THE EUROPEAN DORIS DOWNSTREAM SERVICE AS A MULTI-SCALE SYSTEM FOR LANDSLIDES AND SUBSIDENCE RISK MANAGEMENT

M. Manunta(1), *F. Calò*(1), *C. Ojha*(1,2), *F. Ardizzone*(3), *F. Guzzetti*(3), *A. C. Mondini*(3), *P. Reichenbach*(3), *S. Bianchini*(4), *N. Casagli*(4), *A. Ciampalini*(4), *C. Del Ventisette*(4), *S. Moretti*(4), *I. Garcia*(5), *G. Herrera*(5), *R. M. Mateos* (5), *B. Füsi*(6), *M. Graniczny*(7), *Z. Kowalski*(7), *A. Piatkowska*(7), *M. Surala*(7), *H. Retzo*(8), *T. Strozzi*(9), *D. Colombo*(10), *O. Mora*(11), *C. Sánchez*(11)

(1) IREA-CNR, Naples, Italy; (2) University of Rome 'La Sapienza'; (3) IRPI-CNR, Perugia, Italy; (4) University of Firenze, Italy; (5) Geoscience Research dept., IGME, Madrid, Spain; (6) MFGI, Budapest, Hungary; (7) PGI, Poland; (8) FOEN, Bern, Switzerland; (9) GAMMA Remote Sensing, Gümligen, Switzerland; (10) TRE s.r.l., Milano, Italy; (11) Altamira Information, Barcelona, Spain.

ABSTRACT

We focused on the joint exploitation of satellite and ground-based technologies in order to understand the kinematic behavior of landslides and subsidence phenomena relevant to different test sites in Europe. In this context, we efficiently exploited C-band and X-band satellite and ground-based SAR data for the investigation of the temporal and spatial pattern of ground deformations caused by natural and human-induced hazards.

The present work has been conducted within the FP7-EU DORIS project.

Index Terms— SAR, Interferometry, PSI, DORIS, landslides, subsidence.

1. INTRODUCTION

Ground deformations, including landslides and land subsidence, widely occur in Europe and often result in high socio-economic impact on the affected communities. The large number of areas affected by such deformations, the frequency and extent of the triggering events, and the severity of the resulting damage make mandatory a multi-scale, systemic approach. Furthermore, the complexity of the problem is such that it cannot be tackled (and solved) at an individual, site specific scale, or using a single technique or methodology, but should be approached only through the integration of data and information taken at different scales.

The FP7-EU DORIS project well fits into this context; indeed, it is aimed at improving both the understanding of the complex phenomena that cause ground deformation and the capabilities of Civil Defence authorities to manage the associated risks. To this aim, DORIS focuses on the effective exploitation of satellite and ground-based technologies for the risk prevention and mitigation.

Among the several satellite technologies, within DORIS a key role is played by Differential SAR Interferometry (DInSAR) techniques, aimed at investigating the spatial and temporal pattern of ground deformation. DInSAR is a remote sensing technique allowing to produce spatially dense deformation maps with centimetre to millimetre accuracy by exploiting the phase difference (i.e. the interferogram) between pairs of SAR data acquired over the same area at different epochs. Recently, the DInSAR technique has been applied to retrieve the temporal evolution of the detected displacements through the generation of deformation time series [1]-[7].

In this work, we show how the current DInSAR scenario impacts on the mapping and monitoring of landslides and subsidence phenomena and can be effectively exploited to improve the knowledge and understanding of their kinematics. In particular, we focus on the efficient exploitation of the huge C-band ERS-1/2 and ENVISAT data archive for detailed back-analysis and on the mapping capabilities at very high resolution, both in time and space, offered by the new generation X-Band SAR constellations, as COSMO-SkyMed and TerraSAR-X systems. The presented results are relevant to european test sites characterized by different ground deformation phenomena and representing a wide range of physiographical and environmental settings: i) Umbria (Central Italy); ii) Messina (Southern Italy); iii) Dunaszekcső, Rácalmás and Hollóháza (Hungary); iv) Silesian Coal Basin (Poland); v) Tramuntana Range (Mallorca, Spain); vi) St. Moritz and Zermatt (Switzerland).

2. RESULTS

This section is focused on the results achieved for some of the areas investigated within DORIS.

