Long-term Monitoring of Surface Deformation over Datun Volcanoes in Northern Taiwan

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Abstract: Datun Volcano group is the largest volcano group in Taiwan. The existing monitoring over this area reveals that Datun Volcano group is active and is of potential to erupt in the future. As the volcanoes are very close to Taipei City and Yangmingshan National Park, it is critical to understand the behavior of the volcanoes. To this end, this paper aims to apply remote sensing method to monitor the surface deformation of the Datun Volcanoes. Synthetic Aperture Radar (SAR) is capable of penetrating cloud, and the most importantly, achieving sub-centimeter level deformation detection after interferometric processing, SAR data and associate processing techniques were proposed as the main method for deformation monitoring. In which a number of 14 ENVISAT ASAR archived images covering 2003 to 2008 were employed. Persistent Scatterers Interferometric SAR (PS-InSAR) technique was then performed to determine surface deformation over Datun Volcanoes. As a result, the amount of deformation of every PS-candidate point over the test area was revealed and shown in the paper.

1. INTRODUCTION

Datun Volcano group is the largest volcano group in Taiwan. It consists of 29 volcanoes and the distribution of Datun Volcanoes is shown in Figure 1. To protect abundant biological, volcanic resources and landscape, the government found Yangmingshan National Park in this area. Although there was no eruption occurring for a long period, the existing monitoring reveals that Datun Volcanoes are still active. As Datun Volcanoes are very close to Taipei City, serious damages would occur if the volcanoes erupted. Therefore it is critical to understand the behavior of the volcanoes. Based on the observation, the government is able to perform corresponding action to prevent or reduce destruction caused by such disaster.

Remote Sensing is one of the methods broadly applied to monitor surface deformation. Among the remote sensing techniques, as Synthetic Aperture Radar (SAR) is capable of operating under difficult weather condition, covering wide range, and the most importantly, achieving sub-centimeter level deformation detection after interferometric processing, SAR and associate processing techniques were therefore proposed as the main method for deformation monitoring. With a series of SAR data, differential synthetic aperture radar interferometry (D-InSAR) technique could be performed to investigate the surface deformation over time. The technique has been applied successfully to monitor mm-level surface displacement occurring over large area. However, as high noise ratio was expected in the interferograms, it was realised that the D-InSAR technique was ineffective for observing area covered with vegetation or affected by serious atmospheric condition. To overcome such limitations, the Persistent Scatterer (PS-) InSAR technique was developed. Based on the pixels of high-correlation (i.e. PS candidate) determined in a time series SAR images, the displacements occurring over time were calculated. A number of researches were conducted to develop algorithms for PS-InSAR implementation, including Ferretti et al. (2001), Lyons and Sandwell (2003), Hooper et al. (2004) and etc. With the development, effective and accurate monitoring of surface deformation over cities, vegetated area or volcanoes was demonstrated.

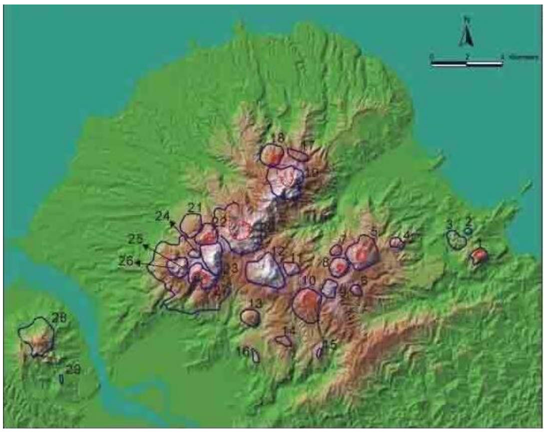

Figure1: Distribution of 29 volcanoes of Datun Volcano group (Lin, 1998).

This paper focused on deformation monitoring over Datun volcanoes area (Figure 1). Due to the forest land cover of the observing area, PS-InSAR was introduced to monitor the target site. The detailed SAR processing method results and resulting surface deformation occurring in the test site are described in the following sections.

2. METHODOLOGY

Images used in this study are acquired by European Space Agency's ENVISAT satellite. The SAR sensor installed on the orbiter provided C-band ASAR images. In order to perform a long-term monitoring, a total of 14 ASAR images from November 2003 to February 2008 were selected to compute the displacement field of the Datun Volcanoes area.

