The role of grain to grain interactions and turbulence in sediment transport

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Bedload transport impacts sedimentary records as well as channel and delta morphology. Predictions of the onset of sediment motion are notoriously difficult and recent studies have focused on the detailed mechanics of grain movement to improve larger scale sediment flux estimates. In particular, the importance of the duration and magnitude of flow turbulence events that drive grain motion, or the intergranular dynamics that resist sediment movement have been highlighted as being fundamentally important. Despite such recent advances, few studies directly investigate the coupling of these driving and resisting mechanics. Here we use a combination of Discrete Element Method (DEM) modeling and laboratory flume experiments to elucidate the feedbacks between grain to grain interactions and flow turbulence. In the laboratory, we conducted a set of runs in which we measured gravel transport rates for a range of applied shear stresses using a high-speed video (250 frame/s) taken from above the flume. Spectral analysis of the bedload transport time series revealed that sediment movement did not follow the well-known turbulence energy cascade and in some cases scaling between power spectral density and frequency was absent. Such a lack of scaling at some frequencies implies that grain to grain interactions are obscuring the signal of turbulence in bedload transport rates, and flow turbulence alone will not adequately describe sediment transport. To further investigate this we conducted a set of DEM model runs in which we placed a test sphere on a bed of other spheres and applied forces to the test sphere to cause its motion. The model tracked sphere positions and velocities, as well as the force chains between any interacting spheres. Between different model runs, we applied three different random sequences of fluctuating forces on the test sphere. The test sphere was immobile for one of the runs despite all applied force distributions having the same mean force and maximum impulse. In this one run, movement did not occur because the sequence of applied forces caused the test sphere to move in a way that altered the intergranular arrangement of the bed. For example, particle rearrangement in this run caused a lower bed porosity that effectively increased the forces resisting test sphere motion that could not be overcome by subsequent applied forces. If we had separately considered the effects of intergranular dynamics or flow turbulence, we would have incorrectly predicted the mobility of the test sphere. Taken together, our laboratory and DEM model results demonstrate that sediment transport calculations must include both of these two effects and in particular, how the applied and resisting forces on grains interact to control motion.

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