ASAR parallel-track PS analysis in urban sites

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Abstract— **In this work we present a methodology for developing a Permanent Scatterers (PS) analysis jointly exploiting data acquired from parallel orbits to estimate height and deformation trend of multi-angle urban targets. The methodology allows applying the PS technique also in areas where the number of ASAR acquisitions per single track would prevent to get reliable estimates. Preliminary experimental results achieved in the Shanghai test site confirm the promising potential of the proposed methodology.**

Keywords: PSInSAR, ASAR, parallel track combination, urban sites.

I. INTRODUCTION

It is well known that in the framework of SAR multi-temporal analysis, the Permanent Scatterers (PS) [1] approach is the best solution to overcome the limits of the classic InSAR (decorrelation and atmospheric effects) and to get very accurate measurements of position and displacement of SAR targets. Reliable estimates of the targets height and displacement can be achieved by means of the PS technique if the number of available images is large enough. Usually more than 20 images are needed for a reliable analysis. After 5 years ASAR data acquisition by means of the ESA sensor Envisat, a sufficient number of images is not available everywhere. This fact is mainly due to unavoidable conflicts in the request of different acquisition modes (i.e. the natural counterpart of the desired instrument flexibility). This problem has been overcome by means of the coherent combination of ERS and ENVISAT data, exploiting techniques that have been successfully studied and implemented in the last years [2]. In this work we propose a new processing methodology able to combine ASAR data acquired from two different parallel tracks in order to get a sufficient number of images for a PS-like analysis. In such a way, the feasibility of a PS analysis with ASAR data is no more conditioned by the presence of ERS data, even when not enough ASAR images per single track are available. The key point of this technique is the automatic identification of multi-track coherent targets as dihedrals, trihedrals or poles, a large number of which is usually expected in urban sites. The identified multi-track coherent targets act as a sub-set of quasi-pointwise PS that can be coherently observed from parallel orbits, which can be thus jointly exploited for estimating height and displacement of the targets.

II. ASAR DATA AVAILABILITY

In March 2002 the ESA satellite Envisat was launched in orbit. The ASAR sensor mounted on the satellite provides a lot of acquisition modes, giving the possibility to change the signal polarization both in transmission and in reception, to change the incidence angle and also to work in burst-mode (as for ScanSAR and alternating polarization products). The very high flexibility of the instrument however has a main drawback: the mutual exclusion of the mentioned acquisition modes. The heaviest consequence of this fact affects the possibility of systematic monitoring a given area. Figures 1 and 2 show the ASAR world coverage (ascending and descending orbits) of Envisat (courtesy of T.R.E.). The pictures show the planisphere with rectangles in correspondence of acquired strips (identified by a track and a frame numbers), with a colour denoting the number of acquired images of each strip. Figures 1 and 2 clearly show that only in a few places in the world more than 20 ASAR images on the same orbit have been collected. Most of the world is uncovered and a large part of the areas interested by the acquisitions have less than 15 images. Considering that a reliable PS analysis has to be based on at least 20 data, alternative methodologies have to be developed in order to fully exploit the ASAR dataset.

III. ALGORITHM

As already mentioned, a way to make use of the ASAR data is to combine it coherently with ERS data [2]. The concept can be easily sketched as in Figure 3 on the left, where ERS (blue dots) and Envisat (red triangles) images are connected to the same ERS Master acquisition in the temporal-normal baselines space. The main advantage of such a combination is the possibility of guaranteeing the continuity between the two datasets; the main drawback is the possible loss of coherence due to the geometrical decorrelation (ERS and Envisat have slightly different carrier frequencies). The core concept of the proposed new methodology can be sketched in a similar way as in Figure 3 on the right: the two datasets are not coherently combined, since each dataset is referred to a different Master acquisition. However, if the radar in the two different geometries is looking at the same target, the interferometric phase in the two datasets will depend on the same target parameters (height and linear deformation trend). Consequently, the two datasets can be jointly exploited to estimate the targets height and velocity.