2.1 Umbria (Central Italy)

A good example of landslides occurring in urban areas is the Ivancich landslide, in the Assisi municipality, Central Italy (Fig. 1), affecting a neighbourhood of tens of single buildings, and a hospital. In this case, we have applied the SBAS-DInSAR [1]-[3] technique to ERS-1/2 and ENVISAT data in order to investigate the spatial and temporal pattern of the deformations covering almost two decades (1992-2010), allowing us to point out the kinematic behaviour of the landslide. The SBAS-DInSAR technique has been subsequently applied to the high-resolution X-Band COSMO-SkyMed (CSK) dataset in order to analyse its capability to map and monitor landslide phenomena.

Thanks to the improved spatial resolution (3 m), the reduced revisit time (1 week) and the shorter analyzed time period (2.25 years), the X-Band data allow us to perform more detailed analyses on areas affected by mass movements (Fig. 1). In particular, the improvements of the coherent pixel density obtained from CSK analysis give us more insights on the movement distributed along the unstable mass, thus allow for better understanding the kinematics of the investigated phenomenon, with relevant advantages in landslide mapping.

2.2 Zermatt (Switzerland)

From the panoramic point of view offered by the peak, in the late afternoon of 19 September 2012, the Gamma Portable Radar Interferometer (GPRI) measured surface deformation of (from left to right in Fig. 2) the Grenzgletscher, Schwärzegletscher and Breithorngletscher. In a period of 1 hour and 33 minutes, the GPRI performed 32 successive scans, with an interval of 3 minutes between each scan. Analysis of the images allowed determining the average displacement rate, expressed in Fig. 2 by the daily rate of movement. The red colours identify surface movements, clearly visible for the Schwärzegletscher.

2.3 Tramuntana Range (Mallorca, Spain)

In the Tramuntana Range, the SAR datasets collected within the 1992-2010 time interval, ALOS-PALSAR (ascending), ERS (descending), and ASAR-ENVISAT (ascending and descending), have been processed through the SPN technique [4]-[5]. In this case, the different datasets have been properly exploited for investigating the impact of their characteristics (i.e., acquisition geometry, spatial and temporal resolution, and wavelength) on the landslides mapping. The LOS displacement velocity measured from all the available satellite sensors is shown in Fig. 3.

From the obtained results a total amount of 690,683 Persistent Scatterers (PS) was detected by ALOS, 170,316 and 155,923 by ENVISAT (ascending and descending data, respectively), and 177,970 by ERS. The recorded displacement rates are in the range between -10 mm/yr to +10 mm/yr for ERS and ENVISAT descending orbits, and between -24 mm/yr to + 22 mm/yr for ascending orbits of

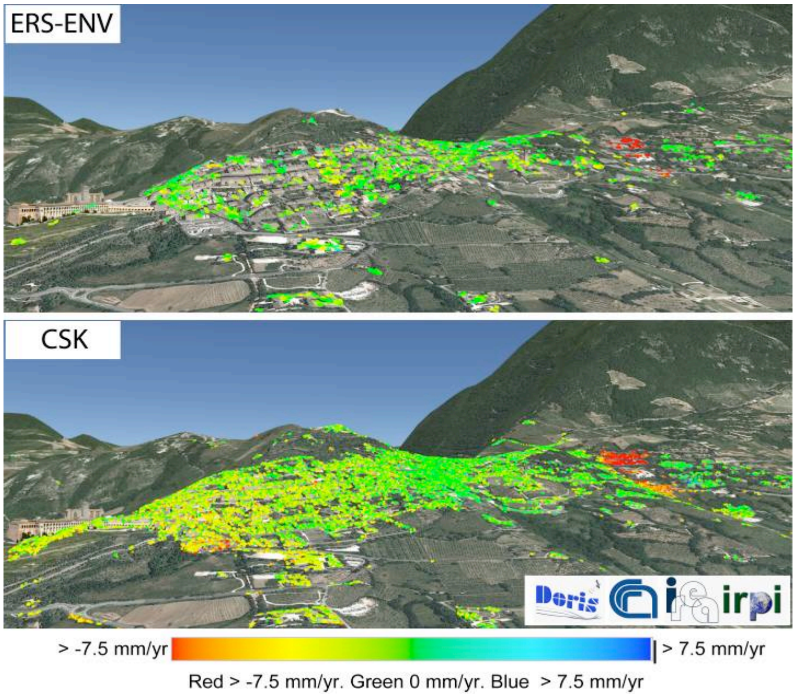

Figure 1. Comparison between ERS-ENVISAT (top) and CSK (bottom) SBAS-DInSAR results relevant to the Assisi urban area, Central Italy. Note the surface deformation induced by the Ivancich landslide.

