Aeolian transport of cohesive particles

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Introduction

We investigate the influence of particle cohesion on the aeolian sand transport.

(i)We conducted well-controlled wind tunnel experiments with wet sand beds at different wind speeds and tried to assess the aerodynamic and impact threshold of transport.

(ii)We also characterized the averaged mass flow rate as a function of the wind speed and the water content as well as its temporal fluctuations at short and long times scales. process.

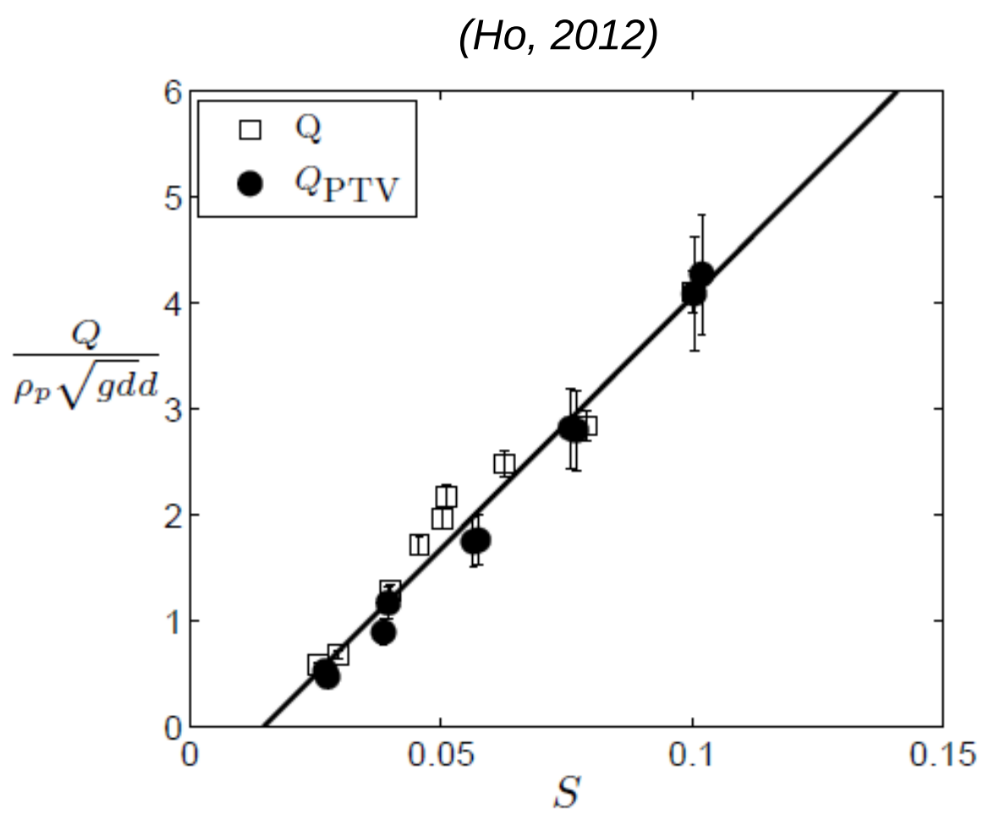
Aeolian sand transport with dry sand

Transport features

Numerous experimental works (Rasmussen et al., 2008; Creyssels et al., 2009; Ho et al., 2012) have been carried out in wind-tunnels to characterize saltation transport.

Saturated transport rate

(Ho, 2012)



Shields number : $S=\rho_{air}u_*^2/\rho_{grain}gd$

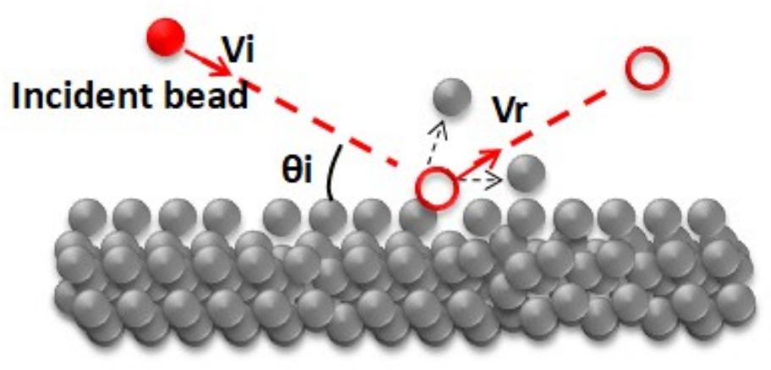
Mass flow rate : $Q=Q_0(S-S_d)$

where S_d is the critical Shields number corresponding to the cessation of the transport

