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A Fokker-Planck model of bedload transport and morphodynamics

Deterministic, time-resolved simulations of turbulence, such as using the Large Eddy Simulation technique, are increasingly common in river and marine flows. However, current sediment transport models are lacking in similar sophistication and do not account for the temporal and spatial distribution of modeled turbulence structure. Our previous work has shown that these elements are critical to physics-based modeling of sedimentary bedforms. In river and marine flows the smallest turbulence length scales are much larger than the molecular length scales of the fluid, and the continuum approximation is valid. However, the number density of sediment grains is rarely large enough to justify this continuum assumption, and the velocity and position of sediment should be regarded as a stochastic process.

Bedload grains undergo frequent collisions with the bed during transport and are also entrained and deposited in response to near-bed turbulent fluctuations of the fluid velocity. These factors contribute to a broad probability density function of bedload grain velocity and concentration, particularly at low transport stages. We derive a Fokker-Planck sediment transport equation. From the Fokker-Planck equation we also derive a probabilistic Exner equation for the change in bed elevation with time. This formulation of the erosion equation includes advective and dispersive flux terms. A bedload Peclet number is proposed to scale the advective and diffusive flux terms in the Fokker-Planck-derived Exner equation. When the bedload Peclet number is small, the diffusive term in this modified Exner equation should not be ignored in bedform stability analyses. We derive parameters for the stochastic bedload model using an ongoing set of high-speed video experiments of bedload transport in a laboratory flume.