Monitoring terrain motion in China by means of spaceborne SAR images

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***Abstract*— In this work we recall a recently developed processing chain (called Quasi-Permanent Scatterers –QPS- technique) that, by analyzing all possible interferometric pairs in a given SAR data-set and by evaluating the spatial interferometric coherence, is able to exploit partially coherent targets to estimate the ground motion. The technique has been successfully applied in the Badong site in China for retrieving the local DEM and for individuating active landslides. The possibility of processing effectively short-term coherent scatterers will turn out particularly useful to process series of high-resolution SAR data with short repeat-cycles.**

I. Introduction

As soon as stacks of high-resolution SAR data will be available, suitable techniques will have to be applied in order to get rid of the atmospheric disturbances, whose phase contribution increases with the frequency of the sensor. As well known, the Permanent Scatterers (PS) technique [1], developed in the late nineties by POLIMI, is a multi-temporal technique that exploits natural radar benchmarks not affected by spatial and temporal decorrelation in order to estimate and remove geometrical and deformation phase trends from the stack of interferometric data. In this way, the phase delay due to the spatially variant water vapor density can be isolated and estimated. The PS technique can be successfully applied to urban areas or in presence of natural stable targets (as exposed rocks, sparse constructions, lava flows), but it can be ineffective in vegetated areas. The full exploitation of the capabilities of high-resolution data in rural areas needs therefore the development of new techniques that allow detecting and making use also of partially coherent targets.

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 Li Deren, Wuhan University), had as objectives studies on 1) urban subsidence, 2) landslide analysis and monitoring, and 3) Three Gorges Dam site stability [2,3,4].

II. PARTIALLY COHERENT TARGETS

The PS 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, 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 the QPS technique [10] that relax the strict conditions imposed by the standard PS analysis 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, China.

III. 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 it 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.

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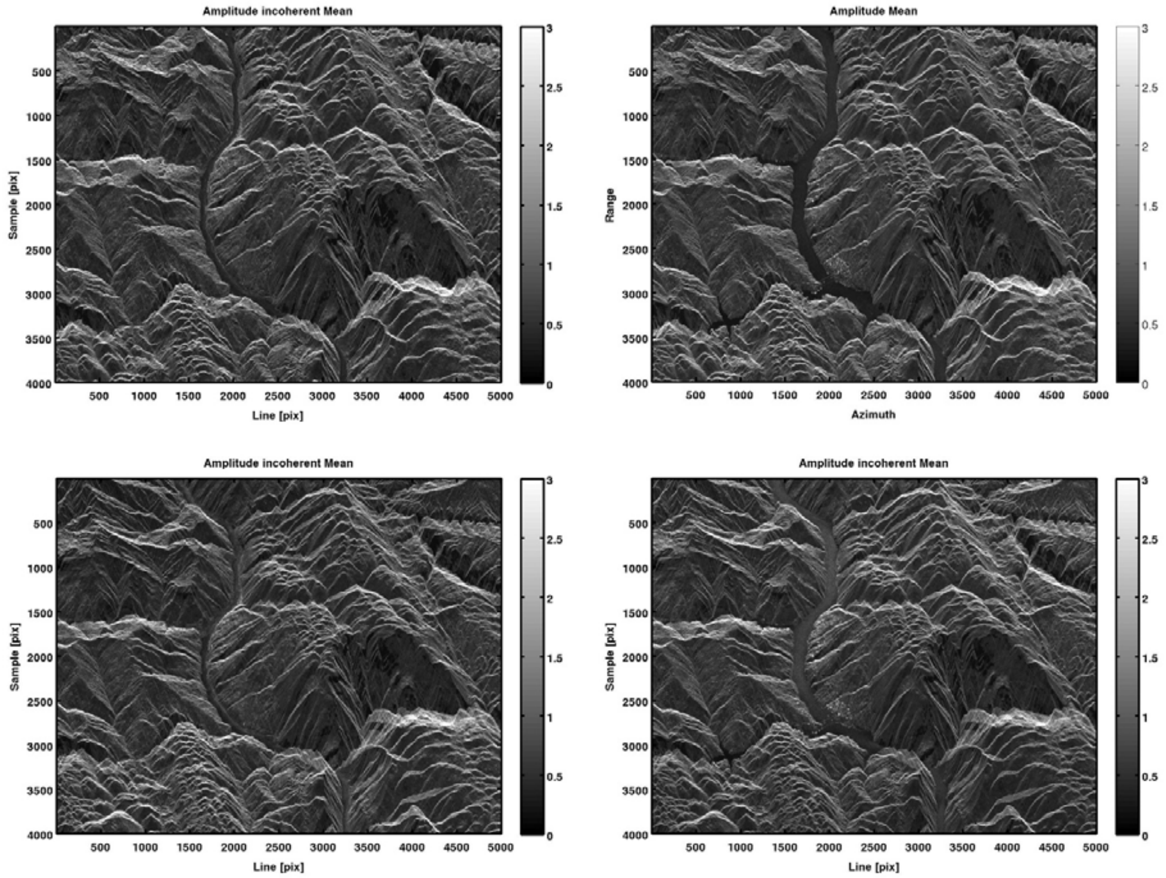