➢The mass flow rate increases linearly with the Shields Number

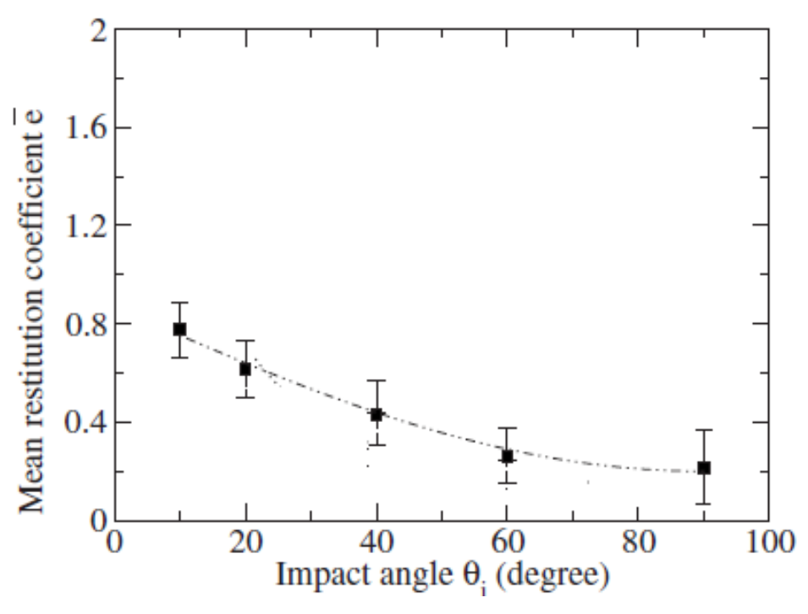
Splash process

The Splash process has been recognized to be a key element to explain the main features of the saltation transport. Numerical and experimental (Werner et al., 1988; Rice et al., 1995; Beladjine et al., 2007) studies have been conducted to characterize it.



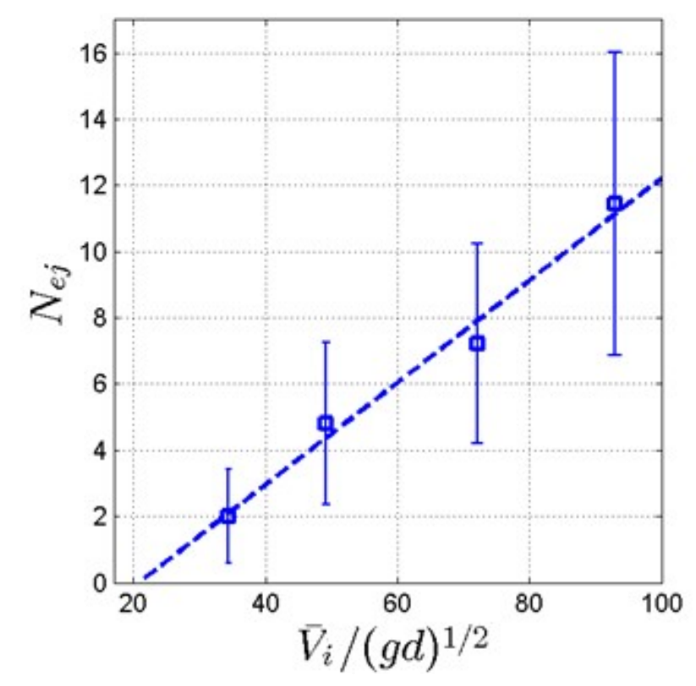
Restitution coefficient for the rebound particle

$$\bar{e} = \frac{\bar{V}_r}{\bar{V}_i}$$



➢The restitution coefficient decreases with increasing impact angle and is independent of the incident velocity

