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Incipient motion in gravel bed rivers due to energetic turbulent flow events

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This contribution reviews recent developments and contributions in the field of incipient motion and entrainment of coarse sediment grains due to the action of near bed turbulent flows. Specifically, traditional shear based spatio-temporally averaged concepts and instantaneous stress tensor criteria are contrasted to the newly proposed flow event based impulse and energy criteria. The energy criterion, suggests that only sufficiently energetic turbulent events can remove a particle from its resting position on the bed surface and result on its entrainment downstream. While the impulse and energy criteria are interconnected through the energy-impulse equation, the later appears to be more versatile and appropriate for generalising to sediment transport. These flow event based criteria have a sound physical basis for describing the intermittent character of particle entrainment as inherited by near boundary turbulence at near threshold conditions. These criteria can be derived from fundamental laws of physics such as Newtonian classical mechanics and the Lagrange equations respectively. The energetic events that are capable of performing geomorphic work at the scale of individual particles are shown to follow a power law, meaning that more energetic events (capable of removing larger stones) are expected to occur less frequently. In addition, this paper discusses the role of the coefficient of energy transfer efficiency introduced in the energy equation for particle entrainment. A preliminary investigation from analysis of a series of mobile grain flume experiments illustrates that different signatures of turbulence or sequence of flow structures may have different effectiveness towards particle transport. Characteristic cases of specific energetic flow events and the associated particle response are shown and classified with regard to the time required for complete entrainment. Finally these findings are commented with respect to the implications for sediment transport.