Figure 1. Reflectivity maps around the Badong area. Two top images: Track 75. Bottom: Track 347. Two left images: ERS (images before 2002). Right: Envisat (images after 2003). The river filling is evident.

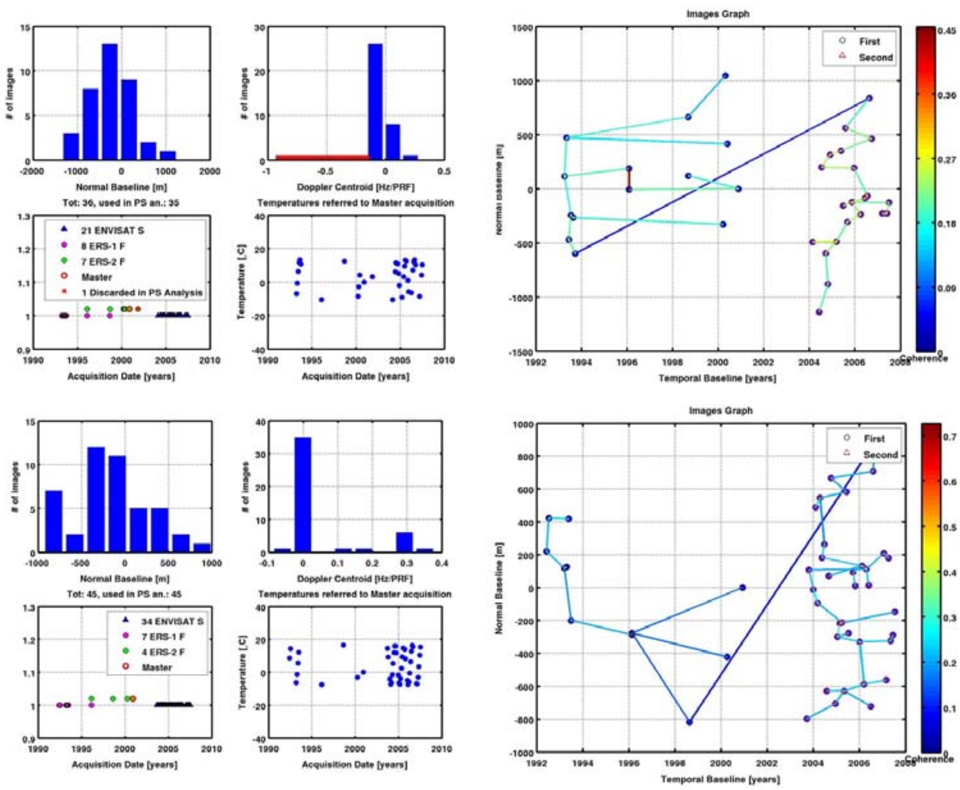

Figure 2. Images datasets Track 347 (top) and Track 75 (bottom). Left images (clockwise): normal baseline and DC frequency histograms, temperatures, dates. Right images: images graph, the colour indicating the coherence of each connection.

