Spatial analysis using *ArcGIS* of the *Valles Marineris* region of Mars during the 2018 global dust storm

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During the 2018 Mars opposition a global dust storm developed in the period from May to July and declined again in September. Interestingly, when the storm vanished an accumulation of dust could be detected at several locations, including the *Valles Marineris* region. In order to correlate local topographic features with the distribution of dust we have investigated the nature of the *Valles Marineris* terrain using *ArcGIS* software and detailed elevation data. Spatial analysis using *ArcGIS* seems to be a useful tool to obtain more insight into dynamic features on Mars and other planets.

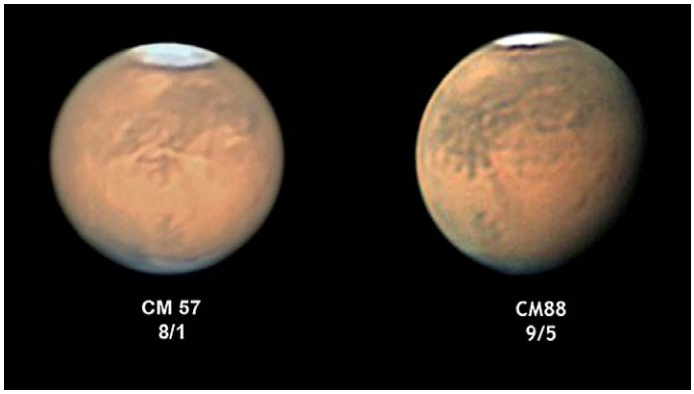

Figure 1. Dust in *Valles Marineris* on 2018 Aug 1. The Sep 5 image is shown for comparison. South is up.

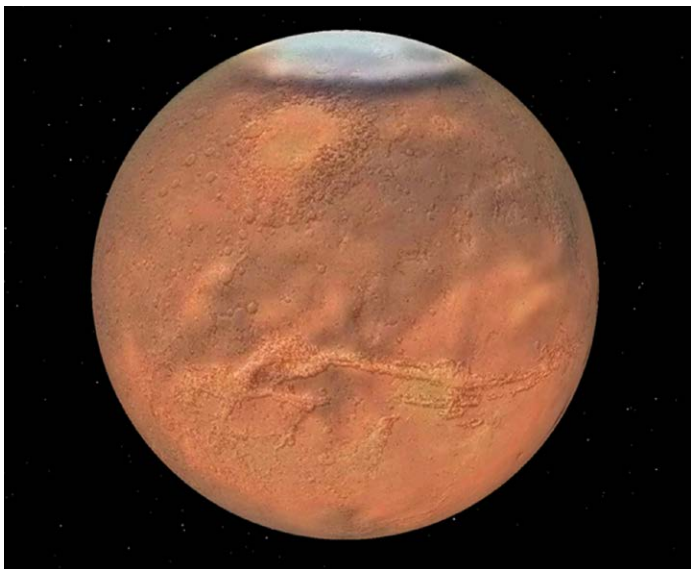

Figure 2. Mars image of 2018 Aug 1, superimposed on the USGS MOLA map using *ArcGIS*. South is up.

Introduction

Mars was imaged during the 2018 apparition using a Celestron C8 Schmidt–Cassegrain telescope in Curaçao (E. S.) and a C14 in Houten, the Netherlands (J. S.). Since the altitude of Mars was the highest on Curaçao (54° as compared to 14° in the Netherlands), and this Caribbean island often has excellent seeing conditions, the most detailed information was collected there.

Starting at the end of May a big dust storm developed in the northern hemisphere, in the Moab region. At the end of June, the storm covered almost the entire Martian surface and at the end of September it had almost completely vanished again. The initiation of the 2018 storm in the northern hemisphere is remarkable, since all known global dust storms so far (1909, 1925, 1956, 1971, 1973, 1975, 1977, 1982, 2001 & 2007) originated in the southern hemisphere.[1] A short communication of our observation of the 2018 Mars opposition has been published.[2]

Dust in the *Valles Marineris* region

On 2018 Aug 1 we obtained an interesting observation. Whereas under normal conditions the eastern end of *Valles Marineris* can often hardly be traced, in images of that date the complex canyon system was very distinct as compared to images from Sep 5 (Figure 1). A similar phenomenon occurred during a regional storm in 2005 November.[3] Our observation prompted us to study the presence of dust in the *Valles Marineris* region in more detail.

