Geophysical Research Abstracts
Vol. 21, EGU2019-1164-2, 2019
EGU General Assembly 2019

Semi-automated regional analysis of slow-moving landslide activity and kinematics using PS-InSAR data

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Large slow-moving landslides (Deep-Seated Slope Deformations, DSGSD, and large rockslides) are widespread in mountain ranges worldwide and pose significant risks related to their involved volumes (up to billions of cubic meters), interaction with man-made infrastructures, and complex creep behaviour. These phenomena evolve over the long term by progressive failure processes resulting in slow creep, possibly accelerating until catastrophic collapse. Moreover, they are characterized by sectors with different activity, kinematics and heterogeneous strain fields, resulting from complex failure mechanisms and structural controls. In Lombardia (Italian Central Alps), 205 slow rock slope deformations (133 DSGSD (Crosta et al., 2013) and 72 large landslides covering an area exceeding 580 km2 and affecting sensible infrastructures have been considered till now according to specific criteria (interaction with elements at risk, presence of monitoring, area > 1.5 km2). A reliable and cost-effective characterization of their activity and kinematics is then key to perform regional scale susceptibility mapping for landplanning and to identify sites candidate to catastrophic evolution.

In this work, we use PS-InSAR data to perform a semi-automated classification of DSGSD and large landslides according to their activity and kinematics, supported by an original geomorphological and morpho-structural mapping performed by means of aerial imagery on regional scale, yet including local-scale information (e.g. tectonic lineaments, morpho-structural features, main landforms, secondary deep-seated landslides).

For our analysis, we used PS-InSAR and SqueeSAR datasets derived from ERS-1, ERS-2, RADARSAT and Sentinel-1A images acquired between 1992 and 2017. For each landslide, we selected the reference dataset by optimizing the spatial density of persistent (PS) and distributed scatterers (DS) and the acquisition geometry. After removing PS/DS related to movement of slope shallow debris deposits, we modified the approach by Frattini et al (2017) to classify landslide activity based on the average LOS velocity and a hybrid density/clustering index. Then, we performed a fast, automated characterization of landslide kinematics by discretizing each area in square cells and combining PS of ascending and descending tracks to retrieve the vertical and horizontal displacement components and the 2D total displacement vector T in the E-W vertical plane (Eriksen et al. , 2017). Based on these components, we characterized the local kinematics (slip, translation, bulging) by comparing the dip of vector T to the slope dip in each square cell, and by using distribution statistics to define a new index correlated to global landslide mechanisms. We calibrated our activity and kinematics classifications through mapped morpho-structural features, InSAR velocity profiles at local scale and simplified 2DFEM models, and we used another subset for validation. All these steps are run sequentially in a workflow implemented in Matlab and GIS environments, and provide regional scale maps of landslide activity and kinematics. Our procedure can be applied upon site-specific calibration in different geological, morpho-climatic and landslide settings worldwide, to provide a fast and cost-effective support to landplaning, risk analyses and prioritization of local-scale studies aimed at granting safety and infrastructure integrity.