The StaMPS (Stanford Method for Persistent Scatterers) software implementing persistent scatterer In-SAR method and Small BAseline Subset (SBAS) together (Hooper et al., 2004) was applied to perform D-InSAR processing and determine PS pixels in this study. With the identified time series PS pixels, the displacement occurring over target areas could be identified. Successful monitoring applications using StaMPS were listed in Hooper (2012). The workflow using StaMPS is shown in Figure 2. The processing began with two pre-processing steps once the SAR images were derived. The first was to focus the raw data, and the second was to form interferograms from single-look complex (SLC) images. In which the ROI_PAC routine developed in Jet Propulsion Laboratory (JPL) and California Institute of Technology (CIT) (Rosen et al., 2004) was used for the SAR image focusing, and the DORIS software developed in Delft Institute for Earth-Oriented Space Research (DEOS) was applied for interferogram formation (Kampes, 2005). Based on the coherence and amplitude data produced by DORIS, PS candidates were selected and permanent PS pixels were further identified in the StaMPS routine. Once this was achieved, the SNAPHU package (Chen and Zebker, 2002) was then used to unwrap PS phase. At the last stage, the StaMPS was implemented again to perform DEM error correction and atmospheric filtering. The ground displacement was also solved at this stage.

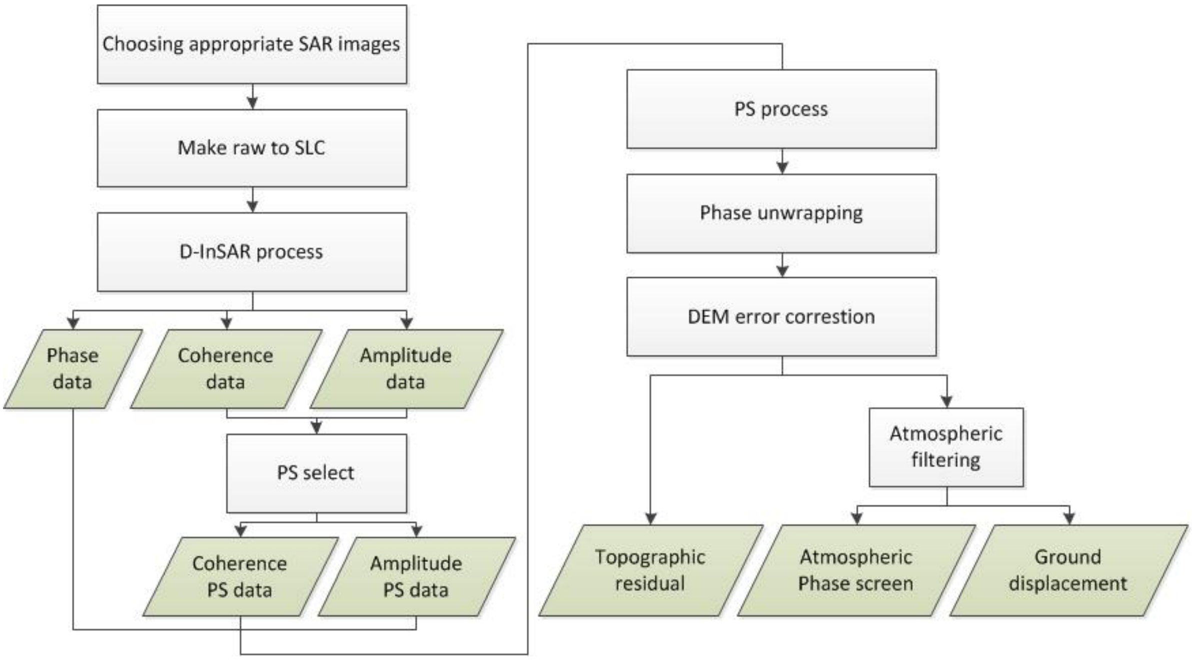

Figure 2: Workflow of StaMPS processing.

3. RESULTS

Small baseline processing was performed in StaMPS software. As a result, a number of 44 interferograms was established. The plot of perpendicular baseline of the interferograms and the resultant SB interferograms are shown in Figures 3 and 4 respectively.

