MONITORING OF SURFACE DEFORMATION IN NORTHERN TAIWAN USING PSINSAR TECHNIQUES

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ABSTRACT: We investigated the surface deformation of the northern Taiwan area, including the Taipei basin and its surrounding mountainous areas of the last few years using the ERS-1, ERS-2 and ENVISAT SAR images. Although the Taipei basin now is well developed and amenable to research gathering using the Differential Interferometric Synthetic Aperture Radar (DInSAR) technique, the mountainous areas surrounding the basin are densely covered with various vegetation throughout different seasons inducing high noise ratio in interferograms. Therefore the DInSAR technique is ineffective for observation of surface deformations of these areas. As a result, we developed the Persistent Scatterer (PS) InSAR technique to extract the phase signal of the chosen PS points for this study. Our analysis result shows that the atmospheric disturbance and DEM residual can be successfully reduced and the precise information of surface deformation can be effectively obtained by the PSInSAR technique not only in the basin but also in the mountainous areas. Integrating the DInSAR and PSInSAR results, we observed conspicuous deformation events in northern Taiwan including: (1) the slight uplift in the Western Foothills, the Tatun volcanoes, the Linkou Tableland and the Taoyuan area; (2) the subsidence at the border of the Taipei basin; and (3) relative slight uplift rebound in the center of Taipei basin. The displacements along the Shanchiao, Chinshan, and Kanchiao Faults are large enough to be observed; the Taipei, Hsinchuang, and Nankang Faults are too small and cannot be discerned. Further comparison between the DInSAR, PSInSAR, and their corresponding leveling data shows a very coincidental pattern and measurably improves the authenticity of radar interferometry.

INTRODUCTION

Taipei, the most densely populated area, center of politics and economics in Taiwan, is located in the Taipei basin at the northern part of Taiwan. The basin is a triangular-shaped, tectonically controlled basin. More than 600m of Quaternary sediments, unconformably overlying the Tertiary basement have previously been divided, in ascending order, into four stratigraphic units: the Banchiao, Wuku, Chingmei and Sungshan Formations (Teng et al., 1994). Nevertheless, during the Quarternary arc-related volcanism erupted a number of volcanoes in northern Taiwan, including the Tatun volcanoes, so the Tatun volcanoes might erupt is an issue that needs to be discussed. Moreover, several faults in and around the basin have been reported (Fig. 1). In order to understand the tectonic activity and mitigate the potential geological hazards of Taipei basin, monitoring the surface deformation in and around this basin should be a top priority.

In the past few years, Differential Interferometric Synthetic Aperture Radar (DInSAR) and Persistent Scatterer (PS) InSAR has proved to be a powerful technique for monitoring neotectonic activities and natural hazards. But DInSAR technique have some limitation, including the atmospheric effects, the topography and covered vegetation, all of these will affect the radar images. Development of PSInSAR is aimed at solving the weakness of DInSAR. This technique considers only the stable scatterer that is brighter than the background scatterer and thus can reduce the noise ratio in radar image and effectively extract the deformation signal.

We chose ERS-1, ERS-2 and Envisat SAR images to generate PSs in the northern Taiwan area. And compared the PSInSAR result with the DInSAR result (Chang et al., 2009) and leveling data (Chen et al., 2007), in order to understand the consistency between them.