Number of ejected particles vs the impact velocity



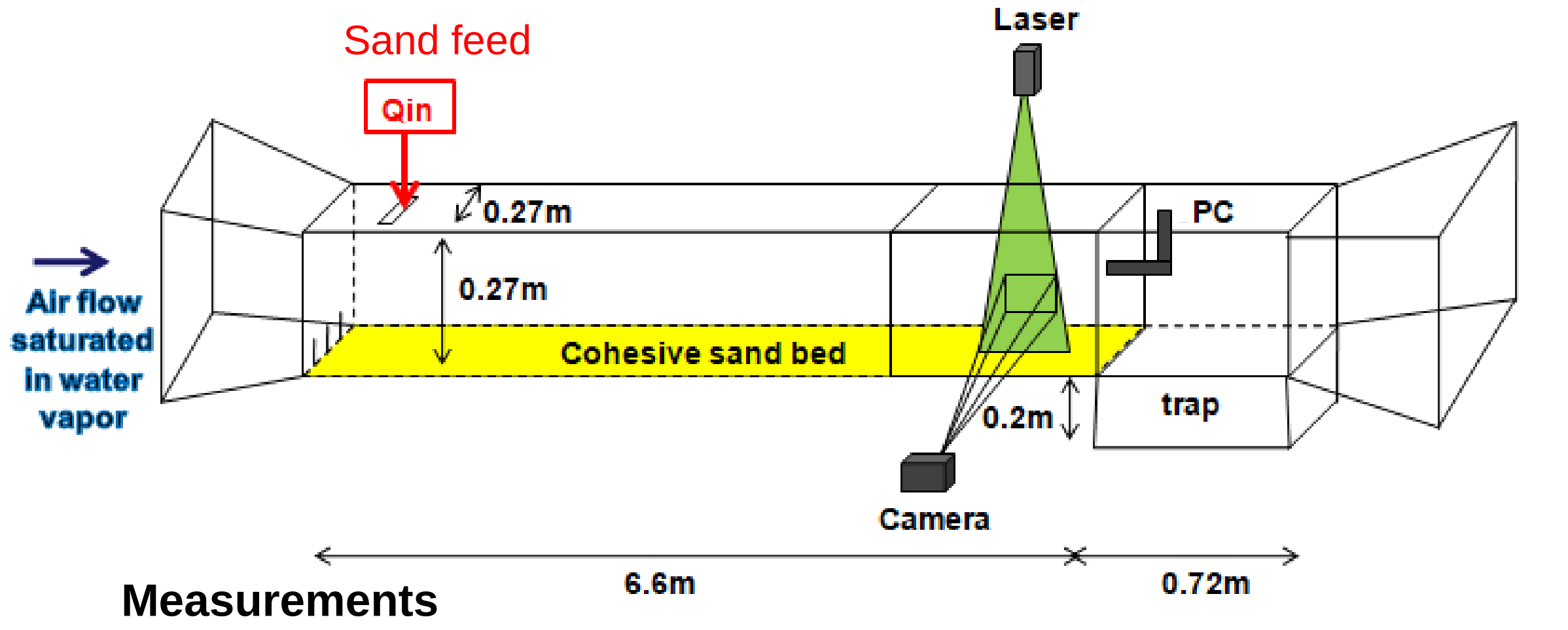
$$N_{ej} = (1-\bar{e}^2)[\frac{V_i}{V_{ic}} - 1]$$

V_{ic}: Critical velocity below which there is no ejecta

➢The number of ejected particles is linear with the incident velocity *Vi.*

Aeolian sand transport with wet sand

Experimental setup and protocols



Measurements
- Sand trap to assess the time averaged mass flux
- Particle counter (PC) to measure instantaneous mass flux density

Sand features
-Sand diameter and density: d= 200µm, ρ= 2650 kg/m3
-Gravimetric water content: 1.4 – 3.8%

