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Observational modelling to improve the prediction of shallow landslides

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Weather-induced shallow landslides in coarse-grained soils are first failure phenomena often occurring as multiple slides in natural slopes over wide areas. Diffuse monitoring over the area of interest is required if one wants to predict the possible location of future landslides or the soil conditions leading to triggering for early warning purposes. This study aims at highlighting the role played by ground-based monitoring devices when they are used, singularly or combined together, as tools to assess the conditions of slopes in granular soils leading to shallow first-failure slides. Monitoring is discussed in relation to expectations coming from analytical and numerical models within an "observational modelling" framework, i.e. methods and procedures that use inverse analysis techniques to update the numerical model of a boundary value problem using monitoring data. The influence of the location of the monitoring instruments is assessed in different stratigraphic conditions and considering the saturation degree of the soil layers. The time-dependent soil parameters considered are the following: positive pore water pressure, suction, soil water content, stress, surface and subsurface displacements. All these parameters can be monitored employing static permanently deployed point sensors and, potentially, using low-cost instruments providing high resolution data in time and space. The focus of the contribution is on the meaning of the measurements as potential detectors of soil conditions leading to failure within a slope. To this aim, a series of parametric analyses employing analytical and numerical methods, in 1D and 2D conditions, will be presented. The analyses investigate the soil response to applied boundary conditions. When only hydraulic modelling is performed, the prediction of the groundwater regime in a slope in relation to time-dependent atmospheric conditions is used as input in limit equilibrium slope stability analyses to derive the variation with time of the factors of safety along potential slip surfaces. When hydromechanical coupling is explicitly considered, the numerical simulations are aimed at reproducing the stress-strain evolution associated with the transient seepage processes induced by changing hydraulic boundary conditions. In both cases, the results of the parametric analyses are used to evaluate the modelled response of a slope at the onset of failure, in different locations and in relation to many monitoring parameters (e.g., pore water pressures, soil water contents, stresses, displacements). The presented results should be seen as a contribution towards the aim of defining and adopting an economically sustainable and technically reliable monitoring strategy for early warning purposes, by predicting the conditions leading to the triggering of shallow slides in coarse-grained soils over wide areas.