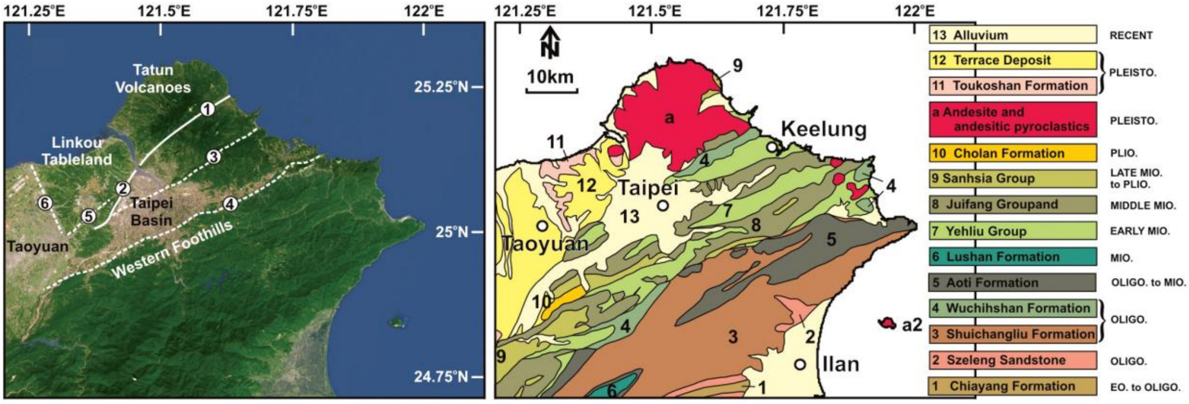

Figure 1. (a) Morphology of the Northern Taiwan area. Shaded picture from SPOT satellite imagery (data from Center for Space and Remote Sensing Research Center, National Cnetral University, 2006). The Taipei basin is nearly triangular in shape and is bordered by the Western Foothills to the south and east, the Tatun volcanoes to the north, and the Linkou Tableland to the west. Some fault lines marked by black lines include: (1) the Chinshan Fault; (2) Shanchiao Fault; (3) Kanchiao Fault; (4) Taipei Fault; (5) Hsinchuang Fault; and (6) Nankang Fault. After the Central Geological Survey's report (Lin et al. 2000) only the Chinshan and Shanchiao are active faults (in solid white line). (b) Generalised geology of the northern Taiwan area. Adapted from the Geological Map of Taiwan (published by the Central Geological Survey) and other maps.

METHODOLOGY

The DInSAR technique provides continuous observation for the flat area. However, for the mountainous area around the Taipei basin, because of the low correlation, this technique is unable to determine the phase change signal upon which to draw any conclusions about the regional surface deformation. However, if a pixel is dominated by only one stable scatterer that is brighter than the background scatterers, the variance in the phase of the returning signal due to the change of the background scatterers will be reduced, and may be small enough for extracting the underlying deformation signal. Ferretti et al. (2000 and 2001) first indentified this type of pixel as a Permanent Scatterer™.

Hooper et al. (2004 and 2007) developed a new PS method to extract the deformation signal from SAR data of the area that contains few man-made structures and that deformed at variable rates during the time interval analysis. This method largely increases the accuracy of the estimated displacements and also makes it applicable in area with widely varying deformation gradients. In this study, we apply Hopper's method, the StaMPS (Stanford Method for PS, Hooper et al. 2007), for identifying PS pixels and estimating their displacement. The detail processing procedure is shown in Fig. 2.

Figure 4 shows the unwrapped phase of PS pixels of each image referenced to the master image. In these interferograms the Taiwanese digital elevation model mentioned before has been applied to remove the topographic effect; however, the residual phase results shown in Figure 4 still contain errors from several other sources. Theoretically, the residual phase, ϕ, of the xth pixel in the ith topographically corrected interferogram can be written as the sum of 5 terms,

$$\phi_{x,i} = \phi_{def,x,i} + \phi_{\alpha,x,i} + \phi_{orb,x,i} + \phi_{\varepsilon,x,i} + n$$

Where ϕ_{def} is the phase change due to movement of the pixel in the satellite line-of-sight (LOS) direction, ϕ_{α} is the phase equivalent of the difference in atmospheric retardation between passes, ϕ_{orb} is the phase due to orbit inaccuracies, ϕ_{ε} is the residual topographic phase due to error in the DEM and n is the noise term due to variability in scattering from the pixel, thermal noise and coregistration errors. Because the PS pixels were defined where n is small enough, this component will not be discussed below (Chang et al., 2009).

