SUBSIDENCE MAPPING IN JAKARTA - PSI PROCESSING OF L-BAND ALOS PALSAR DATA

Rachel Holley [(1)], Richard Burren[(1)], Hasanuddin Z. Abidin [(2)]

[(1)] Fugro-NPA Ltd, Crockham Park, Edenbridge, Kent, TN8 6SR, UK, Email:r.holley@fugro-npa.com
[(2)] Geodesy Research Division, Faculty of Earth Science and Technology, Institute of Technology Bandung (ITB), Jl. Ganesha 10, Bandung 40132, Indonesia, Email: hzabidin@gd.itb.ac.id

ABSTRACT

Jakarta is a heavily populated city, which has been experiencing ongoing ground subsidence for several decades, due to heavy use of groundwater, soil characteristics and tectonic motion. It is expected that this ground motion will increasingly impact upon flood risk management and ongoing development of the city, in particular critical infrastructure.

Persistent Scatterer Interferometry (PSI) is an ideal technique for deriving accurate and detailed historical motion studies over urban areas. However, available C-band data stacks for Jakarta do not include sufficient images for PSI. This work instead applies PSI processing to a stack of L-band images from JAXA's ALOS PALSAR instrument.

The PSI results show a variety of subsidence features across the city at various spatial scales, with some areas experiencing average annual velocities of up to ~180 mm/yr. Comparisons with Envisat and ERS DifSAR interferograms show a promising agreement in both the spatial distribution and magnitude of deformation within the city. Results are also compared with existing GPS measurements from the city.

1. INTRODUCTION

Jakarta Metropolitan Region is known to suffer from subsidence, with much of this motion due to water abstraction [1]. The city has undergone a large increase in urban and industrial growth over the past few decades, resulting in an increased demand for water abstraction. This has been exacerbated by urban growth encroaching onto aquifer recharge areas.

Until now the majority of subsidence measurements have been point-based (levelling, GPS) and relatively limited in spatial extent. A requirement existed for a historical motion study to give detailed, wide area coverage of the city at high accuracy.

Persistent Scatterer Interferometry (PSI) is an ideal technique for deriving accurate and detailed historical motion studies over urban areas. However, the available archive of C-band data is rather limited over Jakarta, with a maximum stack of 10 suitable ERS images available between 1996-1998, and 8 Envisat from 2007-2009. This restricts both temporal coverage and processing options, since neither archive contains enough SAR images for PSI processing. Given the requirement for PSI, an alternative data source was identified.

2. PALSAR PSI PROCESSING

This work applied PSI processing to a stack of 18 archived L-band images from the PALSAR (Phased Array type L-band Synthetic Aperture Radar) instrument aboard JAXA's ALOS (Advanced Land Observing Satellite) platform. To enable use of a sufficient number of SAR images, a combination of single- and dual-polarisation images have been used. The HH component of the dual-polarisation images is interferometrically-compatible with the HH single-polarisation images, but requires over-sampling prior to InSAR processing.

The perpendicular baseline (B_{perp}) and altitude of ambiguity (h_a) characteristics of PALSAR data differ from those of the C-band datasets more conventionally used in PSI processing. Although baselines are larger, this is partly compensated by an approximately six-fold increase in the corresponding altitude of ambiguity, due to the longer wavelength.

Baselines are commonly correlated in time, particularly at higher latitudes. This has the potential to introduce bias in PSI (and other network/SBAS-type techniques, for example [2]), which assume topographic phase signals are not correlated with time and hence can be separated from time-correlated deformation. This effect was mitigated by applying a pre-processing height correction derived using a filtered subset of interferograms.

