# Terrain Deformation monitoring in Three Gorges Area using Permanent Scatterers SAR Interferometry

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**Abstract.** As a new technique of SAR interferometry (InSAR), permanent scatterers SAR interferometry (PS InSAR) has been successfully applied on some urban areas to measure the terrain deformation.[1][2][5] But it is not easy to use it in the mountainous and humid areas due to the uncorrelated and atmospheric errors. Wanzhou is such a place where landslides frequently take place. It locates in the Three Gorges region, China. In this paper, we present our PS InSAR application on Wanzhou. Investigations are also made on PS processing flow.

## 1. Introduction

The Three Gorges Reservoir is the biggest hydropower project on the earth and has attracted worldwide attention. There used to be frequent geology disasters such as landslides, earthquake, and mudflow in Three Gorges Reservoir region before. After the completion of the project, the hazard risk of this area became an issue of common concern.

The synthetic aperture radar interferometry is a new development in remote sensing earth observation technology during last decades. It has shown a great deal of potential in detecting deformation of millimetric level in several important geophysical applications such as earthquake co-seismic dislocations, glacier notion studies, and subsidence monitoring. Permanent Scatterers differential SAR Interferometry (PS D-InSAR) is developed by the scientists in Politecnico di Milano in 1999 based on the traditional SAR Interferometry. It aims at resolving the problems caused by loss of coherence and atmospheric inhomogeneity which restrained the InSAR to be more effective on terrain deformation monitoring.

In this paper, we take on a PS InSAR application in Wanzhhou area with the ENVISAT ASAR data from ESA. A 2 $km^2$ deformation field is derived.

# 2. PS Technique

PS InSAR was introduced by Ferretti et. al in 1999. It was first applied on the terrain subsidence of Ancona, Italy using 34 ERS SAR images.[1] In 2000, they used 41 ERS images to monitor the deforming of urban area in Pomona during 1992 to 1997.[2] Most of the applications of PS are concentrated in the urban area.

PS InSAR technique makes a systematic analysis of D-InSAR data (>30 images) taking advantage of the huge available data set (ERS1/2, ENVISAT ASAR), processing only the information of the coherent targets, which are slightly affected by temporal and geometrical decorrelation. After the estimation and removal of the Atmospheric Phase Screen (APS), the phase contribution due to target motion will be extracted with high accuracy (0.1mm). Fig.1 clearly depicts the flow of PS D-InSAR processing With PS InSAR, we can measure the slow tiny terrain deformation during several years. It is nearly impossible with the traditional InSAR, because of the poor coherency in such long period.

## 2.1 PSC Selection

As the PS InSAR technology is based on the statistical of the great amount of PS samples, the reliability of the PS samples is the most important for the accuracy of the result. Amplitude index [1][4] method is used to pick out the stable targets. This threshold method is focused on every pixel's amplitude dispersion along the time sequence. Amplitude index is proved to be a measure of phase stability. Each pixel whose amplitude index is under a given threshold is selected as a PS candidate (PSC).

## 2.2 Deformation field retrieval

The PSCs are distributed stochastically. The Atmospheric Phase Screen (APS) for each image pair and the average deformation vector of each PSC can be retrieved by resolving this sparse grid systematically based on the temporal and the spatial dimensions simultaneously. During the retrieving process, linear distributed model and deformation model are used respectively to monitor the atmosphere field and the terrain deformation process. After the removal of the APS from the differential interferograms, a deformation field is derived at last.

# 3. Wanzhou Application Result

Wanzhou is one of the areas in Three Gorges reservoir region where landslides frequently take place. It is mountainous, rainy and with flourish vegetation. These are all negative factors to the InSAR application.

