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Frictional weakening of Landslides in the Solar System

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Landslides are an important phenomenon that shapes the surface morphology of solid planetary bodies, including planets and small bodies. In addition, landslide science aims to predict the maximum distance travelled and the maximum velocity reached by a potential landslide in order to quantify the damage it may cause. On the one hand, observations show that the so-called Heim's ratio (i.e. the ratio between the difference of the height of the initial mass and that of the deposit, and the traveling distance) decreases with increasing volume for landslides observed on Earth [1] and other planets like Mars and icy moons like Iapetus [2], but whether this quantity is a good representation of the effective friction during the flow is still a controversial issue. On the other hand, numerical simulations (either continuous or discrete) of real landslides commonly require the assumption of very small friction coefficient to reproduce the extension of deposits [2-5]. We investigate if a common origin can explain the characteristics of landslides in such variety of planetary environments.

Based on analytical and numerical solutions for granular flows constrained by remote-sensing observations [3, 7], we developed a consistent method to estimate the effective friction coefficient of landslides, i.e. the constant basal friction coefficient that reproduces their first-order properties. We show that: i) the Heim's ratio is not equivalent to the effective friction coefficient; ii) the friction coefficient decreases with increasing volume or, more fundamentally, with increasing sliding velocity. Inspired by frictional weakening mechanisms thought to operate during earthquakes [8], we propose an empirical velocity-weakening friction law under an unifying phenomenological framework applicable to small to large landslides observed on Earth and beyond (including icy moons of giant planets) whatever the environment and material involved.

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