Coherent vs. Persistent Scatterers: A Case Study.

Luca Marotti, German Aerospace Center, Wessling, Germany
Alessandro Parizzi, German Aerospace Center, Wessling, Germany
Nico Adam, German Aerospace Center, Wessling, Germany
Kostas Papathanassiou, German Aerospace Center, Wessling, Germany

Abstract

In this paper a comparison between two typologies of point-like scatterers in SAR images, named Persistent Scatterers (PSs) and Coherent Scatterers (CSs) is proposed. The PSs are detected through the analysis of large stack of data, implying their temporal stability, and have been principally used for SAR interferometric applications. Differently, CSs are detected in single SAR images through their spectral correlation properties and have been applied for parameters extraction by means of polarimetric data. The main research in this paper is focused to the CSs temporal stability and to the result obtained, for image time series and with both categories of point-like scatterers, concerning Line of Sight (LOS) displacement measurements.

1 Introduction

The search for point-like scatterers in SAR images is linked, principally, to the possibility to measure the phase of the radar signal, received from those scatterers in different acquisitions, very accurately minimizing any fluctuations due to stochastic contributions. This is a very important requirement for SAR interferometric applications and even more for measuring Line of Sight (LOS) displacements by means of Differential Interferometry. The Permanent Scatterers (PSs) selection is achieved through the estimation of the phase stability of the resolution cell backscattering [1]. Accordingly, assuming the availability of large time series of data, it is possible to analyze the amplitude dispersion of the image pixels or alternatively the value of Signal to Clutter Ratio (SCR) estimated [2]. Both quantities, indeed, have been demonstrated to be related with the phase error of the signal received from the illuminated target. A different approach, based on the spectral properties of a point-target, is considered for the Coherent Scatterers (CSs) technique [3]. Ideal point-like scatterers, in fact, are characterized by a completely correlated spectrum. One slice of the object spectrum is acquired in a SAR image thus, image sub-look spectral correlation can be used to separate deterministic from distributed targets. In this case no temporal analyses are involved in the procedure and the detection can be applied on a single image basis. In the following the CSs temporal stability has been investigated and the complementarities between the two techniques have been addressed.

2 CSs and PSs selection

The detection and analysis of the two classes of point-like scatterers is performed processing a stack of 86 C-band ERS - ERS2 SAR data acquired between 1992 and 2002, with 16 MHz system bandwidth, over the city of Munich in Germany.

In previous studies, the standard CSs detection method has been applied on a single SAR image basis. Accordingly, two sub-look images are created by splitting into two parts the original image range spectrum [3],[6]. Then, the correlation coefficient between the two sub-look images is computed and pixels with high value of sub-look coherence, according to a given threshold, are selected as CSs. Nevertheless, this kind of detection approach does not need to take into account the availability of a large number of images. In particular, for every pixel, it is possible to trace the time evolution of the sub-look coherence value calculated in each acquisition. This value is changing in time depending on the variability of the scattering contributions occurring inside the resolution cell. For this reason, a detection procedure performed with a fixed threshold and on a single image basis will discard potential stable CSs even if their value of sub-look coherence drops below the threshold only once in 86 acquisitions.

In order to overcome the problem, for each image of the stack, the sub-look coherence map is generated and, in the end, the mean sub-look coherence image (fig. 1) and the standard deviation image are calculated. Pixels with high mean value, over a certain threshold, and low standard deviation are considered as CSs. However, since the standard deviation for all the points in this data set is small, within the interval 0-0.2, the effective detection criterion is the mean value.

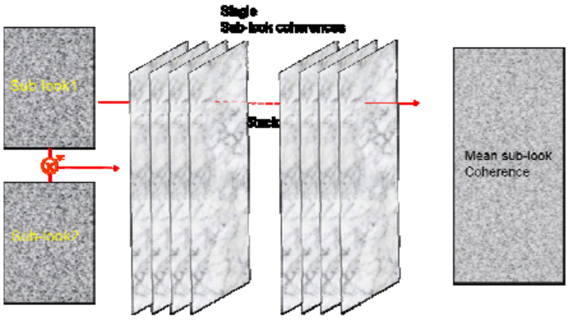


Figure 1. CSs detection method adapted to a large stack of data.