To correlate the albedo features in our Mars images with real three-dimensional geological structures, we have used *ArcGIS*.[4] This Geographic Information System (GIS) software is frequently used for geospatial analysis with a wide range of applications, *e.g.* crime analysis, environmental studies, geology, mapping, 3-D analyses, utility companies, transportation *etc*. Using *ArcGIS* and

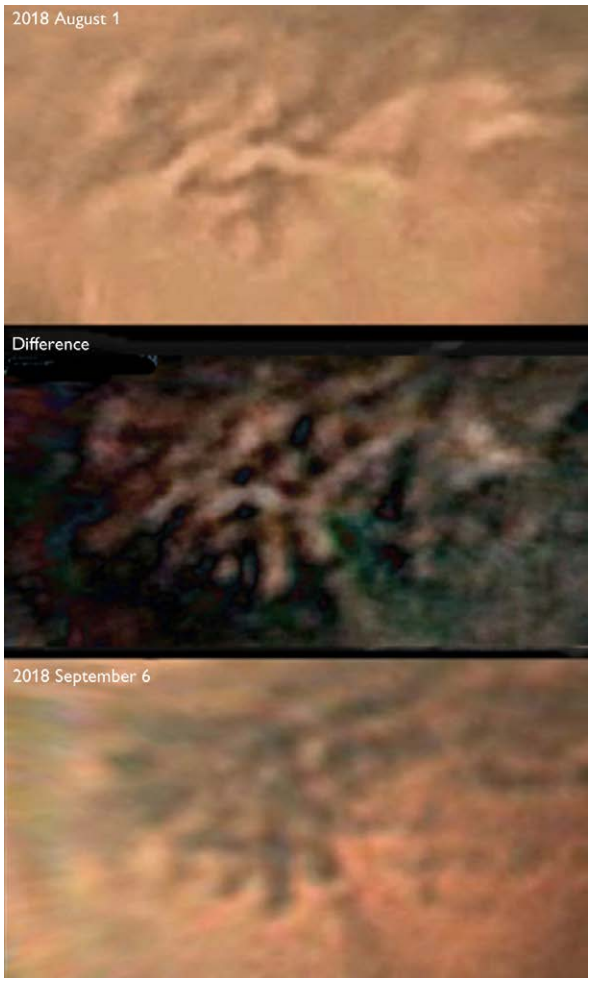

Figure 3. Dust distribution in the *Valles Marineris* on 2018 Aug 1 (top) compared to 2018 Sep 6 (bottom). The difference between the two images is shown in the middle panel. South is up.

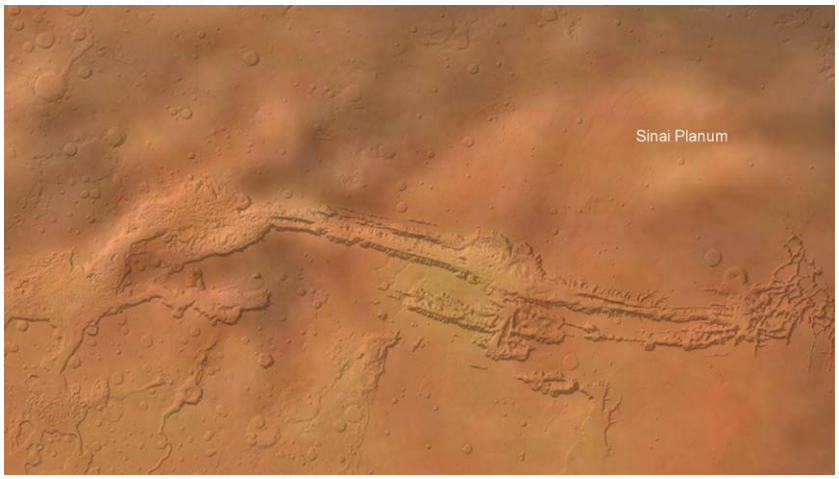

Figure 4. Distribution of dust on 2018 Aug 1 in *Valles Marineris* and *Sinai Planum*.

the US Geological Survey (USGS) Mars Orbiter Laser Altimeter (MOLA) elevation data for Mars,[5] albedo features in our images could be correlated with elevation and topographic features at specific sites (Figure 2). We have investigated whether there is a correlation between the accumulation of dust and the local nature of the terrain. We have also checked whether there is a preference of dust accumulation in valleys. In particular, the distribution of dust in the *Valles Marineris* region has been investigated (Figures 2 & 3).

Figure 3 clearly illustrates the accumulation of dust in the *Valles Marineris* canyon complex. The course of the canyon can hardly be traced in our images of September. In contrast, on Aug 1 the course of the canyon can easily be detected as a bright channel of dust following the *Valles Marineris* borders.

By subtracting the image of 2018 Sep 6 from the image of 2018 Aug 1, a difference image is obtained in which the location of dust in the region can easily be detected (Figure 3, middle panel). Most of the dust is located in the complex canyon system, but accumulation of dust is also detected in other regions, in particular *Sinai Planum* (Figure 4).

