GRANULE RIPPLES ON EARTH AND MARS: DOCUMENTED MOVEMENT AT GREAT SAND DUNES NATIONAL PARK, AND IMPLICATIONS FOR GRANULE MOVEMENT ON MARS.

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Introduction: We have been investigating ripples and dunes of diverse scales throughout the western United States [1-5], for comparison with the numerous aeolian features revealed in recent data from Mars [6-9]. Recently we were able to document the movement of granule ripples at Great Sand Dunes National Park and Preserve (GSDNP) in southern Colorado, and compare that movement to wind records from nearby Alamosa airport. These new data have implications for coarse particulate transport on both Earth and Mars, such as the granule ripples observed by both Spirit and Opportunity rovers.

Granule Ripples: Granule ripples typically are sand-cored but coated with a layer of granules (particles 1 to 2 mm in diameter) [e.g., 10]. Large granule ripples are abundant at GSDNP, where 1-2 mm granules from nearby Medano Creek are transported northeastward by the wind to collect along the southwestern margin of the main dune mass. We have tried to document the movement of granule ripples at GSDNP for several years; last LPSC we reported the first minimum movement length for granule ripples [5]. We visited GSDNP in September of 2006 during a time of prolonged strong winds, conditions that complicated fieldwork but provided the opportunity to document granule ripple movement in real time. Several granule ripple crests were flagged at 11 am on September 15, and in less than two hours the granule ripples had moved perceptibly (Fig. 1). We returned to the flagged ripple crest locality at 10 am on September 16, where the flags in small ripples (like that in Fig. 1) were blown out but flags in larger ripples showed pronounced movement (Fig. 2). On the 15th we obtained a detailed topographic transect across some of the largest ripples at the location where the crests were flagged (Fig. 3), consistent with similar profiles we have collected for granule ripples throughout the western U.S. [1-5]. The topography of the granule ripples obtained from this survey was used to calculate ripple shapes based on the ripple height measured or estimated for some of the flagged granule ripples. Here we report results for two of the best documented flagged ripples (those shown in Figs. 1 and 2). Using a lee slope of 7° for the granule ripples, the 3-cm-high ripple in Fig. 1 indicates that

Figure 1. Oblique view of granule ripple showing 2.1 cm movement (to left) in 109 minutes since flag was placed on the crest. Wind intensity had ripped flag material, which is 6.7 cm tall. JRZ photo, 9/15/06.

Figure 2. Oblique view of granule ripple showing 10.5 cm movement (to right) in 1380 minutes since flag was inserted on crest. Flag material is 6.7 cm tall. JRZ photo, 9/16/06.

52.1 cm^3 (per cm crest length) of granules were transported across the crest in 109 minutes. A similar calculation for the 10-cm-high ripple in Fig. 2 indicates that 848.8 cm^3 (per cm crest length) of granules were transported across the crest in 1380 minutes. We then obtained two-minute-average wind data from the National Climatic Data Center (NCDC) measured at the Alamosa airport, 56 km (35 mi) SSW of GSDNP (Fig. 4). Impact of saltating sand induces

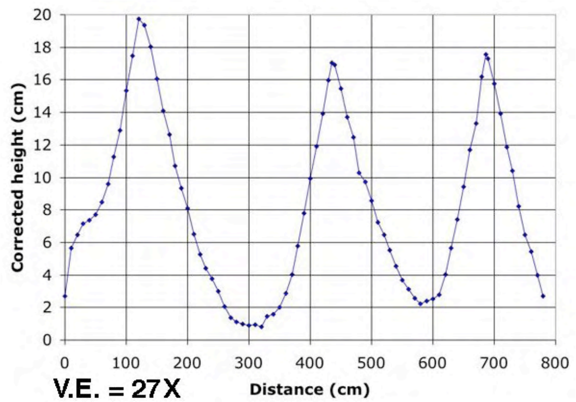

Figure 3. Surveyed profile across three granule ripples near flagged ripples. A local slope of 1° has been removed. Wind was coming from the left.

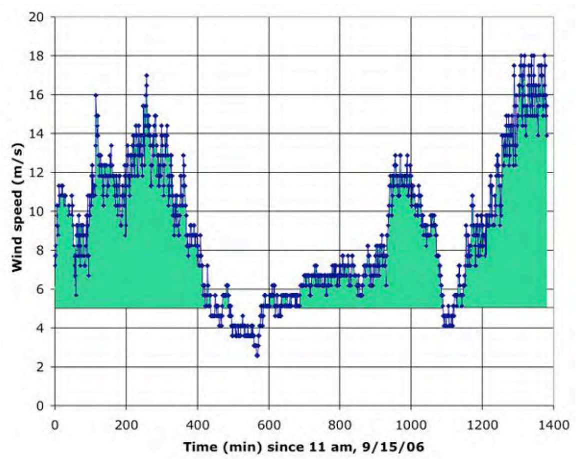

Figure 4. Two-minute-average wind speed, Alamosa airport (from NCDC). Plot starts when flags were placed on ripple crests. Green indicates wind above sand saltation threshold (5 m/s). Compare to Fig. 5.

creep of the granule particles [10], and the flux of windblown sand is directly proportional to the cube of both the wind shear velocity and the wind speed [11, 12]. Temporal integration of the transport rate, scaled with the cube of velocity above the threshold of motion for sand (~5 m/s), predicts that the volume of sediment moved by time 2 should be 16.7 times the volume moved by time 1 (Fig. 5). This agrees well with our observation that the volume of granules moved by time 2 (Fig. 2) is 16.3 times the volume moved by time 1 (Fig. 1). The cumulative estimated sand flux indicates that, on average, sustained wind just above threshold should move 5.1 (1-mm-size) granules per hour across each cm of ripple crest length, and stronger wind would give a higher flux scaled by the cube of the wind speed above threshold.

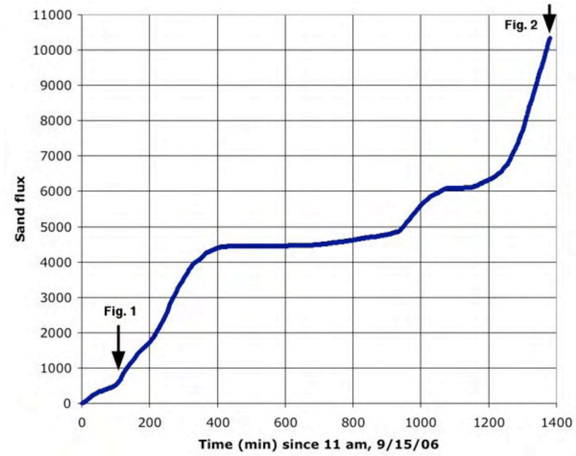

Figure 5. Sand flux scaled to cube of wind velocity, relative to the flux for wind speed just above threshold. Arrows show photo times (Figs. 1 & 2).

Granule Ripples on Mars: Saltating sand flux is not only proportional to the cube of wind speed, it is also directly proportional to the atmospheric density and inversely proportional to the acceleration of gravity [11, 12]. Using values appropriate for both Earth and Mars [13], the sand flux just above threshold on Mars should be 3.8% of the flux just above threshold on Earth. Our estimated rate of granule movement at GSDNP then translates to an estimate of 0.19 (1-mm-diameter) granules/hr per cm of crest length for winds just above threshold on Mars (at 0 km elevation). Models provide indications of what the surface winds on Mars should be under various climatic conditions [14, 15]; both models and lander observations suggest that the threshold speed is rarely exceeded on Mars under present conditions. Thus, the granule ripples observed by the rovers required very large time intervals for their formation.

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