Monitoring land subsidence in Semarang City Indonesia using Multiple Acquisition Radar Interferometry (MARI)

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Abstract

Based on field observation, it was reported that the ground subsidence associated with groundwater extraction became one of environmental problems in Semarang Indonesia. In order to understand time and spatial distribution of land subsidence in Semarang city Indonesia, we performed Multiple Acquisition Radar Interferometry (MARI) of ALOS-PALSAR satellites data. We created 20 interfrogram images from 13 scans SAR data and removed topography phase using DEM three-arcsec (90 m) from each initial interferograms. We performed precision baseline estimation of each pairs to vanish the fringes derived by baseline between master and slave data. The improved phase unwrapping image shows land subsidence about 5-12 cm/y, which mainly caused by groundwater extraction and landuse changing from agriculture and cultivation purposes to industrial estates and house in Semarang. The fringe patterns are detected very clearly in center of Semarang city and northern part of city where the number of pump of groundwater concentrated in this area and large amount of water supply for the communities and industries. Our results are comparable to our previous work and shows the centre of the city was subsided continually after March 2008. The pattern of land subsidence in Semarang city derived by MARI is good relationship with past result obtained by both leveling data and digital elevation modeling (DEM) interpolated and benchmark points.

Key words: Radar Interferometry, subsidence, groundwater, landuse,

1. Introduction

It was reported that in Semarang, located on the northern part of Central Java Province in Indonesia at latitudes 6°58'S and longitude 110°25'E (Fig. 1), surface water and groundwater became mainly water supply for the communities and industries [1]. When groundwater levels decline sufficiently so that stress on the aquitards becomes greater than the maximum previous stress, then the aquitards compact and the land surface subsides permanently. Many buildings in Semarang city are severely affected by land subsidence (Fig. 2) which is mainly due to excessive groundwater extraction and natural consolidation of alluvium soil.

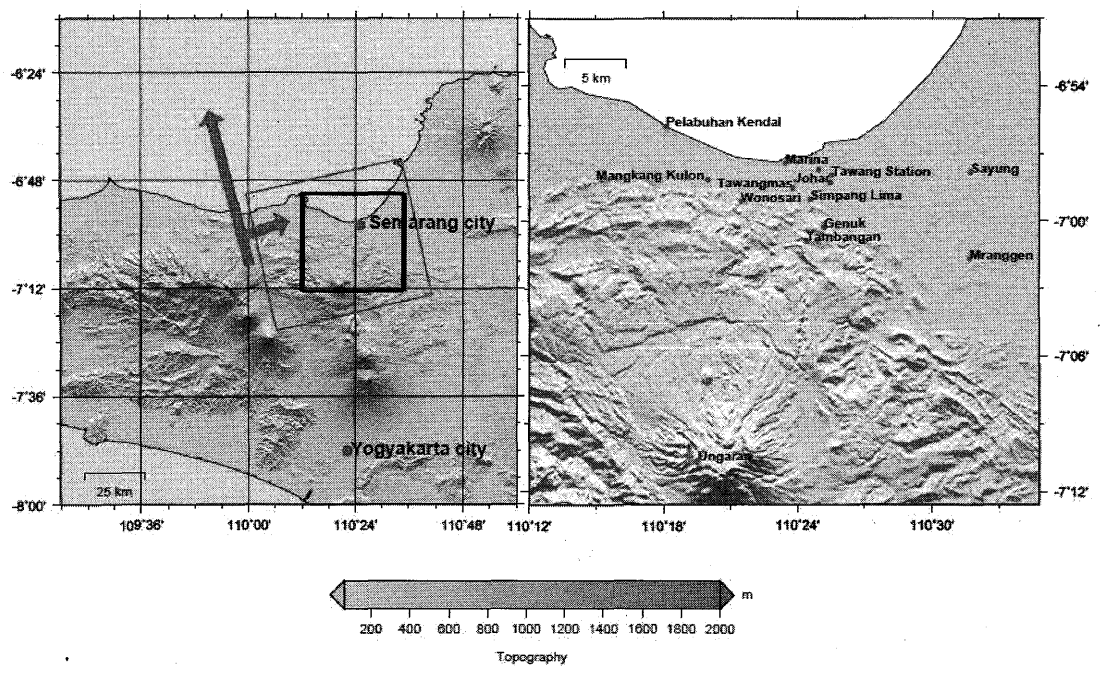


Figure 1. Map of Semarang city, shaded digital elevation model data shown in the figure. Red rectangular is location of PALSAR acquisition.

