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Supporting the analyses of a high-density landslides basin by A-DInSAR

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RIASSUNTO

L'uso della tecnica A-DInSAR a supporto dello studio di un bacino ad alta densità di fenomeni franosi.

Nel presente lavoro si presentano i risultati di un'indagine eseguita con diverse tecniche (tra cui l'A-DInSAR satellitare) su un bacino densamente interessato da fenomeni franosi. I risultati confermano come l'integrazione tra le diverse tipologie di dati a disposizione rappresenti un approccio efficace per la caratterizzazione dei dissesti di versante.

All'interno di tale bacino, ubicato nel basso-collinare chietino, sono state riconosciute e mappate oltre 90 frane, dotate di caratteristiche molto diverse in termini di geometrie, orientazioni, cinematismi e grado di antropizzazione.

Al fine di definire nel dettaglio l'evoluzione spazio-temporale dei fenomeni, misurando gli spostamenti avvenuti nelle ultime due decadi, è stata condotta un'analisi con A-DInSAR sull'area di studio.

Oltre al classico approccio PS-InSAR, è stato eseguito lo studio delle serie temporali di spostamento tramite analisi interferometriche a scala locale, ottenendo importanti risultati in termini di accuratezza ed affidabilità nell'individuare spostamenti non-lineari.

KEY WORDS: *A-DInSAR, basin, landslides, PS InSAR.*

INTRODUCTION

The aim of this study was to characterize the landslides affecting a small basin in the Abruzzo region by means of an integrated use of field surveys, aerial photogrammetry and, especially, Advanced DInSAR (A-DInSAR) technique (specifically Persistent Scatterers InSAR – PS InSAR).

In order to improve detection and estimation of the non-linear displacements, and to define more accurately the areas of highest interest, interferometric analyses were conducted also with a "small area" (local) approach.

Integration of classical investigations and PS-InSAR data was fundamental to properly define the gravitational instability condition of the basin.

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THE STUDY AREA

The herein presented study has been carried out in a small basin located in the central sector of the Apennines, between the Maiella Mountain and low-hilly area in the Abruzzo Region (Italy). The basin is about 15 km^2 in area and it is crossed by the Dendalo torrent. From the morphological point of view, the landscape is featured by a hilly structure with altitude ranging from 150 m to 440 m a.s.l., and gentle slopes frequently affected by gravitational instability processes.

The basin, North-South oriented, falls within the Periadriatic Marche-Abruzzo basin, built on Plio-Pleistocene marine deposits (BIGI *et alii*, 1995). The geological substrate of the investigated basin is characterized by the Mutignano Formation, a marine Plio-Pleistocene sequence characterized by silty clays containing sands which gradually increases towards the upper part of the formation. The terms of Pleistocene transition are represented by clays and conglomerates and can be found mainly on the top of reliefs in the right bank of the Dendalo torrent. Continental Quaternary formations characterized by debris and colluvial materials, mainly of gravitational and alluvial origin, also crop out in the basin.

From the structural point of view, the area is rather regular and homogeneous, mainly due to extensional tectonic that has displaced all the outcropping Plio-Pleistocene sequences. This tectonic setting is expressed primarily through normal and high-angle transtensional faults, with slips ranging from a few meters to a few tens of meters (BIGI *et alii*, 1995; CENTAMORE *et alii*, 1997).

LANDSLIDES FEATURES

By field surveys and multi-temporal analysis of aerial photos from 1954 to 2002 more than 90 landslides were identified and mapped. Landslides affect more of the 75% of this portion of the Dendalo torrent basin and were classified as translational sliding (38%), earth-flows (31%) and complex

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This work has been carried out in the frame of the ESA Cat-1 project: "Landslides forecasting analysis by displacements time series derived from Satellite and Terrestrial InSAR data" (ID: 9099).

mass movements (31%). Landslide area ranges from very few hundreds m^2 to some km^2.

Landslide deposits are related to the mobilization of pelitic and psammitic lithologies belonging to the Mutignano Formation, especially in the middle and lower portions of the slopes. In the mainly pelitic areas, geomorphological elements related to the largest landslide phenomena, such as crowns, scarps and counterslopes, are highly altered and degraded, and often modified by the strong anthropic activity in the area.

The main factors responsible for the strong landslide activity are the joint action of tectonic setting, physical and mechanical properties of soils, surface and ground water dynamics, and land use.

