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When does a sediment particle stops ?

Joris Heyman
CNRS, Geosciences Rennes, France (joris.heyman@univ-rennes1.fr)

In most rivers, sediment transport by bedload strongly affects stream morphology and controls global sedimentary budgets. Our understanding of the physics of bedload remains very shallow, notably because of the strong stochasticity and non-linearity showed by transport rates close to the threshold of motion, where sediment starts to move. Today, oversimplified modelling approaches (stream power based formula for instance) often outperform more refined bedload flux predictive models, suggesting that the key physics governing sediment fluxes are not completely understood yet. Recently, novel experimental and numerical developments have provided original data on individual grain motion dynamics allowing reconsidering particle-based formulations, first popularized by H.A. Einstein (1). Those formulations rely on the three fundamental mechanisms of sediment transport—particle entrainment, transport and deposition—to derive statistics of sediment fluxes and bed evolution. Substantial attention has been drawn to both entrainment (in relating turbulent velocities to particle incipient motion) and transport processes (in recognizing the dispersion caused by particle velocity fluctuations for instance) but much less have been done to question Einstein' initial guess that "all the particles with a particular diameter D are just performing an individual step of 100 D [before depositing]" (1).

In this talk, we revisit the physics of bedload particle deposition by analysing a few kilometres of particle trajectories obtained in an experimental laboratory flume. In contrast to the classical viewpoint, we found that depositions rates are inversely correlated to bottom shear velocities, and diverge under vanishing shear. We also show that particle deposition mainly occurs by a trapping phenomena in the granular bed asperities, when particle velocities are not sufficient to sustain motion. By a simple parametrization of the particle velocity statistics, we are able to characterize the probability of particle trapping, and reproduce precisely the dependence of the bedload particle deposition rates upon the flow conditions. We show how this result may affect bedload flux estimates, saturation length, and naturally favor hysteretic dynamics.

(1) Einstein, Hans Albert, 1950. "The Bed-Load Function for Sediment Transportation in Open Channel Flows," Technical Bulletins 156389, United States Department of Agriculture, Economic Research Service.