DATA OPTIMALIZATION IN PERMANENT SCATTERER INTERFEROMETRIC SYNTHETIC APERTURE RADAR (PS-INSAR) TECHNIQUE FOR LAND SUBSIDENCE ESTIMATION

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ABSTRACT:

Since the introduction of the persistent scatterer technique (PS-InSAR) in the early 1999, the applicability of radar interferometry has increased considerably.

In this research, PS-InSAR technique is proposed to retrieve the volume change of long-term continuously land deformation. This technique is used to analyze subsidence in Bandung City, West Java-Indonesia by assessing 19 ALOS PALSAR images (Japanese L band spaceborne) during the periods of July 2007-February 2011. In this research, data are optimized by reducing set data images with iterative PS-InSAR processing. This PS-InSAR processing chain based on a rigid quality assessment of the estimated parameter like minimum coherence (0.9) and PS density point (200), in order to get an optimum quality of light PS-InSAR (LPS-InSAR) concept technique. Moreover, a strict quality validation of PS-InSAR with other geodetic techniques such as DInSAR and GPS methods. The result of validation has resulted such as $1,4 \pm 1,4$ cm/year (PS InSAR-DInSAR) and $1,6 \pm 0,7$ cm/year (PS-InSAR-GPS). For land subsidence velocity in Bandung City has results between $0,6 \pm 0,4$ cm/year and $2,1 \pm 1,2$ cm/year.

This research shows a capability of data optimalization in PS-InSAR technique as basic concept of LPS-InSAR processing.

Keyword: DInSAR, Geodetic, GPS, Land Subsidence, PS InSAR.

INTRODUCTION

A case study is Bandung city which is located in western Java Island-Indonesia at longitude $107^{\circ}10'48''$ - $108^{\circ}13'12''$ and latitude of $6^{\circ}10'48''$ - $7^{\circ}44'24''$ as shown in Fig 5.

The compaction in alluvial sediments containing clay causes land subsidence in Bandung. Compaction is a natural process that it happens by uncontrolled usage and overexploitation of ground water, especially in Bandung's industrial area. This over-exploitation of ground water is leading to a rapid decline of water levels, drying out clay layers that finally results in land subsidence [2]. The PS-InSAR technique is used to derive long-term consecutive deformation changes at the surface and eliminate decorrelation effects in final result. We implemented the phase information of consecutive multiple complex data as PS-InSAR data to retrieve the volume change caused by long-term consecutive land surface deformation especially subsidence or uplift.

PS-InSAR technique was published in first time in Permanent Scatterers in SAR interferometry journal [6] at International Geoscience and Remote Sensing Symposium-Hamburg Germany, 28 June-2 July 1999. The advantage of this method compared to other method such as

DInSAR method, it can eliminate decorrelation effects and improve result accuracy. But the disadvantage of PS-InSAR method were needed a large number radar images and a high hardware specification. In this research, we try to optimize images data with iteratively reducing a number images data. Beside to know the optimal time processing, the PS-InSAR was validated by the other methods like DInSAR and GPS. From this validation, we knows the best of number images data in PS-InSAR processing in order to get an accurate land subsidence value.

PS-INSAR METHOD

PS-InSAR technique is applied in a long duration measurement ALOS PALSAR data and is used to investigate the land subsidence rate in Bandung city.

Nineteen ALOS PALSAR images are used to observe study area from the period September 10th, 2007 through February 11th, 2010, as shown in Tab 1. In order to get and visualize the subsidence rate in study area, we will combine the other data like geographic and geodetic data. To get one master image from stack ALOS PALSAR images, we use precise estimation method and the most recent image will become slave images, as shown in Fig 1. Based on this rule, we can get a lot of combination between master and slave image that it is depend on a number of images. From 19 ALOS PALSAR images, we must analyze the critical baseline and normal baseline between images pairs (master image and slave images set). We put minimum coherence value (0.9) and PS density point (200), in order to get good coherence between master slave images combination. Otherwise, the geometry of radar geometry for land deformation [10] as shown in Fig 2.

