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Bed-load sediment motion and dispersion over a smooth bed

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Under the assumption that bed-load sediment motion be drive by mechanisms of (i) flow-particle, (ii) roughness-particle and (iii) particle-particle interactions, appropriate experimental campaigns designed to switch off any of these interactions may provide insight in individual effect of each interaction. In the context of a long-term project undertaken in cooperation with the Environmental and Industrial Fluid Mechanics group at the University of Aberdeen (UK), results are here presented for experiments with bed-load motion of isolated particles over a plane, smooth bed. Such a condition, evidently much distant from that of natural streams, represents a case where the contribution of bed roughness and particle-particle interaction is filtered out, thus highlighting the role of flow turbulence for particle dynamics.
Experiments were performed at the Hydraulics Laboratory of the Politecnico di Milano. Three flow conditions were tested. Motion of particles was almost continuous, differently from the intermittent motion typically detected at weak bed load over rough beds. Sediment particles were individually tracked along their paths, measuring position, velocity and acceleration of the single grains. The collected database was considerably wide, counting more than 450 identified paths (resulting in more than 60,000 instantaneous velocity values) for each experimental configuration.
A number of analyses was applied to the data: probability density function, auto-correlation and spectra of grain velocity; Kolmogorov and generalized structure functions of sediment velocity; temporal growth of variance of particle position as representative of the sediment dispersion process. Results for the various hydrodynamic conditions proved a good collapse when normalized using the friction velocity of the flow as the kinematic scaling parameter. Several dimensionless time scales of particle motion, obtained from the different analyses, were compared to each other and, whenever possible, to those resulting from few available measurements of the flow field, for a phenomenological interpretation of the experimental findings.