Title: Intermittent motion and sediment transport -- Experimental and theoretical insight

Christophe Ancey

We investigate the entrainment, deposition, and motion of coarse spherical particles within a turbulent shallow water stream down a steep slope. This is an idealization of bed-load transport in mountain streams. Earlier investigations have described this kind of sediment transport using empirical correlations or concepts borrowed from continuum mechanics. The intermittent character of particle transport at low water discharges led us to consider it as a random process. Sediment transport in this regime results from the imbalance between entrainment and deposition of particles rather than from momentum balance between water and particles. We develop a birth-death immigration-emigration Markov process to describe the particle exchanges between the bed and the water stream. A key feature of the model is its long autocorrelation times and wide, frequent fluctuations in the solid discharge, a phenomenon never previously explained despite its ubiquity in both nature and laboratory experiments. We present experimental data obtained using a nearly two-dimensional channel and glass beads as a substitute for sediment. Entrainment, trajectories, and deposition were monitored using a high-speed digital camera. The empirical probability distributions of the solid discharge and deposition frequency were properly described by the theoretical model. Experiments confirmed the existence of wide and frequent fluctuations of the solid discharge, and revealed the existence of long autocorrelation time, but theory overestimates the autocorrelation times by a factor of around three. Particle velocity was weakly dependent on the fluid velocity contrary to the predictions of the theoretical model, which performs well when a single particle is moving. For our experiments, the dependence of the solid discharge on the fluid velocity is entirely controlled by the number of moving particles rather than by their velocity. We also noted significant changes in the behavior of particle transport when the bed slope or the water discharge was increased. The more vigorous the stream was, the more continuous the solid discharge became. Moreover, while 90% of the energy supplied by gravity to the stream is dissipated by turbulence for slopes lower than 10%, particles dissipate more and more energy when the bed slope is increased, but surprisingly, the dissipation rate is nearly independent of fluid velocity.