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Preferential flow related to differential displacement in slow-moving landslides

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Hydrology has long been recognized as a crucial factor in initiation and reactivation of landslides. In slow-moving landslides local hydrological regimes are complicated due to highly heterogeneous sliding material with dynamically changing hydraulic properties resulting from differential displacement. The distribution of fissures (open, filled or partly filled) within a landslide can change due to displacement or changes in stress field. However, shifts and hysteresis in landslide activity have not been linked to feedback mechanisms between fissure formation, hydrological behaviour and differential movement.

This research aims to investigate the interaction between fissure occurrence and spatial and temporal variations in slope stability. The dynamics of fissure patterns make them act both as preferential flowpaths for infiltration and as lateral groundwater drains. That behaviour creates differences in local hydrological regimes in the soil, and thus influences slope stability. These dynamics have been included in STARWARS, a distributed model coupling hydrological and stability dynamics developed in the PCRaster environmental modelling software package. In this model several mechanisms of deformation were introduced controlling the activity of slow-moving landslides. The ensuing feedbacks in landslide activity were explored, using fissure geometries based on the Super-Sauze landslide in the French Alps and one year meteorological data for this region, by running the model statically, i.e., without deformation, and dynamically, i.e., with deformation included.

This work presents the results of the static and dynamic modelling. In the static modelling it was proved that both the appearance of fissures and their connectivity is very important for the landslide hydrology. Appearance of fissures increases infiltration capacity and, additionally, connected fissures strongly determine draining capacity while disconnected fissures controlled storage capacity. By means of a sensitivity analysis the range of landslide responses were determined as function of fissure geometries and their connectivity. When allowing for dynamic feedback between differential displacement and changes in fissure patterns and their characteristics the significant spatial and temporal changes in hydrological responses were modelled. Mutual dependence between fissures distribution, slope stability and hydrology is showed.

Moreover, the study highlights the importance of knowledge on the feedback rules between the slope stability and soil hydraulic characteristics. Furthermore, the future research directions and the value of that knowledge for landslide hazard assessment are discussed.