Air flow features
-Air flow is saturated with water vapor to minimize evaporation (90 %<HR<100%)

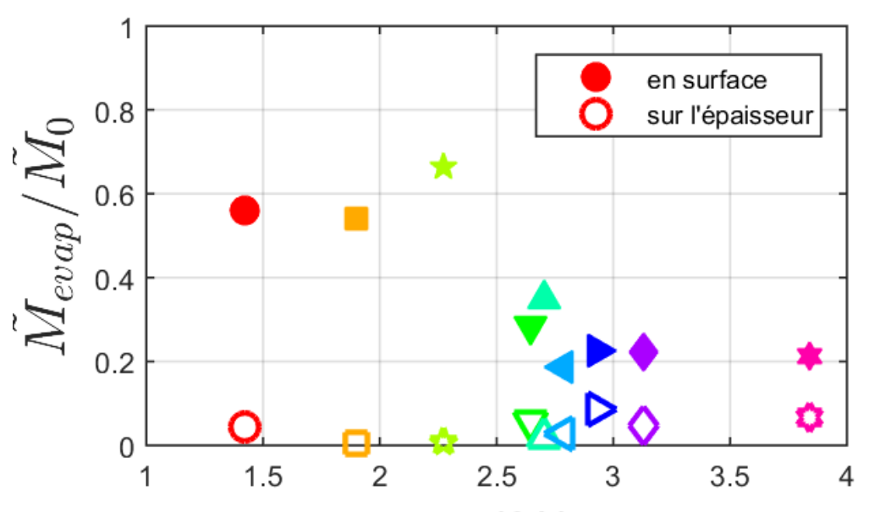
Upwind condition
- Sand feeding system allowing to set a finite upwind flux Q_{in}

Water-Sand mixture preparation

Use of concrete mixer

➢The sand-water mixture is mixed for an hour in a concrete mixer and then sealed in a hermetic container for 48 hours

Evaporation after a 20 mm transport experiment

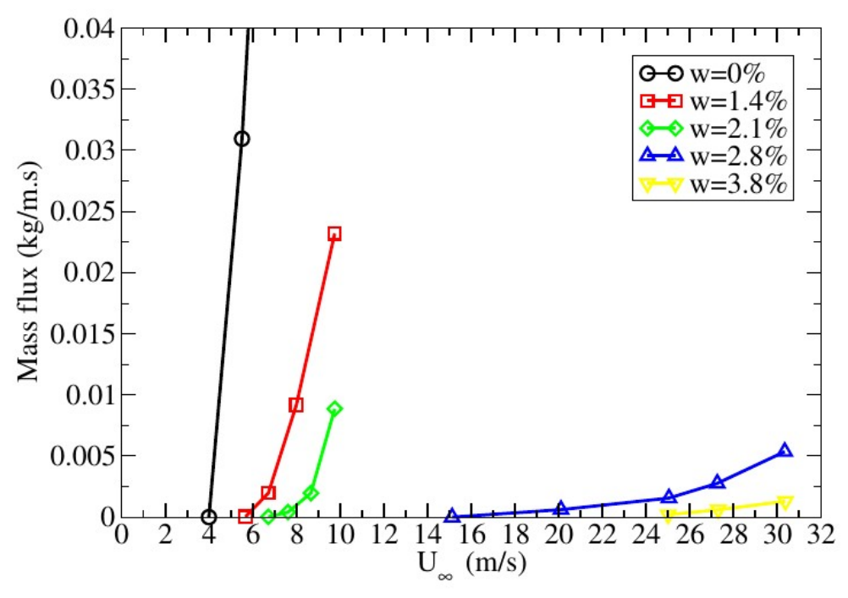


➢The evaporation rate of the superficial layer is relatively important for low water content. Up to 50 % of the initial water content has gone

