Transition from Saltation to Collisional Regime in Wind-blown Sand

J-L. Ralaiarisoa[1], J-B. Besnard[1], B. Furieri[2], P. Dupont[3], A. Ould El Moctar[4], F. Naaim-Bouvet[5], and A. Valance[1]

1 : Univ Rennes, CNRS, Institut de Physique de Rennes, UMR 6251, 35 042 Rennes, France ; 2 : Universidade Federal do Espírito Santo, DEA, 29060-970 Vitória, ES, Brazil
3 : Univ Rennes, INSA Rennes, LGCGM, 35 043 Rennes, France ; 4 : Univ Nantes, Laboratoire Thermique et Energie, UMR 6607, 44306 Nantes Cedex, France
5 Univ. Grenoble Alpes, INRAE, UR ETNA, 38000 Grenoble, France

Abstract

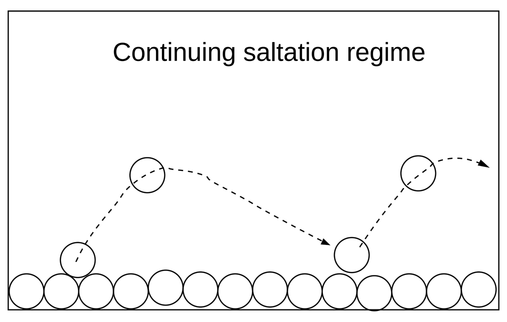
We report wind-blown sand experiments that highlight a transition from saltation to collisional regime [1]

- The transition is seen through the mass flow rate Q, which deviates from a linear trend with the Shields number
- Other evidences confirm this transition:

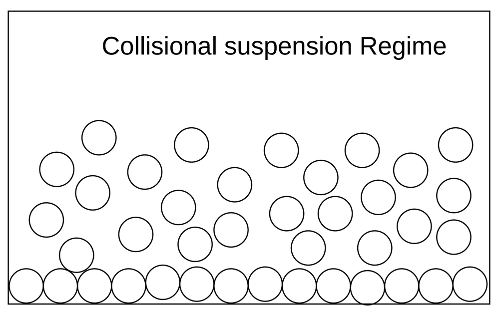
-the particle velocity and the height of the transport layer increases with increasing Shields number in the collisional regime while the latter are invariant with the wind strength in the saltation regime.

-Discrete numerical simulations support the experimental findings and ascertain that mid-air collisions are responsible for the change of transport regime.

