AEOLIAN SALTATION ON MARS AT LOW WIND SPEEDS. R. Sullivan[1] and J. F. Kok[2], [1]CCAPS, 308 Space Sciences, Cornell University, Ithaca, NY 14853 rjs33@cornell.edu, [2]UCLA Atmospheric and Oceanic Sciences, Box 951565, Los Angeles, CA, 90095.

Introduction: Experiments modeling the wind strength required to move ripples and dunes on Mars indicate the fluid threshold friction speed, u_{*tf}, to initiate fully developed saltation is an order of magnitude higher on Mars than on Earth [1,2]. An important discrepancy exists between Mars climate models that do not predict winds this strong, and observations that sand-sized particles are indeed moving [e.g., 3-13]. Mitigations, including invoking wind friction speeds between u_{*tf} and the grain impact threshold, u_{*ti}, to accomplish most bedform migration, still require relatively high u_{*tf} values to initiate sand grain movements [14-15]. Evidence for widespread mobilization of sand on Mars raises the question: Must each new instance of sand movement begin with u_* exceeding the u_{*tf} values indicated from wind tunnel experiments? If so, very high wind speeds, even if only in short-lived turbulence, would have to occur regularly at numerous locations on the martian surface. While this might be possible, could there be circumstances in which saltation is initiated with less wind energy? This work utilizes numerical experiments and rover observations to describe and constrain how lower wind friction speeds, between u_{*ti} and u_{*tf}, can both initiate and sustain low flux saltation on Mars.

Previous wind tunnel experiments with slowly increasing u_* typically show some grains in irregular creep or participating in occasional low bounces at wind energies below where most other grains are set into motion, so that initiation of particle motion is gradational for u_* around the value of u_{*tf} [e.g., 16-19]. There are at least three reasons for this. (1) Small variations in grain size and shape in even well-sorted sands can introduce variations in susceptibility to entrainment. (2) Turbulent eddies cause short-term fluctuations of the wind stress at the surface. (3) Even the smoothest test beds of well-sorted sand are very rough on the scale of a sand grain, so provide numerous locations where individual grains are either more exposed than average or less exposed to direct fluid drag from the boundary-layer, and/or are oriented more favorably or less favorably for dislodgement. This bed roughness is inherited from high-speed grain impacts from the most recent saltation to affect the surface [16].

Grains moving sporadically at wind speeds below u_{*tf} as a consequence of natural bed roughness and other factors is a phenomenon likely to be more common on natural surfaces compared with wind tunnel test beds due to (1) surface relief of ripples and drifts that is orders of magnitude greater than the irregularities of a wind tunnel test bed, (2) natural atmospheric boundary layer turbulence of larger scale and magnitude than can be replicated within the confines of a wind tunnel, and (3) exposure of natural surfaces to different wind azimuths, putting surface environments evolved from winds of one azimuth out of equilibrium with subsequent winds from a different azimuth..

Numerical experiments utilizing the program GrainWind.c indicate a continuum of grain behaviors as a function of u_*, when grains are launched with sufficient energy to rise only 10 grain diameters, analogous to the kind of low-energy grain movements observed sporadically at $u_* < u_{*tf}$ in wind tunnel experiments. Sand grains on Mars (or Earth) mobilized occasionally at $u_* < u_{*ti}$ will bounce downwind for a short distance but will not achieve sustained saltation. But at higher friction speeds $u_{*ti} < u_* < u_{*tf}$, grains sporadically mobilized on Mars will develop, over fetch lengths longer than generally available within low-pressure wind tunnels, self-sustaining saltation trajectories. These trajectories will have impact energies that surpass impact energies of similarly-sized grains in saltation clouds on Earth, therefore will be capable of splashing grains at each bounce and contributing to impact-related bedform migration (Fig. 1). This type of low flux saltation, which could involve bursts of many grains sourced initially from the same exposed area by a passing turbulent eddy (the subsequent effect referred to here informally as a saltation cluster) represents a localized, low-flux phenomenon that is consistent with aspects of experiments between u_{*ti} and u_{*tf} on Earth first performed by Bagnold [16-17]. Saltation clusters on Mars should produce cumulatively slow changes to aeolian bedforms over long periods in which winds remain close to u_{*ti}, and never or rarely reach u_{*tf}.

