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Landslides triggering and precursors: new insights from Fiber Bundle Models (FBM)

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Identifying imminence of gravity-driven failure in natural media is a daunting task, mainly because the abrupt rupture is a highly nonlinear process sensitive to unknown heterogeneities inherent to natural media. Nevertheless, the occurrence of the catastrophic rupture in heterogeneous materials is not an instantaneous event, but typically is preceded by smaller internal failures prior to rupture. Such mechanical failures release elastic energy measurable as microseismic or acoustic emissions (AE). Monitoring such activity should provide insights regarding the mechanical status of loaded natural systems. To explore potential use of AE as prediction tools, a numerical model based on Fiber Bundle Model (FBM) was studied to better understand the nature of progressive failure events towards the final rupture. We focused on the nature of stress redistribution and the role of heterogeneity (represented as spatial correlation) on failure statistics and global failure. Results show that failure mode may vary dramatically with load redistribution rules from diffuse damage (for global load sharing) to brittle and single crack growth (for correlated and local load sharing FBM). These changes affect the statistical properties of micro-cracks activity preceding rupture. While diffuse damage behavior exhibits clear precursory signs (such as increased seismic activity prior to ultimate rupture), single crack growth behavior gives rise to sudden failure without such clear precursors. These results suggest that heterogeneous slopes with limited spatial correlations (soil type or root reinforcement) are likely to behave as ductile materials with ample precursor events, whereas drier slopes with strong root reinforcement would likely fail like brittle materials with limited early warning. Interestingly, for large spatial correlations (expected to behave as brittle slopes) we observe spontaneous appearance of logperiodic oscillations that could help assess imminence of the final rupture. Although increasing spatial correlations in material properties promotes abrupt ruptures at lower load, an independent rupture criterion could be deduced from energetic considerations. This study provides new insights on landslide triggering and points out the importance of spatial organization of heterogeneities on hillslope failure behavior.