A-DINSAR ANALYSIS

In order to refine the landslides mapping and to derive state of activity and evolution rate, an Advanced Differential InSAR (A-DInSAR) investigation has been performed. This study has been carried out by using images derived from the European Space Agency (ESA) archives, available in the frame of the CAT-1 project "Landslides forecasting analysis by displacements time series derived from Satellite and Terrestrial InSAR data" (ID: 9099). Four different datasets have been used to characterize the landslides historical displacements (Table 1). Specifically, ERS1-ERS2 and Envisat satellite data both in ascending and descending orbit acquisition geometry have been selected for the period 1992-2010.

The SAR data have been processed through SARPROZ (PERISSIN, 2009; PERISSIN *et alii*, 2011), a specifically developed software tool for multi-image InSAR analyses such as PS (FERRETTI *et alii*, 2001) and QuasiPS (QPS) (PERISSIN & WANG, 2012). For this case study two different approaches have been used:

- standard PS analysis, where velocities are evaluated applying a linear trend model (FERRETTI *et alii*, 2001);
- local analysis of small areas, performed for the most interesting zones, which allows to achieve higher accuracy in the displacements estimation, and, especially, to detect non-linear trends.

It is worth noting that non-linear movements are considered crucial for a suitable investigation of the landslide processes affecting the investigated area (Fig. 1).

RESULTS

The A-DInSAR analysis allowed to derive useful information for more than 30% of the mapped landslides

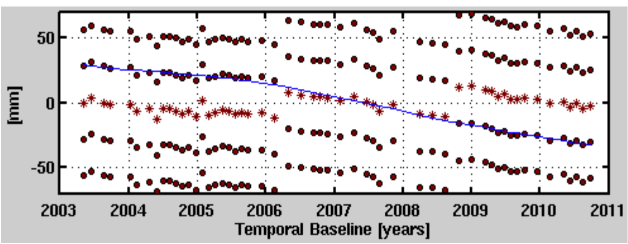

Fig. 1 – Example of displacement time series provided by SARPROZ Small Area function: it is possible to note the phase replicas, useful to detect the real displacement trend.

TABLE 1.

Used datasets features.

Satellite	Geometry	Track	Frame	Images	Period
ERS1-2	descending	36	2763	72	1992 - 2001
ERS1-2	ascending	129	837	47	1995 - 2001
Envisat	descending	36	2763	35	2003 - 2010
Envisat	ascending	129	837	55	2003 - 2010

affecting the Dendalo torrent basin (more than 55% in terms of area), especially for the largest ones and those affecting urbanized areas.

Thanks to the long-term data available (1992-2010) displacements information allowed to refine the landsides mapping and to derive the state of activity. Furthermore, some landslides previously mapped as coalescent were recognized as a unique event, while some other landslides were internally distinguished thanks to the identification of differential deformations.

Four areas of particular interest have been then analysed by a local analysis (Fig. 2).

In the Area 1 displacements affecting the landslide body (1992-2010) and the upper part of the crown (1992-2001) have been detected with displacement rates between 3 and 5 mm/yr along the LOS. The movement trend is linear and no acceleration stages have been recognized.

In the Area 2, located at the foot of a wide complex landslide with many coalescent bodies, displacements during the overall period 1992 – 2010 were detected. Thanks to the ascending and descending geometry combination it was possible to infer the movement direction that is mainly horizontal. The upper part shows lower displacements starting from 2003 while in the lower part displacements are evident since 1992, with a higher rate and a more horizontal component. Furthermore, the movement trend is strongly not linear with several acceleration stages recognized. Displacement rates are high (>15 mm/yr).

Area 3 was classified as inactive by the preliminary investigation, but it shows phases of activity detected thanks to the ascending geometry especially in the period from 1995 to 2001. Observed displacements are homogeneous across the landslide portion and the movement trend is linear over the time; displacement rates are quite low (<3-4 mm/yr).

Also in the Area 4 displacements were recognized thanks to the ascending geometry due to its orientation. Observed displacements are heterogeneous across the landslide area with some portions affected by higher displacements and some others more stable, especially in the period 2003-2010; the movement trend is linear.

The Area 5, instead, is a typical exapmple of no DInSAR information mainly caused by absence of good backscattering targets on the landslide surface.

CONCLUSIONS

The analysis performed through the integration of field surveys, aerial photos investigation and A-DInSAR allowed to achieve a complete knowledge framework on the study area.

