DEM RETRIEVAL AND LANDSLIDE MONITORING IN BADONG, THREE GORGES, CHINA BY MEANS OF INSAR PARTIALLY COHERENT TARGETS

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ABSTRACT

In this work we present the first results achieved in the Three Gorges area by means of a new InSAR processing technique. Where standard interferometric tools and the PS technique fail to achieve reliable results, the proposed technique, which exploits partially coherent targets, is able to estimate terrain height and average deformation trend with reduced accuracy but remarkable spatial coverage. The results here shown have been achieved by processing ESA ERS and Envisat data over Badong, China.

1. INTRODUCTION

The work here presented has been carried out within the Dragon cooperation project between the European and Chinese space agencies (ESA and NRSCC respectively). In this framework, the 'topographic measurement' group (whose partners are represented by profs. F. Rocca, Politecnico di Milano and L. Deren, Wuhan University), had as objectives studies on 1) urban subsidence, 2) landslide analysis and monitoring, and 3) Three Gorges Dam site stability.

Indeed, works have been published during the cooperation by analyzing ESA SAR data over different sites. We remember here the subsidence monitoring in Tianjin [1], where a preliminary investigation on the urban targets physical nature has been carried out by exploiting 23 ERS images. Figure 1 shows 10,000 Permanent Scatterers (PS) detected in Tianjin with temporal coherence greater than 0.8, the color indicating the estimated linear deformation trend.

As other test-site it is worth to recall also Shanghai, where the high rate city growth and the few available data prevented from obtaining results over 3 out of 4 existent satellite tracks. The urban character of Shanghai suggested then as solution the exploitation of multi-angle targets as dihedrals to combine data acquired from parallel tracks [2]. In this way it was possible to double the number of data samples to carry out the estimate of height and deformation trend of dihedrals. Figure 2 shows the result of the novel technique: a comparison between the subsiding rate as estimated from ERS images Track 3 and Envisat images, Track 268 and 497 together. The developed method allowed the updating of the subsidence monitoring in Shanghai. Figure 3 shows the comparison between the ground motion as estimated by the PSs and as detected with optical leveling.

Therefore, important outcomes have been obtained in

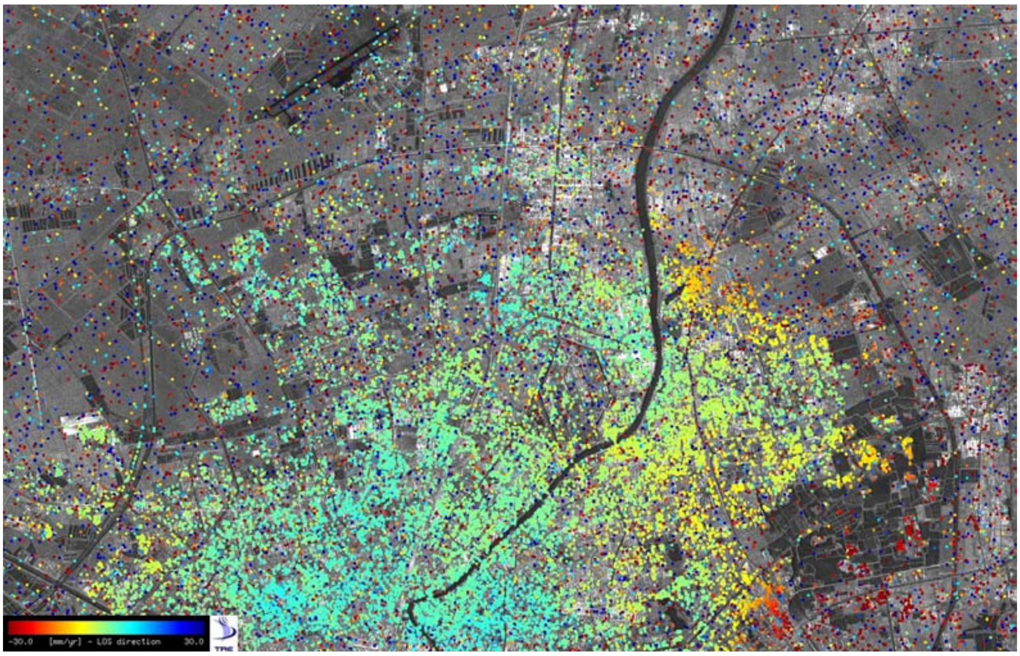

Figure 1. About 10,000 PSs detected in Tianjin. Colour scale: average deformation trend (-30 – 30mm)

