325 The Use of DInSAR Data for the Analysis of Building Damage Induced by Slow-Moving Landslides

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Abstract

The paper aims at checking the contribution that DInSAR data, processed via different algorithms, can provide to the analysis of damages recorded to buildings located in slow-moving landslide affected areas. For this purpose, an urban area in Calabria region, southern Italy, was selected due to the availability of both DInSAR data since 1992 and historic information concerning damage data recorded via municipal ordinances. The combination of DInSAR data and the results of supplementary damage surveys allowed the preliminary investigation of a cause (maximum velocity)—effect (damage) relationship which, once validated, can be valuably used for damage analysis and forecasting.

Keywords

Slow-moving landslides • DInSAR data • Building • Damage

325.1 Introduction

Slow-moving landslides are widespread in different geological contexts all over the world and they often cause significant damage to structures and infrastructures with them interacting (Mansour et al. 2011). The analysis and forecasting of landslide-induced consequences usually requires a huge amount of data—dealing with the kinematical features of the unstable slopes as well as the damage to affected facilities—which can turn out to be not affordable especially over large areas. As for the retrieval of ground surface displacements of slow-moving landslide affected areas, a relevant contribution can be provided by remote sensing data, such as those derived from the processing of Synthetic Aperture Radar images via Differential Interferometry techniques (DInSAR) (Cascini et al. 2010, 2013). In particular, the available datasets allow the analysis of displacement time series of targeted elements (e.g. building, roads, etc.) over about 20 years since 1992 with an accuracy of about ±1 mm/year on the average velocity.

In the present work a preliminary investigation of the relationship between DInSAR-derived average velocity over SAR-targeted buildings and the occurrence of damage of given severity is carried out with reference to a study area in the northwest portion of Calabria region, southern Italy.

325.2 The Case Study

The study area corresponds to the urbanised territory of Verbicaro municipality (Cosenza Province) whose geological setting consists of the Frido Unit tectonically overlying the Lungro–Verbicaro Unit (Amodio Morelli et al. 1976). The former is constituted by low-grade metamorphic rocks, usually marked by extensional brittle–ductile shear zones, and includes metapelites, phyllites, shales and metalimestones. At the top of the Unit, locally covered by colluvial deposits, blocks and fragments of metamorphic rocks in a

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prevalently clayey matrix (derived from the degradation and claying of phyllites) can be found.

The urban area of Verbicaro has been suffering from slope instability for a long time as testified by the Royal Decree 445 (dated 1908) which included Verbicaro in the list—never implemented—of those municipalities whose households should have been relocated. Since the early 1960s, the seriousness of the problem has been highly increasing due to the urban sprawl towards the unstable slopes located in the area north-west of the old centre. Currently the whole urban area of Verbicaro is affected by several slow-moving landslides of different typology which have been causing damages of different severity to the existing facilities located in the historic centre (mainly including old masonry buildings) and in the north-western quarter (where reinforced concrete buildings built up in the 1960s experienced damages compromising their stability). As a result, during the last decades many structures were demolished and rebuilt; moreover, several roads frequently undergo repair works.

325.3 The Available Dataset

With reference to the study area of Verbicaro, topographic maps at 1:5,000 scale were used to obtain the building footprints. Then, on the basis of multi-temporal aerial-photo interpretation, a landslide inventory map was derived (Fig. 325.1). The mapped phenomena consist of: roto-translational slides; complex landslides; landsliding areas (Antronico et al. 2013); they mainly involve detrital covers constituted by colluvial deposits and completely degraded phyllites, with grain size distributions varying from slightly sandy clay with silt to silt with clay (Gullà 2001).

As for the remote sensing information, ERS data on descending orbit (period 1992–2000) and ENVISAT data on ascending orbit (period 2003–2010) were provided by Italian Ministry of the Environment and Protection of Land and Sea as results of Piano Straordinario di Telerilevamento and processed via the Permanent Scatterers technique (Ferretti et al. 2001). These data were integrated with ENVISAT data on descending orbit processed by IREA-CNR, Naples (Fornaro et al. 2009).

As for the damage to structure/infrastructures, within the period 1989–2009 the municipal council issued a series of ordinances of evacuation/repair/demolition for a large number of severely damaged buildings. The information contained in those documents was collected and organized, for the purpose of this study, according to: the year of issue; the type of order (i.e. evacuation/repair/demolition); the reference location of the building in a GIS map; some descriptive notes on the state of damage experienced by the structure. A total of 95 ordinances, mainly concentrating in the period 1998–2000, were analysed (42 % evacuation; 33 % repair; 25 % demolition).