In this region, close to *Valles Marineris*, we also detected short-lived dust storms on Jul 26 & 30 (Figure 5). On 2018 Jul 25 & 27 no local dust storm could be found. Analysis by McKim (1999) of all dust storms recorded over the years revealed that in the region south of *Valles Marineris*, dust storms have developed more often (1879, 1926, 1946, 1973 & 1984).[1]

To investigate the local conditions using *ArcGIS*, we made cross-sections of *Valles Marineris* and *Sinai Planum* using the MOLA elevation map of Mars (Figure 6). Elevation profiles of the dust storm in *Valles Marineris* nicely show the deep canyons present in *Valles Marineris*. The observation of accumulated dust in the valles suggests that it is captured between the mountain walls of the canyon system. As for the dust in *Sinai Planum*, a profile of this region produced using the MOLA elevation map shows that this accumulation is positioned on a flat region with a minimal slope. Investigation of the geological situation of dust at *Sinai Planum* (Figure 7) indicates that it is located at the transition between two geological structures (coloured regions): a younger region (pink) with distinct lava flows (red arrows in Figure 7); and an older region (brown) with many wrinkles (black lines with dots in Figure 7).

Discussion

The distinct accumulation of dust in *Valles Marineris* during the global dust storm in 2018 June & July prompted us to investigate

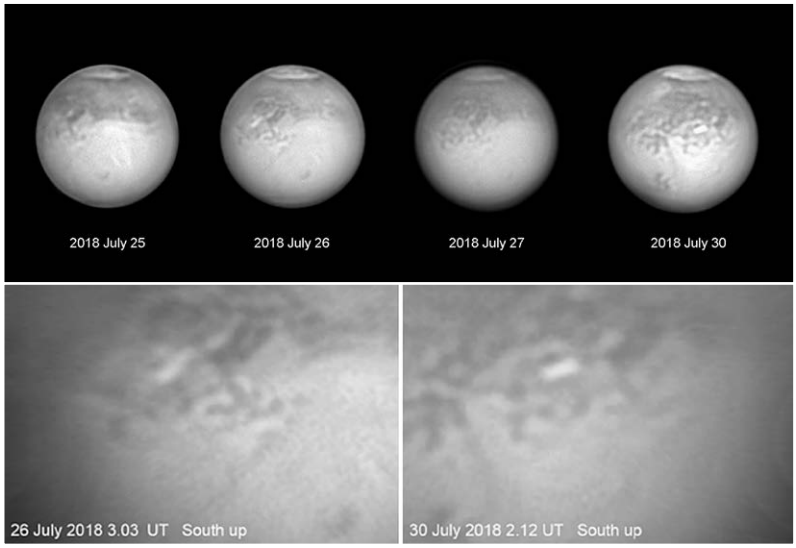

Figure 5. Short-lived dust storms in *Sinai Planum* on 2018 Jul 26 & 30 (upper and lower panels). On 2018 Jul 25 & 27 no storms are detected in this region (upper panel). South is up.

