GRAND FALLS DUNE FIELD – SEDIMENT FLUX MEASUREMENT AND ANALYSIS AT A MARS ANALOG SITE.
T. N. Titus[1], R. K. Hayward[1], and R. Bogle[1], [1]U.S. Geological Survey, Astrogeology Science Center (2255 N. Gemini Dr., Flagstaff, AZ 86001, ttitus@usgs.gov).

Introduction: The modern surface of Mars is modified by interactions with the atmosphere through polar and aeolian processes. This abstract focuses on aeolian processes, specifically the characterization of sediment flux and what lessons are to be learned from terrestrial analogs. One such analog site is the Grand Falls (GF) dune field.

Analog Site: The GF dune field (~1.6 km x 1 km) is located ~70 km NE of Flagstaff, AZ, and just north of the Little Colorado River (LCR). The dunes at GF are in a local topographic minimum, migrating toward higher ground that will impede their progress. This setting is analogous to the setting of an estimated 1000 dune fields on Mars that occur within craters and valleys [1]. A more detailed description of the analog site can be found in Bogle et al. [2]. Most of the dune sand on Mars is likely of basaltic composition [e.g., 3]. Basalt sand is also present in significant amounts at GF, allowing us to observe its behavior under various atmospheric conditions. Bimodal grain size is another sand characteristic common to both GF and Mars [e.g., 4].

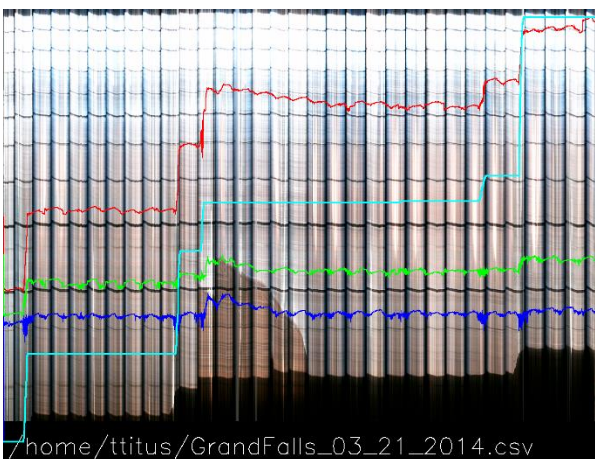

Figure 1: A composite figure showing data from five instruments: the weighing BSNEs (red, green, blue), the saltation sensor (cyan) and the high-volume capacity imaging Mars BSNE (background image). The x-axis is time while the y-axis is a normalized amount of sediment collected or detected. The regions of the background image that are black correspond to the times and volume of sediment collected. The region that is brown indicates times and volume of precipitation collected. The lighter colors indicate the part of the BSNE where the pan is empty.

Instruments: Instrumentation included sediment catchers (weighting Big Springs Number Eight or BSNEs) and an experimental high volume capacity image BSNE, informally called the Mars BSNE), anemometers, and a saltation sensor. A more detailed description can be found in [5]. The weighing BSNEs have a calibration coefficient of 0.162 kg/V.

High Sediment Flux Daytime Events: We will focus on just a few of the several high sediment flux daytime events that occurred in February/March of 2014 (see Fig. 1). The larger of these events are shown in Table 1.

Scale Heights: For the purposes of these large events, a single scale height is used, denoted as z_0. The scale height is calculated using equation 1.

[1] $\dot{q}(z) = \frac{m}{At\varepsilon} = \sigma e^{-z/z_o}$; where $\dot{q}$ is the sediment horizontal mass flux, m is the mass collected in the BSNEs, A is the cross-sectional area for the opening, t is the sampling time, ε is the collection efficiency, usually assumed to be 0.4 [6], σ is the effective mass flux at one scale height and z is the height of the BSNEs.

Horizontal Mass Transport (HMT): The total sediment flux can be estimated as either a rate (mass/horizontal length/time) or as the total amount (mass/horizontal length) over the duration of the event. HMT is calculated using equation 2 [7]:

[2] $HMT = \int_0^\infty \dot{q}\, dz = \sigma z_o$

Particle Mass Estimate: Once a scale height, z_o has been determined, the Sensit™ particle count can be used to estimate the effective particle mass, m_p.

[3] $m_p = \frac{\dot{q}(z_s)}{\dot{n}/A} = \frac{\sigma e^{-z_s/z_o}}{\dot{n}/A}$ where z_s is the height of the saltation sensor, n is the particle count rate, and A is the cross-sectional area of the sensor.

Sediment Volume: The Mars BSNE provided an independent characterization of sediment flux. It provided an independent validation of extremely high volume sediment flux events and served as a "rain gauge." In Fig. 1, evidence of collected water can be seen as dark brown shading.

Daytime Results: The results are shown in Table 1. The sediment events typically occurred during daytime hours lasting between 5-9 hours. The amount of sediment transported usually ranged between 100 and 300 Metric Tons per meter (MT/m). The Mars BSNE collected sediment during each event (see Fig. 2) but the uncertainties for small amounts of sediment (less than

50 cc) are large. The value of the Mars BSNE was greatest for extreme events, such as the one discussed next.

