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MTInSAR long-term monitoring of nonlinear slope instabilities on hilltop villages in Southern Italy

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1. Introduction

Multi-temporal SAR interferometry (MTInSAR) provides mean displacement maps and displacement time series over coherent objects on the Earth surface, allowing analysis of wide areas to identify ground deformations, and studying evolution of displacement phenomena over long time scales. MTInSAR techniques have proven very useful for detecting and monitoring also slope instabilities.

Nowadays, several satellite missions are available providing InSAR data at different wavelengths, spatial resolutions, and revisit times. The Italian X-Band COSMO-SkyMed constellation acquires data with spatial resolution reaching metric values, and provides revisit times of up to a few days, leading to an increase in the density of the measurable targets, thus improving the monitoring of local scale events as well as the detection of non-linear displacements. The recent Sentinel-1 C-band mission from the European Space Agency (ESA) provides a spatial resolution comparable to previous ESA SAR missions, but a nominal revisit time reduced to 6 days. By offering regular global-scale coverage, better temporal resolution and freely available imagery, Sentinel-1 improves the performance of MTInSAR for ground displacement investigations. In particular, the short revisit time allows a better time series analysis by improving the temporal sampling and thus the chances to catch pre-failure signals characterised by high rate and non-linear behaviour. Moreover, it allows collecting large data stacks in a short time periods, thus improving MTInSAR performance in emergency (post-event) scenarios. These characteristics are very promising for early warning of slope failure events and monitoring subsequent displacements trends.

2. Result overview

In this work, we present the results obtained by using both COSMO-SkyMed and Sentinel-1 data for investigating the ground stability of hilly villages located in Southern Italian Apennine (Basilicata region). In the area of interest, several landslides occurred in the recent past (Montescaglioso in 2013) and more recently (Pomarico in 2019), causing extensive damage to houses, commercial buildings, and infrastructures.

SAR datasets acquired by COSMO-SkyMed and Sentinel-1 from both ascending and descending orbits have been processed by using the SPINUA MTInSAR algorithm, in order to exploit the potentials of these two satellite missions to investigate ground displacements related to slope instabilities. Mean velocity maps and displacement time series have been analysed looking, in particular, for non-linear trends that are possibly related to relevant ground instability episodes and, thanks to the high spatial resolution, useful in terms of early warning, in the case of rigid soil masses.

Figures 1 and 2 show the mean velocity maps over the municipalities of Montescaglioso and Pomarico, respectively, derived by processing with the SPINUA algorithm SAR data acquired by Sentinel-1 (from both ascending and descending orbits) and COSMO-SkyMed (from ascending obits). In both cases all the maps are comparable, showing just few differences related to the projection of the ground displacements along ascending and descending line of sights.

Both COSMO-SkyMed and Sentinel-1 provide also interesting deformation time series with nonlinear trends, which are very useful for studying the temporal evolution of the ground displacement and performing geotechnical modelling. Figure 3 shows examples of time series with different interesting kinematics.

Concerning the Montescaglioso site, no significant differences are present between MTInSAR results already published, covering a period up to 2013, and our results, that arrive to 2018 (Figure 1): this means that only minor local processes are ongoing. The analysis confirms the stability of the area, except for very local displacements, likely related to structural deformations.

COSMO-SkyMed is more effective over infrastructures, being able to provide high density of coherent targets over buildings and also over roads that are not covered by Sentinel-1. For instance, in the case of Pomarico, COSMO-SkyMed has been able to capture better the building deformations preceding the landslide and the collapse. The ongoing deformations were also confirmed by cracks on the buildings, which prompted the evacuation.

On the contrary, Sentinel-1 is more effective than COSMO-SkyMed in catching signals from unurbanised areas. For instance, it has been able to capture signals from the Montescaglioso landslide body, which is covered mainly by vegetation and rock outcrops. By analysing both Sentinel-1 mean velocity maps and time series, it has been possible to identify an area that is still moving after the main event, as confirmed also from a recent study that processed LIDAR data.

3. Final remarks

The joint exploitation of different MTInSAR datasets provided valuable results: COSMO-SkyMed is more effective over man-made structures, while Sentinel-1 over rock outcrops.

