#1028

A wind tunnel study of the effect of pressure on saltation threshold conditions

E. V. Nield[1] (enield@vols.utk.edu), D. M. Burr[1], N. T. Bridges[2], J. K. Smith[3], J. P. Emery[1], J. R. Marshall[4] and J. F. Kok[5]. [1]University of Tennessee Knoxville, [2]JHU Applied Physics Laboratory, [3]Arizona State University, [4]SETI Institute, [5]University of California Los Angeles

Introduction

Aeolian activity occurs under a wide range of atmospheric pressures in the Solar System. Dunes have been observed on Earth (average surface pressure of 1 bar), Mars (6 mbar), Venus (92 bar), and Titan (1.5 bar)[1, 2]. The formation of dunes requires the movement of sand in saltation. The initiation of the saltation process may occur at fluid or impact threshold wind speeds.

Fluid threshold: minimum wind speed necessary to initiate saltation due to the direct pressure of the fluid[3].

Impact threshold: minimum wind speed at which saltation can be sustained through collisions from upwind grains[3].

The COMSALT model is a numerical model used to predict threshold speeds and grain trajectories over a variety of surface air pressures[4,5].

COMSALT results: at lower air pressures, impact entrainment dominates and at higher air pressures, fluid entrainment dominates.

- In higher pressure environments, a lower threshold speed is required to entrain a grain compared to lower air pressure environments.
- As a result of the lower threshold speed, the grain impacts the bed at lower speed, thus less kinetic energy is available to entrain grains by impact.
- The opposite is true in low pressure environments.

This work will investigate the validity of this model result by observing grain entrainment from 1-20 bar in the Titan Wind Tunnel using high-speed videography.

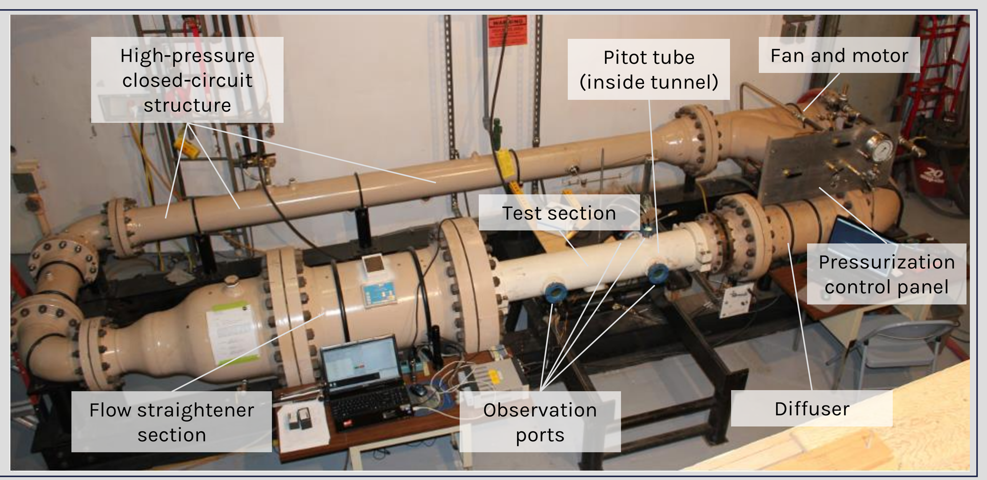
Hypothesis

At lower air pressures, impact entrainment dominates and at higher pressures, fluid entrainment dominates. If this is proven, then the results of the COMSALT model would be validated[4,5].

Data Collection

Titan Wind Tunnel[6]

- Location at NASA Ames, Mountain View, CA
- Closed-circuit wind tunnel
- Pressure ranges from 1-20 bar
- Fan generates wind, goes around tunnel in an anticlockwise direction
- Bed materials placed in test section

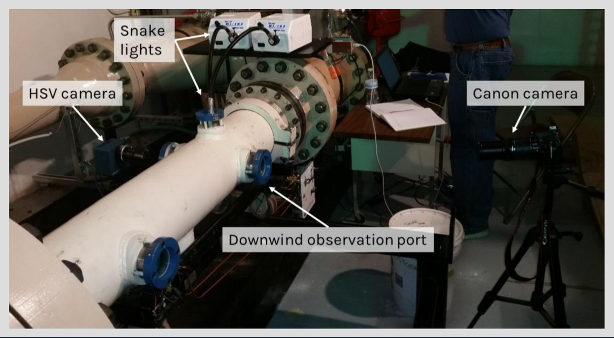


Bed Materials

Experimental matrix includes materials covering a wide range of densities and grain diameters, such as: quartz (2.65 g/cm³), basalt (3 g/cm³), beach sand (2.5 g/cm³), and walnut shells (1.1 g/cm³).