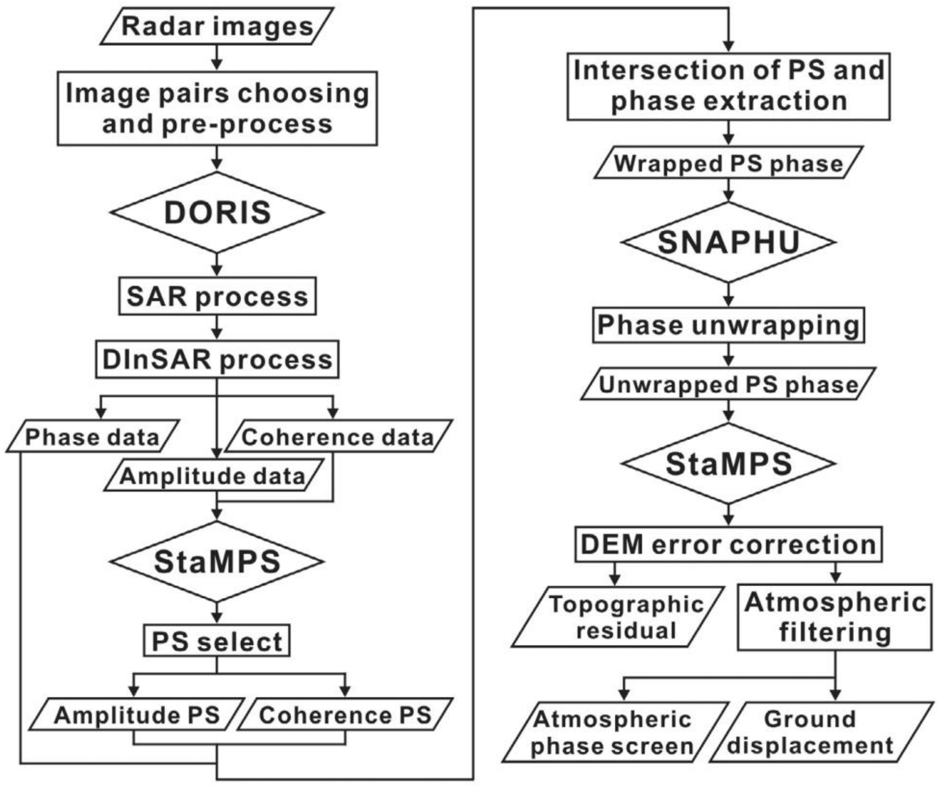

Figure 2. Processing flowchart for PSInSAR analysis used in this study. The main processes include: Raw data process, SAR image process, differential interferometry process, PS selecting, intersection of PS and phase extracting, phase unwrapping, DEM error correcting, atmospheric filting. The SAR image and differential interferometry process were done by DORIS software, all PS processes were done by StaMPS software developed by Hooper et al. (2004).

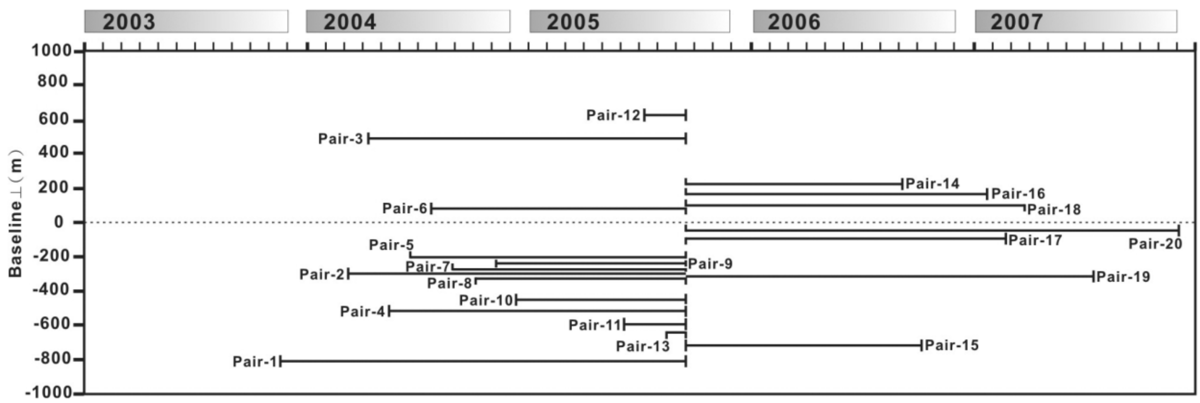

Figure 3. Image pairs used for PSInSAR analysis in this study. All images are acquired by satellite ENVISAT in the descending orbit track 461, frame 3105. Cross axle: acquisition time; vertical axle and the number in parentheses: perpendicular baseline (B⊥) in meter.

