SEDIMENT FLUX FROM DUST DEVILS ON MARS – INITIAL CALCULATIONS.  S. M. Metzger1, J.R. Carr2, J.R. Johnson3, M. Lemmon3, and T.J. Parker12Geology Dept, Univ. NV Reno, 89557, metzger@scs.unr.edu, 2USGS Flagstaff, AZ 3LPL, Univ AZ 4JPL, Pasadena, CA

INTRODUCTION  It is entirely possible that dust devils play a major role in the rapid delivery of fine particulate into the Martian planetary boundary layer and are a likely trigger for the planet-encircling dust storms to which Mars is subject [1]. The wind-blown transport of fine-grained particulate material is the dominant evident geomorphic process currently at work on Mars [2]. Airborne dust on Mars has a mean radius of 1.6 µm ± 0.15 µm [3], [4]. Given the low air pressure at the Martian surface (6 - 12 mbar), high wind speeds are required to loft dust (defined in [5] as particulates < 25 µm) on Mars via turbulent wind shear (2 m/s surface friction shear velocity [6], also ≥ 30 m/s measured approximately 1.5 m above the surface [5]). The Martian dust cycle has significant relevance to that planet’s current and past climates because airborne dust alters atmospheric thermal structure and circulation dynamics [1]. The presence of dust also complicates remote sensing efforts by obscuring the spectral signatures of underlying rock surfaces [7], [8]. Furthermore, dust and the mechanisms that loft it from the surface link the surficial geology and its interaction with the atmosphere.

Entrainment threshold shear velocity was rarely exceeded during the three Mars years of Viking Lander 1 operation [9]. Time-averaged threshold speeds resulting from turbulent shear were never approached in Ares Vallis as witnessed by the Mars Pathfinder lander (MPF) which operated during the late Martian summer (beginning L 1, 145°) when general circulation models (GCMs) correctly predicted the regional winds to be gentle [10]. Maximum wind speed recorded by MPF was 12 m/s (at a mast height of 112 cm), although midday wind velocities averaged below 5 m/s [10], [11]. Both the Viking lander and MPF cameras witnessed considerable airborne dust loading but not the means by which it had developed.

Dust devils are localized vorical air columns which form after solar heating creates an unstable layer of hot ground-level air that generates buoyant thermal plumes [12], especially when gust-wake eddies impart spin to the plume. Large thermal gradients develop in the Martian lower boundary layer during the day. The Pathfinder profiling meteorology mast (ASI-Met) revealed that daytime surface temperatures reached 17°C, but were concurrently -7°C at 1.5 m above that ground surface [11]. Twenty thermal vortex “pressure events” were detected crossing the lander. These vortices may not have had sufficient erosive power to become true dust devils, although one such event resulted in a momentary 1.5% drop in solar power panel output to suggest that it was indeed dust-charged [11]. Assuming the occurrence of such vortices to be a Poisson distribution, we consider that any given m² of landscape around the lander has ≤ 50% probability daily (within a factor of 2) of being crossed by a well structured thermal vortex.

APPROACH AND METHODS For this study, we assumed that airborne dust materials on Mars consist of reddish minerals, primarily secondary oxides and oxyhydroxides of iron derived through weathering, having a relatively high reflectance at 670 nm and poor reflectance at 440 nm [10]. The ubiquitous haze is a result of scattering by small, non-spherical particles with high efficiency reflectance in red wavelengths and low reflectance in blue wavelengths. An increased concentration of dust, as in a localized dust devil plume, blocks both background red and blue light from traveling toward the IMP camera. Whereas sunlight illuminating the dust column effectively scatters red wavelengths toward the camera and replaces much of the lost background red light, the dust’s poor reflective efficiency in blue wavelengths does not substantially replace the background blue light blocked by the column. Therefore an occultation feature is produced in the blue image. We proposed that simple subtraction of a 440 nm image (visible blue) from a 670 nm image (visible red) would emphasize local concentrations of airborne dust, as was the case for “proof-of-concept” trials conducted on terrestrial dust devil images prior to MPF launch.