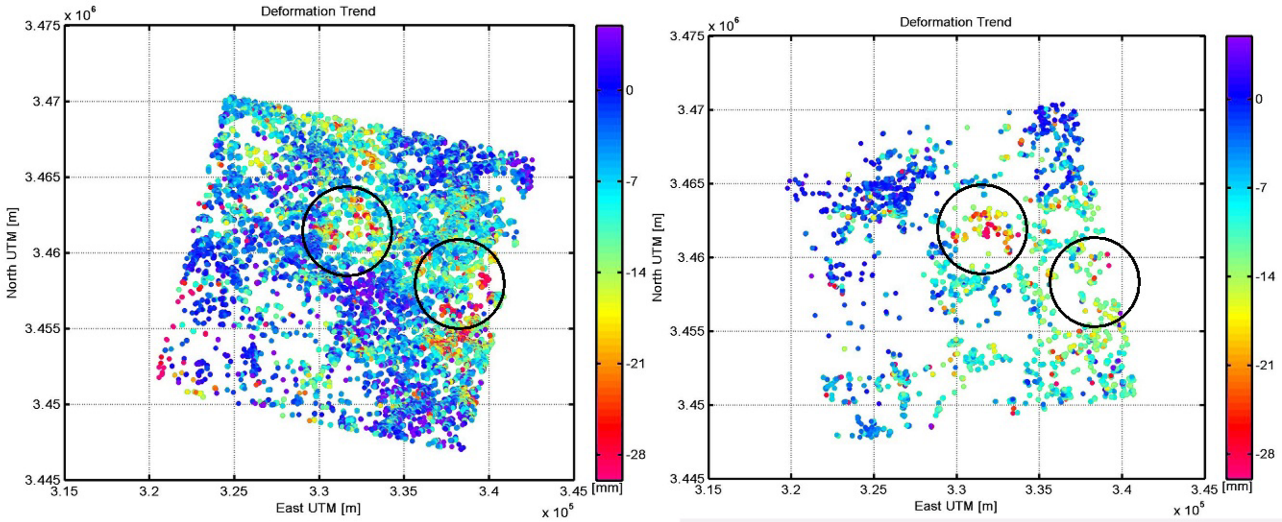

Figure 2. Comparison between PSs detected with ERS data acquired along Track 3 (left) and dihedral PSs detected by Envisat along Tracks 268 and 497 in Shanghai. Colour scale: average deformation trend (-30 – 0mm)

urban areas, both from practical and technical points of view. However, no reliable results along the Yangtze River were yet achieved (even if different strategies are still being tested, as shown in Figure 3 and published in [3]), due to the local terrain conditions and the limited amount of SAR data. All the area interested by the dam construction, indeed, underwent many human changes, whereas not-touched zones are highly vegetated. Thus, both standard interferometry and the PS technique fail to retrieve significant information under the given conditions. In this work we briefly recall a recently developed technique, able to exploit targets that show a coherent behavior only in subsets of interferograms. We show then the results of the area around Badong, along the Yangtze River, in which we analyzed ERS and Envisat data together to estimate the local topography and ground motion.