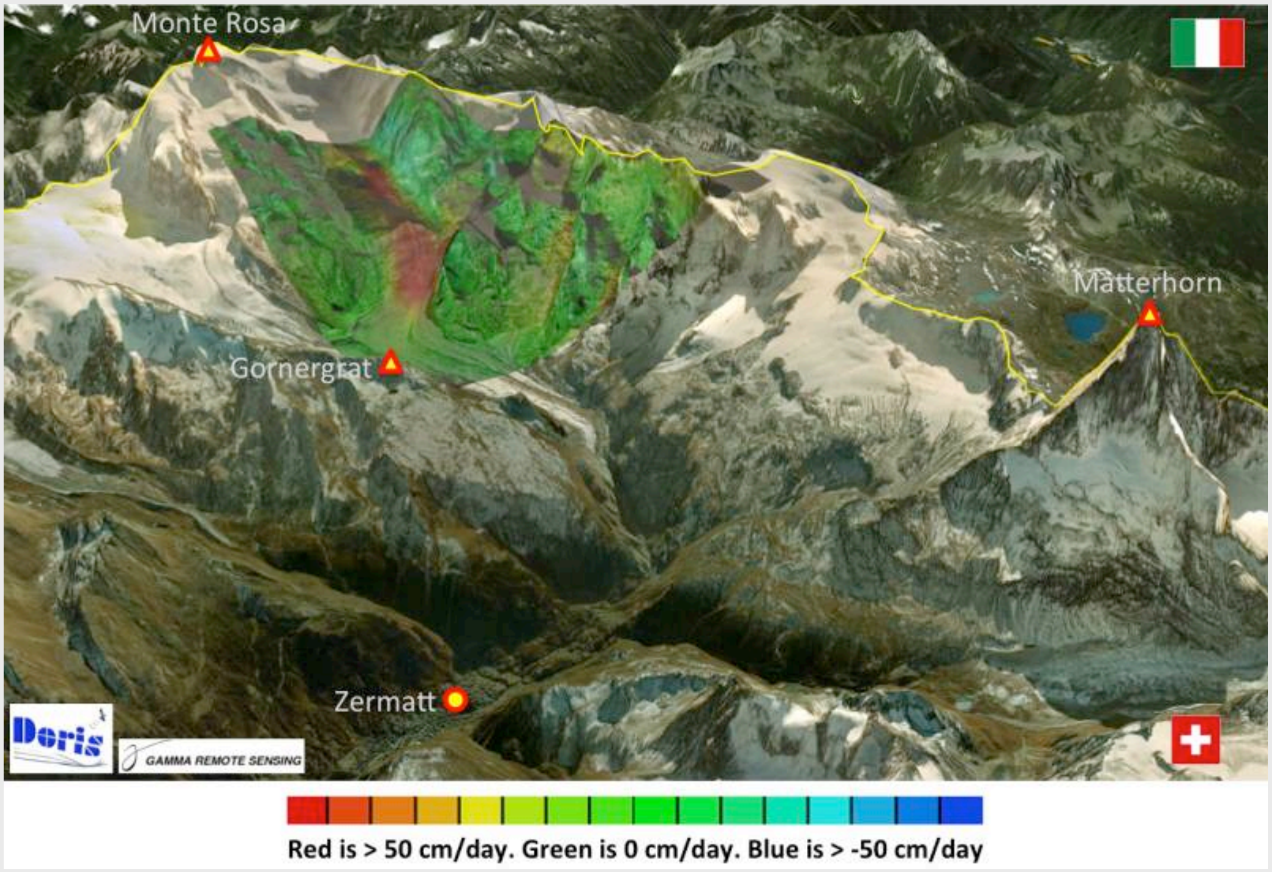

Figure 2. Mean deformation velocity map retrieved, on 19 September 2012, through the Gamma Remote Sensing Portable Radar Interferometer in the Schwärzegletscher (Switzerland).

ENVISAT and ALOS data. The number of PS is higher in ascending orbits (i.e. for ALOS and ENVISAT data), because the ascending geometry is more suitable to detect E-facing slopes, that are the most frequent ones in the Tramuntana Range area.

Significant differences can be observed by comparing the PS spatial density of C- and L-band analyses. The PS density obtained from ALOS dataset (388 PS/km2) is 3-times higher than one of the C-band datasets (133 PS/km2 for ERS data, 117 PS/km2 and 128 PS/km2 for ENVISAT data, in descending and ascending orbit, respectively), thanks to the higher spatial resolution and wavelength used in L-band microwave acquisitions.