PSI processing produced a high point density across the urban area of Jakarta, with up to ~1500 PS/km^2 in some areas. Sufficient points were retained across the majority of surrounding rural areas for patterns of deformation to be examined. Eighteen images would normally be considered toward the smaller end of suitable stack sizes for PSI, particularly in areas with high potential for atmospheric artefacts from strong

Proc. 'Fringe 2011 Workshop', Frascati, Italy,
19–23 September 2011 (ESA SP-697, January 2012)

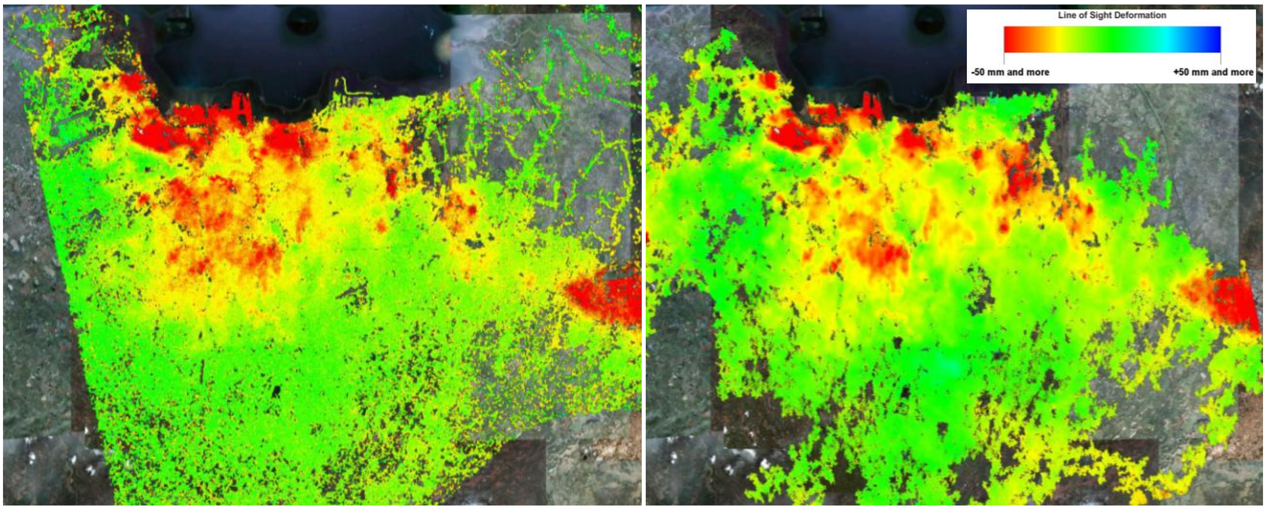

Figure 1. Subsidence maps of Jakarta derived using PALSAR PSI 2007-10 (left) and a single Envisat DifSAR interferogram 2008-09 (right) showing average annual motion rate (mm/yr). For copyright details see acknowledgements.

topographic contrasts. This prevented robust analysis in the mountainous terrain south of the city, but the urban area has low relief and residual atmospheric influence appears minimal.

Residual orbital gradients must also be considered when utilising relatively small data stacks, particularly since the presence of relatively wide areas of deformation have the potential to bias orbital corrections. A post-processing empirical correction was estimated and removed from the average annual velocity field, after masking areas of deformation, however potential for residual bias still exists.

3. RESULTS

The PSI results (Fig. 1A) show a variety of subsidence features across the city at various spatial scales, with some areas experiencing average annual velocities of up to ~180 mm/yr.

While a fairly large portion of central and north-western Jakarta is experiencing subsidence, it is noticeable that many of the areas experiencing the strongest motion are relatively close to the sea. This may have particular implications for flood risk, and in the longer term susceptibility to sea level change.

In some areas, zones of subsidence appear to be bounded by fairly well-defined lineaments. In some cases these appear to correspond with ground features, and may relate to differences in land use or areas of industrial water abstraction, for example. In other areas, there is no obvious correlation with surface features, and these lineaments could potentially relate to deeper structural or tectonic influences.

Despite the relatively high levels of uncorrelated noise, in many areas close examination of the results reveals interesting details. For example, an area extending southward from the historic core of Jakarta shows an undulating ribbon of subsidence (Fig. 2), which resembles a meandering river channel. Although no such feature is visible in optical imagery, it is possible this could represent an abandoned channel, for example.

4. VALIDATION

Scenes from the limited ERS and Envisat SAR archives wee used to construct ten DifSAR interferograms, panning periods of up to 1.4 years between 1996-1998 and 2007-2009. Comparison of these showed that many of the main areas of subsidence have persisted for some time, although the magnitudes of motion are subject to fluctuation. From comparison of ascending and descending interferograms the influence of horizontal motion appears limited.

