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Revisiting slope influence in idealized turbulent bedload transport: consequences for transport rate scaling

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Slope influence in turbulent bedload transport has been extensively studied regarding its importance for sediment transport rate. Yet, a rigourous characterization is still lacking and a gap exists between applied semi-empirical studies and idealized particle scale analysis. We attempt to bridge this gap revisiting the analysis of slope influence in idealized turbulent bedload transport. Studying theoretically and numerically a system of monodisperse spherical particles in steady unform configurations, we put in evidence that the classical studies at the particle scale rely on an erroneous expression of the buoyancy force. Going further, we explicit the entrainment mechanisms of the granular phase and give a clear picture of the mechanisms associated with a variation of slope. In addition, this theoretical analysis allows us to predict the scaling of the sediment transport rate in gravity-driven turbulent bedload transport. The obtained scaling is in agreement with the classical semi-empirical approaches of Smart & Jaeggi (1983) and Capart & Fraccarollo (2011), where the Shields number is based on the mixture depth instead of the water depth. Performing simulations with a coupled fluid-discrete element model (Maurin et al. 2015), we show that the prediction are validated in idealized bedload transport for a large range of slopes. It enlightened the link between particle-scale mechanisms and transport rate scaling, and opens perspectives for a mechanically-based understanding of slope influence in bedload transport.