Figure 1. PS-InSAR methodology in the present study

Figure 2. Radar geometry for earth surface deformation (Sumantyo *et al.*, 2009)

Table 1. ALOS PALSAR images used in the present study

No.	ALOS Images	Format	Level	Acquisition
1.	ALPSRP086653760	FBS	1.0	10-09-2007
2.	ALPSRP106783760	FBS	1.0	26-01-2008
3.	ALPSRP133623760	FBS	1.0	28-07-2008
4.	ALPSRP153753760	FBS	1.0	13-12-2008
5.	ALPSRP160463760	FBS	1.0	28-01-2009
6.	ALPSRP187303760	FBS	1.0	31-07-2009
7.	ALPSRP207433760	FBS	1.0	16-12-2009
8.	ALPSRP254403760	FBS	1.0	03-11-2010
9.	ALPSRP078707040	FBD	1.1	17-07-2007
10.	ALPSRP085417040	FBD	1.1	01-09-2007
11.	ALPSRP125677040	FBD	1.1	03-06-2008
12.	ALPSRP132387040	FBD	1.1	19-07-2008
13.	ALPSRP186067040	FBD	1.1	22-07-2009
14.	ALPSRP199487040	FBD	1.1	22-10-2009
15.	ALPSRP246457040	FBD	1.1	09-09-2010
16.	ALPSRP248937040	FBD	1.1	26-09-2010
17.	ALPSRP255647040	FBD	1.1	11-11-2010
18.	ALPSRP259877040	FBD	1.1	10-12-2010
19.	ALPSRP269067040	FBD	1.1	11-02-2011

Based on Fig 2 [10], we can compute vertical deformation from equation 1, 2 and 3 below:

$$dc_{i,j} = -dz_{i,j} \cdot \cos \theta' + dx_{i,j} \cdot \sin \theta' \dots\dots\dots(1)$$

$$z' = -\frac{r_m \sin \alpha}{B_p} \left(\frac{\lambda \phi}{4\pi} - B_h + dc_{i,j} \right) \dots\dots\dots(2)$$

where λ is wavelength. i, j ($=1, 2, \dots$) shows sub-pixel position. Then B_h and B_p are horizontal and perpendicular baseline distance then α is off-nadir angle. Φ' is incidence angle on a deformed pixel. $dx_{i,j}$ and $dz_{i,j}$ are the displacement of a sub-pixel or a small area at range and elevation directions. $dc_{i,j}$ is the total displacement of a sub-pixel. r_m is slant range distance. We assume the incidence angle on a deformed sub-pixel is same with the incidence angle Φ' at whole area within Φ a pixel. Hence the phase difference ϕ shows the topographical information (z') and total surface deformation ($dc_{i,j}$) in sub pixel as shown in Eqs (2). If we consider only the land deformation at vertical direction (uplift or subsidence) and assume the horizontal deformation could be neglected or $dx_{i,j}$ in Eqs (1) to be zero. The vertical deformation could be derived by employing the Eqs. (1) and (2) as

$$dz_{i,j} = \frac{1}{\cos \theta'} \left\{ \frac{z' B_p}{r_m \sin \alpha} + \frac{\lambda \phi}{4\pi} - B_h \right\} \dots\dots\dots(3)$$

In this PS-InSAR processing, we use two kind of hardware specifications with a great differences in process capability, as shown in Tab 2. We compare time processing in two kind of hardware in same method (PS-InSAR) to know pattern of optimal time processing.

RESULTS AND VALIDATION

Based on PS-InSAR processing in two kind hardware, we can see a pattern of time processing between notebook and workstation as shown in Fig 3. In workstation, we do PS-InSAR processing in Bandung city area that is more larger and heavier than PS-InSAR processing in notebook. It shows the hardware specification requirement in PS-InSAR method held an important factor in order to get an optimal process.

Figure 3. Time processing results from consecutive decreasing number radar images in notebook and workstation hardware.