Saltation regime

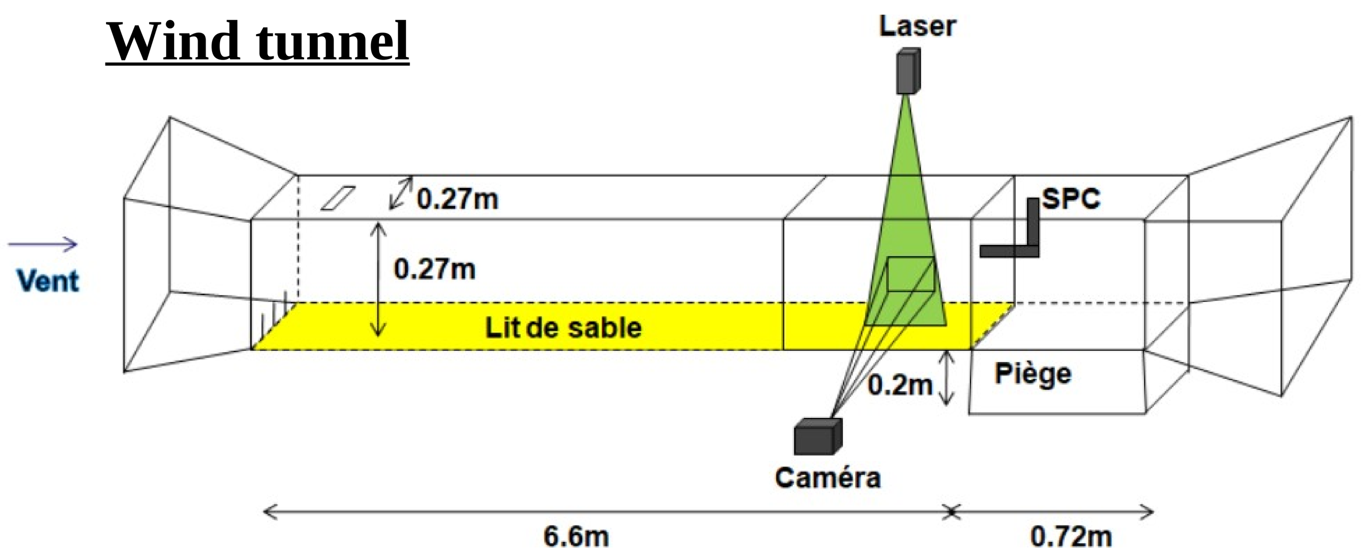


Collisional regime



Experimental set up

Wind tunnel

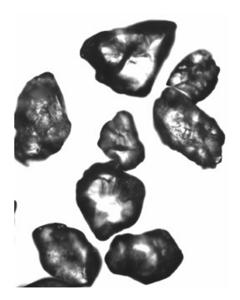


Instrumental tools :

- Pitot tubes (air velocity profile)
- PTV system (particle concentration and velocity profile)
- Particle Counter (flux density profile)

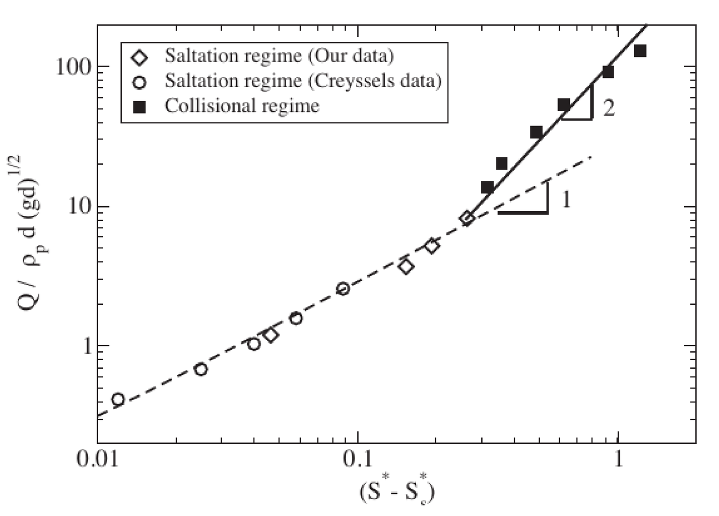
Granular Materials :

-Sand grains with median diameter d=0.2mm



Experimental results

Mass flow rate



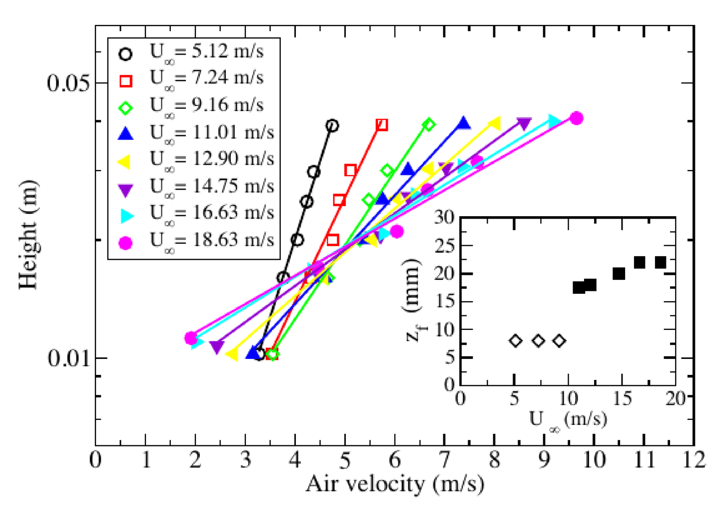
(i) Saltation regime: $S_s < S < S_c$

(ii) Collisional regime: $S_c < S$

Critical Shields numbers:

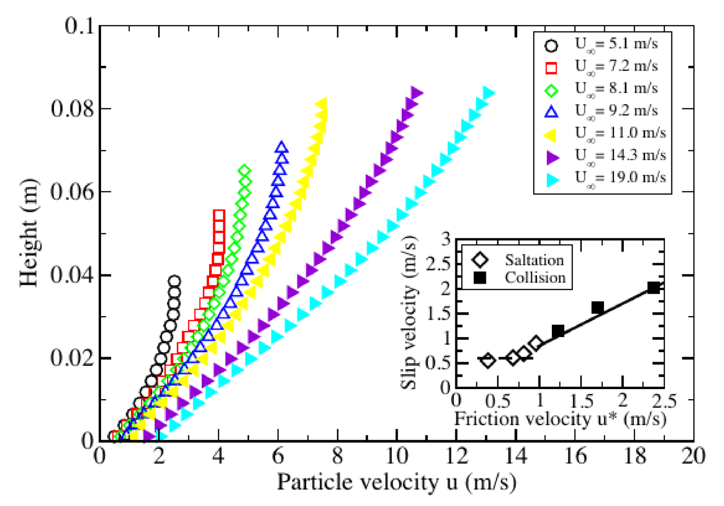
S_s=0.008 and S_c=0.3

Air velocity



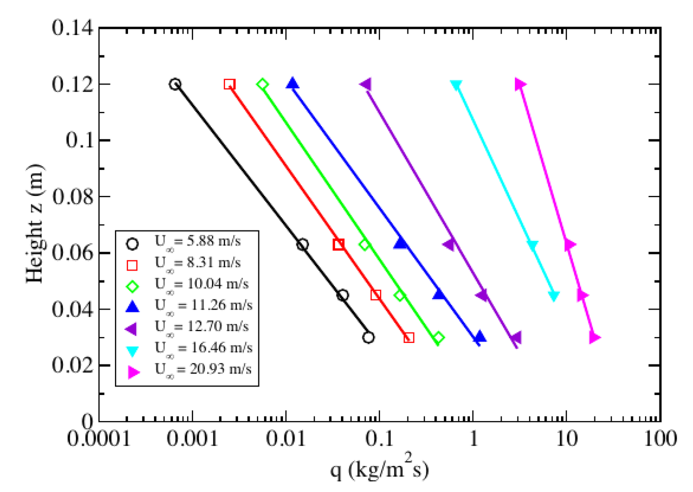
- Logarithmic velocity profiles
- Two distinct focus points : z_{f1}=8mm and z_{f2}=20mm

Particle velocity



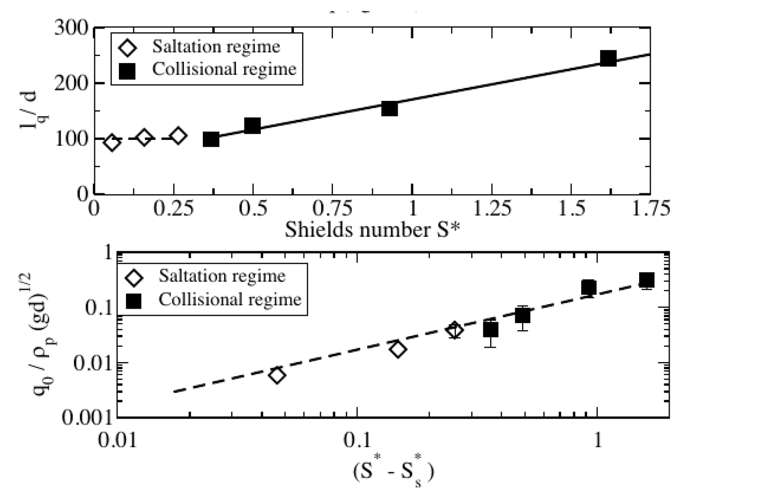
- Saltation regime : particle velocity insensitive to the wind strength
- Collisional regime : particle velocity increases with increasing wind speed