In this study, we performed Multiple Acquisition Radar Interferometry (MARI) of ALOS-PALSAR satellites data to access land subsidence in Semarang city Indonesia.

Figure 2. Impact of land subsidence in Semarang city [2].

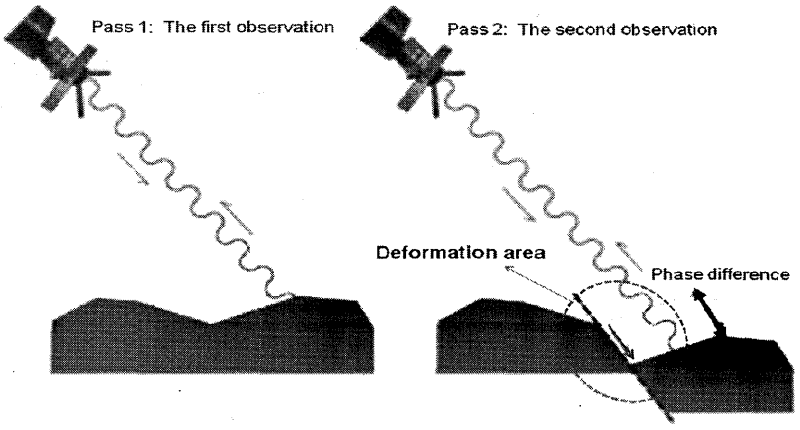


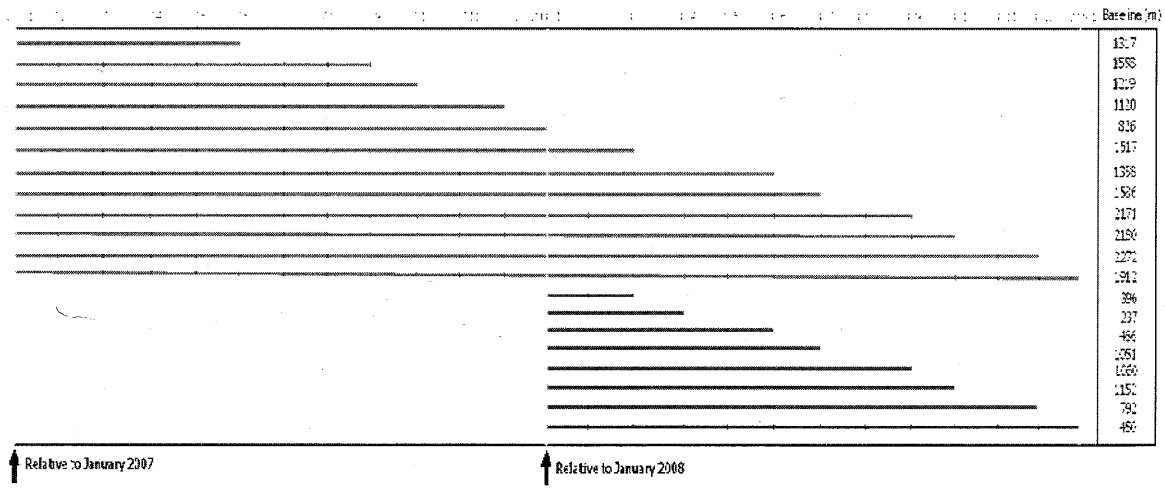
Figure 3. Carton of InSAR observation

2. Method and Result

In this research we used row data from two passes of ALOS PALSAR satellite (Tables 1). All of our data cover area around Semarang city (Fig 1). The principal measurement for Synthetic Aperture Radar Interferometry (InSAR) for monitoring land deformation in target area is shown by Fig 3. Two satellites send radar waves to the same point on the ground at different times. If the earth moves between passes, the wave will return at a different phase. Knowing the length of the wave, it is possible to calculate the precise amount of deformation.