325.4 Joint Analysis of DInSAR Data and Building Damage

In order to select the buildings to be included in the joint analysis, DInSAR data and building damage were firstly separately analysed. In particular, a preliminary check on DInSAR coverage on buildings highlighted that for 198 and

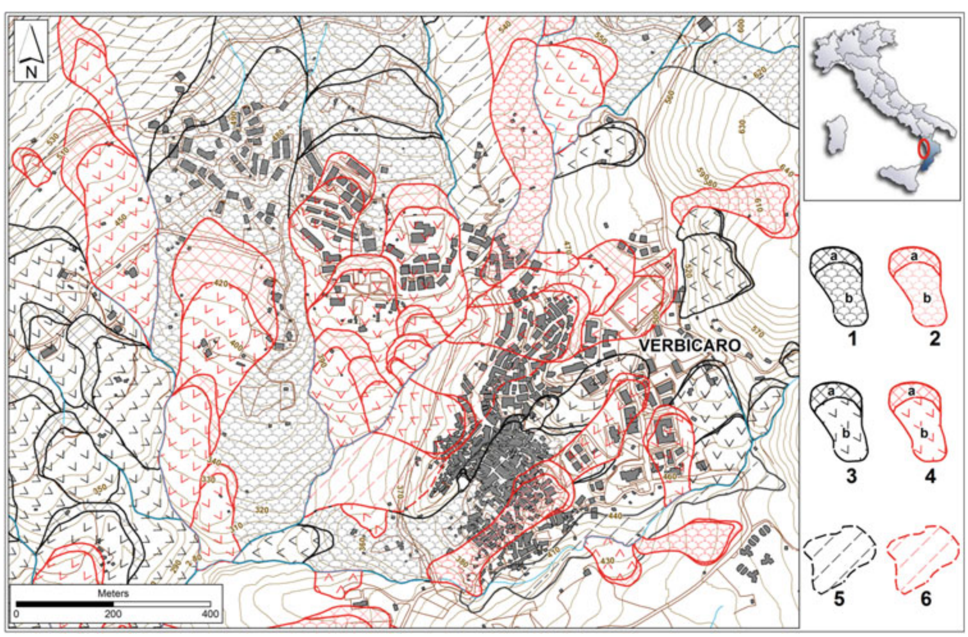

Fig. 325.1 Landslides inventory map of Verbicaro: (1) dormant complex landslide (a, scarp; b, body); (2) active complex landslide (a, scarp; b, body); (3) dormant roto-translational slide (a, scarp; b, body); (4) active roto-translational slide (a, scarp; b, body); (5) dormant landsliding area; (6) active landsliding area

348 buildings ERS and ENVISAT data, respectively, are available.

Moreover by setting a movement threshold of 1.5 mm/year on the Line of Sight (LOS) velocity (Cascini et al. 2010) 93 buildings, which are covered by at least one moving PS over 20 years (period 1992–2010), were selected. Then, on the basis of simplified geomorphological criteria (Cascini et al. 2010) it was assumed that PS located over the buildings within the head of mapped phenomena measure, along LOS direction, a displacement mainly occurring in the vertical direction; whereas a mainly translation movement along the steepest slope direction is assumed for the other PS located over the buildings within the main body of the mapped landslides. Thus operating, a projected velocity value was associated with each of the 93 moving buildings (Fig. 325.2) corresponding to the highest projected velocity recorded by the PS within their footprints. For the purpose of the analysis the velocity values refer only to ENVISAT dataset (period 2003–2010) since damage survey was carried out in March–April 2013.