2. PARTIALLY COHERENT TARGETS

The Permanent Scatterers (PS) Technique [4], developed at POLIMI in late nineties, is a powerful tool in the context of InSAR. By looking at radar targets that maintain unchanged their electromagnetic signature during the whole observation span, the PS technique allows to solve the classical problems of interferometry (temporal and geometrical decorrelation and atmospheric artifacts). The technique has been successfully applied to different cases, from ground deformation monitoring [5] to building stability analysis [6], and also to recover digital elevation maps (DEM) [7]. The accuracy achievable by means of the PS technique is in the order of 1m in the estimate of the target height [8] and 1mm in the estimate of the target displacement [9]. The main drawback of the PS approach is the low spatial density of permanent targets,

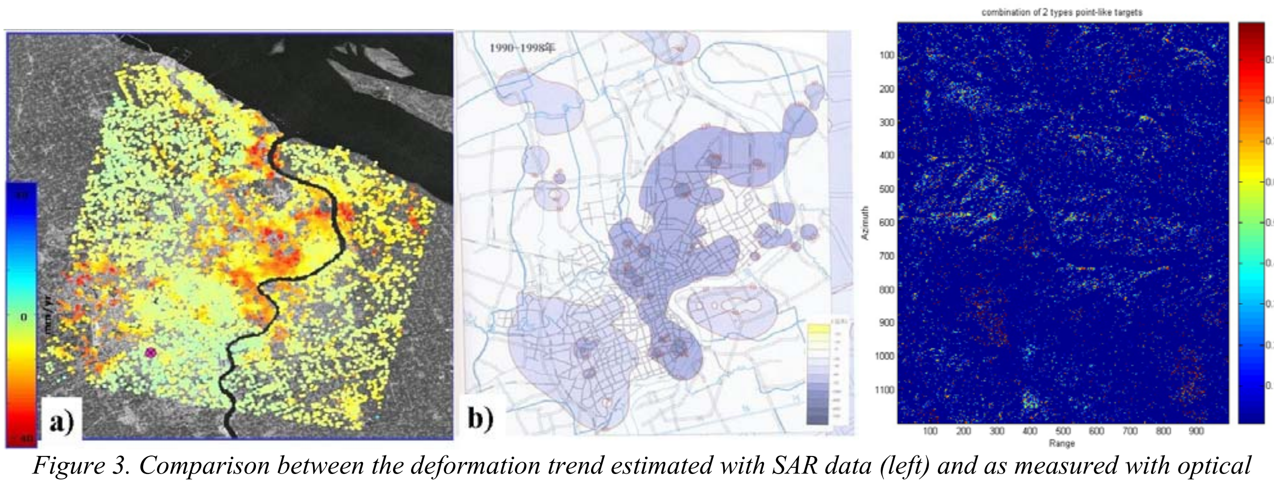

Figure 3. Comparison between the deformation trend estimated with SAR data (left) and as measured with optical levelling (centre) in Shanghai. Right: point-like scatterers identification in Badong by means of coherence decomposition analysis [3].