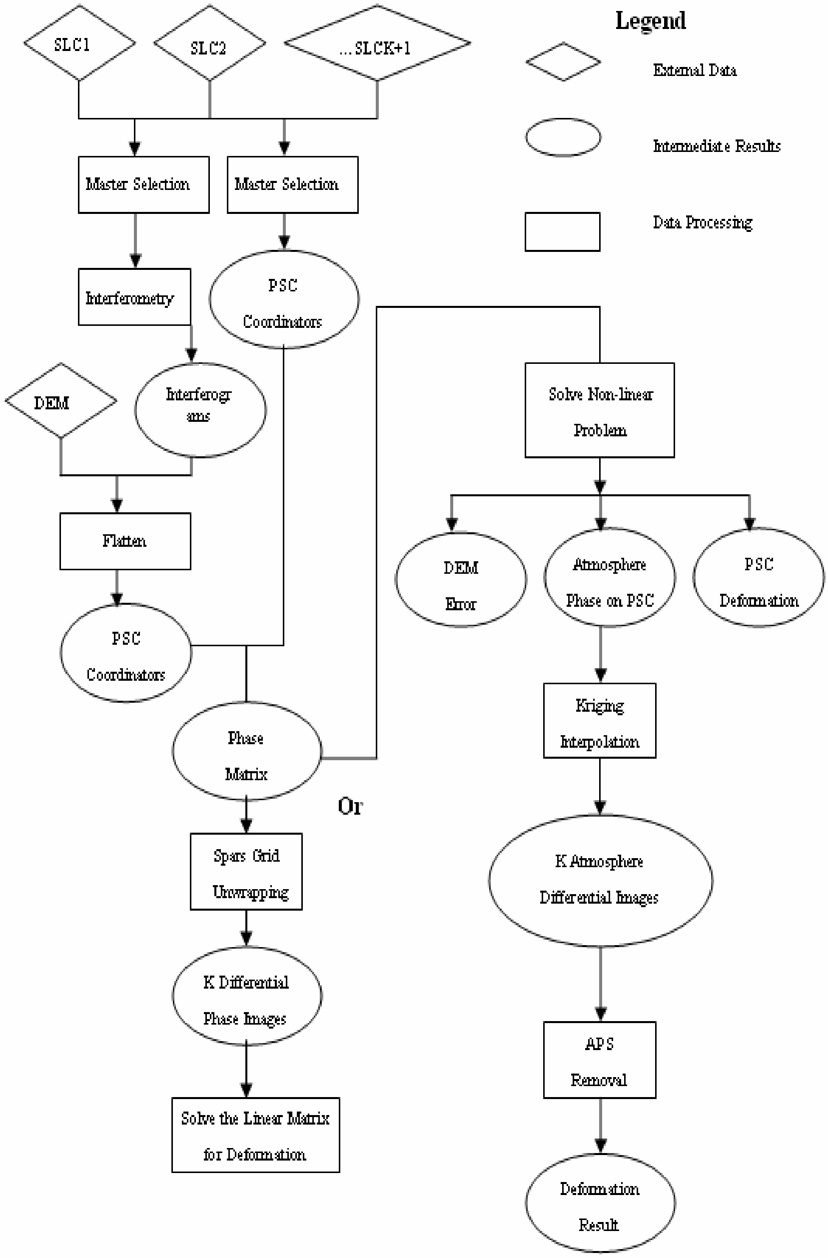


*Figure.1* PS processing flow chart

We get all the 11 available ASAR SLC images in Wanzhou. The images are dated from 2003 to 2005. All the images are co-registered to a master image we select considering the factors of temporal spatial baselines and the season factors. The maximum spatial baseline difference is 1420m. Using the co-registered SRTM3 as the external DEM, 10 differential interferograms are generated by traditional D-InSAR processing.

The intensity of the PSCs we select in a research area is about 35/km$^2$. Comparing to mountainous area, there will be much more stable Scatterers in urban area. Usually, in urban area the PSC intensity can achieve 100/km$^2$.

Fig.2 and Fig.3 are two of the 10 APS generated by Kriging interpolation. Phase delay of 0.5 radians corresponds to 2mm Two Way Zenith Delay [3].