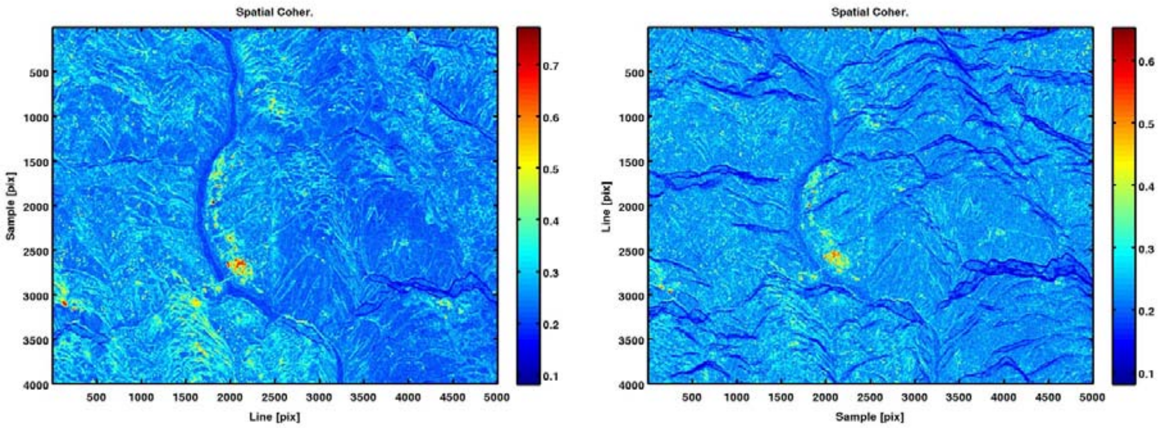

Figure 3. Spatial coherence in the area of Badong. Left: Track 75. Right: Track 347.

The ESA data available over the area of interest are reported in Figures 1 and 2. 35 images have been acquired by ERS and Envisat from Track 347, 45 images from Track 75. Figure 1 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.

From Figure 2 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 2, where the average spatial coherence is reported for the two tracks (75 left and 347 right). In Figure 3 it's easier to recognize the Badong urban center and the bridge in front of it that crosses the river.

Finally, Figure 4 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.

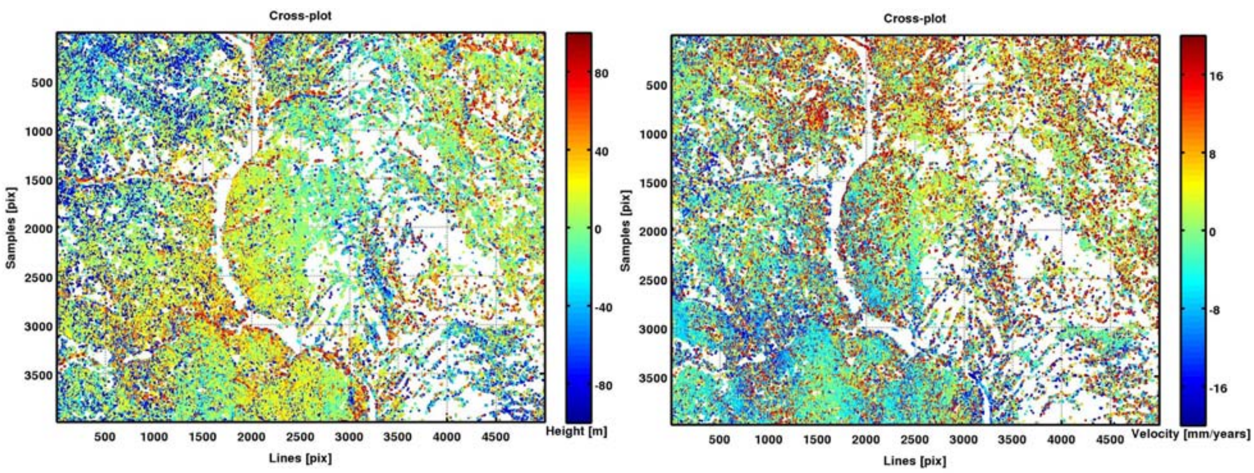

Figure 4. Residual topography and average deformation trend as estimated in Badong. ~200,000 pixels analysed, without skimming.

