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How space-borne InSAR can provide insights into coastal instability problems: the Cirò Marina case (Italy)

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A sudden and impulsive ground settlement, not preceded by any precursory sign and occurred in a time interval of a few hours along a 2 km long discontinuity, caused on July 28th 2004 severe damage to infrastructures and buildings in the Cirò Marina village (Southern Italy). Following the destructive phenomenon a multi-disciplinary investigations based on geological, geophysical and remote sensing techniques, was committed by the Italian Civil Protection Department to its network of Centres of Competences in order to clarify the movement's origin. Indeed, it was initially ascribed to different possible phenomena, including land subsidence induced by fluid extraction (water and/or gas), a large and partially submarine landslide and the acceleration phase of an aseismic creep along a pre-existing tectonic structure.

To retrieve the spatial distribution of past movements occurred in the Cirò Marina area, including those connected to the 2004 failure, and their temporal evolution all the available SAR images acquired by ERS1/ERS2 and Radarsat satellites were processed through a multi-interferometric approach, namely the Permanent Scatterers (PS) technique. The availability of both ascending and descending SAR datasets allowed, through the combination of the two l.o.s. geometries, the retrieval of the vertical and horizontal components of the displacement vectors over the whole unstable area.

The PS analysis revealed the presence since 1992 of very slow movements (2-3 mm/y) with a predominant vertical component, extending over the village sector located between the 2004 fracture and the sea. The analysis of the 2003-2005 data showed the same spatial distribution of displacements, but with higher velocities and a different

movement geometry. Vertical settlements were recorded near the linear discontinuity, while moving towards the sea a strong horizontal component was identified. By looking at the temporal series of displacements a sudden acceleration of the movements between the two SAR acquisitions covering the 2004 event was clearly visible, with average displacements of 7-10 mm in 24 days, not preceded by any precursory sign. After the failure PS measured residual displacements with velocity values higher than the pre-event ones.

Then, an inversion of the superficial displacement vectors obtained from the combination of ascending and descending PS was used to estimate the movement geometry, e.g. depth and shape of the sliding surface. A graphical method developed for reconstructing the slip surface of landslides was applied along several cross sections based on the displacement vectors and the location of the main scarp provided by the InSAR analysis. Such a method, which assumes rigid deformations between each available couple of measures, allowed the estimation of a three-dimensional slip surface with average depths ranging between 80 m and 200 m below the ground level.

Currently, the combination of the results obtained from the InSAR analysis with conventional methods, such as geotechnical, geophysical and paleo-seismological investigations, and more recent technologies, such as bathymetric surveys carried out with multi-beam techniques, is supporting the civil protection authorities to understand the origin of the movement and consequently to properly define the connected risk scenarios.