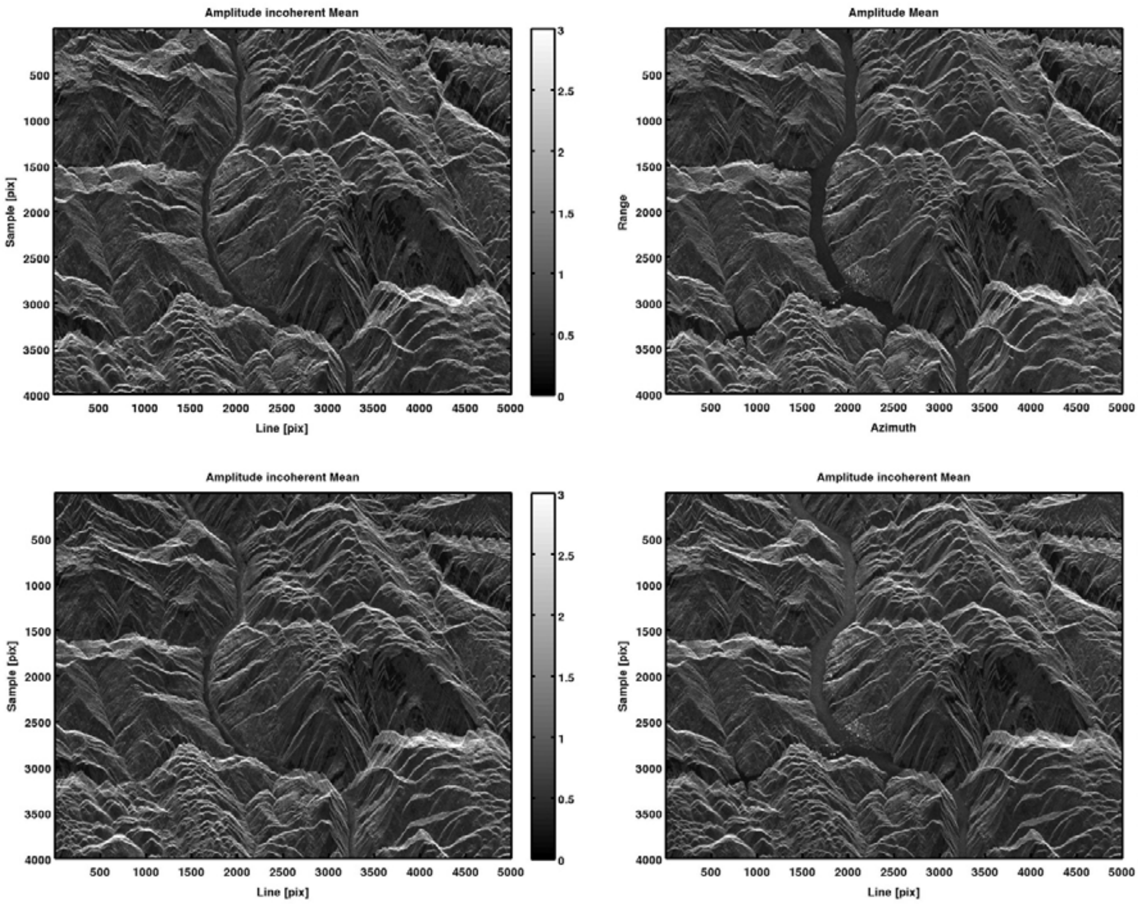

Figure 4. Reflectivity maps around the Badong area. Two top images: Track 75. Bottom: Track 347. Two left images: ERS (images before 2002). Right: Envisat (images after 2003). The river filling is evident.