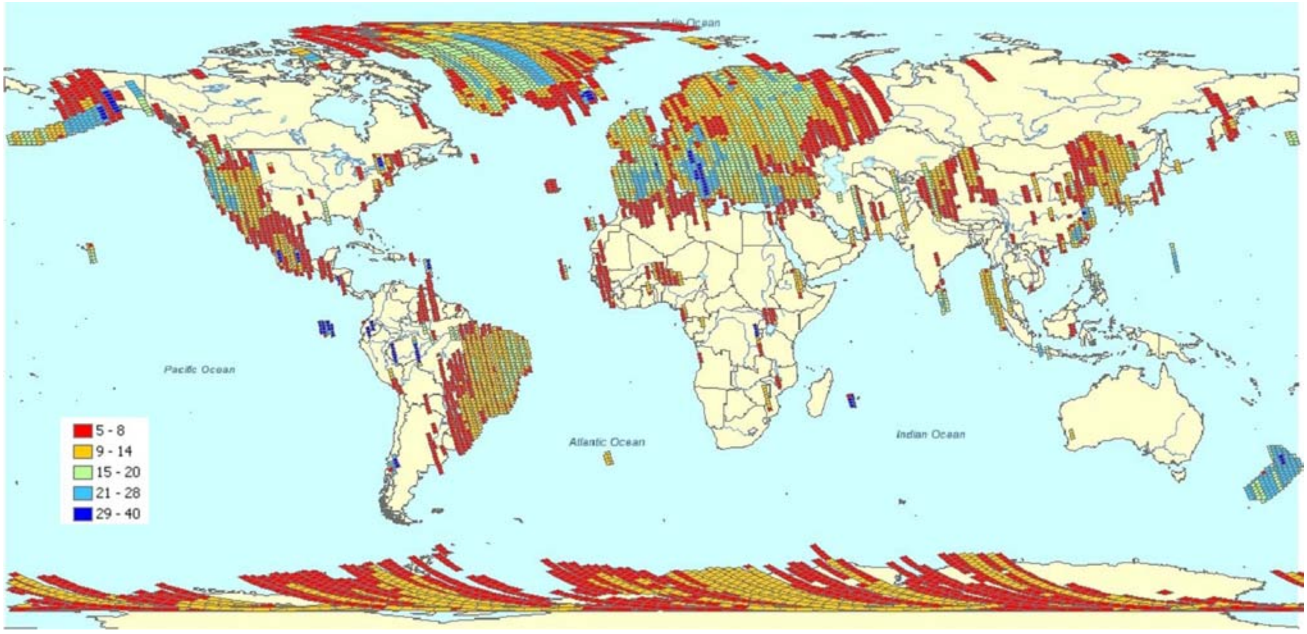

Figure 1. Ascending ASAR world coverage. The number of acquired images is represented by a color according to the legend (Courtesy of T.R.E.).

The main task of a combination of data acquired from parallel tracks for carrying out a PS analysis is the identification of multi-angle targets. In [4], multi-angle targets are identified by analyzing phase and amplitude of many SAR images. Here we suppose to deal with few images acquired by two parallel tracks, thus the physical analysis described in [4] in not applicable because of the low number of available data. The pixel selection for PS candidates (PSC) has then to be developed without a-priori information. Similarly to the classical PS technique, a possible procedure for the PSC selection is to look for pixels showing sufficient amplitude stability. In our case, such condition has to be met in both datasets acquired from parallel orbits. Then, a correspondence between points of the two tracks has to be found. To this aim, a very precise co-registration of the two SAR geometries must be performed. Here the idea is not to implement a whole-image co-registration but to find a correspondence between sparse points in the two SAR grids. The co-registration process that we developed can be summarized in the following main points:

- First PSC are selected separately in the two datasets by means of the amplitude stability index [1].
- The offsets of the orbital data (closest approach and acquisition time of the first sample) are precisely corrected in both datasets using ground control points.