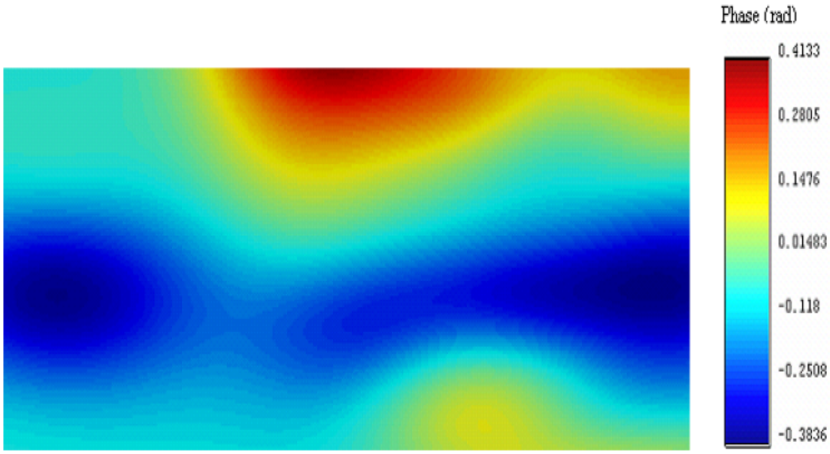


*Figure 2*: APS for the pair of Dec.22, 2003 and Apr. 5, 2004

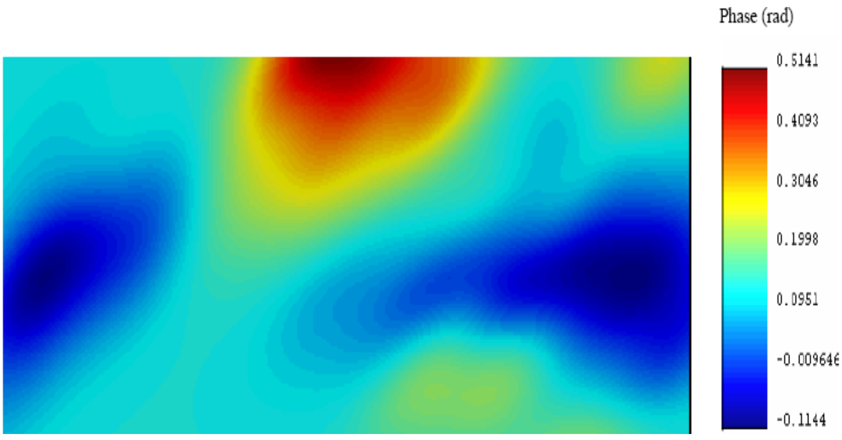


*Figure 3*: APS for the pair of Dec. 22, 2003 and July 19, 2004

Figure 4 shows the terrain movement directions of PSC locations before and after atmospheric correction using APS. There are neighbor PSCs closed in distance but demonstrating opposite deformation directions which is not reasonable. It may because that when the terrain slop is big enough, the direction of deformation along side of look will be opposite to the real direction. Furthermore, complicated topography can also introduce uncertainty in interpretation. Other reasons for the confused results may be imprecise baseline, residual topographic and unresolved atmospheric phases.

A deformation field of $2km^2$ in Wanzhou area is derived using Kriging interpolation. There are 67 PSCs. Figure 5.b shows the derived deformation field of research area which is marked with the red rectangle in Figure 5.a. It reveals that the primary deformation trend of this area is subsidence. The motion velocity is focused on +/- 2mm/year along radar line-of-sight (LOS) direction.

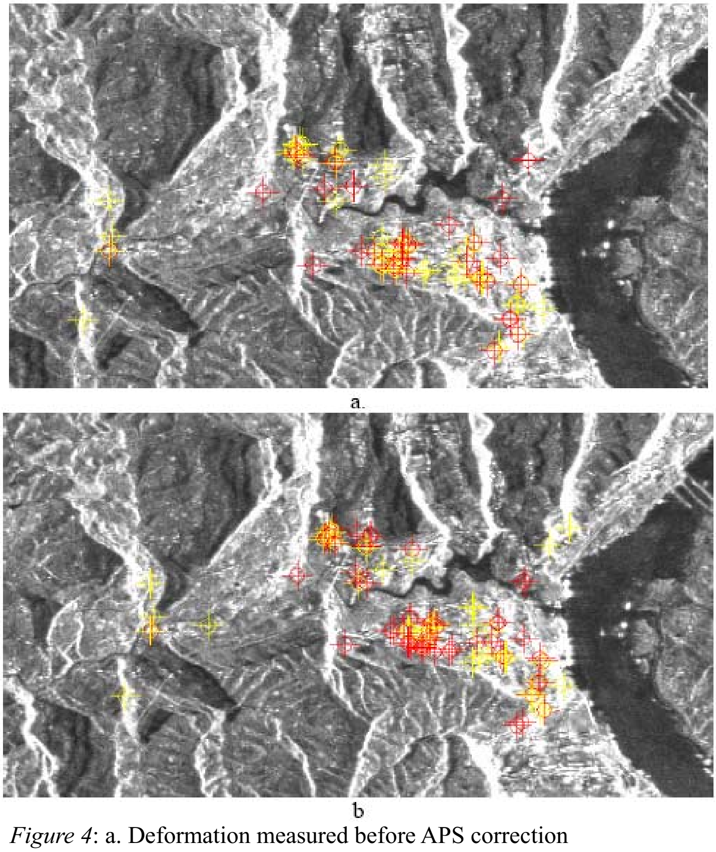

*Figure 4*: a. Deformation measured before APS correction
b. Deformation after correction
Red: Outward along LOS direction (down and away);
Yellow: Toward along LOS direction (lift up)