Concerning the PSs, in [1] the selection has been obtained by means of the Dispersion Index method. In this paper, instead, it has been considered the Signal to Clutter (SCR) method [2] that is based on the identification of targets having a suitable SNR to be classified as PSs. The main idea is to estimate a mean Rayleigh distribution of the clutter surrounding the PS candidate using the realizations of the neighbourhood pixels during the whole time span [4]. Finally, the pixels which have a value of SCR higher than a given threshold are selected as PSs candidate. This technique results to be less biased and has the advantage to be able to track the evolution of the SCR in time.

3 Experimental Results

A large amount of PSs (~ 112K) has been selected for the processing choosing a relatively low threshold. At the same time the sub-look coherence threshold has been accordingly adapted to have almost the same amount of CSs detected (~ 111K) for comparison reasons.

The further interferometric processing has been achieved by means of the PSI-GENESIS processor developed at the Remote Sensing Technology Institute (IMF) of DLR [5]. This software module is able to estimate important quantities as deformation velocity displacement, topography and atmospheric contributions.

The processor input are the CSs and PSs initially selected. Many of these points, not suitable for interferometric analysis, have been discarded during the processing. The final set of CSs and PSs is located in the urbanized regions (fig. 2) in accordance with the expected deterministic nature of the majority of the man made targets.

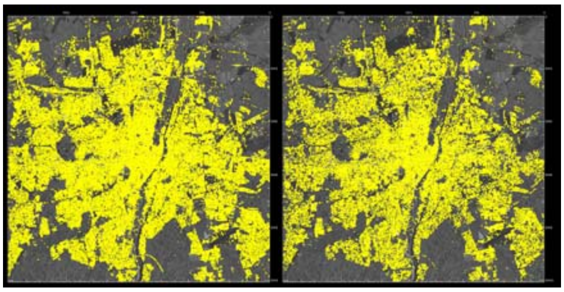


Figure 2. Left: final PSs. Right: final CSs.

Concerning the CSs temporal stability, the retrieved number of stable CSs, that survived the interferometric processing, is about 55K while the number of final PSs is about 67K. Furthermore, only one part of CSs and PSs are located in the same positions of the scene while many of them correspond to disjoint resolution cells. This statement can be observed in fig. 3, where four enlarged image of different city regions are displayed. Red dots correspond to CSs positions, green to the PSs positions while yellow dots represent the pixels detected using both techniques.

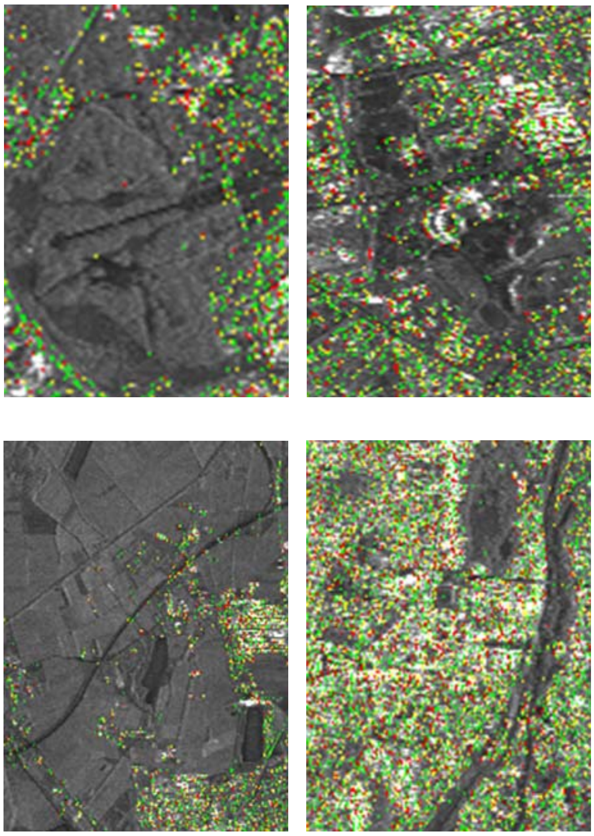


Figure 3. Detected CSs and PSs in Munich. Upper left: Nynphenburg. Upper right: Olympia Zentrum. Lower left: suburban region. Lower right: city center. Red: CSs. Green: PSs. Yellow: common.