Particle flux density



Exponential decrease : $q=q_0 \exp(-z / l_q)$

q_0 and l_q versus Shield number

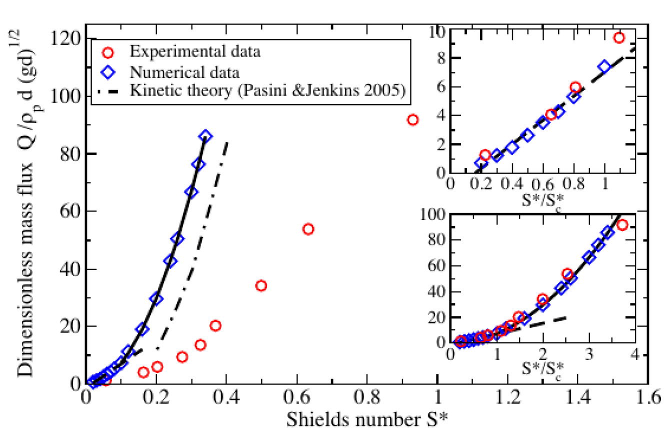


2D Hybrid DEM-RANS Simulations

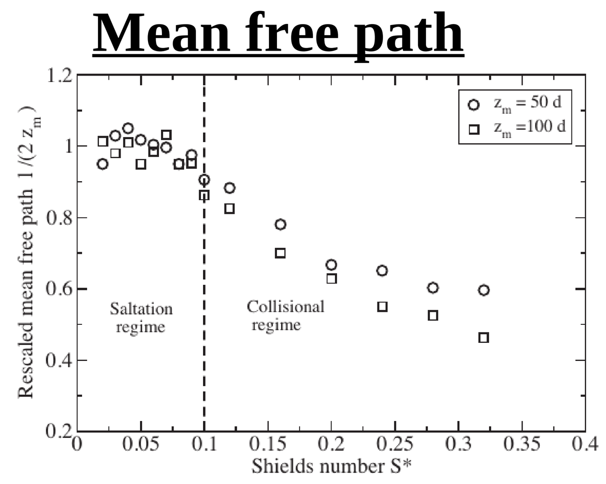
Method : numerical simulations based on a discrete element method for particle dynamics coupled to a continuum Reynolds averaged description of hydrodynamics [2]

Parameters: d=0.2 mm, particle density= 2650 kg/m^3, air density=1.2 kg/m^3, e_n=0.9 and μ=0.5

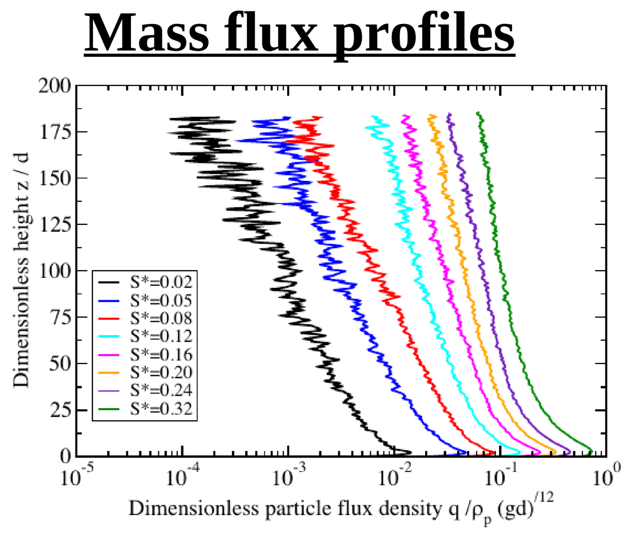
Mass flow rate



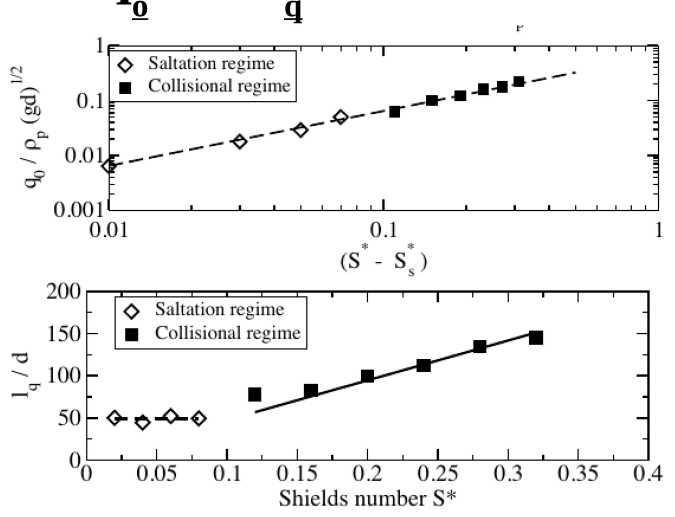
Mean free path



Mass flux profiles



q_o and l_q versus S



- Simulations corroborate experimental findings
- There are however quantitative discrepancies concerning the critical Shields number to transit to the collisional regime: S_c=0.15 against S_c=0.3 in the experiments
- The presence of mid-air collisions in the collisional regime are confirmed by the simulation through the computation of the mean free path

Conclusion

- The transition observed in experiments and simulations occurs at the same critical flow rate Q_c but at different critical Shields number
- The fact that Q_c is similar in experiments and simulations gives credit to the hypothesis that the transition is driven by mid-air collisions
- In the saltation regime, the mass flow rate is proportional to the depth-averaged particle concentration and is thus expected to control the onset of particle collisions within the transport layer.

References

[1] J-L. Ralaiarisoa , J-B. Besnard , B. Furieri , P. Dupont, A. Ould El Moctar, F. Naaim-Bouvet , A. Valance (2020). *Phys. Rev. Lett.* ***124**, 198501.*

[2] O. Duran, P. Claudin, and A. Andreotti (2011), Aeol. Res. 3, 243.