The total differential of the phase difference is represented by three kinds of fringes which are caused by orbital fringe, topographic fringe and fringe land displacement due to earthquake, volcano eruption, oil, gas and water extraction, and landslides. To remove fringe related to topographic effect we mosaiced conventional digital elevation data a 3-arcsecond SRTM digital elevation model. e performed precision baseline estimation to vanish the fringes from baseline between master and slave data, and improved signal to- noise ratio of each differential interferogram using a weighted power spectrum filter as discussed in [3]. The minimum cost flow (MCF) was applied for unwarping process since the interferometry phase is wrapped modulo 2π, and an integer number of 2π must be added to recover the absolute phase difference.

Table 1. Row data of ALOS PALSAR satellite used in this study.



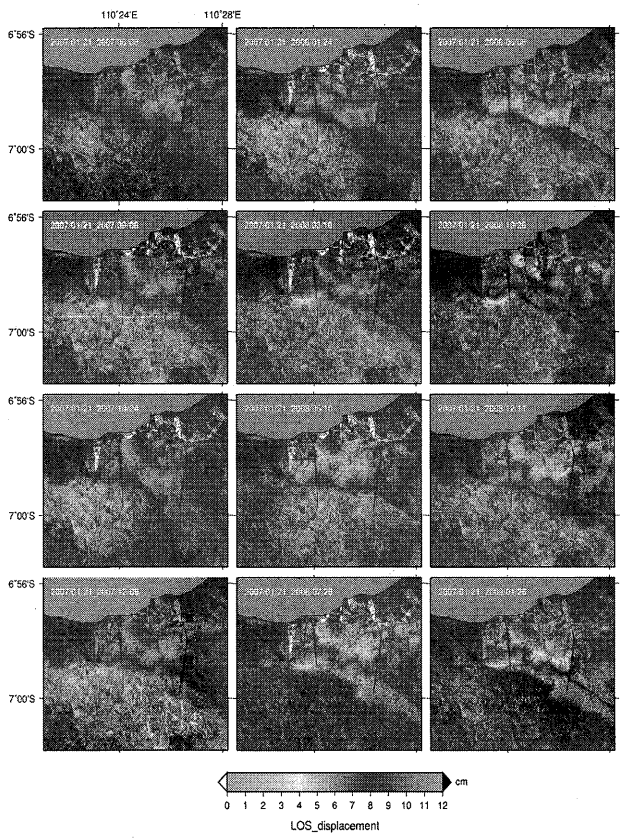


Figure 4. Land deformation images during 2007-2009 relative to January 2007.

In Both pair relative to January 2007 A (Fig. 4) and pair relative to January 2008 B (Fig. 5), the fringe patterns are detected very clearly in center of Semarang city and we can also see that high-subsidence rate occurred especially along the coastal area where in these areas the groundwater became mainly water supply for the communities and industries.

We estimated land deformation about 5-12 cm/y during January, 2007 to January 2009. The images of deformation show that the pattern of land displacement is increasing with extending time span observation. It can be noticed the significant difference from each pair with increasing time evolution of observation. Result of deformation during 2007-2009 and 2008-2009 observation shows similar pattern where fringe patterns of 2007-2008 are almost the same in comparison to 2008-2009 InSAR data which revealed

that the subsidence was continue after 1 years (2007-2008) time period of observation. Our results in general are similar pattern of land subsidence with Fig 6 derived from Envisat *Persistent Scattered Interferometry* [3] and ldeformation in Semarang city from Leveling data (Fig. 7)