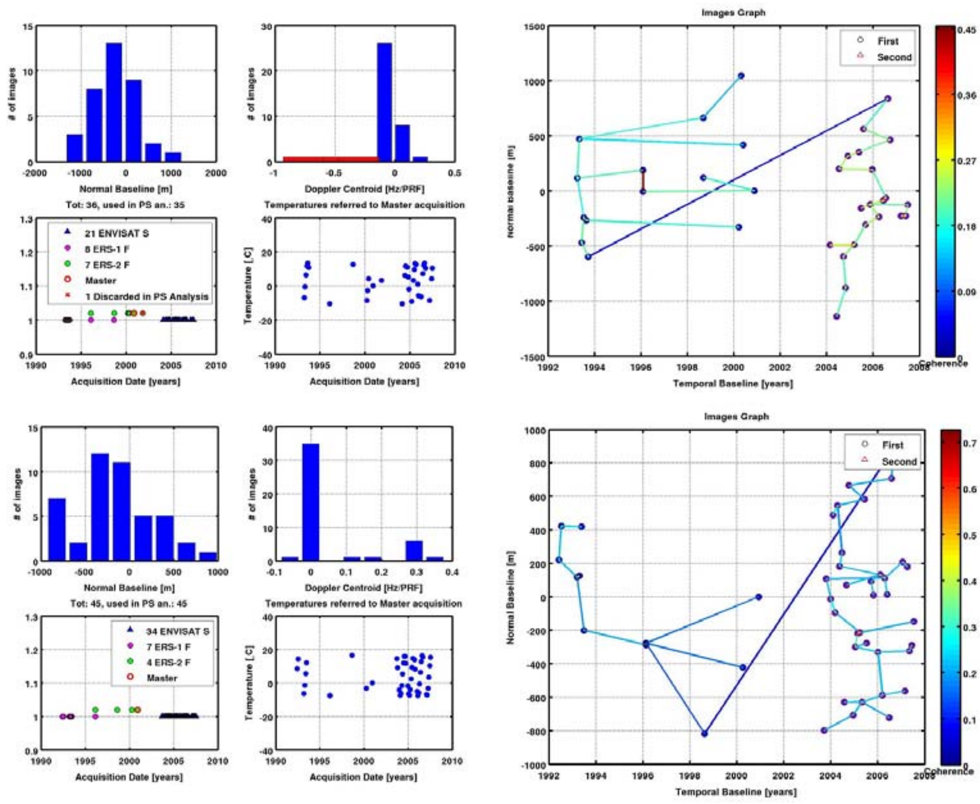

Figure 5. Images datasets Track 347 (top) and Track 75 (bottom). Left images (clockwise): normal baseline and DC frequency histograms, temperatures, dates. Right images: images graph, the colour indicating the coherence of each connection.

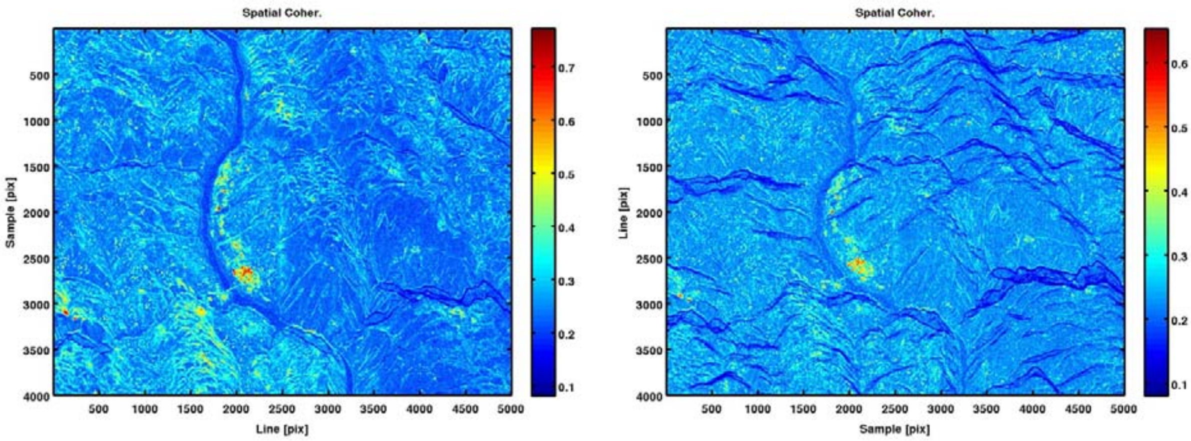

Figure 6. Spatial coherence in the area of Badong. Left: Track 75. Right: Track 347.

in particular in extra-urban areas. Indeed the lack of measure points can prevent from monitoring with spaceborne SAR techniques an area of interest affected by deformations. Here we recall a new approach [10] that relax the strict conditions imposed by the PS technique in order to extract information also from partially coherent targets and thus to increase the spatial distribution of measure points. In particular, three main modifications are introduced:

1. the images of the data-set are no more required to interfere with a unique common Master image as in the PS technique;
2. in the estimate of the target height and displacement only an appropriate sub-set of interferograms is evaluated;
3. considering extended targets a spatial filtering is applied to enhance the signal to noise ratio of the interferometric phase.

The new approach was successfully applied mountainous areas in Italy and France [10]. In the following we describe the results achieved in the Badong area.

3. RESULTS

Badong lies on the southern bank of the Yangtze and to the east of the Daba Mountains. The town is a strategic communication hub between Sichuan and Hubei Provinces, and is the main center for collection and distribution of goods from the mountain areas of western Hubei. With the advent of the Three Gorges Dam, Badong was rebuilt about 2 miles upstream on the south bank, opposite Guandukou, with which it is now linked by a brand new cable-stayed bridge. Since the Dam was built and the water level increased 135m, the surrounding area began being affected by ground motions.