Cosmo-SkyMed has been able to capture better the building deformations preceding the landslide and the collapse in Pomarico. Sentinel-1 provided indications about the ground stability within the Montescaglioso landslide body.

Non-linear trends in the deformation time series are very useful for geotechnical analysis and modelling and deserve more attention. In order to fully exploit the content of MTInSAR products, methods are needed for automatically identifying relevant changes along displacement time series, and, consequently, classifying the targets on the ground according to their kinematic regime.

Acknowledgements

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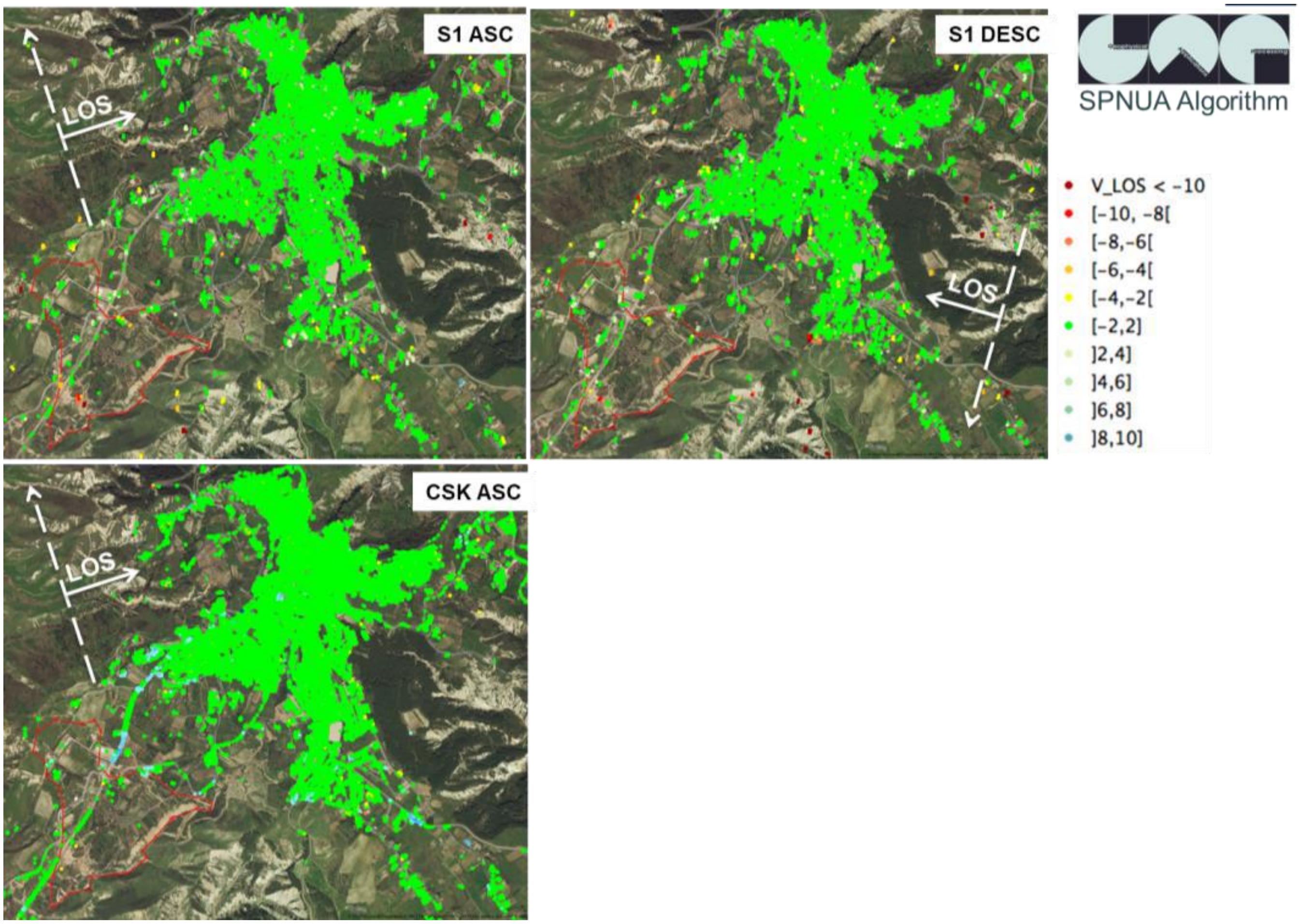

Figure 1. Deformation maps over the Montescaglioso site derived by processing with the SPINUA algorithm three datasets acquired by Sentinel-1 (from both ascending and descending orbits) and CSK (from ascending orbit).