The number of common points detected is about 25K. This makes clear that it is possible to increase the density of points detected by combining the two

approaches. Of course this could be not a strong requirement in urban areas where the density of CSs or PSs is already high but could be helpful in rural regions, for example, where the detection of point-like scatterers is more difficult.
As showed in fig. 4, the LOS velocity displacement has been estimated on the PSs grid (left side) and on the CSs grid (right side) respectively. It is possible to observe that the results are very similar both confirming the stability of the Munich test site characterized by a subsidence rate of less than 1mm per year. The very good agreement of the computations performed by means of PSs and CSs is displayed in the normalized histogram of the velocity displacement values reported in fig. 5.

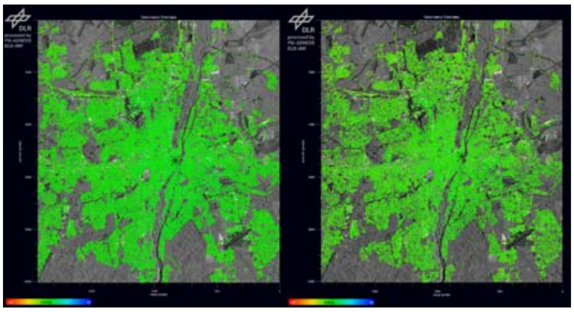


Figure 4. PSs (left) and CSs (right) velocity displacement map.

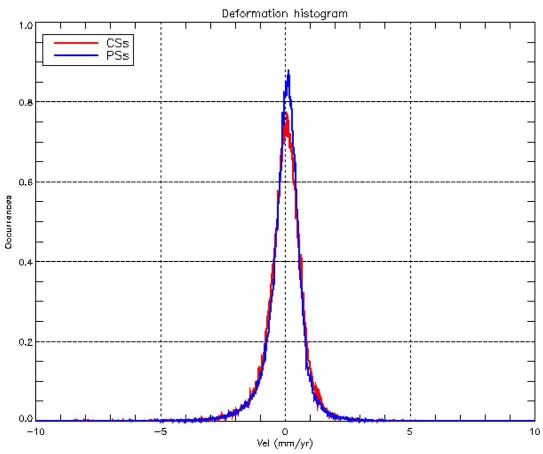
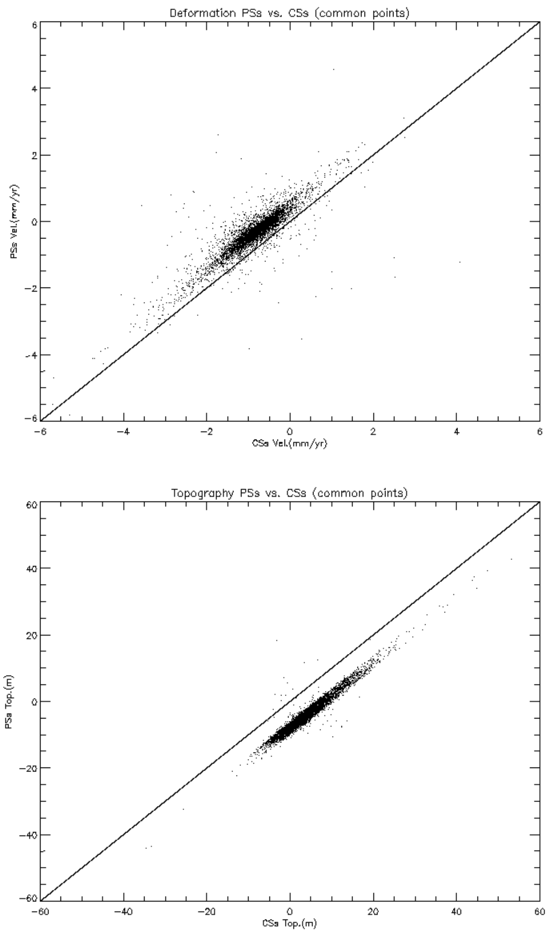