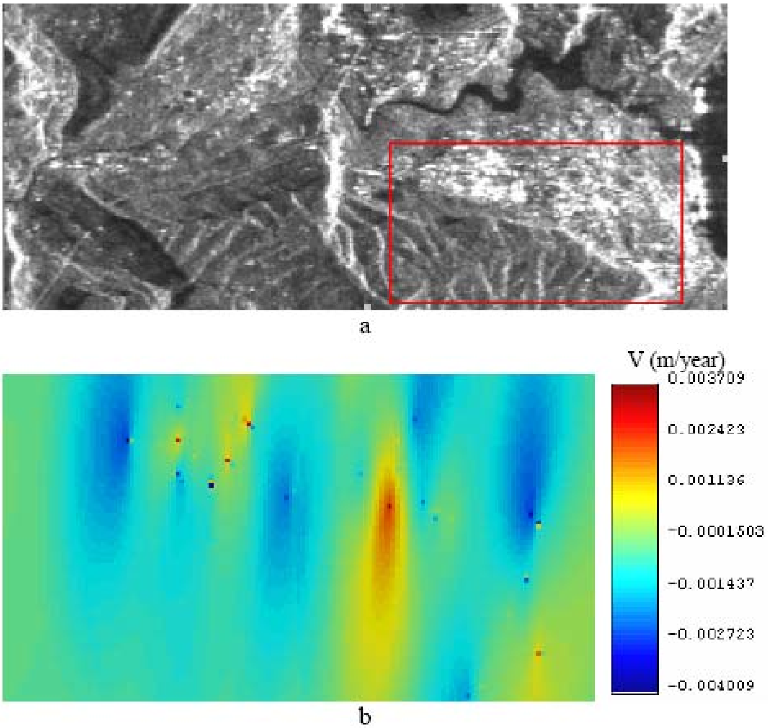


*Figure 5:* a: PSC deformation research area
b: Deformation field

## 4. Conclusion

This paper presents our work on Three Gorges area deformation monitoring using PS InSAR technology. The result reveals the average velocity and the pattern of the terrain deformation in Wanzhou area. It is also concluded that, a more precise atmospheric model related to the DEM needs to be built for the mountainous area in further research. The result needs to be testified with the detecting information on the spot. The complicated climatologically and geologically situation in Three Gorges area is a big challenging to the successfully application of InSAR technique. And the limited number of SAR images is also accused for the imperfection of the experiment results. It is expected that the results will be improved combining with the other monitoring data such as GPS, artificial reflectors [6] and the meteorological satellite images.

**References**

1. Ferretti, A.; Prati, C.; Rocca, F, 1999, Permanent scatterers in SAR interferometry, Geoscience and Remote Sensing Symposium, 1999. Proceedings. IGARSS 1999. IEEE 1999 International Volume 3, pp.1528-1530
2. Ferretti, A.; Prati, C.; Rocca, F, 2000, Nonlinear subsidence rate estimation using permanent

Scatterers in differential SAR interferometry, Geoscience and Remote Sensing, IEEE transactions on, Sept. 2000, Vol. 38, Issue 5, Part 1, pp: 2202-2212.
3. H. A. Zebker and P. Rosen, 1997, Atmospheric artifacts in interferometric synthetic aperture radar surface deformation and topographic maps, J. Geophys. Res.: Solid Earth, vol. 102, pp. 7547-7563.
4. H. Zhang, 2005, Research on the key technique of Permanent Scatterers InSAR measurement, Master thesis, Peking University.
5. Costantini, M., Iodice, A., July 2000, Magnapane, L., and Pietranera, L., Monitoring terrain movements by means of sparse SAR differential interferometric measurements, IGARSS 2000. IEEE 2000 International, vol. 7, pp. 3225-3227.
6. Ye Xia, Hermann Kaufmann and Xiaofang Guo, 2002, Differential SAR interferometry using corner reflectors, IGARSS '02. 2002 IEEE International, vol. 2, 24-28 pp. 1243 – 1246.
7. R. F. Hanssen, Radar Interferometry-Data Interpretation and Error Analysis. Series: remote sensing and digital image processing, Vol. 2. Springer. ISBN-10: 0792369459, ISBN-13: 978-0792369455.
8. L. Gao, 2006, Implementation of Permanent Scatterers InSAR technology and its application to measuring terrain deformation in Three Gorges area, Master thesis, Peking University.