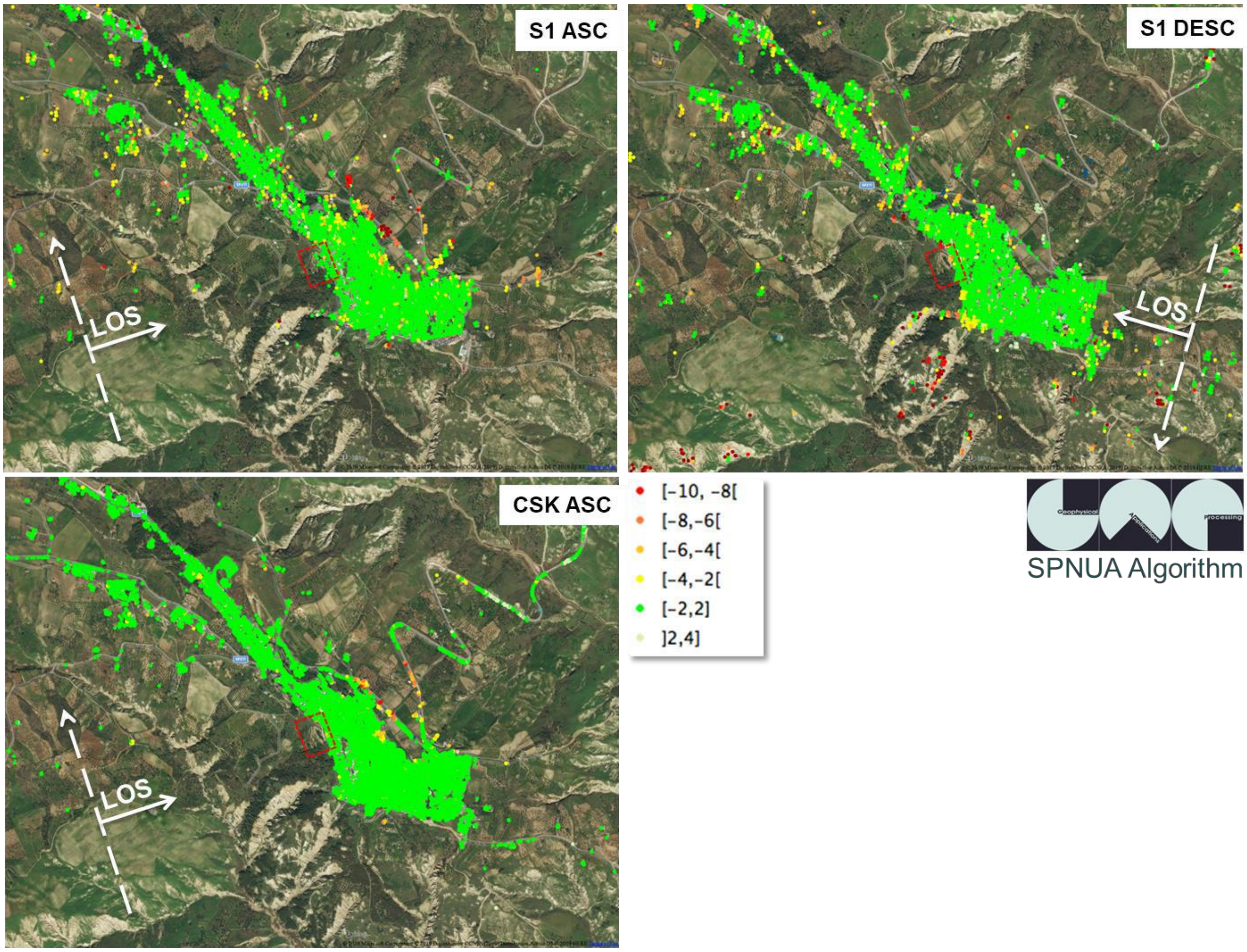

Figure 2. Deformation maps over the Pomarico site derived by processing with the SPINUA algorithm three datasets acquired by Sentinel-1 (from both ascending and descending orbits) and CSK (from ascending orbit).

