Geophysical Research Abstracts
Vol. 20, EGU2018-3784, 2018
EGU General Assembly 2018

Non-suspended sediment transport: transport threshold, entrainment, intermittency, and Bagnold's hypotheses

Thomas Pähtz (1) and Orencio Durán (2)

(1) Institute of Port, Coastal and Offshore Engineering, Ocean College, Zhejiang University, Hangzhou, China, (2) Department of Ocean Engineering, Texas A&M University, Texas, USA

I will present the main conclusion of three recent studies [1-3], based on coupled DEM/RANS numerical simulations, that deal with various aspects of non-suspended sediment transport mediated by the turbulent shearing flow of a Newtonian fluid over an erodible granular bed:

1. The reference method (i.e. extrapolation of the sediment transport rate to zero or a small reference value) and the visual method (i.e. visually judging whether sediment transport occurs) used to determine the fluvial transport thresholds displayed in the Shields diagram are fundamentally different: the former method results in a threshold that is associated with steady granular dynamics and insensitive to turbulent fluctuations around the mean turbulent flow, whereas the latter methods results in a smaller threshold associated with the entrainment of individual particles by turbulent events.
2. A general analytical model predicting the reference method threshold in arbitrary environments (including viscous and turbulent liquids and air) is derived with the help of the simulations. Both simulations and analytical model are consistent with available measurements without parameter adjustment.
3. Sediment entrainment by particle-bed impacts dominates entrainment by the mean turbulent flow in most environments. The relative importance of both entrainment mechanisms is characterized by the values of two novel dimensionless numbers.
4. A new conceptual picture of sediment transport intermittency is proposed, which combines the gained insights on impact entrainment and granular dynamics with the critical impulse criterion for incipient motion due to turbulent events by Valyrakis and coworkers.
5. In contrast to claims of previous studies [4], Bagnold's two hypotheses, which explain the linear scaling of the sediment load (i.e. the mass of transported sediment per unit area) with the Shields number found in experiments and simulations, accurately describe steady non-suspended sediment transport: (i) the friction coefficient (i.e. the particle-shear-pressure ratio) becomes a universal approximate constant, and (ii) the fluid shear stress reduces to value near the reference method threshold, at an appropriately defined interface between granular bed and transport layer. However, the physical reason why these hypotheses work, surprisingly, is fundamentally different from a yield criterion associated with the rheology of dense granular flows and suspensions.

[1] T. Pähtz, O. Durán, Fluid forces or impacts: What governs the entrainment of soil particles in sediment transport mediated by a Newtonian fluid?, Physical Review Fluids 2, 074303 (2017).
[2] T. Pähtz, O. Durán, https://arxiv.org/abs/1602.07079, The cessation of non-suspended sediment transport across environments, under review
[3] T. Pähtz, O. Durán, https://arxiv.org/abs/1609.06005, A Coulomb Friction Law for Granular Gases: The Curious Case of Newtonian-Fluid-Sheared Granular Beds (Sediment Transport), under review
[4] G. Seminara, L. Solari, G. Parker, Bed load at low Shields stress on arbitrarily sloping beds: Failure of the Bagnold hypothesis, Water Resources Research 38, 1249 (2002).