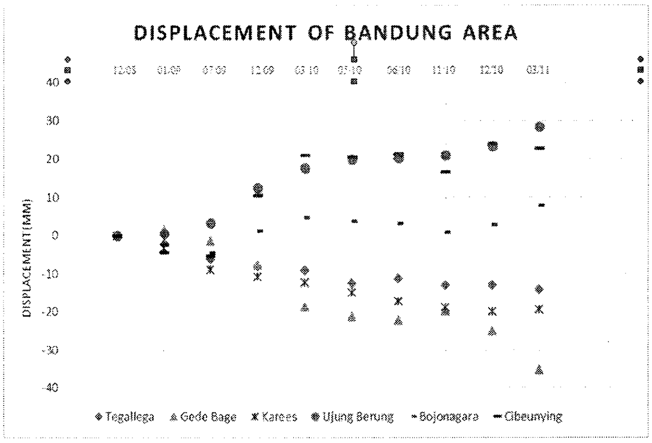

Figure 3. Graphic of Bandung Area Displacement (2009 – 2011).

6. Conclusion

It has been demonstrated the implementation of PS InSAR in Phased Array type L-band Synthetic Aperture Radar (PALSAR) data technique is applicable for mm scale surface deformation monitoring in Bandung. From the result it can be observed that for two years observations a significant decrease in Bandung vicinity reach -149.589 mm.

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