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Investigation of the effect of roughness spacing on the transport of coarse particles in shallow flows

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Sediment transport is a complex field of science, amalgamating both fluid dynamics, and particle physics and their interactions, resulting in the geomorphic processes that shape earth's surface. Considering these intricate complexities, also inherited by fluid turbulence even for the case of uniform particle properties and boundary roughness arrangements, it is necessary to simplify the investigation of particle transport processes by considering a small number well controlled parameters, changing at each time. In this study, a series of experiments are conducted aiming to understand how the transport of spherical particles of the same size is influenced by the roughness of the solid boundary, changed by altering the distance of roughness elements (of similar size to the transported particle) and flow conditions. Particle and roughness element properties are kept simplified compared to what is found in nature, by using 3D printed spherical particles and hemispheres, respectively, of controlled specific density.

The experiment is carried out in a one-dimensional flume (not allowing transport in the transverse direction) to study processes of particle entrainment (including rolling, hopping and saltation) under well-controlled conditions, for a number of particle densities (s>1100kg/m3), flow regimes (Re>106) and bed roughness arrangements.

It is demonstrated, how the mode of transport is controlled by the distance (λ) between individual roughness elements (of diameter D), for: a) single particle and b) multiple particles, traversing along the flume with different bed roughness arrangements and under various hydraulic conditions. The results showcase how flow conditions can affect a single particle's transport (consistent to observations of Valyrakis et al. 2010 and 2013), yet the incorporation of additional mobile particles downstream may result in even more complex particle interactions and inter-particle collisions, resulting on the formation of particle clusters and thus dominating transport processes (Pähtz & Durán, 2017).

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