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Controls on Deep Seated Gravitational Slope Deformations in the European Alps

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DSGSDs are very large, slow mass movements affecting entire high-relief valley slopes. The first orogen-scale inventory of such phenomena at has been recently presented for the European Alps (Crosta et al 2008, Agliardi et al 2012), and then further implemented. The inventory includes 1034 Deep Seated Gravitational Slope Deformations, widespread over the entire orogen and clustered along major valleys and in some specific sectors of the Alps. In this contribution we systematically explore lithological, structural and topographic controls on DSGSD distribution with the help of multivariate statistical techniques (Principal Component Analysis, Discriminant Analysis). Analysis units for statistical analysis were obtained by creating three square vector grids with 2.5 km, 5 km and 10 km grid cell size, respectively, covering the entire area (about 110,000 km2). For each grid cell, we calculated the density of DSGSD, and we assigned a value for each of the controlling variable considered in the analysis. From the NASA SRTM (Shuttle Radar Topography Mission) DEM we derived land surface parameters, such as relief, slope gradients, slope aspect, mean vertical distance from base level and ruggedness. The SRTM DEM was also used to extract the drainage density, with a threshold of 1 km2 and 10 km2. We also computer the stream power of the 1km2 river network Lithology was obtained by assembling different geological maps (1:200.000 map of Salzburg, 1:250.000 map of France, 1:500.000 maps of Switzerland and Austria, 1:1.000.000 map of Italy) and by reclassifying the geological units into 8 lithological classes (carbonate rocks, metapelites, sandstones and marls, paragneiss, ortogneiss, flysch-type rocks, granitoid/metabasite, Quaternary units, and volcanic rocks). To study the role of seismicity, we calculated the number of earthquakes (CPTI11 and USGS-NEIC database) within a distance dmax from the square cell, calculated adopting Keefer's (1984) equation, and the sum of Arias Intensities of all earthquakes lying within dmax. Fission-track ages on apatite have been collected from published sources, and interpolated over the entire Alps by using a natural-neighbour interpolator. Finally, the ice thickness during the Last Glacial Maximum, the modern rock uplift, and the mean annual rainfall have been used.
Results of the multivariate statistical analysis confirm the results of the previous orogen-scale investigations (Crosta et al., 2008; Agliardi et al., 2012) and shed new light on the relative importance of the (positive or negative) contributions of different controlling factors. The most important controls on DSGSD distribution are: lithology, landscape morphology, LGM ice thickness, modern uplift rate and mean annual rainfall. Lithology is the dominant factor, with units highly favourable (chiefly metapelites, followed by paragneiss and flysch-type rocks) and other unfavourable (especially carbonates rocks) to DSGSD. Landscape morphology plays a role that is difficult to correctly evaluate because of the interplay between morphology and geological and hydrological parameters. DSGSDs are more frequent along main alpine valleys, where long and regular slopes can accommodate these large phenomena, but also where the action of glaciers and the presence of main tectonic lineaments are more important. Favourable landscape morphologies seem also controlled by exhumation and uplift rate. Mean annual rainfall is inversely correlated with DSGSD density. This can be interpreted as the long-term effects of climate in shaping large-scale topography and favouring other types of landslides as players of long-term erosion.

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