After PS-InSAR processing, we get a large PS point density and distribution that is contains a land subsidence value, as shown in Fig 3. In next step, we process this PS points with Kriging interpolation method to get a good spatial modelling of land deformation, as shown in Fig 4. The final result, we get a deformation map that is show a deformation pattern of Bandung city.

Figure 3. PS points density distribution of PS-InSAR processing in Bandung city area.

Figure 4. Deformation map from PS-InSAR processing in Bandung city area.

In order to confirm the PS-InSAR processing results that will be used for land subsidence calculation, we compared the vertical deformation or subsidence obtained by DInSAR [12] [13] and GPS observation [13]. Eight points of GPS observation are prepared to investigate the subsidence in the study area and used to validate the PS-InSAR results, as shown in Fig 6. Based on validation results, we know the optimal number of ALOS PALSAR images in PS-InSAR processing compare to DInSAR and GPS methods, as shown in Fig 5. Final results of PS-InSAR processing are land subsidence values in every districts of Bandung city, as shown in Fig 6.

Land subsidence validation results of PS-InSAR processing (9 images set) againts DInSAR and GPS methods

Land subsidence validation results of PS-InSAR processing (10 images set) againts DInSAR and GPS methods

Land subsidence validation results of PS-InSAR processing (11 images set) againts DInSAR and GPS methods

Land subsidence validation results of PS-InSAR processing (12 images set) againts DInSAR and GPS methods

Land subsidence validation results of PS-InSAR processing (13 images set) againts DInSAR and GPS methods

Land subsidence validation results of PS-InSAR processing (14 images set) againts DInSAR and GPS methods

Land subsidence validation results of PS-InSAR processing (15 images set) againts DInSAR and GPS methods

Land subsidence validation results of PS-InSAR processing (16 images set) againts DInSAR and GPS methods

Figure 5. Distribution of GPS Points Observed.

Figure 6. Land subsidence value estimation in Bandung city from 12 ALOS PALSAR images with PS-InSAR technique

CONCLUSION

Based on PS-InSAR results, validation and analysis of the research, we can summarize several conclusions as follows:

1. In order to get better result in land subsidence value computation using PS-InSAR method, we will need a good hardware system with multi-processor core, 4 GB minimum internal

memory and cooling system. Otherwise, a fewer radar images were used in PS-InSAR processing, it could increase time processing. To compensate time processing increase, the highly hardware specification was needed to reduce span time processing. The balancing between hardware specification with a minimum software requirements will optimize the PS-InSAR processing.

2. In this research, PS-InSAR method can process a minimum radar images set with good results in validation step. This method can process 7 ALOS PALSAR images set from 19 ALOS PALSAR raw images to get land subsidence value. It proves that PS-InSAR method can be done with a data images set that are not always large number regardless of the need for accuracy and reliability.
3. The results of PS-InSAR validation to the previous DInSAR (DInSAR¹) produce the smallest difference in standar deviation value ($1.3 \pm 0.4 \text{ cm/yr}$) from 13 ALOS PALSAR images. Otherwise, the results of PS-InSAR validation to DInSAR (DInSAR²-Prof. Josaphat Tetuko Sri Sumantyo, Ph.D) produce the smallest difference in standar deviation value ($1.6 \pm 1.3 \text{ cm/yr}$) from 11 ALOS PALSAR images. Finally, the results of PS-InSAR validation to GPS method (GPS-Prof. DR. Ir. Hasanuddin Zainal Abidin, M.Sc) produce the smallest difference in standard deviation value ($1.6 \pm 0.7 \text{ cm/yr}$) from 8 and 12 ALOS PALSAR images.
4. Based on PS-InSAR processing, Bandung city has a variety land subsidence value in every districts as shown in Fig 6. The maximum values of land subsidence are variety around $28,7 \pm 4,3 \text{ mm/yr}$ through $58 \pm 9,5 \text{ mm/yr}$ in Astana Anyar, Babakan Ciparay, Bandung Kulon and Regol districts.

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