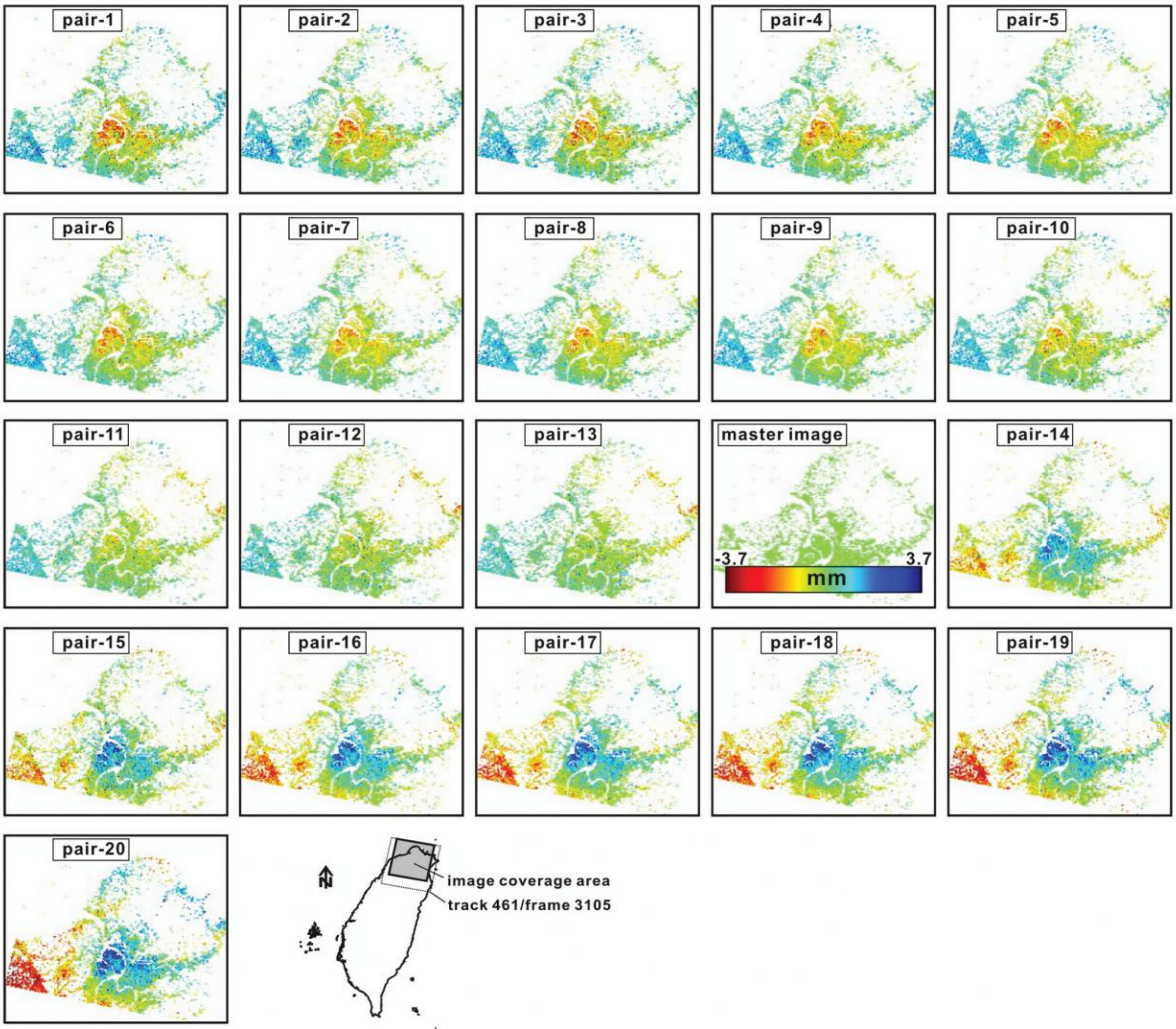

Figure 4. Unwrapped phase of PS pixels of each images referenced to the master image.

CONCLUSION

Development of PSInSAR is aimed at solving the weakness of DInSAR. This technique considers only the stable scatterer that is brighter than the background scatterer and thus can reduce the noise ratio in radar image and effectively extract the deformation signal. Since PSInSAR technique does not use every scatterer on the ground, the resolution (density of pixels) of this technique in a mountainous area with dense vegetation can be consequently reduced; phase unwrapping in the PSInSAR technique is therefore a crucial process for the area with lower PS density. Another constraint for PSInSAR is data acquisition and observation time span. For an effective PS calculation, at least around twenty images are needed, the shortest observation time period, considering the observation cadence as 1 pass per 35 days, is at least 2 years. For the emergent and temporal event, such as the co-seismic surface deformation associated with large earthquake, the PSInSAR technique is thus difficult to apply.
Besides compared the PSInSAR result with the DInSAR result (Chang et al., 2009) and leveling data (Chen et al., 2007).We also utilize the GPS-azimuths to compared with the PSInSAR result, and try to find out some relationship. The final results will be published in the poster.

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