Evaluating Wind Strengths Required to Mobilize Martian Coarse-Grained Ripples: Gusev, Meridiani Planum, and Gale

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1. What This is About

All three Mars rover missions have encountered coarse-grained ripples (aka "megaripples" a term used here for brevity) [1-5] which are large bedforms with surface grains too coarse to saltate, but with finer-grained interiors [e.g., 6]. Megaripple surfaces on Mars are indurated, indicating mobilization is rare and unlikely to be measurable during brief rover encounters. Alternatively, we propose a method to estimate wind conditions prevailing when megaripples were last active. We evaluate the method against a terrestrial field experiment [3], then apply the method to megaripples at Gusev, Meridiani Planum, and Gale.

2. Method

Our fieldwork and wind tunnel experiments [7] indicate that moving the largest grains downwind in creep occurs only when one of the coarsest grains available from the saltating population strikes an optimal location on the target grain. From this, our approach is to assume all kinetic energy from a "coarse-tail" saltating grain is converted to energy just sufficient to move the larger target grain from its resting place socket. One form of our derived relationship is:

$$v = \frac{(M+m)}{2m} R \sqrt{\frac{2g}{R - \frac{1}{4}h}}$$

where v is incoming velocity for a saltating grain of mass m needed to move a resting, larger target grain with mass M and radius R to a height h posed by an obstacle in front of it. The value of h depends on several factors. For simplicity, we adopt an idealized 2D scenario of identical spherical target grains, the target grain M cradled by other M grains yielding h=0.134R and a potential escape angle ~30° from horizontal. The indicated saltating grain impact speed v from eq. (1) is then compared with grain impact speeds from a library of numerical saltation trajectory experiments (section 3) to identify the particular wind+grain combination that delivers saltating grains m with desired grain impact speed v, thereby identifying conditions prevailing when the megaripple was last mobilized (section 4).

3. Impact Speeds

…are *convex-down* curves in the graph. Each point along each *convex-down* curve is an average grain impact speed for a specific grain size in a numerical experiment using Grainwindbounce.c [8]. **Dark green curves** are grain impact speeds for Mars wind friction speeds u_* = 0.5, 1.0, 1.5, 2.0 m/s for basaltic density grains saltating along hard ground (bounce coefficient of 0.8). **Light blue curve** plots grain impact speeds corresponding to the White Sands, NM field experiment of Jerolmack et al. [3]: u_* = 0.41 m/s for gypsum density grains saltating along a loose bed of similar grains, therefore with a bounce coefficient of 0.55 [e.g., 9].

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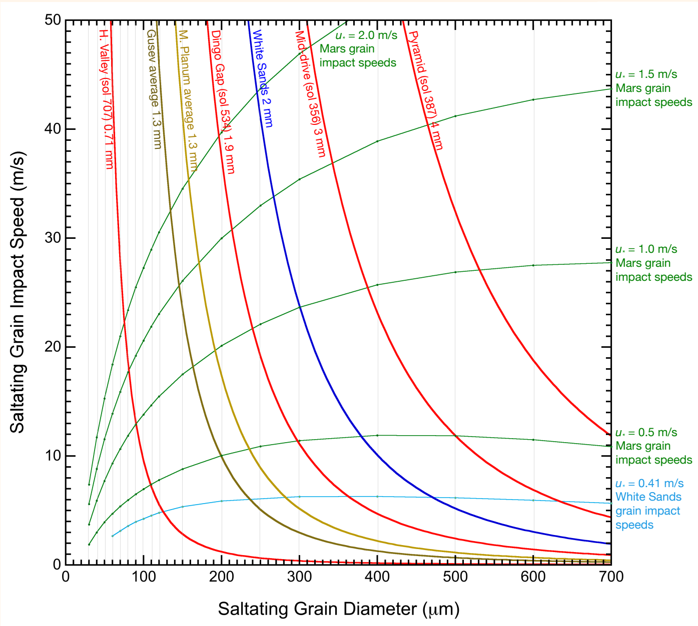
4. Results

The graph below shows how saltation impact speeds (convex-*down* curves, section 3) can be combined with eq. (1) (convex-*up* curves, section 2) to determine wind conditions prevailing when megaripples were last mobilized. (On Mars, this is not the same as "future reactivation" which would require additional saltation energies to overcome surface induration.) Mars grain size measurements are from [10, 11] or measured by the authors from MI, MAHLI, and Mastcam images obtained by the Mars Exploration Rover and Mars Science Laboratory vehicles at Gusev, Meridiani Planum, and Gale.



White Sands, NM. The proposed method was compared against parameters specified by the field experiment of Jerolmack et al. [3] involving megaripples at White Sands, NM: target grain ~2 mm; u_*=0.41 m/s; z_0=0.0001 m; saltating grain and target grain densities ρ=2380 and 2630 kg/m^3, respectively. Figure 1 shows the results, where the pale blue curve of grain impact speeds exceeds the deep blue curve of eq. (1), predicting that an impacting grain ≥0.5 mm was required under the measured wind conditions. This size is consistent with the coarse tail of the saltating population measured by Jerolmack et al. (see Fig. 10 in [3]).

Gale crater. Grain size-frequencies of megaripple surfaces, megaripple interiors, and other sandy deposits show more variation at Gale crater (**four red curves** in the central graph), explored by MSL, than at the two MER sites. This might be due to the significant influence of fluvial processes affecting Gale crater floor deposits in the past, providing a diversity of source grain sizes for aeolian reworking. Four representative examples are shown here, to illustrate this diversity.

Dingo Gap megaripple (sol 534) at Gale crater was last mobilized with stronger winds and/or coarser saltating grains than the MER features.

The **sol 356 mid-drive** and **sol 387 Pyramid megaripples** are but two examples of many encountered at Gale that have crests with surface grains 3-9 mm, implying the availability in the past of correspondingly coarser saltating grains (and wind events strong enough to drive them) when last mobilized. Chain reactions that mobilized a downwind succession of increasing grain sizes during a given wind event might have been involved. For example, ~0.6 mm grains (slightly finer than those of the Hidden Valley ripples), if impacted by 0.2 mm grains driven by u_* = 1.0 m/s winds, would receive far more energy than required to simply rotate downwind out of their sockets; numerical experiments suggest ejection speeds would be enough for 0.6 mm grains to increase hop size into sustained saltation, which could then drive 4 mm grains in creep.

Hidden Valley (sol 707) bedforms at Gale crater, which were impassable to MSL, could have been last activated by only modest winds with u_* ≤1 m/s driving relatively fine ~0.1 mm sand as found commonly in drifts among outcrops along MSL's traverse. If the strongest wind events are the most rare, the Hidden Valley megaripples, with relatively small ~0.7 mm surface grains, might have been mobilized more recently than other megaripples at Gale with coarser surface grains; perhaps allowing less induration to develop.

Gusev crater and **Meridiani Planum**. Dominant megaripple surface grain sizes are ~1.0-1.8 mm [10, 11]. Megaripple interior materials are poorly sorted, <0.3 mm. Saltating grains from the coarse tail of this size-frequency, 0.15-0.2 mm, could have last mobilized Gusev megaripples with wind friction speed u_*=1 m/s (wind speeds ~20-35 m/s at height of 1 m). Meridiani Planum megaripples were last mobilized by somewhat stronger winds or by coarser saltating grains, if target grains are assumed to have hematite density.