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Remote monitoring of the Comba Citrin landslide using discontinuous GBInSAR campaigns

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ABSTRACT

This paper describes the use of the discontinuous Ground-Based Interferometric Synthetic Aperture Radar technique (GBInSAR) to monitor the displacement of the Comba Citrin landslide in the North Western Italian Alps. Two GBInSAR surveys were carried out respectively during the summer and the fall of 2015 separated by a temporal baseline of 63 days. For each GBInSAR survey, which lasted respectively 166.2 h (6 dd, 22 h, 12′) and 238.3 h (9 dd, 22 h, 18′), two sets of 139 and 275 SAR images were acquired. After the selection of a specific stack of Persistent Scatterers, the SAR images of each survey were analyzed separately and in combination with the images of the other survey to detect the possible displacements occurred both in every single survey as well as in the elapsed time between the two different campaigns. The displacement maps showed that two different sectors of the monitored slope were affected by millimetres to centimetres movements during the monitoring period. The results obtained for the Comba Citrin landslide show that the discontinuous GBInSAR can be reliably adopted to monitor the displacement of landslides moving at an average rate of few centimetres per year.

1. Introduction

The Ground-Based Interferometric Synthetic Aperture Radar (GBInSAR) is an active radar-based remote sensing technique, designed in general terms to monitor the displacements of objects (Rudolf et al. 1999, Tarchi et al. 2003). In the last fifteen years, the GBInSAR has proven to be a powerful tool for monitoring displacements and deformation affecting natural and engineered slopes, glaciers and volcanic flanks (e.g. Barla et al. 2010; Casagli et al. 2010; Intrieri et al. 2013, Farina et al. 2013, Strozzi et al. 2012) as well as for monitoring structural deformation (e.g. Barla & Antolini 2015a, Alba et al. 2008, Tapete et al. 2013). A comprehensive review of the state of the art of the ground-based SAR interferometry technique and its main application can be found in Atzeni et al. (2015) and in Monserrat et al. (2014).

Two different acquisition modes, namely continuous GBInSAR and discontinuous GBInSAR, can be applied to monitor the displacements of natural, engineered slopes and man-made objects (Monserrat et al. 2014).

In continuous GBInSAR monitoring, the radar sensor is generally installed in a stable position, i.e. an area not affected by deformation, and it acquires data at regular intervals during a unique survey which can last up to several months or years. This approach is particularly suitable to monitor landslides belonging to velocity classes 3 and 4 up to 2.1 m/day (Fig. 1) and for mining applications (Barla & Antolini, 2015b). In the same Fig. 1 the time to reach the ambiguous displacement of λ/4 for a radar device with wavelengths of 17.4 mm (Ku band), similar to the instrument used in this work, is also indicated. Due to the fact that the minimum scan time to acquire two consecutive SAR images varies from about 3 to 9 min (depending on the radar model and on the scanned range), the maximum unambiguous velocity which can be monitored lies in the range 0.7–2.1 m/day. If the slope is moving at higher velocity, the intrinsic phase ambiguity of the interferometric technique hinders the correct measurement of the real displacement.

When very slow and/or extremely slow slope displacements are expected, i.e., the velocity rate is comprised between few mm per years to few cm per years, a more efficient monitoring approach is the discontinuous GBInSAR monitoring. Very slow and extremely slow moving landslides are widespread in the Alpine region and, despite the low seasonal velocity, need to be constantly monitored to early detect the possible acceleration phases. For these applications, in addition to space-borne InSAR (Wasowski and Bovenga, 2014a,b), the discontinuous GBInSAR monitoring may be a cost-effective alternative to continuous GBInSAR and to point-wise in situ monitoring systems. Few works dealing with discontinuous GBInSAR applications currently exist, e.g. Corsini et al. (2011), Crosetto et al. (2014), Noferini et al. (2005b, 2008) and Luzi et al. (2010).

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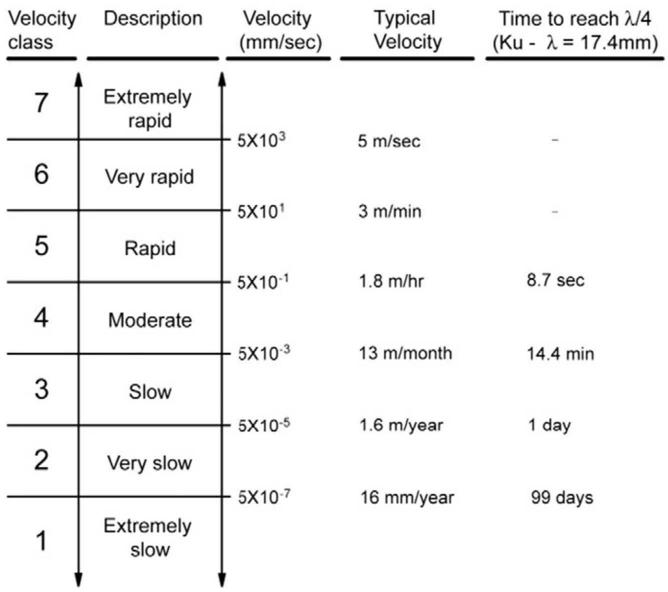

Fig. 1. Landslides velocity scale by Cruden & Varnes (1996) compared to the time to reach ambiguous displacement for a radar device working at Ku band (λ = 17.4 mm) (Antolini, 2014).