However, due to the significant dust loading that generates the Martian haze, the resulting Red-minus-Blue IMP image product still suffers from a low plume-to-haze signal ratio. Subtracting a similarly generated “sky flat” from the “subject image” area of interest rectifies this. The sky flats were chosen from Red-Blue image sets within the same pan as the other target images but which had essentially no landscape. These sky flats thus provided the means to separate out the spectral contributions of the ubiquitous dust haze. Once the sky flats were subtracted from a target image set, any existent plume would stand out as a few intensity levels above a now neutralized (= black) sky.

We used raw images from the Gallery Pan [10] because (a) it included relatively low compression
(6:1) data, (b) taken in the necessary wavelengths (440, 530, 640 nm), (c) at the appropriate mid-day period of thermal activity. This experiment identified several features in Pathfinder imagery that morphologically resemble dust devils [13]. One feature was found in IMP sequence 164 (MPF Sol 10 at 11:31 LST) and at least five features were found in IMP sequence 165 (Sol 11 beginning at 12:12 LST).

**RESULTS AND CONCLUSIONS**

To date, at least five dust plume features have been identified in 16 IMP camera images as dust devil vortices. All have been found in portions of the Gallery Panorama sequence [10]. Once so identified, monochromatic processing of 440 nm images highlights dust devils as distinct occultation features against the horizon. Given interpreted geographic locations relative to the lander, the dust devils are 14 to 79m wide, 46 to over 350 m in height, and travel over ground at 0.5 to 4.6 m/s. Large terrestrial dust devils often have the same shape of base as the feature traveling up the west flank of Big Crater; a broad truncated inverted cone with a sand ejecta skirt base and a central column extending upward. The interpretation of a sand ejecta skirt is the only indication that any of these vortices may contain particles larger than the 1.6 μm material in the general dust haze.

At 0.5 deg above the horizon (high enough to be immune to edge effects), the dust devil on the flank of South Twin Peak has a contrast of -4% in the blue filter; the dust devil west of Big Crater has a contrast of -3%. In order to determine a dust loading within the dust devil, we constructed a Monte Carlo scattering model with the capability for horizontal and vertical inhomogeneities. The atmosphere was set to the dust loading observed by [14] with the dust phase functions assumed to be those of [15]. The phase functions were measured for sol 14, but are not expected to show significant variation within a few sols, and they are appropriate for scattering by small, irregular dust grains. We modeled the dust devil as a 1km X 1 km X 10 km box and compare the brightness near the horizon at the (horizontal) center of the dust devil with that for the atmosphere in the absence of a dust devil. For the case of the Sun shining directly down the dust devil, a -4% contrast was achieved for a Δτ = 0.15, where Δτ is the additional dust in the dust devil along a horizontal path through its center. For more likely geometries of glancing illumination of the column, a -4% contrast required Δτ = 0.5. Assuming a Δτ of 0.3 (estimated to be accurate to within a factor of 2), we derived dust loading within the dust devil. The background dust content of the atmosphere is 1.8E-7 kg m-3 using the Tomasko et al. size distribution and their dust load of τ=0.485, and assuming a 13-km scale height. Scaling this, the product of the dust load, δ, and the path length L, is δ * L = 5E-3 kg m-2. For a dust devil 10 m in diameter, δ = 5E-4 kg m-3; for one 1 km in diameter δ = 5E-6.

Given the above dust loading calculations, the sediment transport efficacy of a particular dust devil can be examined. Using the Mars Observer Camera, the Mars Global Surveyor spacecraft has imaged parallel tracks on presumably loose, fine-grained material at 15.4° N, 311.6° W in eastern Arabia Terra. These have been interpreted to be the tracks of 2 dust devils. The longer east-west feature is 7.7 km wide and averages 35 m in width. We speculate that the regional winds must have been fairly strong (ex. 5 m/s) to produce such near-straight tracks. Therefore, the track would represent a dust devil which lasted at least 24 minutes. Based on the terrestrial observation that most dust devils which are several tens of meters in widths will develop a clear, well-defined core (ex. 29 m, thus a total dusty annulus of 300 m^2), and that they often have vertical velocities of 10 m/s, we can estimate the dust devil’s particulate flux and total sediment transport. Using an intermediate dust loading estimate of 5E-3 kg m-2, the flux would exceed 5 g m-2 s-1 (as the dust devil base takes 7 seconds to cross a given spot) and total transport exceeding 200 kg. Such numbers become more significant in light of the high frequency of strong thermals acting across much of the Martian surface.

**REFERENCES**