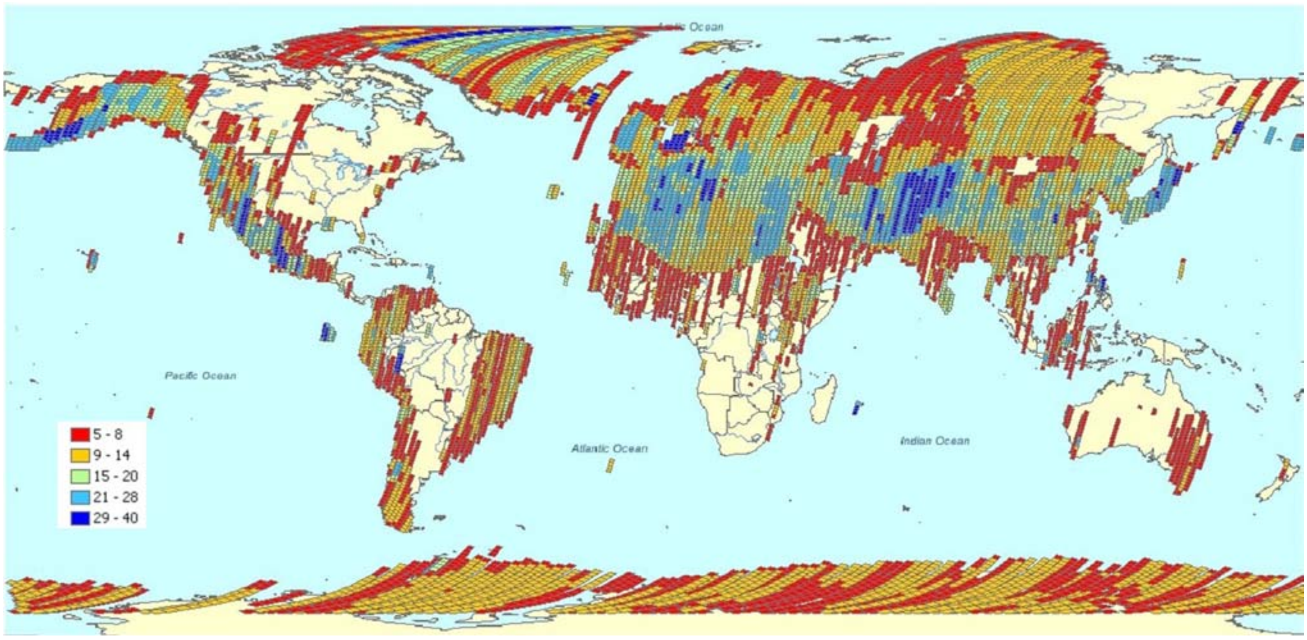

Figure 2. Descending ASAR world coverage. The number of acquired images is represented by a color according to the legend (Courtesy of T.R.E.).

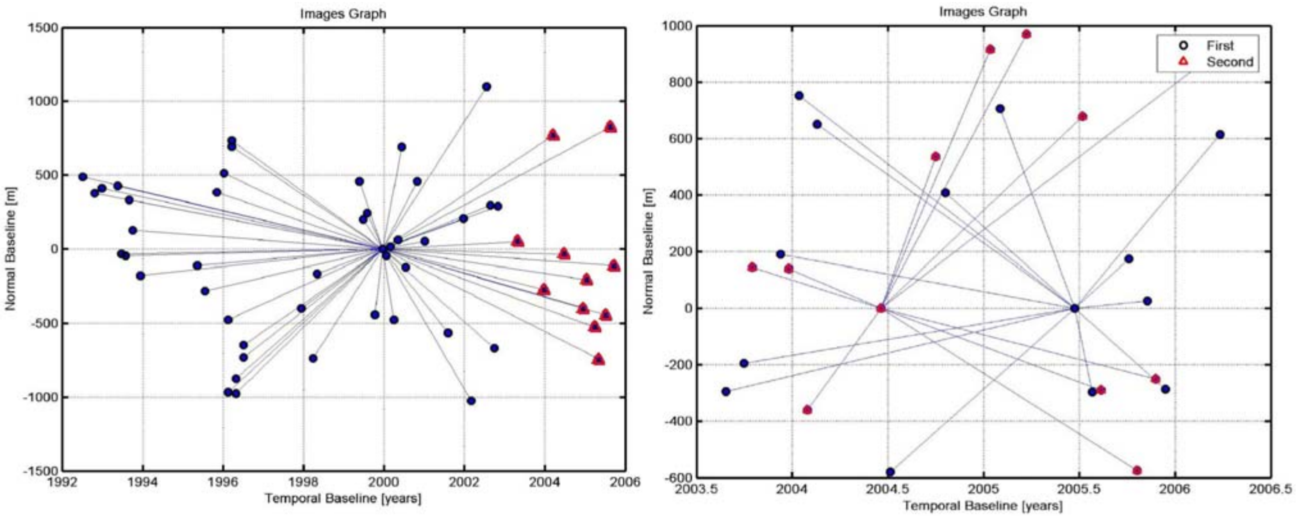

Figure 3. Different strategies to exploit ASAR data. Left: coherent combination of ERS (blue dots) and Envisat (red triangles) data of the same track, in a single master configuration. Right: uncoherent combination of parallel tracks, in a double master configuration. The two plots represent the images in the normal-temporal baselines space. Data are relative to the Shanghai test site (left Track 3, right Track 268 and 497).