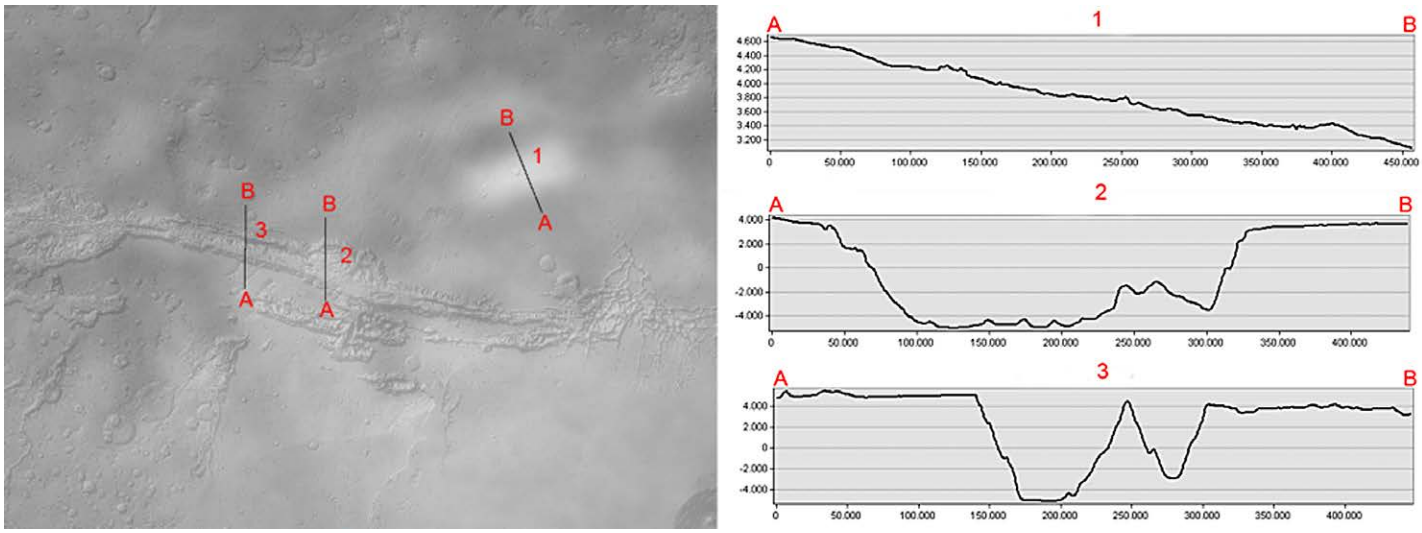

Figure 6. Cross-sections of *Valles Marineris* and *Sinai Planum* showing local elevation profiles (2018 Jul 30). South is up.

in more detail the local geological conditions. For that purpose we applied *ArcGIS* and detailed Mars maps collected with the *Mars Global Surveyor*. We have shown before in a study of the Great Red Spot of Jupiter in different spectral bands that this software is a useful tool with which to get more insight into cloud structure.[6]

Elevation profiles of *Valles Marineris* obtained with *ArcGIS* demonstrate the canyon structure of this region. Dust easily accumulates between the mountain walls of the canyon system, facilitating the detection of the valles in amateur images.

Interestingly, there is a region south of the valles, in *Sinai Planum*, where dust also accumulates. Elevation profiles of that region reveal that at this site a shallow inclination is found; no distinct craters or canyons are present. To get more insight into this location, we collected data about the local geological conditions. It appears that the dust is located at the border of two distinct geological structures: a younger region, with lava flows, collapses against an older region, with many twisted wrinkles. This might lead to unequal heat absorption of the local surface, facilitating dust storm formation. Clearly, further studies are required to understand the meaning of this phenomenon.

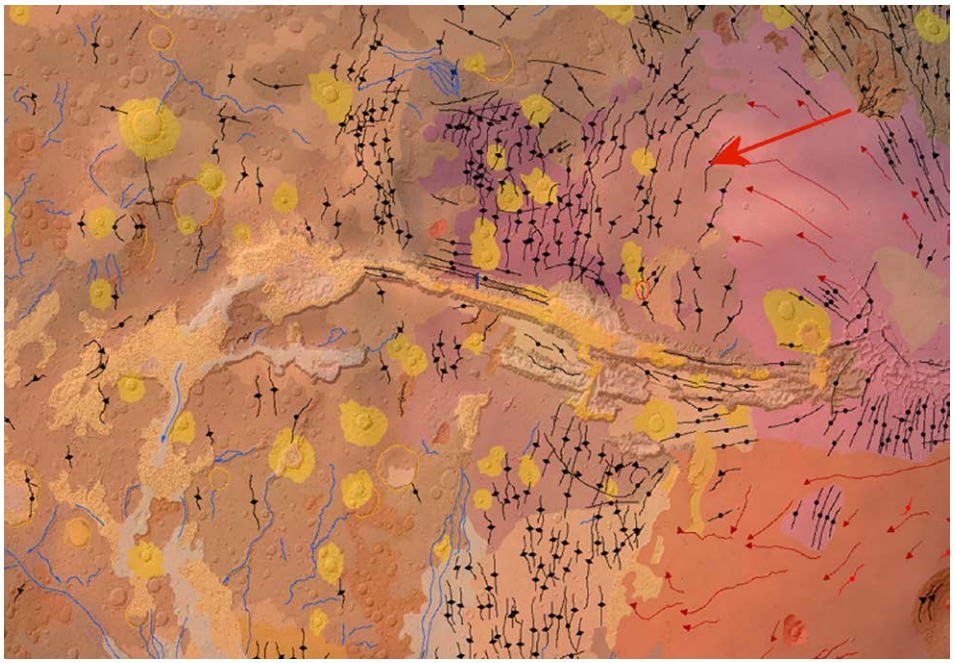

Figure 7. Geological data for the region in Figure 6, superimposed on a geological map.[7] Coloured regions indicate distinct geological eras, while the small red arrows and black lines with dots indicate lava flows and wrinkles, respectively. Dust accumulation in the *Sinai Planum* is indicated by the large red arrow. *Source: T. Gaither, M. Hunter, D. H. Scott, M. H. Carr, USGS Astrogeology Science Center*

We have demonstrated that *ArcGIS* is a useful tool for amateur astrophotographers to better understand the features in their images, and might even lead to a better understanding of the surface of Mars and its meteorology.

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