Wave-induced granular flow triggering

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ABSTRACT

Understanding the mechanisms behind the remote triggering of landslides by seismic waves at micro-strain amplitude is essential for quantifying seismic hazards. Indeed, it has recently been demonstrated that long-term, very low-amplitude seismic activity can impact the stability of volcanic and mountainous slopes [1]. Granular materials provide a relevant model system to investigate landslide triggering within the unjamming transition framework, from solid to liquid states.

Here, I will present field observations from an unprecedented 10-year long catalogue of rockfalls occurring in the Piton de la Fournaise volcano crater, La Réunion as well as Discrete Element simulations and lab-experiments investigating granular flow triggering by small seismicity.

Using statistical tools originally developed for earthquakes, our field analysis clearly reveals the effect of low amplitude repetitive seismicity in the triggering of rockfalls located at a few kilometres from the source, due to progressive damaging of the slope. Moreover, we show that the efficiency and time-delay of this dynamic triggering process are controlled by the slope's stability state, i.e. its proximity to the failure, as observed in lab-experiments on metastable granular slopes.

We then present recent laboratory experiments on metastable granular slopes exhibiting similar behavior [2]. Our results suggest that ultrasound-induced granular avalanches may be related to a reduction in the interparticle friction via shear acoustic lubrication of the contacts.

However, investigating slip at the scale of grain contacts within an optically opaque granular medium remains challenging. Here, we propose an innovative coupling model and conduct a numerical investigation of two-dimensional dense granular flows triggered by basal acoustic waves [3]. We model the triggering dynamics at two separated timescales: one for grain motion (milliseconds) and the other for ultrasound (10 μs). The model rely on computing vibrational modes with a discrete element method and reducing local friction. Our results show that ultrasound-induced decrease of interparticle friction occurs in the weak contact forces perpendicular to the strong-force chains. This reduction in interparticle friction initiates local rearrangements at the grain scale that eventually lead to a continuous flow, with a delay depending on the proximity to the failure. In line with experiments, we show that ultrasound-induced flow is more uniform in space than pure gravity-driven flow, suggesting the influence of an effective temperature generated by ultrasonic vibration.

Our results show the need to account for long-term swarm-type seismic activity that can affect the stability of geological structures like slopes and faults, but also buildings.

REFERENCES

[1] V. Durand, A. Mangeney, P. Bernard, et al., "Repetitive small seismicity coupled with rainfall can trigger large slope instabilities on metastable volcanic edifices", *Communications Earth & Environment*, 4(1), 383 (2023).

[2] J. Leopoldes, X. Jia, A. Tourin, and A., Mangeney, "Triggering granular avalanches with ultrasound", *Phys. Rev. E*, 102, 042901 (2020).

[3] H. Martin, A. Mangeney, X. Jia, B. Maury, A. Lefebvre-Lepot, Y. Maday, and P. Derand, P. 2025. "Ultrasound-induced dense granular flows: a two-time scale modelling", *J. Fluid Mech.*, 1004, A10 (2025).