Nighttime Storm: Perhaps one of the most surprising events observed occurred during the nighttime hours. Unfortunately, several of the instruments were not collecting data during this event, due to prior wire damage. During the event weighing BSNEs were completely packed, so that bulk sediment could not be used as an accurate estimate. Fortunately, the Mars BSNE had a high-volume capacity and images acquired from inside the Mars BSNE provided quantifiable data. When combined with the saltation sensor data and estimates for scale height from previous large storms, a reasonable estimate of the size of this nighttime sediment flux event can be calculated.

By assuming a flux scale height of 0.3 m, we can estimate the total HMT was ~4,500 MT/m over a period of 16 hours. The majority of sediment flux occurred at night as can be seen in the images from the Mars BSNE (Fig. 2).

Summary: The data, analysis, and results presented here are just a sampling of the Grand Falls dune field dataset. Hundreds-to-thousands of metric tons per meter were transported during major sediment flux events that usually lasted 5-9 hours, with the longest being 16 hours. While most recorded sediment transport at the site occurred during daylight hours, the largest event, most likely due to a major weather front from the north, occurred at night.

Acknowledgements: This project was funded through a NASA MMAMA grant (award number NNH13AV78I) to investigate sediment flux at the Mars analog site GF and to test a modified sediment sampler for possible use on Mars. We are grateful to the Navajo Nation for allowing us to conduct this experiment on their tribal lands. This project has benefitted greatly from the efforts of John Vogel and Margaret Hiza Redsteer.

References: [1] Hayward, R. K., Fenton, L. K., Titus, T. N., 2014, Icarus, 230, 38-46. [2] Bogle et al., 2015, Geomorphology, 228, p. 41. [3] Herkenhoff and Vasavada, 1999, J. Geophys. Res., 104, 16487. [4] Sullivan et al., 2008, J. Geophys. Res., 113, E06S07. [5] Hayward et al., 2017, This workshop. [6] Goossens and Offer, 2000, Atmos. Envir., 34, 1043-1057. [7] Mendez et al. 2011, Geomorphology, 129, 43-48.

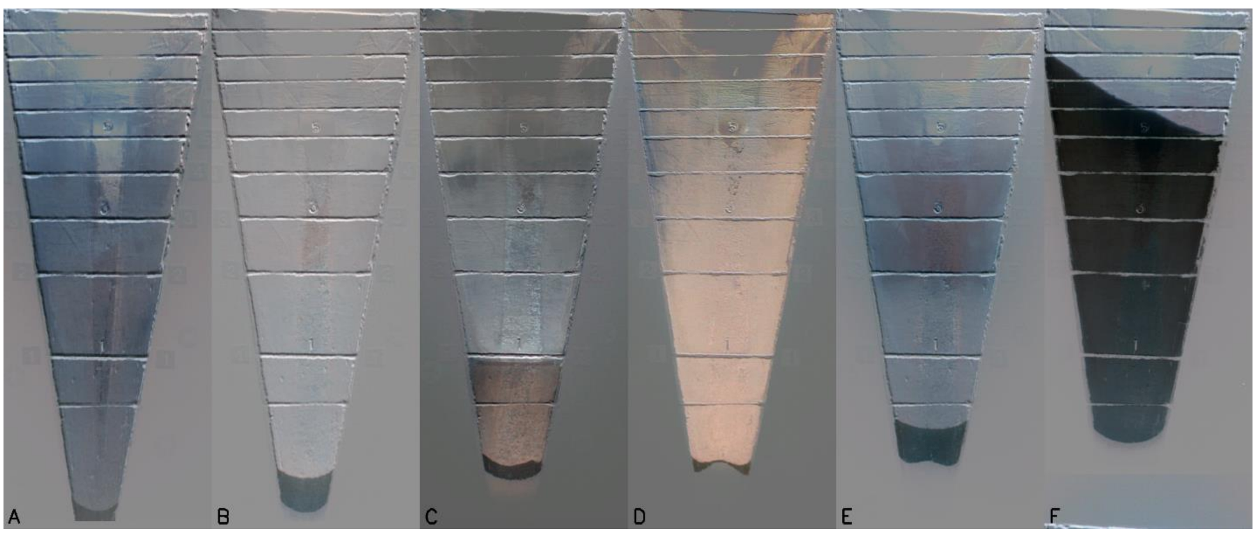

Figure 2: Volume results from the Mars Experimental BSNE. The images are the difference between an image acquired just prior to a sediment flux event and an image acquired after the event. The lines indicate volume from bottom to top: 50 cc, 100 cc, 200 cc, 300 cc, etc. (A) (B) (C) Precipitation (D) (E) (F) Large nighttime event.

Table 1: Characterization of six sediment flux events.

Date	Time	Scale Ht (m)	HMT (kg/m/s)	Duration (Hrs)	HMT (MT/m)	Volume (cc)	Fig.2 Panel	Comments:
2/19/2014	12:23	0.375963	12.0886	5.1	221.947	3.30618	A	
2/27/2014	11:50	0.280776	6.97264	5.83333	146.426	13.1769	B	
2/28/2014	14:11	0.793692	9.63397	8.76667	304.048	8.91802	C	
3/15/2014	8:39	0.150249	3.51818	9.06667	114.833	< 1	D	Precipitation occurred.
3/17/2014	11:28	0.289114	6.32625	6.1	138.925	29.2115	E	
3/28/2016	11:15	0.3 (Assumed)	77.834	16.2167	4543.95	615.584	F	1 BSNE was operating.