Exploitation of Coherence Matrixes in Multi-temporal SAR Datasets: the SqueeSAR approach

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Abstract

Since its development in the late nineties, Permanent Scatteres interferometry (PSInSAR) has become an operational tool for monitoring surface deformation phenomena such as subsidence and uplift, landslides, fault creeping and volcano inflation, using multi-temporal data-stacks of SAR images. As well know, the algorithm aims at identifying and then exploiting PS, i.e. radar targets slightly affected by temporal and geometrical decorrelation, where very precise displacement measurements can be carried out [1], [2].

Typically, PS correspond to man-made objects such as buildings, poles, antenna, but they can also be found in non-urban areas, where some objects on ground can exhibit a fairly high level of phase stability, even if they are not point-wise targets and are affected by temporal decorrelation.

Indeed, during the last two years, and in particular with the coming of X-band sensors, it has become more and more evident the need for a more effective way of monitoring non-urban areas , characterized by distributed scatterers (DS), affected by temporal decorrelation phenomena, but exhibiting good coherence levels in low temporal baseline interferograms and where, at least in principle, it should be possible to retrieve a time series of deformation ([3], [4], [5]).

In order to extend the PS analysis to non-urban areas, characterized by DS rather than PS, it is important to fully characterize all targets within the area of interest, and derive an optimal estimator based upon a statistical analysis of their radar returns.

In standard PS analysis, radar targets are assumed to be point-wise objects affected

by an additive white noise and the so-called amplitude stability index is used as a proxy for phase stability. For this class of points the PS technique provides the optimal estimator to retrieve high quality deformation measurements carrying out an analysis on a pixel-by-pixel basis.

In case of DS ,instead, the data are assumed to be distributed as a Circular Normal Process and so the target statistics are entirely described by the data Covariance Matrix, or, in other words, by the matrix of all the available interferograms.

Obviously the true data Covariance Matrix is unknown and we have to estimate it from the data. The advantages of the sample estimator are ease of computation and the property of being unbiased. Its main disadvantage is the need for gathering a number of samples, coming from the same statistical distribution, substantially larger than the number of images to get a reliable estimate for the Covariance Matrix ([6]). However, when the number of samples is comparable with the number of images it's possible to use a-priori information about the structure of the interferogram matrix to reduce statistical errors contained in the estimate.

Based upon the analysis of the reflectivity amplitudes, the Kolmogorov-Smirnov Test (KS-Test) can provide a selection of statistically homogeneous samples to use in the estimate for the interferograms matrix; but it is equally useful to identify PS in order to preserve their phase quality from possible incoherent surrounding targets. In fact a "blind" uniform spatial filtering process implies a spatial smoothing for the data that could compromise the phase coherence, at least for isolated PS.

Once we have identified the PS and the DS present in the scene, we have to properly process each one according to their statistical properties. It's interesting to point out how to retrieve the best estimate for the deformation, in case of PS, we have to process only the images of the data-set (under the assumption of noise independent in all the images). On the contrary, for the DS we have to process all the possible interferograms in order to identify which have a level of coherence high enough to extract useful information.

Properly using the interferogram matrix information, the SqueeSAR™ approach can combine distributed scatterers, key element of traditional DInSAR, with the wellknown PS, "squeezing" all the information contained in the data-set to estimate any InSAR parameter of interest.

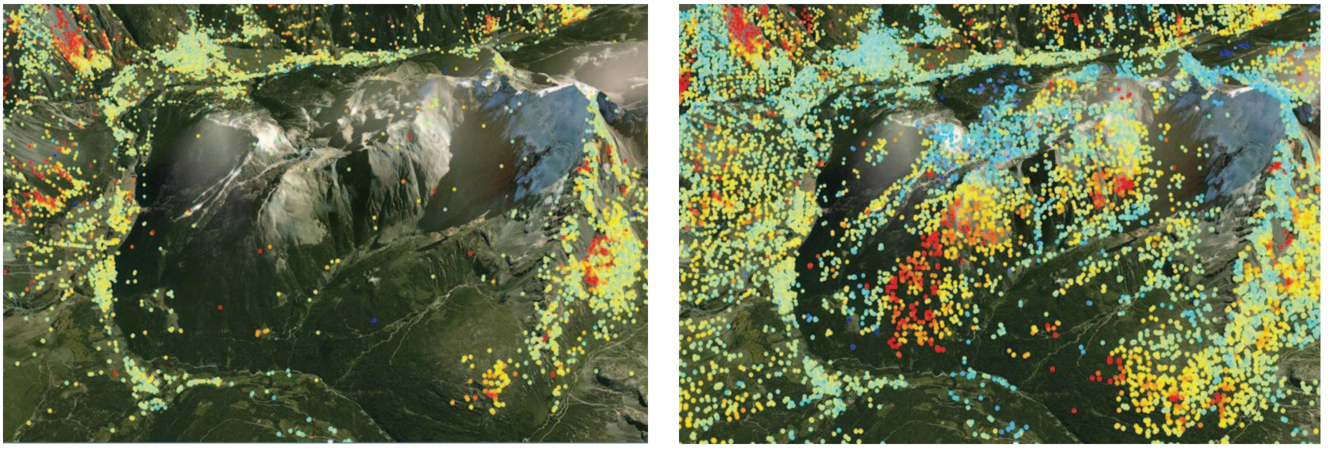

Figure 1: Comparison between PSInSAR™ results (left) and SqueeSAR™ results (right), using the same RADARSAT dataset over the same area of interest.

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