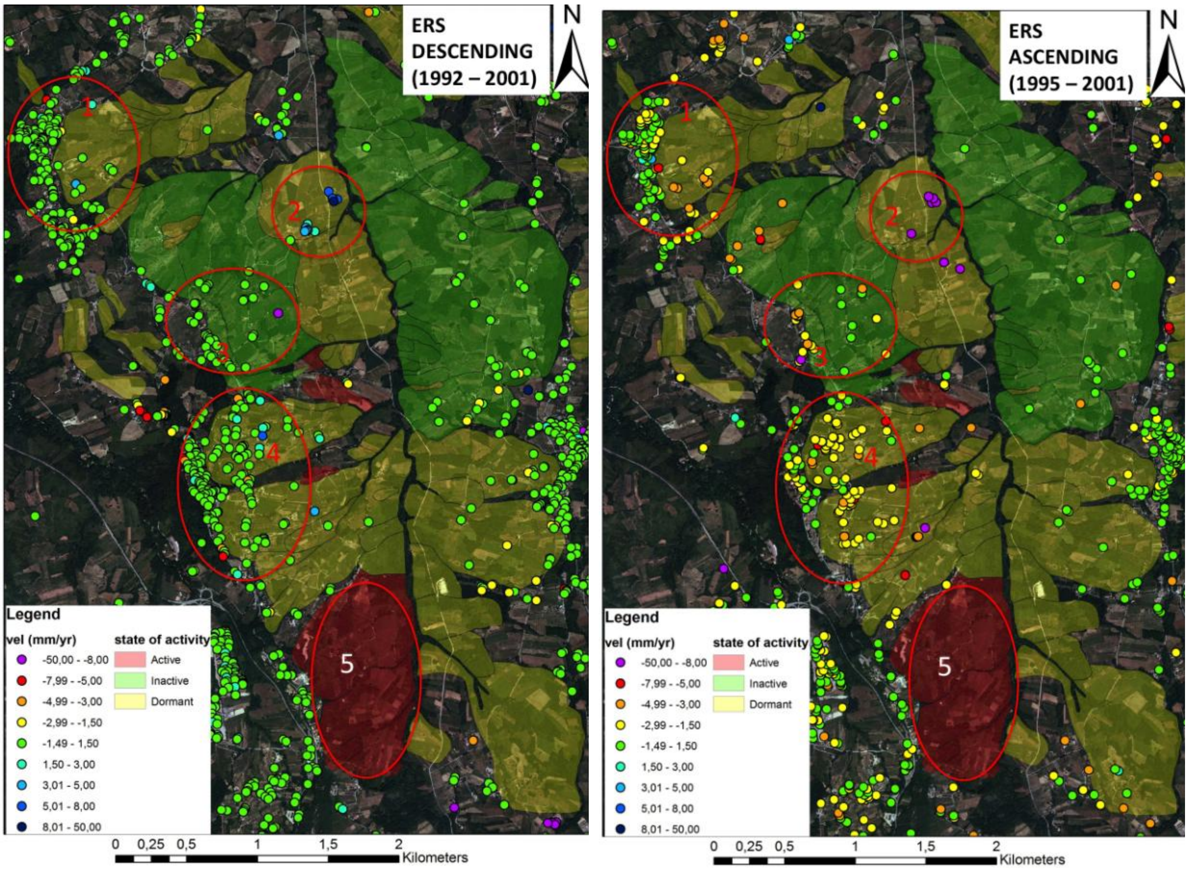

Fig. 2 – ERS descending and ascending PS results. State of activity is here related to the preliminary investigations results and it represented a start point for the PS-InSAR analysis.

Multi-temporal aerial photographs analysis allowed to identify landslides activity in the Dendalo basin since 1954 but it was not enough to quantify the temporal evolution and displacement rate of the landslides. Thanks to PS Local Area analyses, it was possible to better define the state of activity and especially the temporal evolution of some observed phenomena. This aspect is crucial for a proper planning aimed to reduce landslide hazard.

Specifically, the East-facing slopes show a more intense and continuous activity both in the periods 1992-2001 and 2003-2010.

For the sake of completeness, it is well to remember, however, that the A-DInSAR technique is unable to detect displacements in areas without good scatterers, as in the Area 5, where the landslides activity would be very interesting to be investigated. Another aspect to remark is the usefulness of the execution of local analysis which allowed the accurate and reliable determination of the displacements for the most critical areas.

It is, however, fundamental to highlight the importance of different source of data (e.g. both ascending and descending acquisition geometry for A-DInSAR) especially for basin-scale analyses where different phenomena in terms of dimension, orientation, displacements rate have to be investigated.

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