The results derived from SB analysis were further applied for PSC determination and estimation of displacement velocity. The line-of-sight (LOS) velocity occurring in the time period (2003 to 2008) is shown in Figure 5. In addition to the magnitude of displacement velocity, it was observed that the pixels with estimated displacement were distributed as expected from ASAR SB interferograms (refer to Figure 4). However, it was also found that the lack of PS pixels over volcano area occurred when ASAR images was applied.

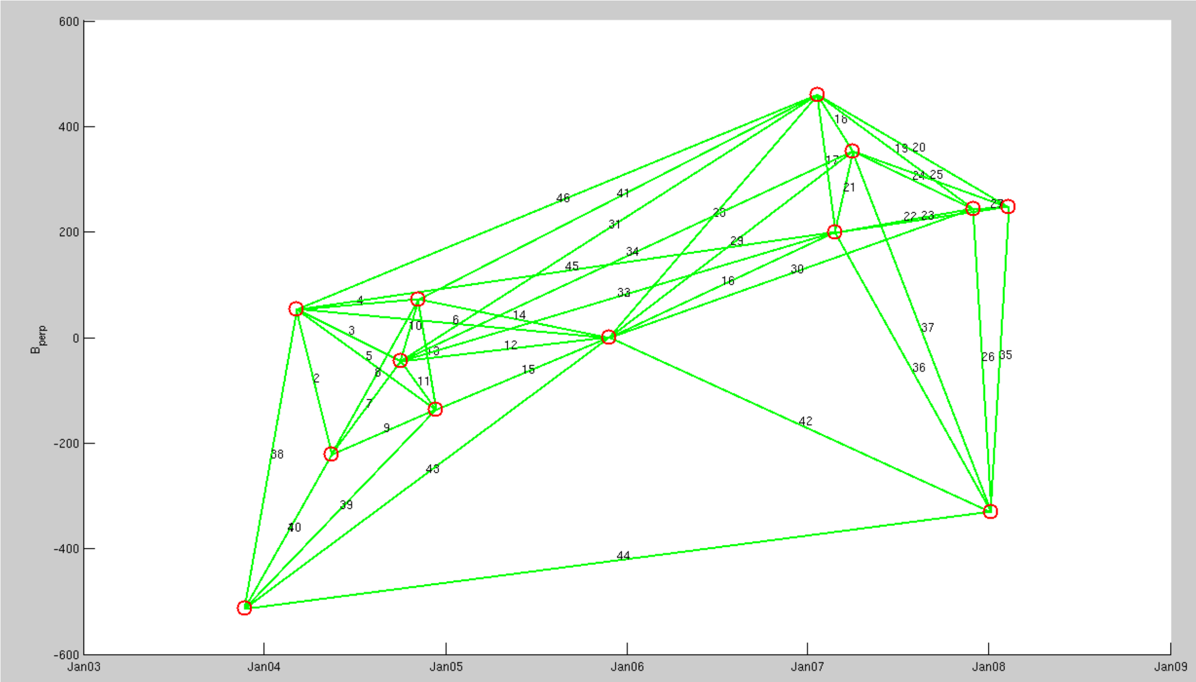

Figure 3: The perpendicular baseline plot of ASAR data. The circles represent the images and lines represent the SB interferograms formed.

