THE UNDERESTIMATED ROLE OF PARTICLE-BED IMPACTS FOR SEDIMENT TRANSPORT IN A NEWTONIAN FLUID

Thomas Pähtz[1] & Orencio Durán[2]
[1]*Institute of Physical Oceanography, Ocean College, Zhejiang University, China*
[2]*Department of Physical Sciences, Virginia Institute of Marine Sciences, College of William and Mary, USA*

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Particle-bed impacts have long been thought to play a predominant role in sustaining aeolian sediment transport, but a negligible role in sustaining subaqueous sediment transport. Here, using numerical simulations with the coupled DEM/RANS model of sediment transport in a Newtonian fluid by Duran et al. [1], we present threefold evidence for the hypothesis that the transition between fluid-sustained and impact-sustained transport occurs at a critical impact number ($\mathrm{Im} = \Theta \mathrm{Re}\sqrt{s} \approx 3$), where Θ is the Shields number, Re the particle Reynolds number, and s the particle-fluid-density ratio. First, we show that the effective particle slip velocity gradient in natural units becomes a universal constant when $\mathrm{Im} \gtrapprox 3$. A constant slip velocity has always been recognized as one of the main implications of the fact that particle-bed impacts ("splash") sustain aeolian saltation [1]. Second, we show that the threshold of sediment-transport cessation for fully viscous transport with sufficiently large transport layers obeys $\Theta_t \approx 3(\mathrm{Re}\sqrt{s})^{-1}$, which indicates that Θ_t is just large enough to achieve the necessary slip velocity gradient required for impact-sustained transport. Third, we show that the efficiency of particle-bed impacts in dissipating fluctuation energy reaches a maximal value when $\mathrm{Im} \gtrapprox 3$, which suggests a strong connection between impact entrainment and fluctuation-energy dissipation. Our results imply that only a few relevant sediment-transport regimes (e.g., transport of quartz in water with boundary Reynolds numbers $\mathrm{Re}_b = \mathrm{Re}\sqrt{\Theta_t} \lessapprox 6$) are sustained through direct fluid entrainment, while the vast majority of regimes are sustained through impact entrainment. Our movies, however, indicate that impact entrainment does not necessarily refer to the ejection of bed particles like for aeolian saltation. In the case of bedload, impacting particles rather tend to drag bed particles in front of them.

References

[1] O. Durán, P. Claudin, B. Andreotti *Numerical simulation of turbulent sediment transport, from bed load to saltation*, Physics of Fluids **24**, 103306 (2012).