The ESA data available over the area of interest are reported in Figures 4 and 5. 35 images have been acquired by ERS and Envisat from Track 347, 45 images from Track 75. Figure 4 shows four pictures, two per track. Each picture is the reflectivity map obtained as the incoherent average of the images acquired by a single sensor. Thus, for each track we have an ERS (images before 2002) and an Envisat (images after 2003) reflectivity map. By comparing them, it is evident to recognize the water filling of the Yangtze River and the moving of the urbanized areas.

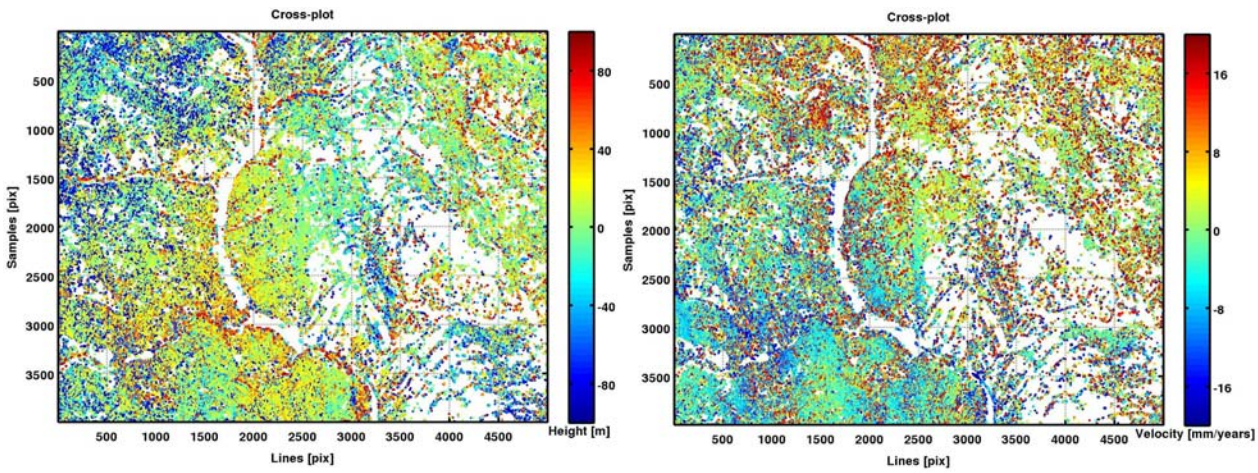

Figure 7. Residual topography and average deformation trend as estimated in Badong. ~200,000 pixels analysed, without skimming.

From Figure 5 it is possible to view the graph used to connect the available images (interferogram generation) for each track. The graph has been chosen by maximizing the spatial coherence of the interferograms. As visible, ERS and Envisat images are connected through an interferogram with normal baseline close to the compensation baseline [11]. Moreover, by looking at the color scale of the two plots, it's already visible that Track 347 (which has also less images) suffers more decorrelation than Track 75. This fact can be seen also from Figure 5, where the average spatial coherence is reported for the two tracks (75 left and 347 right). In Figure 6 it's easier to recognize the Badong urban center and the bridge in front of it that crosses the river.
Finally, Figure 7 shows the final results obtained by applying the technique previously addressed to the Track 75 dataset. The results of Track 347 are not reported since less significant due to the lack of coherence. All the 200,000 analyzed pixels are plotted within the area of interest without skimming. On the left the color is proportional to the estimated residual topography (+-100m after compensating for the SRTM data), whereas on the right the average deformation trend is visible (+- 20mm/year). The estimated height is pretty reasonable and allows to appreciate more topographic details with respect to SRTM. The estimated motion is more noisy, as described in [9]. Moreover, a possible velocity error plane (due to possible orbital uncertainties) can be seen in the image on the right (blue to red from left to right). Still, the subsiding areas (in blue in the image) along the river can be clearly detected.

4. CONCLUSIONS

In this work we have shown the first results on topography and ground motion retrieval in the Three Gorges area, along the Yangtze River, where the city of Badong lies. The results have been achieved by applying a new InSAR processing technique that is able to fruitfully exploit partially coherent targets. The analyzed data have been acquired by the ESA satellites ERS and Envisat.

5. ACKNOWLEDGEMENTS

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