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Modelling the onset of earthquake-induced landslides as triggered slip under rate-and-state friction law

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While the triggering process of landslides remains are multiple, the importance of seismic waves is well established. The leading approach to study coseismic landslides is through statistical studies or simple models such as the Newmark method. While providing useful information, these approaches fall short at predicting landslide triggering especially in complex environments such as submarine conditions. Here we study the possibility to establish a simple physically-based model to fulfill this purpose. Assuming strain is localized in a thin weak layer at the base of the landslide, we model the landslide as slip on a planar sloping surface. By analogy to tectonic faults, we adopt the rate-and-state friction law on this surface, a phenomenological law widely used to describe slow sliding on faults during earthquakes. This approach produces a range of landslide behaviors ranging from stable and unstable conditions. With a one-dimensional mathematical and numerical model, representing a wave incidence normal to the landslide interface, we identify the main triggering factors of slow and fast sliding and characterize the non-linear evolution of the slip instability. In particular, we map the range of slip behaviors as a function of non-dimensional numbers, such as the ratio of incident wave frequency to seismic resonance frequency of the layer. The incident wave amplitude also play an important role in the model: the slip velocity during acceleration depends exponentially on the ratio of the incident stress wave amplitude to the ambient confining stress. This basic model is a starting point that can be extended to include other relevant processes like the coupling between pore pressure and slip.