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Karlsruher Vortragsreihe

Forschung und Praxis in Wasserbau und Wasserwirtschaft

Einladung

zu einem Vortrag von

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Unified Theory of Non-Suspended Sediment Transport Mediated by a Newtonian Fluid

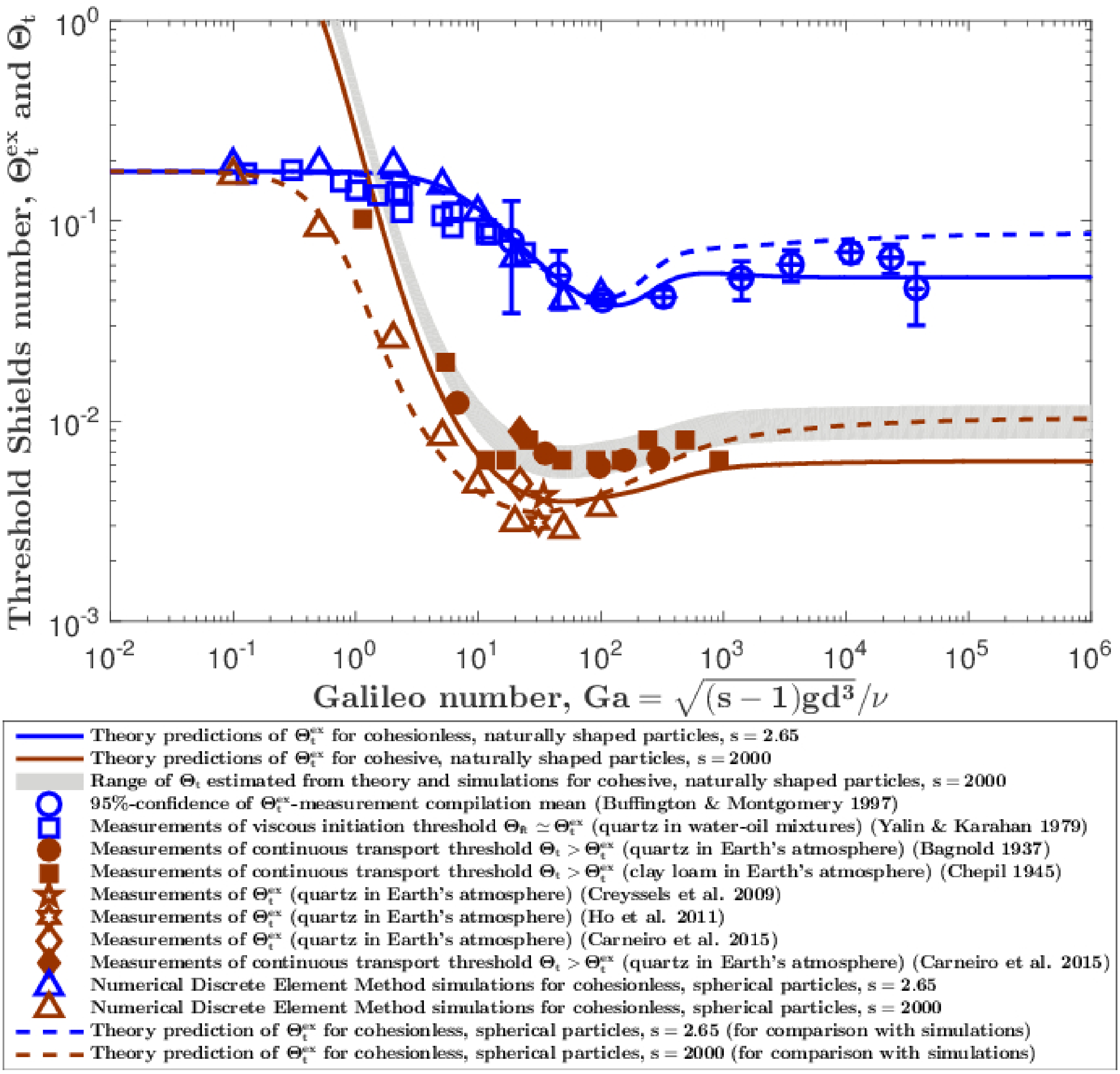
I present a unified theory of steady, homogeneous, non-suspended transport of nearly uniform spheres mediated by an arbitrary Newtonian fluid. The theory consists of elements that are rigorously derived from Newton's axioms and of semi-empirical elements that well describe simulation data, obtained using a coupled DEM/RANS numerical model of sediment transport in a Newtonian fluid (Duran et al., POF 103306, 2012), for the entire simulated range of the particle-fluid-density ratio s, Galileo number Ga, and Shields number S. Despite not being fitted to experimental data, theory and simulations simultaneously reproduce measurements in air (s ~ 2000) and viscous and turbulent liquids (s ~ 1) of the transport cessation threshold T_ex, obtained from extrapolation to vanishing transport, and the sediment transport rate Q.

