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Analytical approach unifying the two-regime scaling for bedload particle motions

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Bedload particle hops are defined as successive motions of a particle from start to stop, characterizing one of the most fundamental processes describing bedload sediment transport in rivers. Although two transport regimes have been recently identified for short- and long-hops, respectively **(Wu et al., *Water Resour Res*, 2020)**, there still lacks a theory explaining how the mean hop distance-travel time scaling may extend to cover the phenomenology of bedload particle motions. Here we propose a velocity-variation based formulation, and for the first time, we obtain analytical solution for the mean hop distance-travel time relation valid for the entire range of travel times, which agrees well with the measured data **(Wu et al., *J Fluid Mech*, 2021)**. Regarding travel times, we identify three distinct regimes in terms of different scaling exponents: respectively as ~1.5 for an initial regime and ~5/3 for a transition regime, which define the short-hops; and 1 for the so-called Taylor dispersion regime defining long-hops. The corresponding probability density function of the hop distance is also analytically obtained and experimentally verified.