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Use of discrete element modeling for a physics-based link between bed surface variability and particle entrainment statistics

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The Exner equation provides a mathematical link between sediment transport and the evolution of bed morphology. It is typically represented in a discrete formulation where there is a sharp interface between the bedload layer and the bed, below which no particles are entrained. For high temporally and spatially resolved models, this is strictly correct, but typically this is applied in such a way that spatial and temporal fluctuations in the bed surface (bedforms and otherwise) are not captured. This limits the extent to which the exchange between particles in transport and the sediment bed are properly represented, particularly problematic for mixed grain size distributions that exhibit segregation. Nearly two decades ago, Parker (2000) provided a framework for a solution to this dilemma in the form of a probabilistic Exner equation.

We present a computational model designed to develop a physics-based framework for understanding the interplay between physical parameters of the bed and flow and parameters in the Parker (2000) probabilistic formulation. To do so we use Discrete Element Method simulations to relate local time-varying parameters to long-term macroscopic parameters. In this presentation we consider time varying parameters that include local grain size distribution, bed heights, velocity variations, and particle entrainment and deposition rates. We consider long-term macroscopic parameters such as average bed shear stress and the standard deviation of bed height variations. While relatively simple, these simulations reproduce long-accepted empirically determined transport behaviors such as the Meyer-Peter and Muller (1948) relationship and statistical relationships proposed by Wong et al. (2007) such as a Gaussian distribution of bed heights whose standard deviation increases with increasing bed shear stress.