During the building damage survey both severity and distribution of damage within the urban area of Verbicaro were checked. The sample of the surveyed buildings summed up to 130 including those moving according to DInSAR

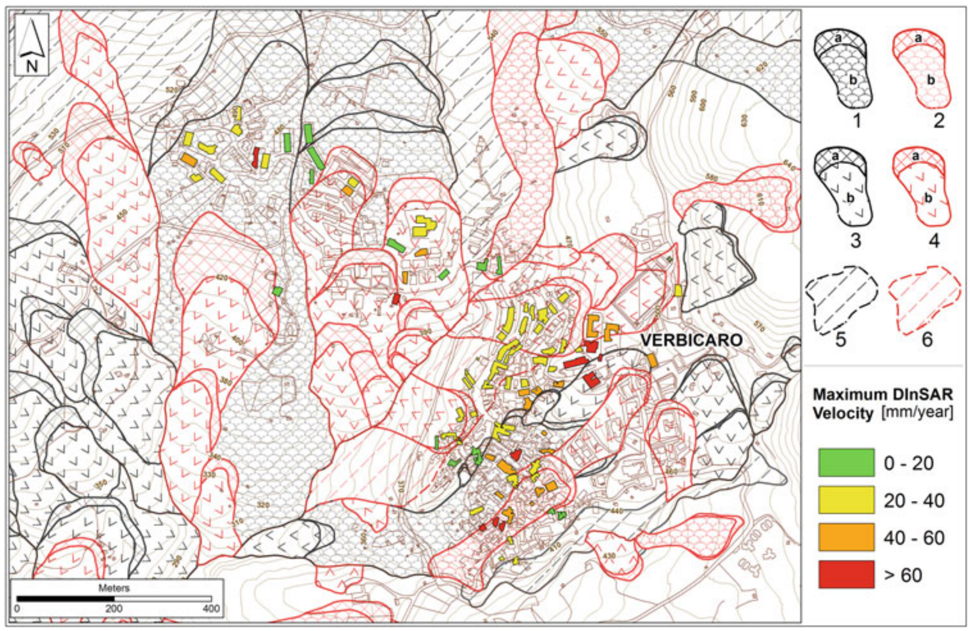

Fig. 325.2 Map of building velocity for the Verbicaro urban area (for the legend see Fig. 325.1)

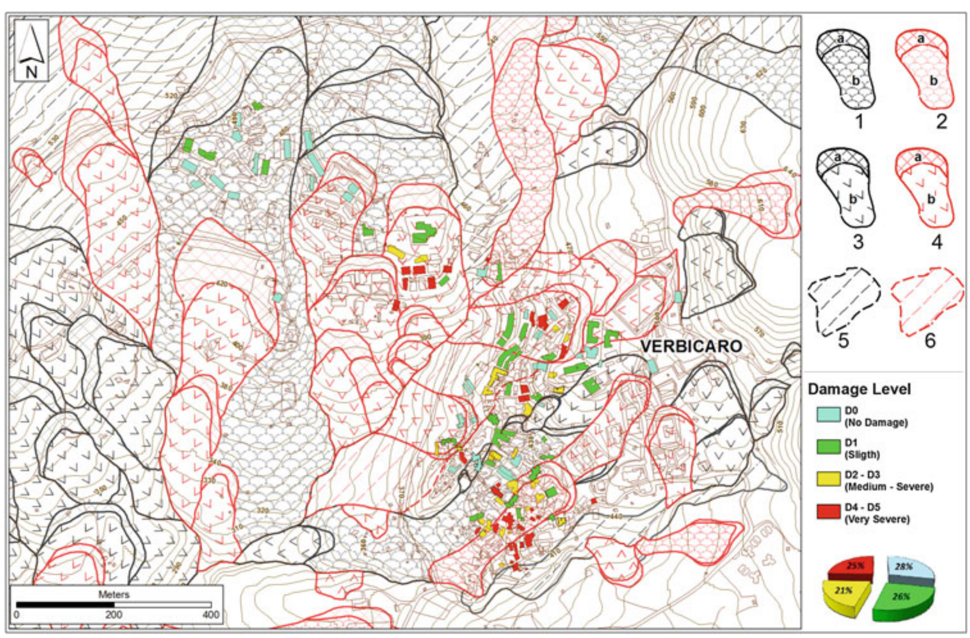

Fig. 325.3 Map of surveyed buildings distinguished according to the recorded damage severity (for the legend see Fig. 325.1)