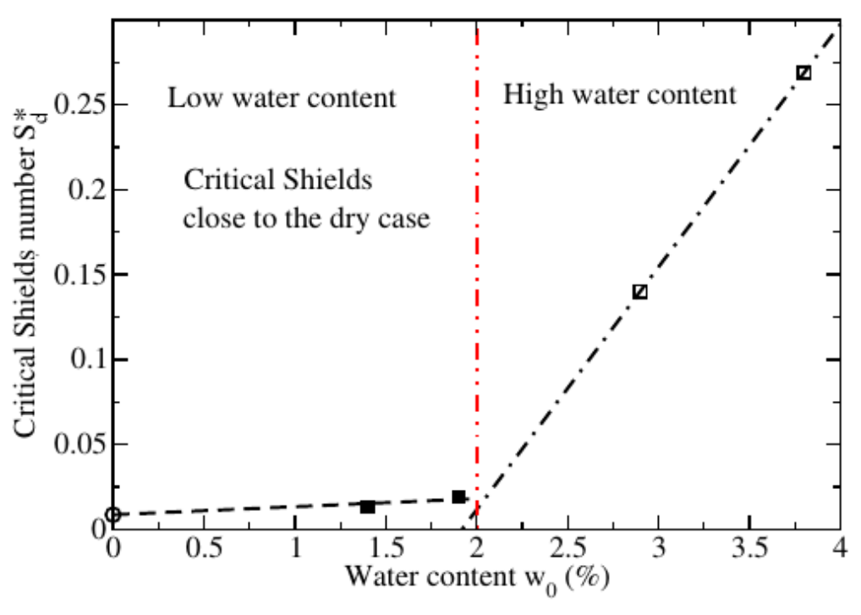
Transport with zero upwind flux (Q_{in}=0)

A: Threshold and transport laws

1. Mass transport rate vs wind speed

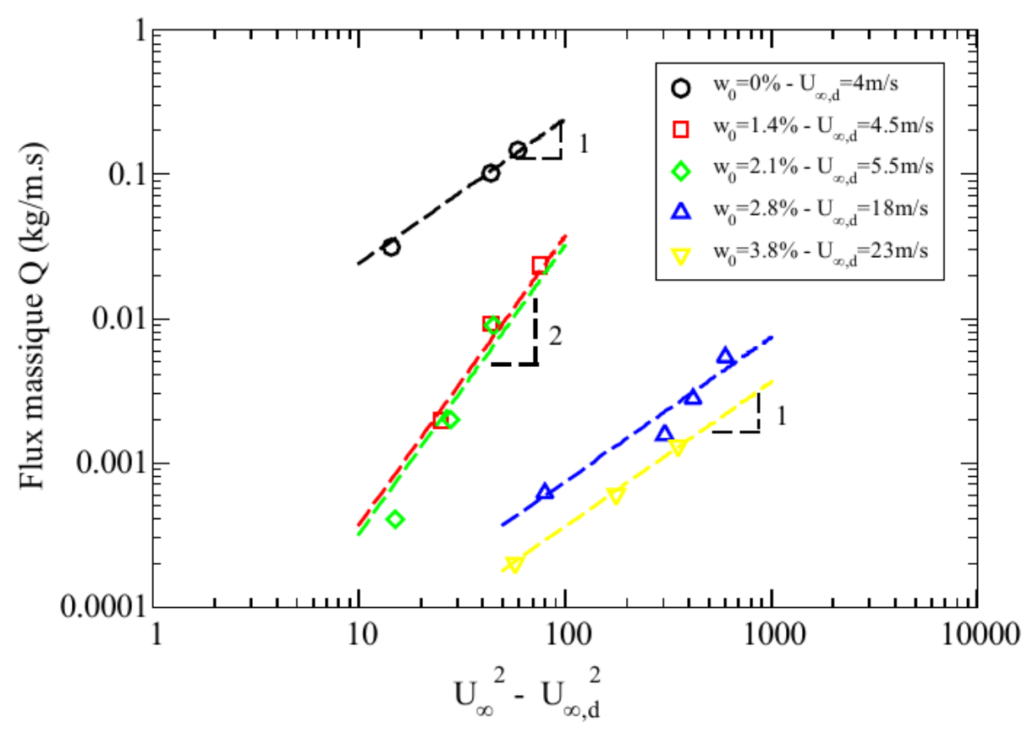


2. Cessation of transport vs water content



➢ Identification of two regimes at low and high water content :
(i) low water content : critical shields number for incipient motion close to that of the dry case
(ii) high water content : drastic increase of the critical Shields number