Impact ripples on Earth reorient in minutes to changing winds blowing typically with $u_* \geq u_{*tf}$. But impact ripples on Mars migrating incrementally from the cumulative effects of numerous saltation clusters at wind friction speeds closer to u_{*ti} are predicted to reorient very slowly due to overall low fluxes, increasing the chances that reorientation will be incomplete before the next wind direction change. This effect, coupled with flatter grain trajectories leading to increased shielding from even minor relief (including from other bedforms at different orientations) should enable fields of impact ripples on Mars to display multiple orientations in close proximity where exposure to multiple wind azimuths is possible.

Field evidence from impact ripples of very fine sand at Meridiani Planum and at Gale crater is generally consistent with bedform migration involving saltation clusters at low friction speeds much closer to u_{*ti} than u_{*tf}, and without obvious evidence for events $\geq u_{*tf}$. The alternative of requiring relatively high u_{*tf} values to initiate sand grain movements is problematic for relatively short deposits of very fine sand with fresh-appearing impact ripples that have been observed along rover traverses. These sand deposits should undergo erosion through short-term suspension when winds $u_* \geq u_{*tf}$ occur, with very little chance for saltation morphologies such as impact ripples to become reestablished during waning winds $u_{*ti} < u_* < u_{*tf}$ afterward (according to previous $u_{*ti} < u_* < u_{*tf}$ wind tunnel experiments [16-17]). The characteristics of these sand deposits imply that recent wind conditions affecting the landscapes in which they are found have rarely experienced winds exceeding u_{*tf}. This is consistent with limited in situ wind measurement records from landers and rovers [20-23].

Some of the key elements of the low-flux saltation processes described here are based on previous observations in terrestrial environment wind tunnels at $u_{*ti} < u_* < u_{*tf}$. Analogous processes probably occur in terrestrial field settings, but should be difficult to notice because they are overwhelmed by the effects on saltation flux from full-scale boundary-layer turbulent fluctuations that can easily span the narrow range between terrestrial impact and fluid thresholds. On Mars, however, three differences should increase the relative contribution of low-flux processes, and potentially make their effects more noticeable: (1) Mars has a much larger range between u_{*ti} and u_{*tf} in which these processes can operate; (2) winds are closer to u_{*ti} most of the time, apparently only rarely reaching u_{*tf}, therefore greatly reducing competitive effects from saltation styles requiring u_* to reach u_{*tf} (even if only to be initiated); and (3) saltating grains, once mobilized, travel at relatively high speeds on Mars, even in winds closer to u_{*ti} than u_{*tf}, leading to flatter trajectories and impact energies exceeding those within terrestrial saltation clouds (that obviously advance bedforms downwind). Overall, the potential utility of the grain mobility processes presented here is that they can operate entirely at more common winds well below u_{*tf}, and so help explain widespread sand movements observed on Mars, particularly wherever evidence might be mostly absent for u_{*tf} being exceeded.

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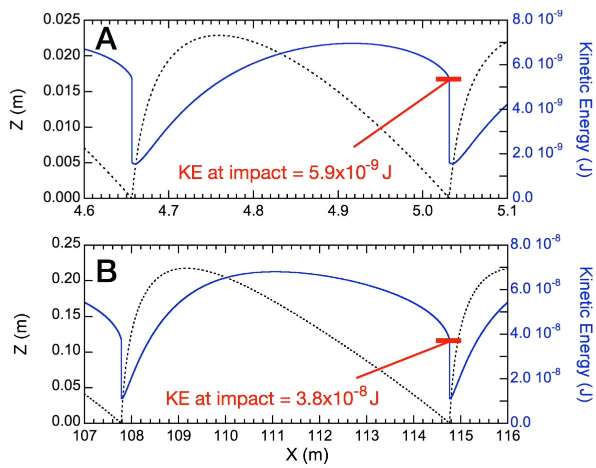

Figure 1. (A) Earth $u_* = 0.3$ m/s saltation cloud profile driving a 100 µm quartz grain along cohesionless sand with bounce coefficient 0.55 and bounce angle 50°. On Earth, these conditions are $u_* > u_{*tf}$. (B) Mars $u_* = 0.5$ m/s log-law wind profile driving 100 µm mafic grain along a cohesionless sand bed with bounce coefficient 0.55 and bounce angle 50°. On Mars, these conditions are $u_{*ti} < u_* < u_{*tf}$. Comparing (A-B), kinetic energy (blue) along representative grain trajectories (dotted) shows higher KE at impacts on Mars indicating sufficient energy at $u_{*ti} < u_* < u_{*tf}$ to splash grains, contribute to bedform migration, and propagate saltation. Note longer hop length in (B).