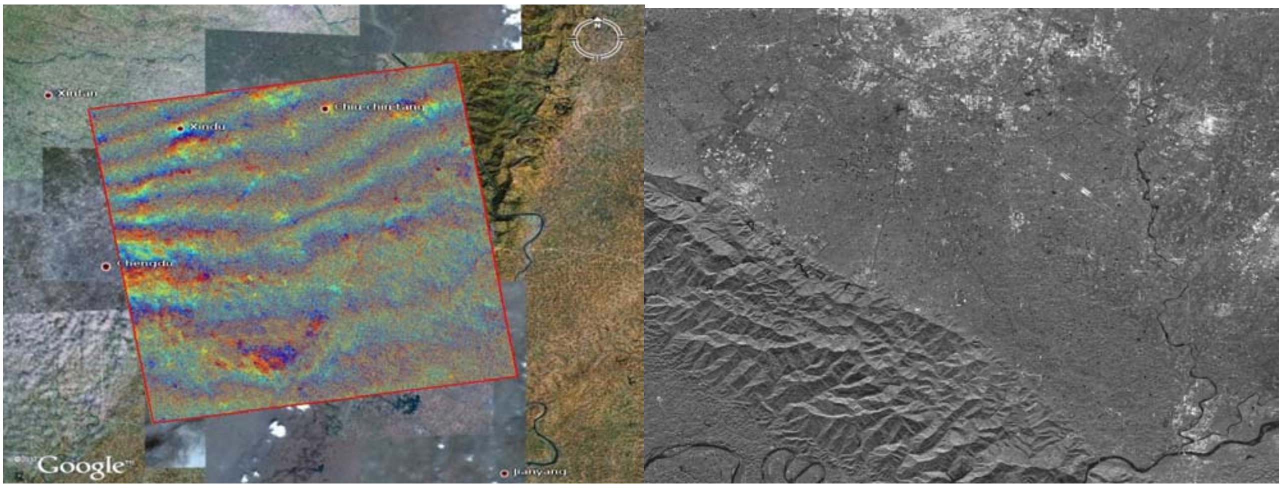

Figure 5..Left: Cosmo Sky-med co-seismic interferogram over Chengdu superimposed to a Google-Earth optical image. Right: amplitude of the interferogram in SAR coordinates. The work was carried out within a collaboration between Politecnico di Milano (POLIMI) and the Department of Civil Protection of Italy, and the data were processed by the POLIMI spin-off companies TRE and Aresys.

IV. HR SAR DATA

The method here proposed is particularly suitable for processing data acquired with a short revisit time, since more temporary coherent scatters are expected. This is the case of the new high resolution SAR satellites, as Cosmo SkyMed launched by the Italian Space Agency (ASI) or TerraSAR-X of the German Aerospace Center (DLR). As an example, in Figure 5 on the left we show a co-seismic interferogram generated with Cosmo data over Chengdu, capital of Sichuan, where the 12th May 2008 a devastating earthquake shook the Earth. The two images, acquired in strip-map mode on the 13th April and on the 15th May (three days after the earthquake), have an extension of 40x40 km2 and a spatial resolution of 10x10 m2. The work was carried out within a collaboration between Politecnico di Milano (POLIMI) and the Department of Civil Protection of Italy, and the data were processed by the POLIMI spin-off companies TRE and Aresys. The interferometric fringes show with impressive details the ground shift occurred during the seism. The image on the right of Figure 5 reports the reflectivity map of the analyzed area. It is worth to note that the obtained coherence is remarkable even in vegetated parts of the analyzed area, highlighting the great potential of high-resolution data for monitoring ground motions.

V. 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. Moreover, we report the co-seismic interferogram retrieved over the city of Chengdu by means of SAR data acquired by the Italian Cosmo Sky Med satellite, that highlight the potentiality of High-Resolution data.

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