3. Mass transport laws for moist sand



➢ Two different power laws :
(i) low water content : $Q \sim (S-S_d)^2$

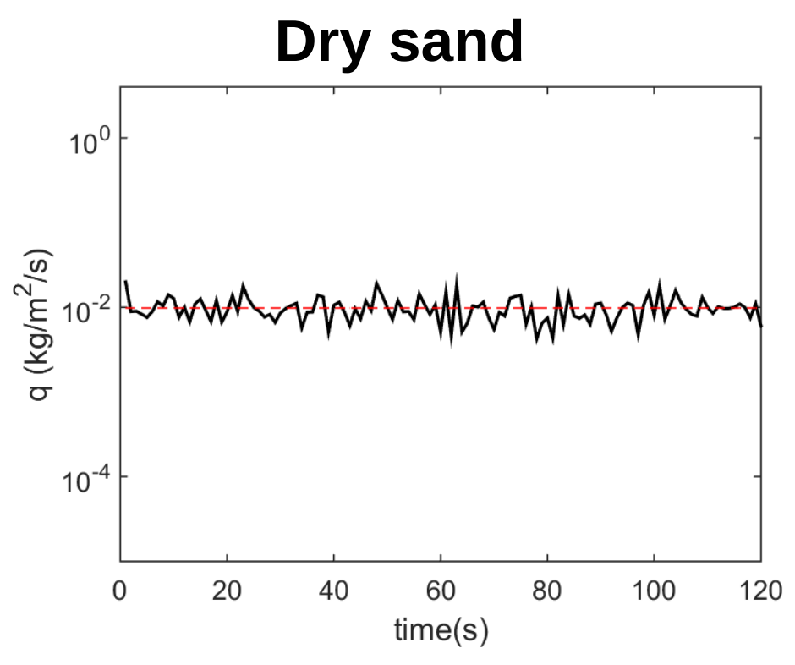
(ii) high water content : $Q \sim (S-S_d)$
Same law as the dry case but with a weaker intensity

➢ We believe that the contrasting behavior between low and high water content originates from the intermittency of the transport at low water content

