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Comparing fractional bedload transport equations with field data

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Despite decades of active research on sediment transport the predictability of transport fluxes remains still poor due to complex driving processes and dynamics. Sediment transport rates are affected both by macro-roughness elements reducing flow energy and the grain size distribution of the bed material. On one hand, particle entrainment for a given shear stress depends on grain size. But on the other hand the entrainment of an individual grain is not only a function of its absolute grain size, but also of its relative grain size. Protrusion and hiding effects can ease the entrainment of a large particle relative to smaller particles, because large particles are exposed to higher drag forces and shield finer grains from the flow. Overall, hiding and exposure effects lead to an increasing critical shear stress for finer fractions and a decreasing critical shear stress for coarser fractions, relative to the corresponding values for single-sized sediments.

In this study we evaluate bedload transport equations that take these effects into account and calculate sediment transport rates for individual grain size fractions (Wilcock & Crowe, 2003 and Parker, 1990). Up to now these equations have not been systematically tested and validated with field data. Williams and Rosgen (1989) compiled USGS data on bedload transport rates, comprising around 2000 data points from 90 US rivers. The channels are characterized by gradients from 0.02 % to 20 % and median grain sizes from 2 to 160 mm, flow rates range from 1E-3 to 1E3 m3/s.

The comparison of the transport equations to the field data shows a large scatter between observed and calculated transport rates over several orders of magnitudes. The performance of the equations strongly depends on channel slope; in lower-gradient channels the equations underestimate the transport rates, whereas in steep streams overestimations are typical. A systematic correlation of the model performances to bed grain size distributions and fractional transport cannot be observed when using the original empirical form of the equations.