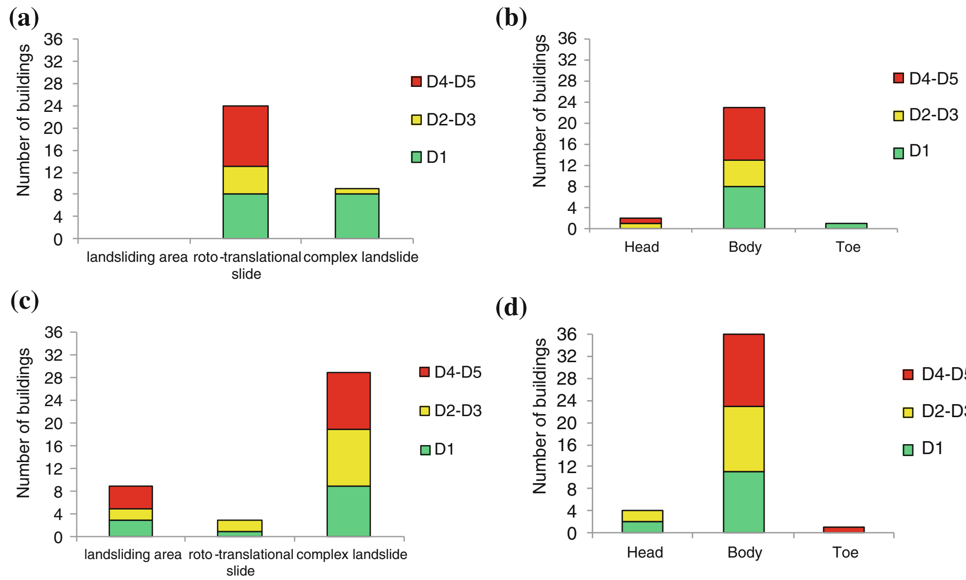

Fig. 325.4 Distribution of damage severity according to landslide typology (**a**) and position (**b**) for reinforced concrete structures; distribution of damage severity according to landslide typology (**c**) and position (**d**) for masonry buildings

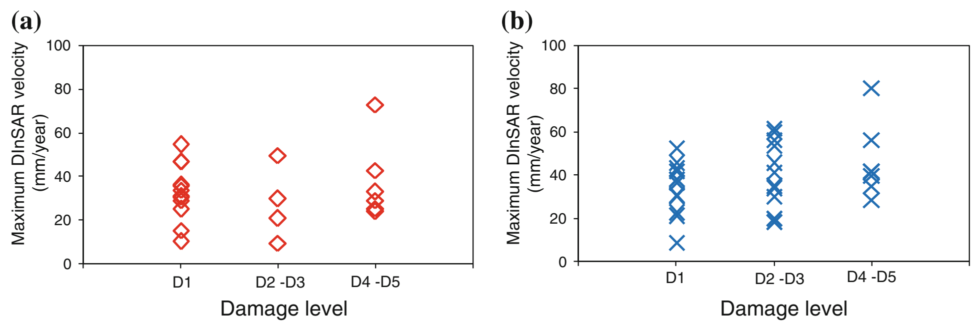

Fig. 325.5 Maximum DInSAR velocity recorded for each building and its correspondent damage severity for (**a**) reinforced concrete buildings and (**b**) masonry buildings

data as well as the ones for which ordinances were issued in the past (if not already included in the group of moving buildings). To this aim, ad hoc predisposed fact-sheets were filled in thus providing an overview of the built-up area as well as of its condition, state of maintenance and damage severity. This latter was, in turn, differentiated in four classes (D0 = no damage; D1 = slight; D2–D3 = moderate-severe; D4–D5 = very severe) adapted from those provided by Burland et al. (1977). The collected data (Fig. 325.3) highlighted that 51 % out of the total are reinforced concrete buildings (up to 7–8 floors), mainly built in early 1960s, whereas 49 % of the structures are masonry buildings (up to 3 floors) mainly located in the old centre.

325.5 Results and Discussion

Focusing on 74 surveyed buildings with damage severity ranging from D1 up to D5 a check on the distribution of damage severity according to landslide typology, building typology and its position within the landslide body was carried out (Fig. 325.4).

The availability of DInSAR data allowed a preliminary analysis of the relationship between the maximum velocity exhibited by each damaged building and the recorded damage severity. With reference to nr. 33 reinforced concrete and 41 masonry buildings, for which D1 up to D5 damage level was recorded and DInSAR velocity exceeded the velocity threshold, Fig. 325.5a and b shows a general increasing trend of damage severity with velocity for both structural categories. However, due to the complexity of the addressed study, further investigations are currently being carried out concerning the landslides' mechanisms as well a more detailed damage data collection in terms of number of surveyed buildings and exact dating of the damage occurrence.

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