PREDICTION OF THE EVOLUTION OF A LARGE LANDSLIDE UNDER DIFFERENT CLIMATE SCENARIOS: A PHYSICS-BASED MODEL APPLIED TO THE RUINON LANDSLIDE (ITALIAN ALPS)

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Purpose: Large slope instability processes result from a complex interaction among geological and climatic factors. Possible variations in meteorological conditions connected to climate change may influence their evolution. Different rainfall inputs can in fact boost triggering mechanisms as well as an exacerbation of atmospheric temperatures can lead to significant induced thermo-mechanical stresses and accelerate mechanical degradation of rock masses. In this work, a multi-coupling method to predict stability and velocity of a landslide was applied by analyzing the cause-effect link between external forcing and its internal response, through a 1D thermo-poro-mechanical mathematical model of the sliding surface. After validating the model reproducing the past landslide behavior, different evolution scenarios were assessed based on future climatic projections. The analysis is applied to the Ruinon Landslide located in the Central Italian Alps. It represents one of the most active cases in the alpine region, with a sliding surface located at a depth of 70 to 90 m, for a total estimated volume of 30 Mm3. Based on the available in situ monitoring data (meteorological data, piezometric levels, Ground-Based Interferometric Radar displacement vectors), velocity–time curves correlate with the piezometric level trend and rainfall, suggesting a key role of water pressure as an accelerating factor.

Methods: The input data required by the model are pore pressure, reference stresses and initial temperature at the sliding surface, as well as velocity of the landslide body assumed to be a rigid block. In addition, to define the constitutive model of the shear band (modelled as a visco-plastic medium with thermal softening and velocity hardening), thermal and load rate sensitivity of the material are necessary. A preliminary 3D FEM numerical analysis was carried out and the stress distribution at the sliding surface was simulated (step 1). Then, triaxial compression tests with thermal control were performed on rock samples representative of the shear band, defining its mechanical behavior (step 2). To calibrate the model, pore pressure data from in-situ piezometers relative to the period 2014-2018 were introduced and a best fitting between modelled and monitored landslide velocities was obtained (step 3). Finally, velocities were forecasted for the period 2018-2020 and a process of validation was applied using field displacement histories (step 4). Once the model was validated, bias-corrected Regional Climate Model outputs were evaluated and statistically downscaled using a two-step approach (change factors and weather simulators) in order to obtain the projected data (step 5).

Results: The downscaled precipitation allowed to evaluate the piezometric levels up to the year 2100 considering scenarios at warming increment above preindustrial temperatures of 1.5, 2, 3, 4°C, and to analyze the evolutionary response of the landslide. Likewise, the future temperature evolution along the slope and at the depth of the sliding surface was also evaluated and introduced into the model verifying its influence on the landslide behavior.

Conclusions: The model represents a first attempt in the formulation of a predictive tool of landslide evolution, aimed toward the definition of a novel physics-based early warning strategy that can account for future climate scenarios.