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Analysis of building deformation in landslide area using multisensor PSInSAR™ technique

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ABSTRACT

Buildings are sensitive to movements caused by ground deformation. The mapping both of spatial and temporal distribution, and of the degree of building damages represents a useful tool in order to understand the landslide evolution, magnitude and stress distribution. The high spatial resolution of space-borne SAR interferometry can be used to monitor displacements related to building deformations. In particular, PSInSAR technique is used to map and monitor ground deformation with millimeter accuracy. The usefulness of the above mentioned methods was evaluated in San Fratello municipality (Sicily, Italy), which was historically affected by landslides: the most recent one occurred on 14th February 2010. PSInSAR data collected by ERS 1/2, ENVISAT, RADARSAT-1 were used to study the building deformation velocities before the 2010 landslide. The X-band sensors COSMO-SkyMed and TerraSAR-X were used in order to monitor the building deformation after this event. During 2013, after accurate field inspection on buildings and structures, damage assessment map of San Fratello were created and then compared to the building deformation velocity maps. The most interesting results were obtained by the comparison between the building deformation velocity map obtained through COSMO-SkyMed and the damage assessment map. This approach can be profitably used by local and Civil Protection Authorities to manage the post-event phase and evaluate the residual risks.

Introduction

Landslides are globally widespread phenomena, causing a significant number of human loss of life and injury, as well as extensive economic damages to private and public properties. In Europe and in Italy in particular, where half a million active landslides exist, mass movements represent the primary cause of death caused by natural hazards (Guzzetti et al., 1999, 2012). Recently, significant results in the study of ground deformation were obtained using spaceborne Synthetic Aperture Radar (SAR) sensors, locally integrated with ground observations (Ferretti et al., 2001; Guzzetti et al., 2009; Lauknes et al., 2010; Herrera et al., 2010, 2013; Tomás et al., 2012). This approach allows delivering innovative and accurate information relevant to the Civil Defense Authorities covering the pre-event, event and post-event management phases. Nowadays slow ground deformations can be easily detected and monitored using satellite radar techniques at a relatively low cost. C-band satellites acquire SAR images since 1992, providing a very wide archive of the ground displacements historical evolution of a selected area. These sensors are characterized by a medium spatial resolution (20 m × 4 m) and a 35 days revisiting time. The new X-band COSMO-SkyMed (CSK) and TerraSAR-X (TSX) missions reduced the revisiting time to 4 (CSK) and 11 (TSX) days, enhancing the spatial resolution to 1 m × 1 m. Classical Differential interferometry (DInSAR) is used to measure the relative motion between two image acquisitions (Costantini et al., 2000; Crosetto et al., 2011). A phase difference image or interferogram, which is directly connected to ground motion, can be obtained. PSInSAR is a non-invasive surveying technique used to calculate motions of individual ground and structure point-like target over wide-areas (Ferretti et al., 2000). The PSI technique takes conventional DInSAR a step further by correcting the atmospheric, orbital and DEM errors in order to derive relatively precise displacement and velocity measurements at specific points on the ground. This well-established technique is particularly useful in landslides mapping and monitoring (Liu et al., 2013; Bianchini et al., 2014a). San Fratello is a town located in the Messina Province (Sicily, Italy), which was affected in the last three centuries by at least three important landslides: the first two, occurred in 1754 and 1922 respectively,

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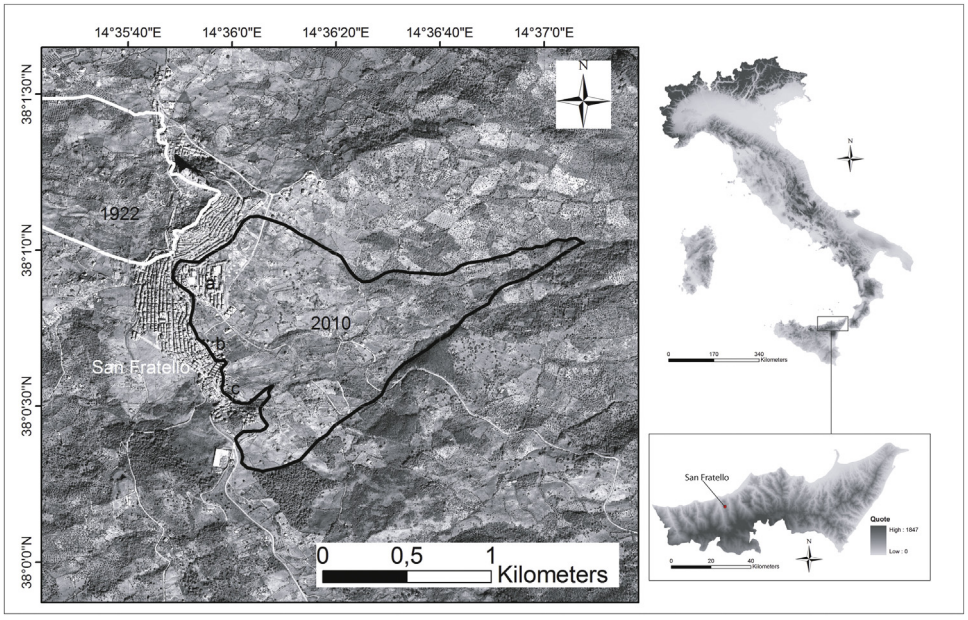