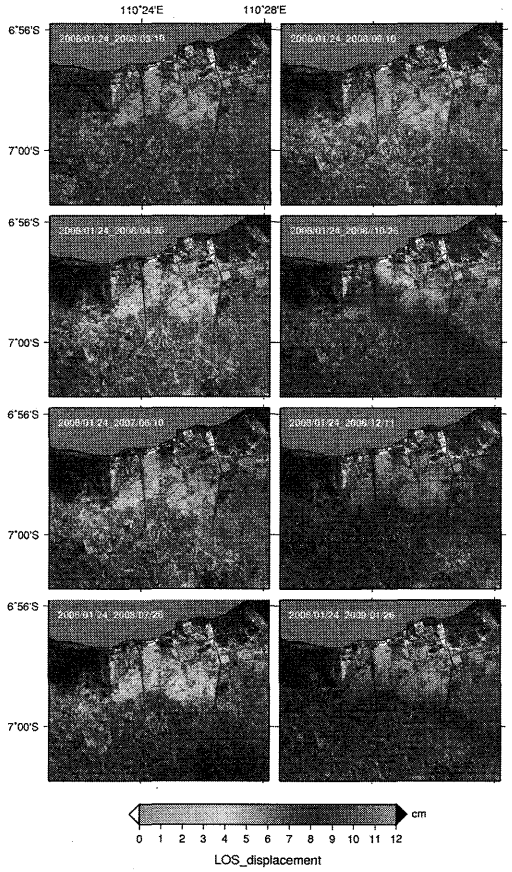


Figure 5. Land deformation images during 2008-2009 relative to January 2008.

The Semarang city can be divided into two major landscapes, namely, lowland and coastal area on the northern part and hill area on the southern part (Fig. 1). The city centre is situated on the lowland area, and landuse was changed rapidly from agriculture and cultivation purposes to industrial estates and house because the population is growing rapidly [1]. According to land deformation distribution from our result, past leveling data and Envisat *Persistent Scattered Interferometry* result, it can be noticed that

land subsidence mostly occurred on the lowland and coastal area of Semarang where in this region increasing populated area and land changing purpose are concentrated since 1990.

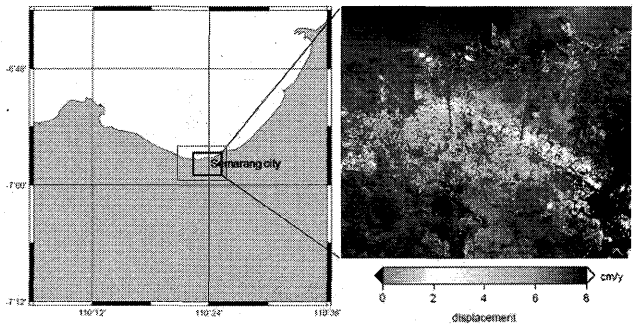


Figure 6. Land deformation in Semarang city from Envisat data [3].

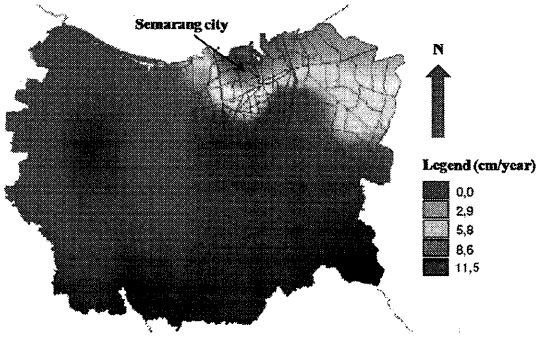


Figure 7. Land deformation in Semarang city from Leveling data [4].

3. Conclusion and Recommendation

We investigated land deformation in Semarang city using PALSAR data interferometry and estimated max. land subsidence 5-12 cm/year. We concluded that ground water extraction combined with landuse change incorporating with house development due to increased urbanization caused land subsidence in Semarang city. To achieve a better understanding and modeling of land subsidence phenomena in the Semarang city, the land subsidence information derived by InSAR method should be integrated with the land subsidence information obtained by geodetic techniques (e.g., leveling, and GPS) by incorporating by geohydrological and geotechnical

measurements (e.g., using automatic water level recorder, piezometer, and drilling). The reliable and best of information of land subsidence will help government, planners, regulators, and administrators to manage landuse and groundwater resources in Semarang city.

References

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