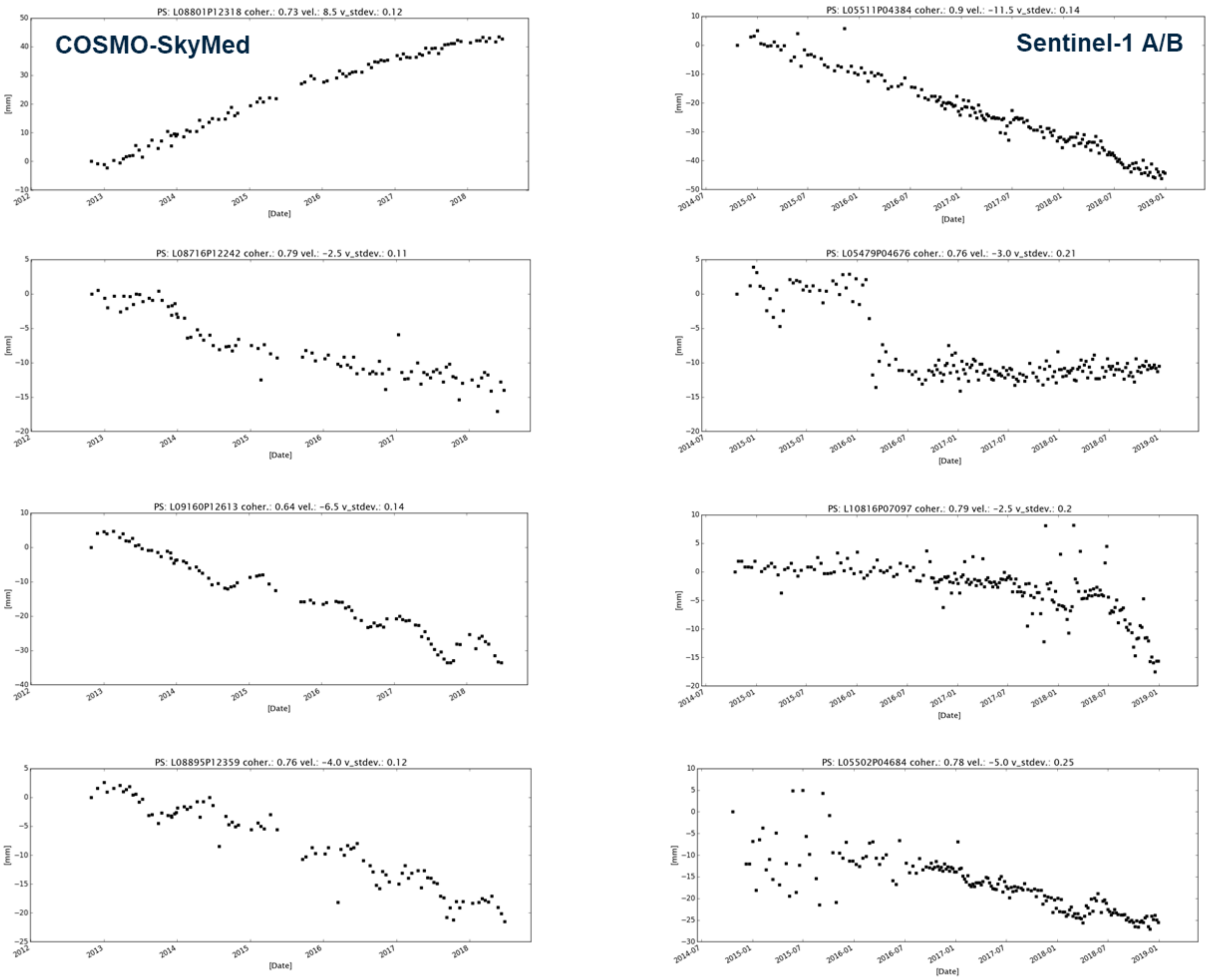

Figure 3. Sample time series from S1 and CSK data, showing more or less pronounced nonlinear behavior.