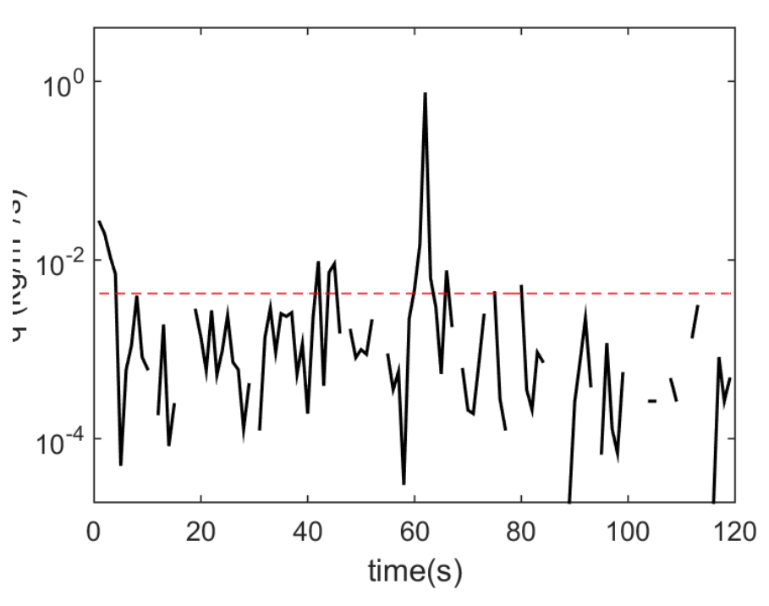
B: Intermittency at low water content

1. Time series of mass flux density at short time scale

Dry sand



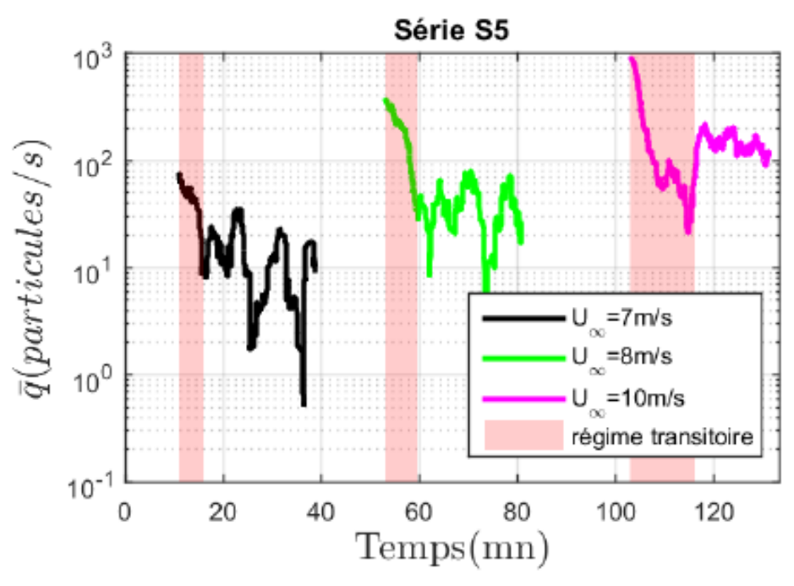
Wet sand : W=2.1 %



➢Continuing transport with low fluctuaction (<20%)

➢ Intermittent transport: Succession of bursts of transport

2. Time series of mass flux density at long time scale



➢Temporal oscillation of the mass flow rate with a well-defined periodicity T

➢ T is on the order of a few minutes (5-10) and decreases with increasing wind speed

➢The period T is compatible with the time needed to dry the superficial layer at the bed of one diameter height

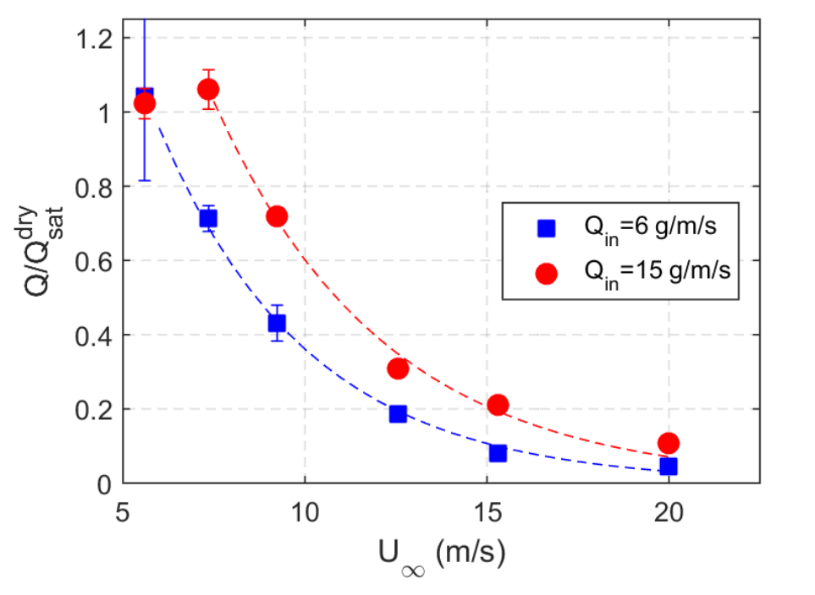
➢A simple diffusive-convection model predicts a characterestic drying time of a few minutes within the condition of temperature and humidity of the experiment

Transport with a finite upwind flux (Q_{in}≠0)

1. Impact threshold

➢ With finite upwind mass flux, the transport with wet sand is triggered at wind speed (5.5m/s) close to the dry threshold (5m/s)