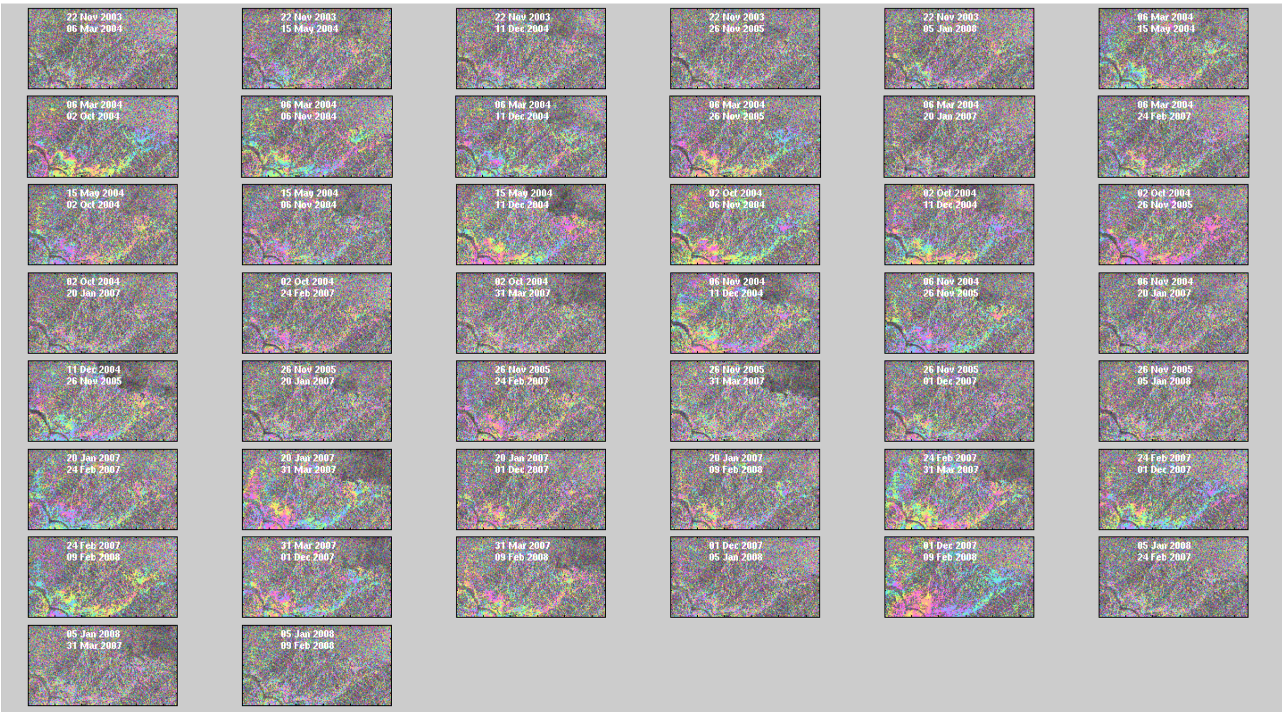

Figure 4: ASAR SB interferograms.