Fig. 1. Location of the study area and 1922 and 2010 landslides boundaries. (a) Stazzone quarter; (b) Riana quarter; (c) San Benedetto quarter.

destroyed the northern sector of the town, while the most recent one took place on the 14th February 2010, affecting the mid-eastern quarters of the town. This latter landslide, which is still active, caused severe damages to buildings and infrastructures with an estimated cost of 300 million Euros for the disaster mitigation and reconstruction program. This work presents an analysis of the San Fratello town building deformation velocities, obtained by the combined of PSI data and buildings map, with the aim of understanding the deformation evolution of the involved structures. In particular, C-band data collected before the 2010 event, were used to evaluate the presence of precursory symptoms of instability, whereas the X-band data, collected after the event, were analyzed in order to detect the residual risks in the post-event phase. Finally, the obtained post-event building deformation velocity map was compared with the damage assessment map. This application, based on the PSInSAR technique, can be suitable to evaluate how the abundance of the elements at risk in a landslide affected area may change with time, contributing to the risk assessment, which is very important for decision making by Civil Protection Authorities, especially during the landslide post-event phase.

Geological setting

The town of San Fratello is located in the northeastern sector of Sicily (Italy), along the Tyrrhenian coastline (Fig. 1), close to the boundary between the Nebrodi and Peloritani mountain chains. The study area was historically affected by landslides (Goswami et al., 2011; Mondini et al., 2011; Del Ventisette et al., 2012;

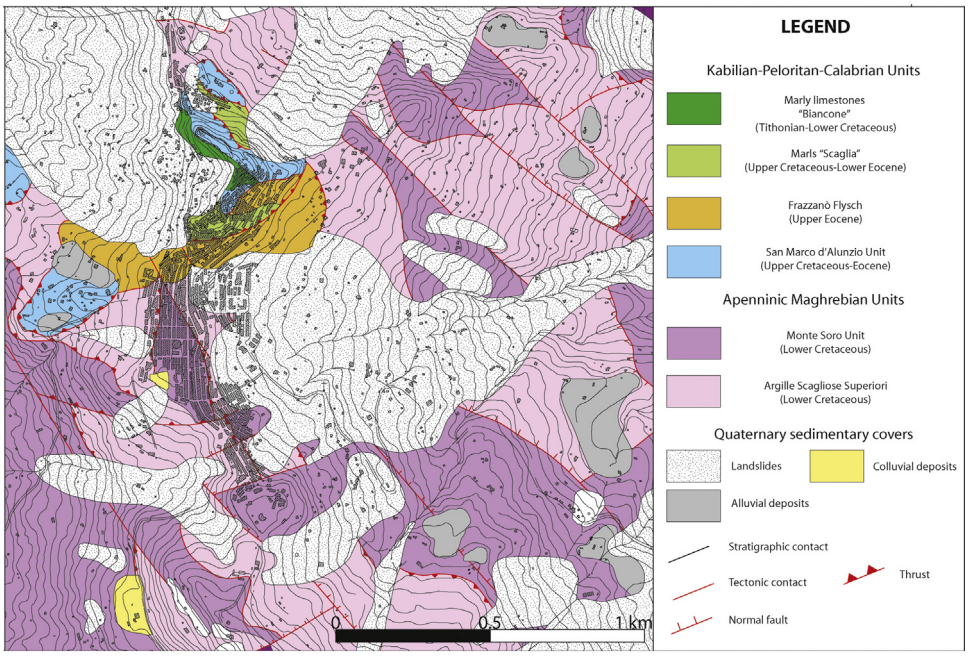

Fig. 2. Schematic geological map of the town of San Fratello (courtesy of DRPC).