Figure 5. Normalized histogram of the deformation velocity for CSs (red) and PSs (blue).

On the about 25K of common points detected it is possible to evaluate the degree of correlation of the velocity displacement between the topography estimated by the processor using CSs and PSs respectively. As depicted in fig. 6, a significant correlation between the measured quantities is shown. The small dispersion and the shift of the plots from the perfect correlation line can be explained with the different choice of the reference point used for the CSs and PSs processing. All the measures, indeed, are referred to this point that is assumed 0m height and motionless. This means that the shifts are equal to the difference of displacement velocities (topographic heights) of the two reference points. However this effect can be eliminated using the same reference or a ground control point. The presence of the variance, instead, is caused by two different reasons. The first is the phase dispersion of the reference points. This error will propagate during the processing affecting all the estimation computed on the other points. The second is a different method used for the extraction of the phase value of the pixels when processing the CSs and the PSs. In the first case the pixel phase is the one corresponding to the point selected while, in the second case, the PS selection is followed by a point target analysis. Then, the value of the phase corresponds to a sub pixel position.

Figure 6. Correlation of the velocity displacement



measured on the common points selected by the two techniques. Correlation of the topography measured on the common points selected by the two techniques.

Fig. 7 represents the final model coherence histogram related to the PSs and the CSs processed. This can be considered as a quality parameter and shows the level of agreement to the linear displacement model for the points selected. As it is observable, for both categories of point-like scatterers, the coherence values are above 0.8 (for the CSs) and 0.9 (for the PSs) confirming the possibility to describe the LOS motion with the linear model.

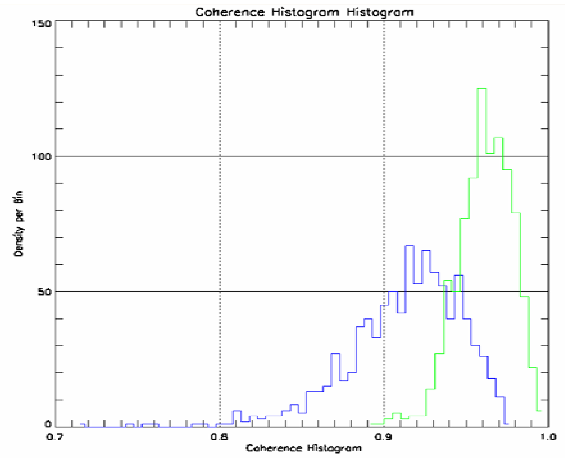


Figure 7. Coherence histogram of CSs (blue) and PSs (green).

3 Conclusions

Through the analysis of a large amount of image time series, the investigation of the CSs temporal stability was realized. Accordingly, it has been possible to implement a slightly modified detection procedure that allowed the identification of many (~ 55K) stable CSs, useful for interferometric applications, in a time period of 10 years. Furthermore, this class of point like scatterers has been compared with another class of point-like scatterers, the PSs, selected by means of a different detection procedure. On the same dataset the PSs number has been of about 67K and, of this amount, only 25K are located in the same position as the CSs suggesting the possibility of potential future techniques combination. Finally, the LOS velocity displacement and the model coherence have been evaluated considering the CSs and PSs grid respectively. The deformation velocity values have resulted to be less than 1mm/yr for CSs as well as for PSs showing a good agreement while, the coherence values, have been over 0.8 demonstrating the reliability of the linear model applied to the motion description.

4 References

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