3. ACKNOWLEDGEMENTS

Work conducted in the framework of the EC FP7 DORIS project (contract n. 242212).

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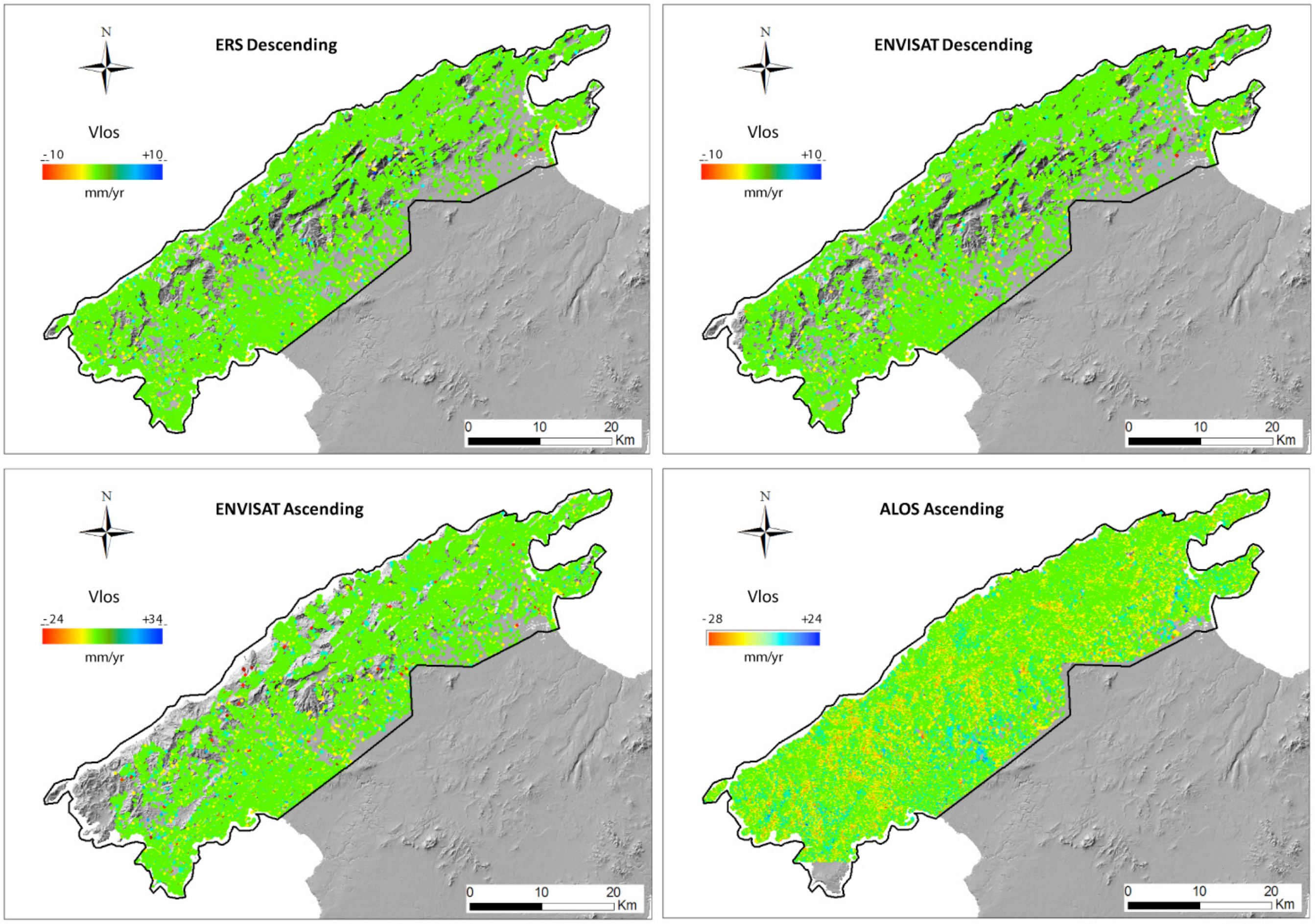

Figure 3. Mean deformation velocity maps obtained from ERS images (06/92-11/00), ENVISAT images (08/03-05/09), ALOS images (06/07-03/10) over the Tramuntana Range area.

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