The ALOS PSI result spans a similar time period to the range of Envisat SAR image dates. The comparison is slightly complicated by the variable time spans of the interferograms; however the correspondence appears to be highly encouraging. For example, comparison of Figs. 1A and 1B (which have comparable colour scales) shows a promising agreement in both the spatial distribution and magnitude of deformation within the city. This represents a reassuring validation of deformation results, given the two sets of data were derived from independent SAR datasets acquired at different wavelengths and processed with contrasting techniques.

Annual GPS surveys have been conducted for a number of points within the Jakarta Metropolitan Area by the Institute of Technology Bandung [1,3]. Yearly vertical displacements are available for 17 locations. PS within 100 m of each GPS location were averaged to reduce the impact of very small-scale deformation variations and noise.

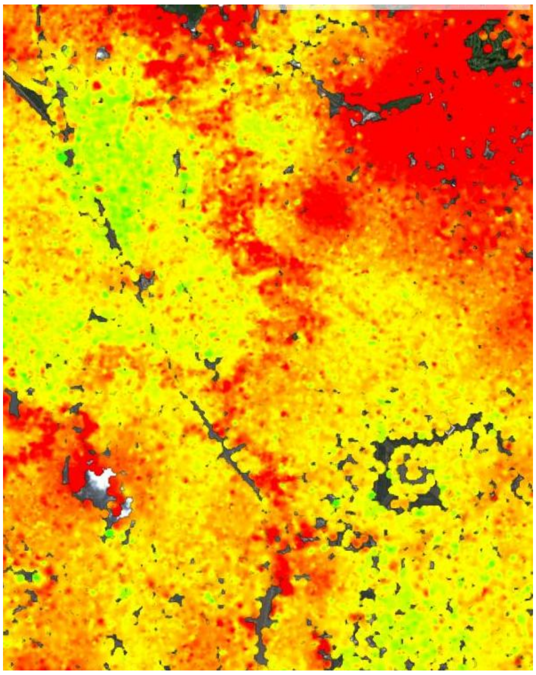

Figure 2. Small section of PSI average annual velocity map showing an undulating area of subsidence appears to resemble a meandering river channel. For copyright details see acknowledgements.

The original PSI reference point was located 2.7 km from the CDTB GPS point. Comparison of the PSI motion rate at CDTB showed a reference point offset of ~23 mm/yr, which closely matched the overall average offset between the GPS and PSI for all points. After subtraction of the reference bias, the GPS-PSI residuals had a mean of -0.4 mm/yr and standard deviation of 19.7 mm/yr. This is of the same order of accuracy as the GPS measurements.

5. CONCLUSIONS

Where insufficient C-band archives are available, L-band ALOS PALSAR provides a viable alternative source of data stacks for PSI. A number of characteristics differ from those of C-band data and require consideration during processing, notably the impact of time-correlated baseline distributions. For Jakarta, PSI processing was successful, revealing strong areas of subsidence with implications for infrastructure, urban development and flood control. Validation against C-band DifSAR and GPS data was encouraging.

6. REFERENCES

1. Abidin, H.Z., Andreas, H., Gumilar, I., Fukuda, Y., E. Pohan, Y.E., Deguchi, T. (2011), Land subsidence of Jakarta (Indonesia) and its relation with urban development. *Natural Hazards*. Doi: 10.1007/s11069-011-9866-9
2. Samsonov, S., Beavan, J., González, P. J., Tiampo, K. and Fernández, J. (2011), Ground deformation in the Taupo Volcanic Zone, New Zealand, observed by ALOS PALSAR interferometry. *Geophysical Journal International*. doi: 10.1111/j.1365-246X.2011.05129.x
3. Abidin, H.Z., Andreas, H., Djaja, R., Darmawa D., Gamal, M. (2008). Land subsidence characteristics of Jakarta between 1997 and 2005, as estimated using GPS surveys. *GPS Solutions*, Vol. 12, No. 1, pp. 23-32.

7. ACKNOWLEDGEMENTS

InSAR work presented here was performed by Fugro NPA Limited (FNPA) within the European Space Agency's (ESA) 'VAE Geo-Expansion of Canadian and European EO Services to South East Asia', run by C-Core and Hatfield Consultants. GPS data presented courtesy of Institute of Technology Bandung.