From theory and simulations, we learn that considering added-mass, lubrication, fluid lift, and/or history forces is not required to quantitatively reproduce measurements. However, collisions between transported particles cannot be neglected as they strongly influence the scaling of Q with S. For instance, we find such collisions are responsible for a transition from a linear to a non-linear scaling of Q with S in turbulent bedload and saltation transport, which we find occurs when the bed surface becomes fully mobile ('stage-3 bedload') at S ~ 0.1.

The probably most controversial conclusion we draw from theory and simulations is that T_ex is usually unrelated to entrainment of bed sediment, which challenges a widely-accepted paradigm. In contrast, T_ex is rather a virtual quantity that solely reflects mechanical equilibrium in the limit of vanishing transport. However, we also find that the cessation threshold T of continuous sediment transport, which is usually larger than T_ex, does depend on sediment entrainment, usually triggered by particle-bed impacts. Transport with Shields numbers T_ex < S < T is metastable and follows a non-random 'collective-entrainment' pattern. This pattern, which is characterized by periods of rest separated by intense burst, was evidenced in laboratory and field measurements.

Ort: **Theodor-Rehbock-Hörsaal, Altes Bauingenieurgebäude**
Hörsaal 59, Gebäude 10.81, Campus Süd - KIT

Zeit: **Donnerstag, 04.05.2017, 17.30 Uhr**


Threshold Shields number, Θ_t^{ex} and Θ_t
Galileo number, $Ga = \sqrt{(s-1)gd^3}/\nu$
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3} 10^{4} 10^{5} 10^{6}
Theory predictions of Θ_t^{ex} for cohesionless, naturally shaped particles, $s = 2.65$
Theory predictions of Θ_t^{ex} for cohesive, naturally shaped particles, $s = 2000$
Range of Θ_t estimated from theory and simulations for cohesive, naturally shaped particles, $s = 2000$
95%-confidence of Θ_t^{ex}-measurement compilation mean (Buffington & Montgomery 1997)
Measurements of viscous initiation threshold $\Theta_{it} \simeq \Theta_t^{ex}$ (quartz in water-oil mixtures) (Yalin & Karahan 1979)
Measurements of continuous transport threshold $\Theta_t > \Theta_t^{ex}$ (quartz in Earth's atmosphere) (Bagnold 1937)
Measurements of continuous transport threshold $\Theta_t > \Theta_t^{ex}$ (clay loam in Earth's atmosphere) (Chepil 1945)
Measurements of Θ_t^{ex} (quartz in Earth's atmosphere) (Creyssels et al. 2009)
Measurements of Θ_t^{ex} (quartz in Earth's atmosphere) (Ho et al. 2011)
Measurements of Θ_t^{ex} (quartz in Earth's atmosphere) (Carneiro et al. 2015)
Measurements of continuous transport threshold $\Theta_t > \Theta_t^{ex}$ (quartz in Earth's atmosphere) (Carneiro et al. 2015)
Numerical Discrete Element Method simulations for cohesionless, spherical particles, $s = 2.65$
Numerical Discrete Element Method simulations for cohesionless, spherical particles, $s = 2000$
Theory prediction of Θ_t^{ex} for cohesionless, spherical particles, $s = 2.65$ (for comparison with simulations)
Theory prediction of Θ_t^{ex} for cohesionless, spherical particles, $s = 2000$ (for comparison with simulations)