Experimental and numerical study of Sharp's shadow zone hypothesis on sand ripples spacing and implication for Martian sand ripples.

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Introduction: Although many works have been done on sand transport by saltation and reptation, and on the formation of sand ripples, it is still unclear what mechanism determines the linear dependence of ripples dimension on wind speed [1]. We thoroughly studied the formation of normal ripples in a wind tunnel as a function of grains size and wind speed. A linear relationship between the wind shear velocity and the impact angle of saltating grains has been found for different grain sizes. This relationship can explain the increase in ripple wavelength with the shear velocity as was already suggested by Sharp [2] (see Fig.1).

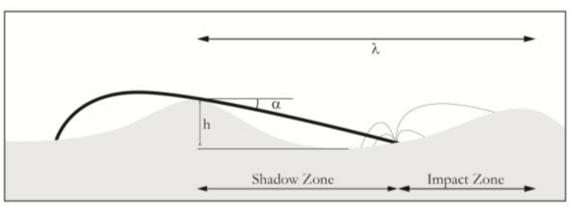

Figure 1. Scematic illustration of the Sharp's impact zone hypothesis. The impact angle of the saltation particle is denoted by α . The sadow zone is the region in the lee side of the ripple that is protected from the bomardemnt of the saltation particles.

In addition to the wind tunnel work we also studied the dependence of the impact angle on wind velocity both on Earth and Mars by numerical simulations with the steady state saltation model COMSALT [3]. COMSALT includes many of the advances of previous models, and in addition it includes: (1) a physically based parameterization of the splashing of surface particles that agrees with experimental and numerical studies [3], (2) a generalization of this splashing process to beds of mixed particle sizes, and (3) a detailed treatment of the influence of turbulence on particle trajectories, which agrees with laboratory measurements. Because of these and other advances, COMSALT is the first physically-based numerical saltation model to reproduce a wide range of experimental data. The model has also been used to show the formation the Basaltic sand ripples in Eagle crater [4].

Materials and Methdes: Quartz sand collected from the northwestern Negev dunefield (Israel) was used for the laboratory wind tunnel experiments on ripple morphology. The sand was taken in the sampling site in the northern Negev– Sekher (in southeren Israel) sands from the upper 10 cm of the sand dunes. Common sizes of the active (loose) sand in Sekher site are at the range of 100-400 µm with modes of 150-200 µm, which are typical of dune saltators. In order to explore the role of particle size in ripple morphology, the sand was segregated into different size fractions due to technical limitation to sieve specific size in natural sands. Three narrow size fractions were obtained using mechanical sieving: 142-200, 200-247, 247-300 µm. These fractions constituted 33.6%, 23.6%, and 12.4% of the bulk sample of Sekher sand, respectively. The aeolian experiments were conducted at the stationary boundary layer wind tunnel of the Aeolian Simulation Laboratory in Ben-Gurion University (BGU) described in [5]. The cross sectional area is 0.7×0.7 m and the working length is 7 m for measurements in the test section. The traps used for measuring the impact angle are shown and described in Fig. 2.

Results: Under high wind velocity conditions the impact angle is smaller, thus the shadow zone grows and the resulting wavelength increases. In addition, the impact angle increases with the grain diameter, thus for unimodal coarse sand, both amplitude and wavelength are small. The shadow zone mechanism is one of the mechanisms contributing to the linear increase of the ripple wavelength with wind speed. The main results of the wind tunnel experiments are shown in Fig.3 and Fig.4; the results of the numerical simulation of the impact angle under Mars conditions (for D=250 µm) is shown in Fig.5.

