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Capturing pre-failure signs of the Maoxian landslide with Sentinel-1 satellites

Emanuele Intrieri (1), Federico Raspini (1), Alfio Fumagalli (2), Ping Lu (3), Sara Del Conte (2), Paolo Farina (4), Jacopo Allievi (2), Alessandro Ferretti (2), and Nicola Casagli (1)

(1) Earth Sciences Department, University of Firenze, Firenze, Italy (federico.raspini@unifi.it), (2) TRE ALTAMIRA, Milano, Italy , (3) College of Surveying and Geo-Informatics, Tongji University, Shanghai, China, (4) Geoapp s.r.l., Academic Spin-off of the University of Florence, Firenze, Italy

Post-event InSAR (Interferometric Synthetic Aperture Radar) analysis on a stack of 45 C-band SAR images acquired by the ESA Sentinel-1 satellites from 9 October 2014 to 19 June 2017 allowed for the identification of a clear precursory deformation signal for the Maoxian landslide (Mao County, Sichuan Province, China). The landslide occurred in the early morning of 24 June 2017 and buried 62 houses, killing more than 100 people in the village of Xinmo. The Maoxian landslide can be classified as a rock avalanche with an estimated volume of about 18 million m3 and a total area of 1.5 km2. Sentinel-1 images have been processed immediately after the event using the SqueeSAR technique, an advanced multi-interferogram analysis capable of maximizing the density of measurement points. Ground deformation maps and displacement time series for an area of 460 km2, straddling the Minjiang River and its right tributary, the Songping Gully, were generated.
The SqueeSAR algorithm applied to the Sentinel-1 data-stack provided valuable information on ground movements before the event, indicating the presence of some areas affected by surface displacements, likely related to slope instability phenomena, along the narrow and deep valleys incised by the Minjiang River and the Songping Gully. SqueeSAR results clearly show the presence of active movements in a large sector of the slope above the Xinmo village. Here, velocity values range between 10 and 20 mm/yr, with peaks of about -27 mm/yr along the line of sight of the satellite. Considering the acquisition geometry and the orientation of the slope, the measured deformation rates are consistent with the occurrence of precursory movements over a large sector of the slope affected by the 24 June 2017 landslide. It is worth remarking that this specific sector of the slope was the origin of the sliding event.
Deformation time series of measurement points identified within the source area of the landslide exhibit an acceleration starting from April 2017. A detailed analysis of the time series within the source area led to the identification of at least 3 different sectors characterized by homogeneous kinematic behaviours which can be grouped in accelerating, linear and stable areas. For the Maoxian landslide, the accelerating areas are located in the NW sector of the source area.
The Fukuzono method for forecasting the time of failure has been successfully applied to the displacement data exhibiting progressive acceleration, pointing out that an accurate estimation of the failure time was already possible since the beginning of June.
These results show for the first time that satellite radar data, systematically acquired over large areas with short revisiting time, could be used not only for mapping unstable areas, but also for actual landslide early warning, at least for some typologies of sliding phenomena. This means that the transition from historical analysis of ground deformation to a sort of continuous monitoring at regional scale using satellite radar data is now possible.