SALTATION ON EARTH AND EXTRATERRESTRIAL ATMOSPHERES

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Key words Geophysical flows, granular materials, mixing, multiphase and particle-laden flows, particle/fluid flow, sediment transport

We present an approximate analytical analysis of particle periodic motion over hydrodynamically rough beds [1]. The analysis is based on the calculation of approximate solutions for average periodic trajectories of particles that are accelerated by the turbulent shearing of a fluid, between collisions with the bed (see Fig. 1). We focus on the case in which the mean fluid motion is strong enough to sustain the saltation of the particles, as continuing rather than intermittent, as often seen in weak bedload transport of particles in water.

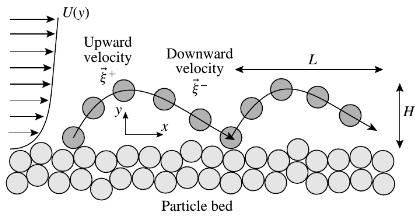

Figure 1. Sketch of the periodic trajectory

From these solutions, we determine the relations between the horizontal particle flux, the strength of the shearing flow and the particle take-off velocity over a range of the grain-to-fluid mass density ratios that vary between those for sand in air and sand in water, in saltation over rigid bumpy and erodible beds. We focus on large values of the Stokes number, where collisions with the bed are not influenced by the fluid.

For saltation over rigid bumpy beds, we predict that there is range of particle flux that the fluid can sustain at a given Shields parameter, irrespective of the density ratio and the Stokes number. That range presents a maximum, which corresponds to the maximum transport capacity of the flow, before particles begin to be deposited and an erodible bed develops. To our knowledge, these findings have been previously demonstrated in the case of aeolian transport only. We also find that the particle trajectory and the fluid shear stress at the bed are essentially independent of the Shields parameter, unlike the particle shear stress and concentration.

For saltation over erodible beds, there is only one horizontal particle flux associated with a given Shields parameter. The analytical solution indicates that this flux scales linearly with the Shields parameter in aeolian transport, while it is roughly proportional to the Shields number to the power of $3/2$ near aquatic transport. These predictions are in agreement with the scaling laws drawn from sand transport experiments in air and water. We also highlight that saltation regimes in air and water are different in nature: aeolian saltation is limited by the splash, while the aquatic saltation is not. In the latter case, the impact velocity of the saltating particles is actually too weak to trigger the splash and, as a consequence, the particle flux is limited by the maximum transport capacity of the system. Interestingly, for intermediate values of the density ratio σ (typically between 30 and a few hundred), we find a crossover regime: the particle flux is proportional to $S^{3/2}$ close to the threshold and linear in S at larger values of the Shields parameter. In other words, for these intermediate values of σ, we observe a transition from an unlimited saltation regime at small Shields parameters to a splash-limited saltation regime at larger Shields parameters. This crossover regime is expected to be relevant for sediment transport in extraterrestrial atmospheres such as on Venus and Titan, where the density ratios are approximately 40 and 200, respectively.

References

[1] D. Berzi, J..T Jenkins and A. Valance, *Periodic saltation over hydrodynamically rough beds: aeolian to aquatic* Journal for Fluid Mechanics **786, 190- 209 (2016).**