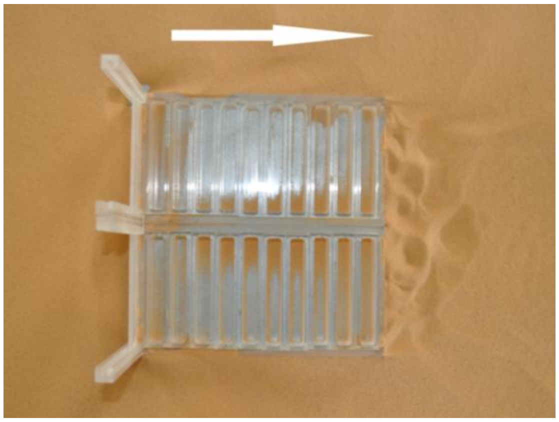

Figure 2: In order to retrieve the impact angle of the saltators, an array of horizontal traps was placed in the test section (the white arrow indicates wind direction). The array is comprised of 10 traps (a cross section of 10 × 1 cm of each). An obstacle at height of 2 cm above the sand bed was installed at the windward side of the array. The obstacle simulated a ripple element while the transported sand accumulated at the windward side to create a ripple slope. Thus the array allows the entering of saltating grains at uniform distances from the obstacle with an interval of 1 cm.

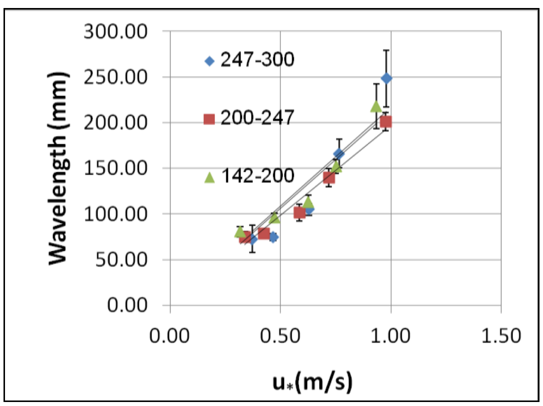

Figure 3. The linear growth of the wavelength with shear velocity is shown, in agreement with previous wind tunnel studies [6]. The largest wavelength was obtained for the fine grain fraction, but the difference between the fractions is quite small and statistically not significant.

Conclusions: Both experimental and numerical results show that the impact angle decreases with the shear velocity as predicted by Sharp [1]. The results also show that the impact angle decreases with the grain diameter in agreement with previous studies [7]. The decrease of the impact angle with the wind speed can explain the linear relation between wavelength and wind speed. For faster winds the impact angle will be shallower and longer wavelength bedforms result. The same behavior was numerically found for Mars (Fig. 5), thus we predict that the linear increase in the wavelength with wind velocity exists also for martian sand ripples. Further study is needed to understand the role of turbulence in ripples formation.

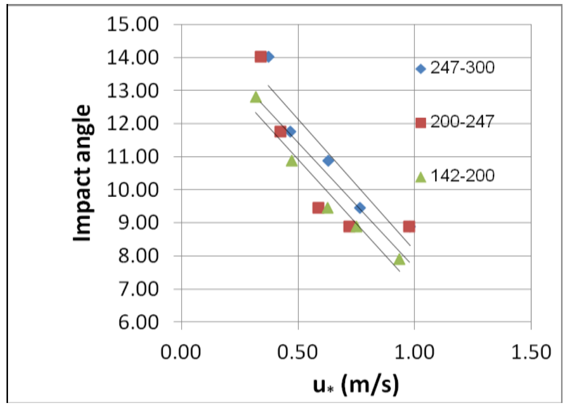

Figure 4: The impact angle of the saltation grains as function of the shear velocity for the three size fractions. The stronger the wind, the smaller is the impact angle, whereas it decreases with the grain diameter as expected by physical consideration of the saltation trajectories.

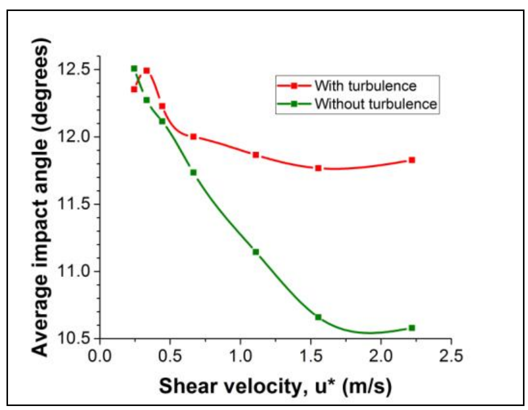

Figure 5: COMSALT simulations of the average impact angle on Mars as a function of the shear velocity with and without turbulence (for D=250 µm).

References:

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