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Unified model of sediment transport threshold and rate across subaqueous bedload, windblown sand, and windblown snow

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Nonsuspended sediment transport (NST) refers to the sediment transport regime in which the flow turbulence is unable to support the weight of transported grains. It occurs in fluvial environments (i.e., driven by a stream of liquid) and in aeolian environments (i.e., wind-blown) and plays a key role in shaping sedimentary landscapes of planetary bodies. NST is a highly fluctuating physical process because of turbulence, surface inhomogeneities, and variations of grain size and shape and packing geometry. Furthermore, the energy of transported grains varies strongly due to variations of their flow exposure duration since their entrainment from the bed. In spite of such variability, we here propose a deterministic model that represents the entire grain motion, including grains that roll and/or slide along the bed, by a periodic saltation motion with rebound laws that describe an average rebound of a grain after colliding with the bed. The model simultaneously captures laboratory and field measurements and discrete element method (DEM)-based numerical simulations of the threshold and rate of equilibrium NST within a factor of about 2, unifying weak and intense transport conditions in oil, water, and air (oil only for threshold). The model parameters have not been adjusted to these measurements but determined from independent data sets. Recent DEM-based numerical simulations (Comola, Gaume, et al., 2019, https://doi.org/10.1029/2019GL082195) suggest that equilibrium aeolian NST on Earth is insensitive to the strength of cohesive bonds between bed grains. Consistently, the model captures cohesive windblown sand and windblown snow conditions despite not explicitly accounting for cohesion.