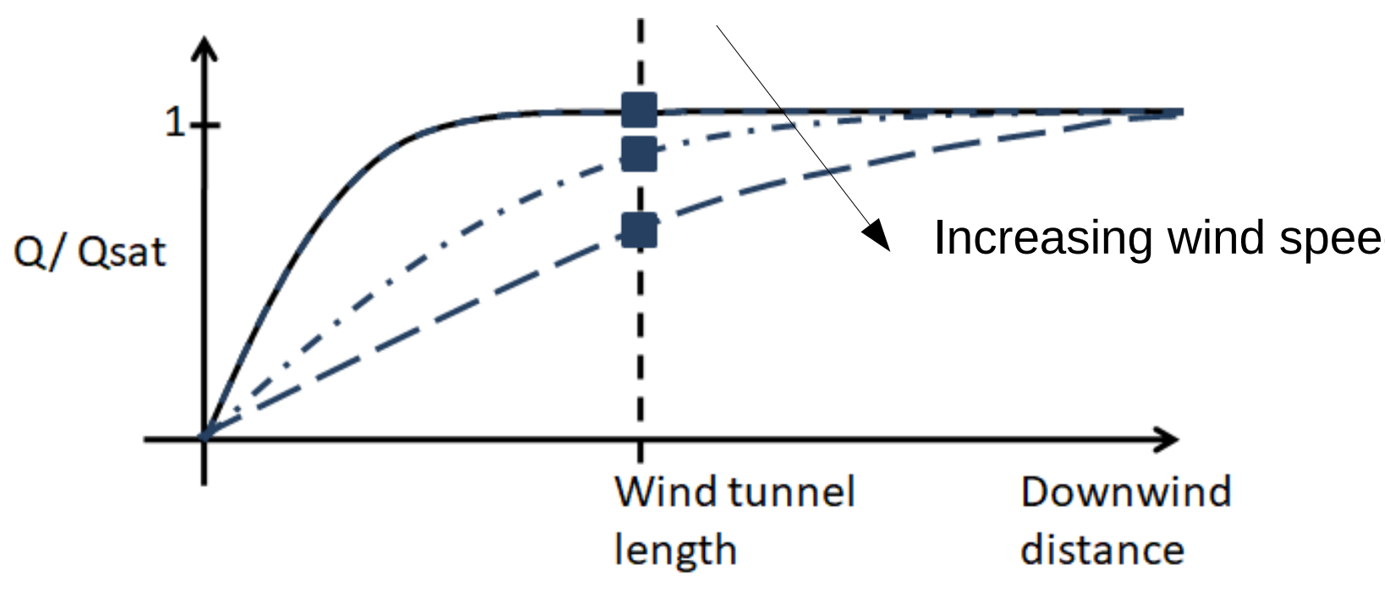
2. Mass flow rate renormalized by the dry saturated flux at w=2.8%



➢ The renormalized mass flow rate measured at the end of the wind tunnel (~ 7m) decreases exponentially with increasing wind speed

➢ At low wind speed, the mass flow rate is equal to that of the dry case

3. Interpretation in terms of the saturation process



➢ For strong winds, the transport rate measured at the tunnel exit is lower than the dry saturated flow rate and can be explained by the fact that the saturation requires a longer distance than the tunnel length

References

- Bagnold, R.A. (1941), London: Methuen.
- Beladjine, D. (2007), Ph.D. thesis, Université de Rennes 1.
- Ho, T. D. (2012), Ph.D. thesis, Université de Rennes 1.
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- Ralaiarisoa, J.L. et al. (2021), Intermittency in aeolian transport of moist sand (Preprint)
- Ralaiarisoa, J.L. et al. (2021), Transport laws for moist wind-blown (Preprint)

Conclusion

- Two different regimes of transport are observed at low and high water content
- The low water content regime is crucially dependent of the drying process of the superficial sand layer
- The impact threshold is almost insensitive to the water content in the range of cohesion investigated so far
- Experimental results suggest that the saturated transport rate over a wet sand bed can reach the same value as that obtained over a dry sand bed but the saturation length is larger than in dry conditions