- Exploiting an a-priori DEM (such as SRTM) PSC of both datasets are georeferenced.
- Points with similar geographical coordinates in the two datasets are selected (distance < 10-15m).
- Fine coregistration is performed by better aligning the two clouds of selected points.

The results of the whole analysis strongly depend on the precision of the geocoding process and this is strictly linked to the precision of the available a-priori DEM. Furthermore, the impact of the residual height of a PS with respect to the used DEM has to be evaluated. To this aim in Figure 4 a very simple case is sketched. Assuming a perfect compensation for the local topography, the impact of residual PS height h on the misregistration in slant range Δy_h can be approximated in

$$\Delta y_h = h\left(\cos\theta_1 - \cos\theta_2 \frac{\sin\theta_1}{\sin\theta_2}\right) \quad (1)$$

where θ_1 and θ_2 are the incidence angles of the two tracks. In the Shanghai case (30deg latitude, about 40km overlap between the adjacent strips and an incidence angle difference of 4deg), to maintain a slant range misregistration less than 5m (corresponding to ~10m on the ground) the residual PS height must be less than 25m. Considering that most PS in urban sites lies on the ground [4], and in particular dihedral-type PS [3], such number is fully acceptable. Moreover, also the SRTM height tolerance (~10m) should guarantee the feasibility of co-registering the two tracks.

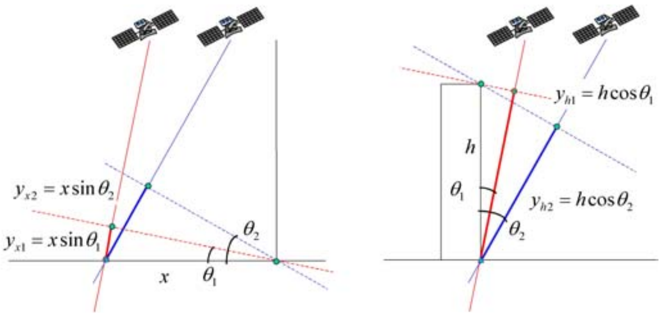

Figure 4. Misregistration between two parallel tracks due to a different height.

Once PSC are selected, the parallel track analysis can be carried out as in the standard PS analysis. The only difference that has to be taken into account is the use of a double-master configuration: the images of the two datasets cannot be referred to the same master acquisition but to two different ones, one for each track, as sketched in Figure 3 on the right. Consequently, assuming constant target velocity, the well known [1] model for the interferometric phase of a target with respect to a reference point in the whole dataset becomes the following:

$$\underline{\Delta\phi} = \frac{4\pi}{\lambda R}\Delta h \underline{B_n} + \frac{4\pi}{\lambda}\Delta v \underline{B_t} \quad (2)$$

where Δh and Δv are height and velocity of the PS and

$$\underline{B_n} = \begin{bmatrix} B_{n,1} - B_{n,M_1} \\ \cdots \\ B_{n,N_{I1}} - B_{n,M_1} \\ B_{n,N_{I1}+1} - B_{n,M_2} \\ \cdots \\ B_{n,N_{I1}+N_{I2}} - B_{n,M_2} \end{bmatrix}, \quad \underline{B_t} = \begin{bmatrix} B_{t,1} - B_{t,M_1} \\ \cdots \\ B_{t,N_{I1}} - B_{t,M_1} \\ B_{t,N_{I1}+1} - B_{t,M_2} \\ \cdots \\ B_{t,N_{I1}+N_{I2}} - B_{t,M_2} \end{bmatrix}$$

the normal and temporal baselines. N_{I1}, N_{I2} are the number of images in the two datasets and M_1, M_2 denote the two master indexes.