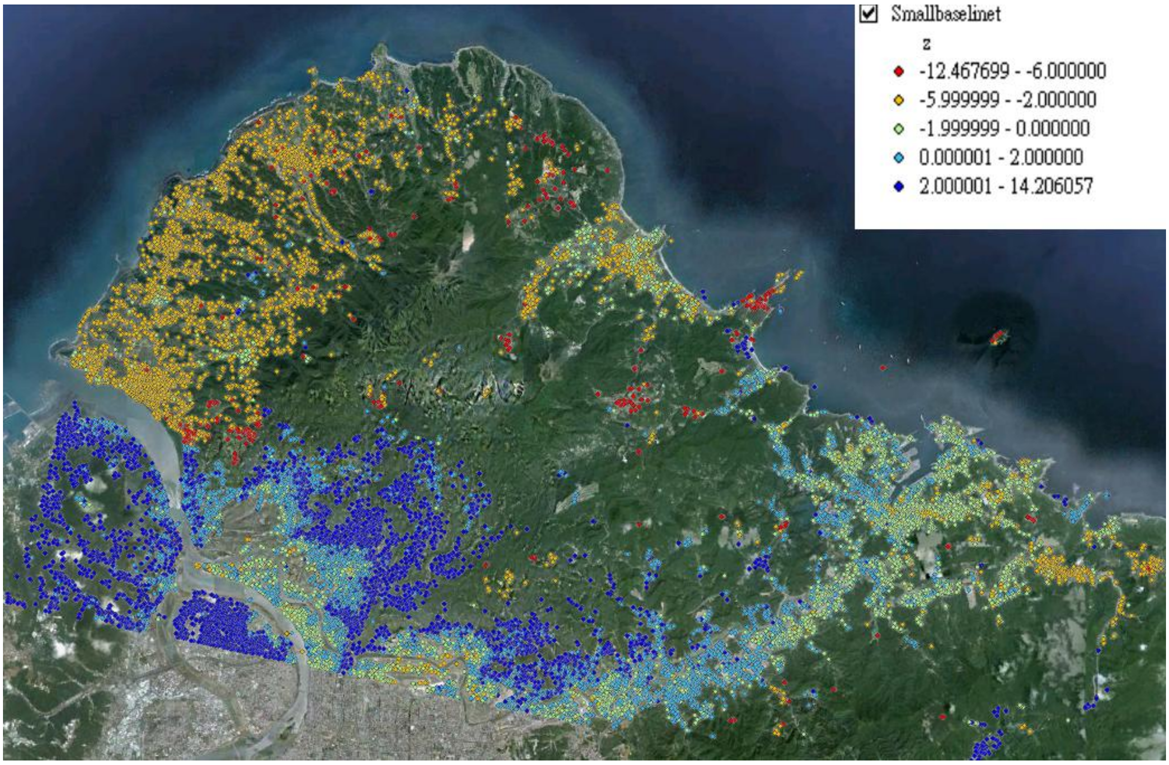

Figure 5: Mean LOS velocities over the test site between November 2003 and February 2008 (mm/year).

4. SUMMARY

This study aimed to investigate the feasibility of PS-InSAR processing over Datun Volcanoes. To this end, SBAS analysis with ASAR data was implemented in StaMPS software. From the results shown in Section 3, the displacement velocity occurring in the time period over the test area was determined. However, due to the heavy vegetated environment, the displacement was not fully determined over the target area. To address the issue, employment of L-band PALSAR data and an appropriate method to add PS candidates in SBAS processing will be carried out in the near future.

REFERENCES:

Chou, F. M., 2009. Measurement of Surface Deformation in Northern Taiwan by Using PSInSAR Techniques, National Central University, Taoyuan.

Ferretti, A., Prati, C. and Rocca, F., 2001. Permanent scatterers in SAR interferometry, IEEE Trans. on Geosci. and Remote Sensing, 39(1), 8-20.

Hooper, A., Zebker, H., Segall, P., and Kampes, B., 2004. A New Method for Measuring Deformation on Volcanoes and Other Natural Terrains Using InSAR Persistent Scatterers,Geophys. Geophys. Res. Letter, 31, L23611, doi:10.1029/2004GL021737.

Hooper, A., Segall, P. and Zebker, H., 2007, "Persistent scatterer interferometric synthetic aperture radar for crustal deformation analysis, with application to Volca ´ n Alcedo, Gala ´ pagos", GeoPHYSICAL RESEARCH. 112(B07407): B07407(07401-07421).

Kampes, B. M., 2005. Displacement parameter estimation using permanent scatterer interferometry, Ph.D. thesis, Delft Univ. of Technol., Delft,Netherlands.

Lyons, S., and Sandwell, D., 2003. Fault creep along the southern SanAndreas from interferometric synthetic aperture radar, permanent scatterers, and stacking, J. Geophys. Res., 108(B1), 2047, doi:10.1029/2002JB001831.

Rosen, P. A., Hensley, S., Peltzer, G., and Simons, M., 2004. Updated repeat orbit interferometry package released, Eos Trans. AGU, 85(5), 47, doi:10.1029/2004EO050004.

Pinel, V., Hooper, A., De la Cruz-Reyna, Reyes-Davila, G and Doin D., M, 2011. The challenging retrieval of displacement field from InSAR data for andesitic strato volcanoes: Case study of Popocatepetl and Colima Volcano, Mexico,J. Volc. Geotherm. Res., 200(1-2), 49-61.

TUDelft, 2008. Delft Object-oriented Radar Interferometric Software User’s manual and technical documentation

Lin, J.H., 2009.敬畏火山, http://www.google.com.tw/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&ved=0CCkQFjAB&url=http%3A%2F%2Fwww.ymsnp.gov.tw%2Fnweb%2Ffilesys%2Ffiles%2Fch%2Fdl%2F231%2F005.pdf&ei=GSRtUIyQEemTmQXv_4DwDA&usg=AFQjCNETyOcfzc84rGqfF2ebLVcQmb2rmQ&sig2=2nO0DtgvIYHzqVxukkCscw (Date Visited: July 10, 2012)