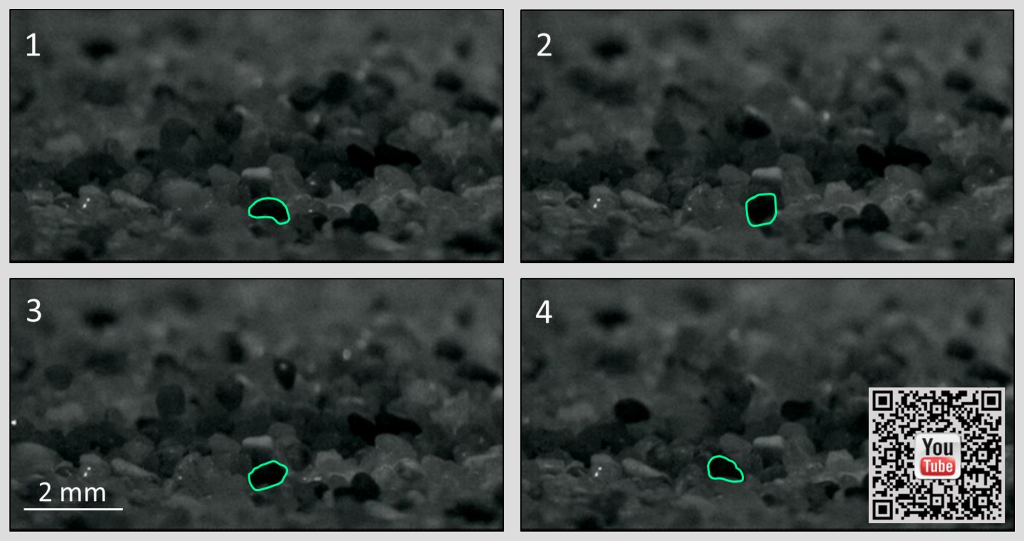
Observing Threshold

- Fan speed is increased until threshold is visually determined by an observer at the downwind observation port
- Defined as 50% of the bed in motion
- Recorded by two cameras in high-speed (HSV @1400 frames/s) and in real time (Canon, 30 frames/s)
- Experiment is repeated three times for each bed and air pressure

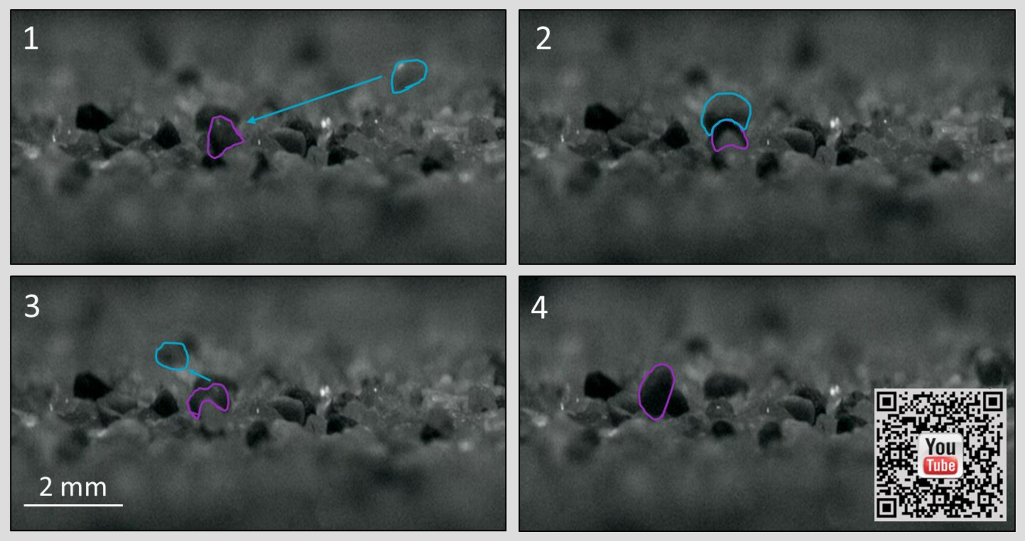


Methodology

- Frames from the high-speed video are extracted for each threshold experiment
- An observer reviews the frames and visually counts the number of grains that are being entrained
- Grains are placed into categories based on:
  - mechanism of entrainment (impact or fluid)
  - mechanism of transport (saltation, reptation, or bed processes i.e. rolling, sliding)



Fluid entrainment: High-speed images of a sand grain (in green) being entrained due to the direct pressure of the fluid at 8 bar. The time step between successive images is 7 ms. Grain diameter sieve range: 707-833 μm. Wind direction: right to left.