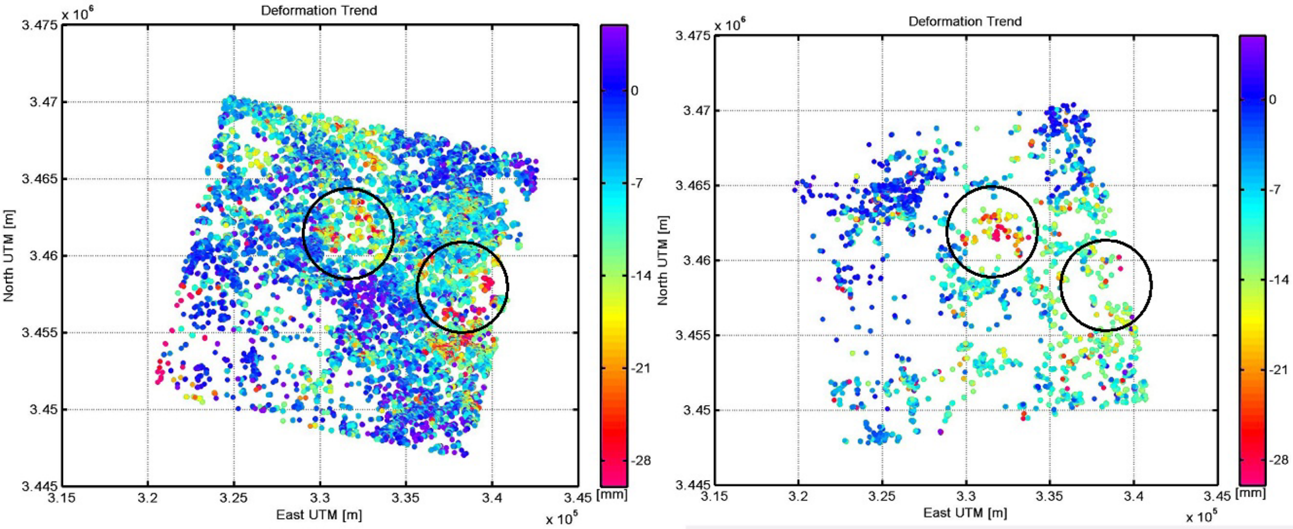

Figure 5. PS velocity fields in Shanghai estimated from an ERS descending track (left, ~30000 PS's) and from the joint combination of two Envisat ascending tracks (right ~5000 PS's). The two black circles highlight the subsiding areas detected in both analysis.

IV. Experimental Results

The preliminary results of the novel technique are shown in Figure 5. The results have been obtained by processing the Envisat ascending tracks 268 and 497 over Shanghai. The image on the right reports the detected multi-track PS (about 5,000 in 400 km^2) in geographic coordinates with a color proportional to the estimated deformation trend. The image on the left shows the results of an ERS PS analysis carried out on the other available dataset (descending Track 3) of the same area (about 30,000 PS's). The subsidence detected in the two independent analyses is pretty congruent. Finally, an example of displacement time series is plotted in Figure 6. The combination of data acquired from parallel tracks allows the reduction of the revisit time of the sensor (about 16 days).

V. Conclusions

In this work, for the first time a PS analysis has been carried out jointly exploiting data acquired from adjacent parallel tracks. The proposed technique allows to make use of ASAR data in multi-temporal analysis even in areas where a sufficient number of images per single track is not available.

Acknowledgments

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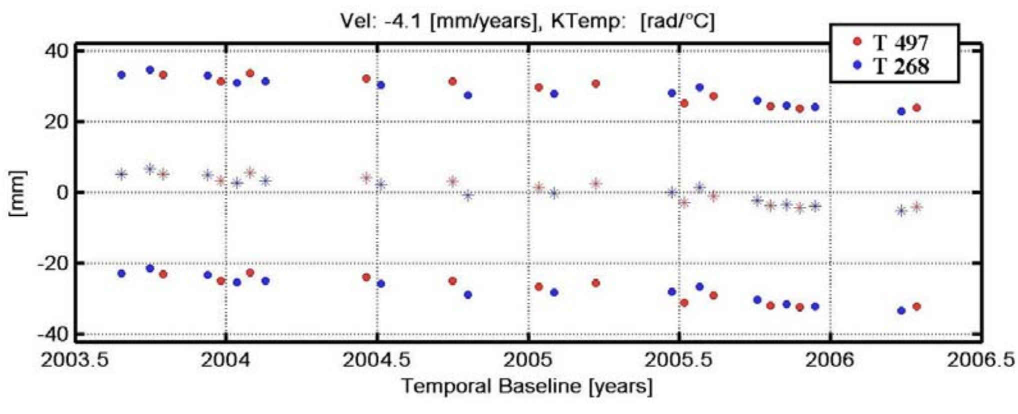

Figure 6. Displacement time series of a PS detected in Shanghai as estimated from the joint combination of two Envisat parallel tracks (T497 red dots, T268 blue dots). The two adjacent replica are plotted for visualization purposes. The combination of parallel tracks allows halving the revisit time.