The correct discontinuous GBInSAR displacement estimation requires solving two main issues related to the processing of SAR imagery:

- the geometric baseline, i.e. the topographic phase component introduced by the inaccurate re-positioning of the system;
- the temporal decorrelation, i.e. the loss of coherence between different surveys separated by large time span (i.e. weeks or months).

Both the aforementioned issues, if not rigorously treated in the SAR images processing chain, represent a severe limitation for a reliable discontinuous measurement of slope displacement.

Generally if a concrete base and a precise mechanical positioning system is used (as in this work), the geometric baseline is zero. This avoids the need of any further processing step devoted to estimate and remove the topographic component in the interferograms.

The processing limits caused by temporal decorrelation were overcome by using Permanent Scatterers Interferometry (Ferretti et al., 2001) on the full temporal data stack of SAR images acquired in the different surveys. The approach is similar to the small baseline technique adopted in the processing of satellite-borne imagery (Berardino et al., 2002). To correctly solve the phase ambiguities in the interferograms, Noferini et al. (2008) integrated the approximate prior knowledge of the monitored slope deformation velocities in the phase unwrapping algorithm. Another indirect approach to solve the ambiguities related to

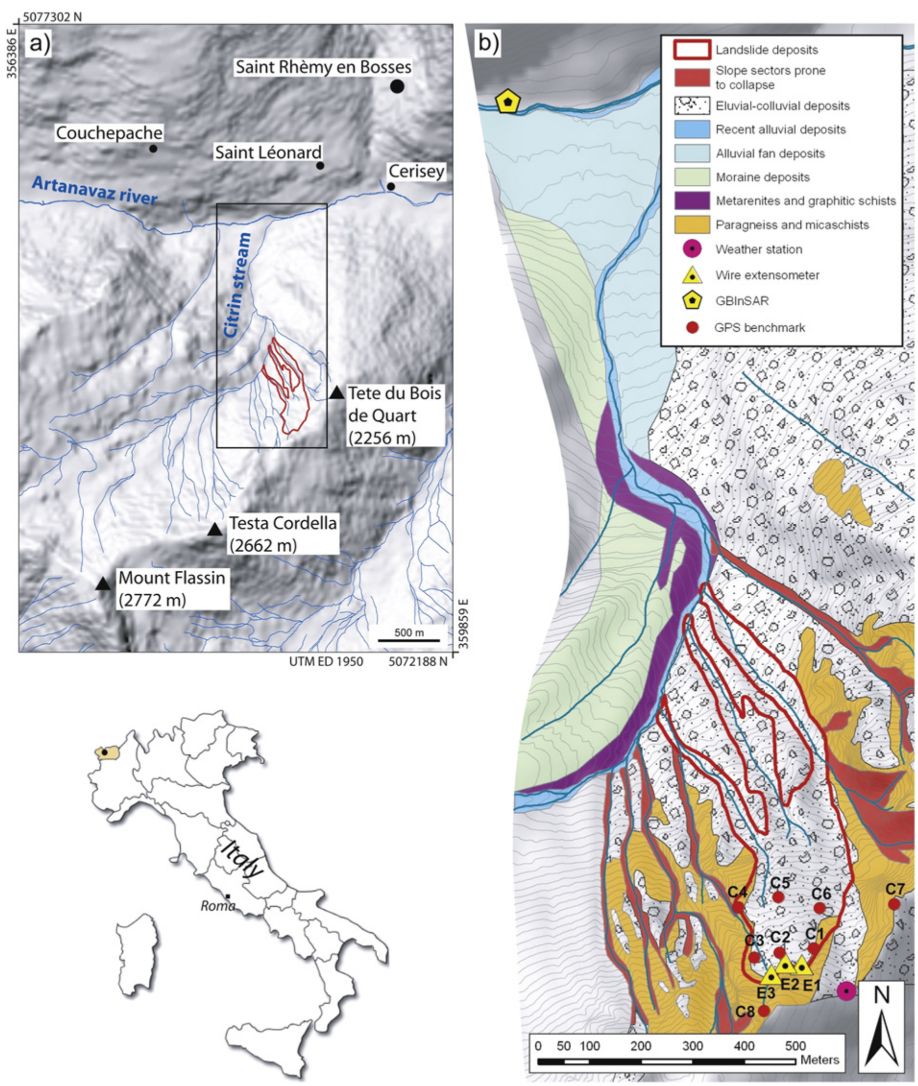

Fig. 2. a) The location of Comba Citrin landslide; b) Geological sketch of the studied area.