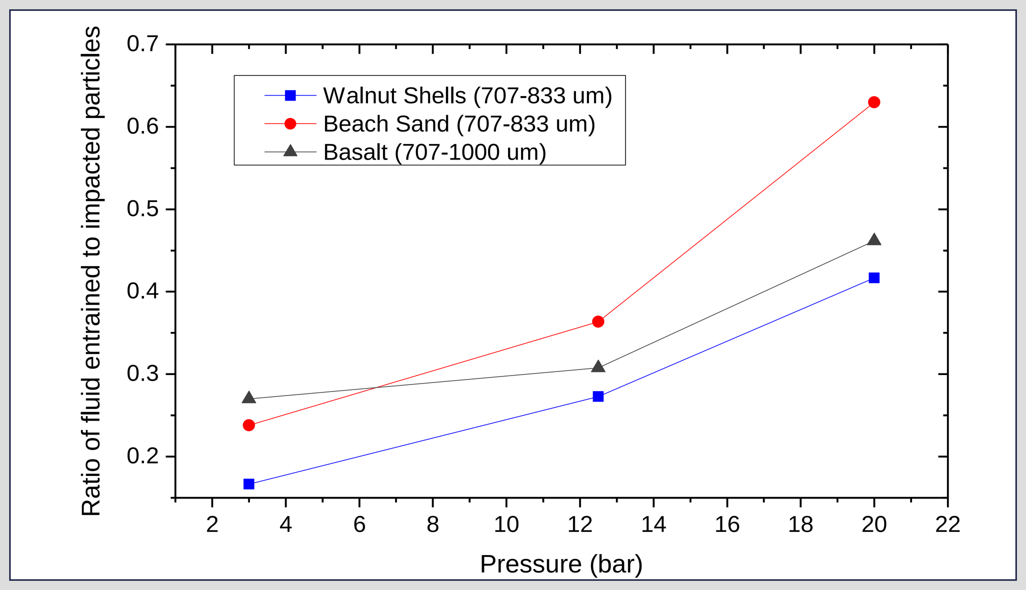


Impact entrainment: High-speed images of a sand grain (in purple) being entrained by an impacting saltating grain (in blue) at 20 bar. The time step between successive images is 14 ms. Grain diameter sieve range: 707-833 μm. Wind direction: right to left.

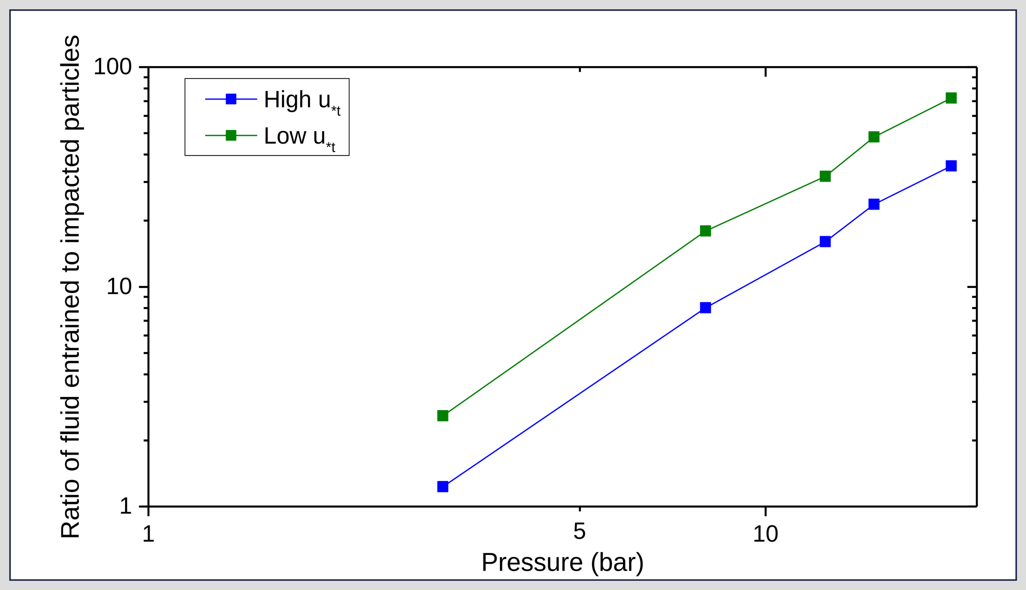
- Calculate the ratio of fluid-to-impact counts for each threshold experiment
- Compare the experimentally derived ratio with the same ratio derived from the COMSALT model

Results

- Fluid-to-impact ratio increases as a function of pressure for both the experimental and COMSALT results



Experimental Results: Ratio of grains entrained by fluid processes to grains entrained by impact processes as a function of pressure. Ratios are calculated from the summed fluid and impact counts for every experimental run for that bed composition and pressure.



COMSALT Model Results: Ratio of grains entrained by fluid processes to grains entrained by impact processes as a function of pressure. Model run for a bed composed of walnut shells (707-833 μm).

Discussion

- The trend of the experimental and COMSALT model results are consistent with the hypothesis that at lower air pressures, impact entrainment dominates and at higher air pressures, fluid entrainment dominates
- However, there is a distinct mismatch between the experimental and COMSALT model ratio results; up to two orders of magnitude greater in the COMSALT model
  - Observational bias in analyzing the high-speed video frames could be the source of this mismatch, as it is easier to detect impact than fluid entrainment
  - Other explanations for this mismatch are under discussion
- In the future, the high-speed videos for smaller grain sizes (down to 200 μm) will be analyzed

References

[1] Greeley R. and J.D. Iversen (1985) *Wind as a Geological Process.* [2] Lorenz, R. D., and J. R. Zimbelman (2014) *Dune Worlds.* [3] Bagnold, R. A. (1941) *The Physics of Blown Sand and Desert Dunes.* [4] Kok J.F. (2010) Geophys. Res. Lett. 37, L12202. [5] Kok J.F. et al. (2012) Reports Prog. Physics 75, 106901. [6] Burr D.M. et al. (2015) *Aeolian Res.* 18, 205-214.