Albedo Contrast Determination in the Neighbourhood of Martian Dust Devil Tracks

Thiago Statella[1], Pedro Pina[2], Erivaldo Antônio da Silva[3]

[1] IFMT – Instituto Federal de Educação, Ciência e Tecnologia de Mato Grosso – Brasil
[2] CERENA - Centro de Recursos Naturais e Ambiente, Instituto Superior Técnico, Lisboa – Portugal
[3] UNESP – Universidade Estadual Paulista - Brasil

Dust Devils and their Tracks

Dust devil tracks are albedo patterns on planetary surfaces that result from the removal of particles by the presence of a dust devil to expose an underlying surface with a different albedo. Albedo measurements can give us clues about the nature of the surface materials. We introduce and test here an automated methodology to compute the albedo contrast between dust devil tracks and their surroundings which can be used to indirectly infer the relative depth of the dust coat on large image datasets of Mars.

Method

The sequence developed to compute the albedo contrast on images is based on 3 main steps:

1. *Segmentation of the tracks*: this task gives a binary image of the tracks as output through a method mainly based on mathematical morphology operators [1] capable of achieving high performances (average of 92% of correct detections in MOC/NA and HiRISE images).
2. *Determination of track widths*: This value permits to establish the dimension of the neighborhood *Nr* to analyse in the albedo computation. The mean width of the tracks in each scene is computed by a morphological granulometric analysis, which gives information about sizes of the connected components (the tracks) in the image. The dilation of the detected tracks permits creating a mask of the neighboring regions.
3. *Computation of the albedo contrast*: Once defined the neighborhood of the tracks, the radiance factor (*I/F*) for the pixels belonging to tracks and for those pixels belonging to their neighboring regions is computed. *I/F* is defined as the ratio of the bidirectional reflectance of a surface to that of a normally illuminated perfectly diffuse surface [2]: $I/F = I/\pi F$.

The radiance factor *I/F* can be further converted into an estimated Lambert Albedo A_L through division by the cosine of the solar incidence angle for each pixel. Two keywords in the Planetary Data System provide a mechanism to translate the *DN* integer value of the HiRISE image to *I/F*: the scaling factor *SF* and *Offset* values. The equation is as follows [3]: $I/F = (DN \times SF) + Offset$.

Results

We selected 41 HiRISE images depicting regions in the Mars Chart quadrangles of Aeolis (MC23), Argyre (MC26), Noachis (MC27), Hellas (MC28) and Eridania (MC29). Fig. 2 shows the distribution of the images selected in our study. The solar longitude (Ls) of the scenes ranged between 180° and 360°. The initial dataset resulted in practice into 107 images that were trimmed to its regions of interest (some images contained two or more of these regions), so irrelevant information such as large areas with no tracks was discarded. We calculated the albedo of the tracks and their neighboring regions for all 107 images. The global results for each MC, also discriminated by spring and summer seasons, are shown in Table 1, which contains the mean albedo for the tracks, for the neighbor regions (*Nr*) and the mean albedo contrast between these two features. In [4] and [5] it was raised the hypothesis that the contrast between albedo tracks and their surroundings, which varies from region to region, may be related to the depth of the dust layer. If so, the regions in Hellas quadrangle have a thinner layer of dust coverage than the others. On the other hand, Aeolis and Noachis have little thicker dust coat.

Table 1: Albedo computation results on five MC quadrangles.

Region	Season	Images	Mean Track Albedo	Mean *Nr* Albedo	Mean Albedo Contrast
Argyre	Spring	2	0.1992	0.2056	0.0064
	Summer	53	0.1747	0.2041	0.0294
	Total	55	0.1757	0.2042	**0.0285**
Aeolis	Spring	1	0.2211	0.2408	0.0197
	Summer	-	-	-	-
	Total	1	0.2211	0.2408	**0.0197**
Eridania	Spring	10	0.1524	0.1739	0.0215
	Summer	9	0.1593	0.1960	0.0367
	Total	19	0.1557	0.1843	**0.0286**
Noachis	Spring	6	0.1568	0.1716	0.0148
	Summer	13	0.1501	0.1806	0.0305
	Total	19	0.1528	0.1778	**0.0250**
Hellas	Spring	-	-	-	-
	Summer	16	0.1776	0.2069	0.0293
	Total	16	0.1776	0.2069	**0.0293**

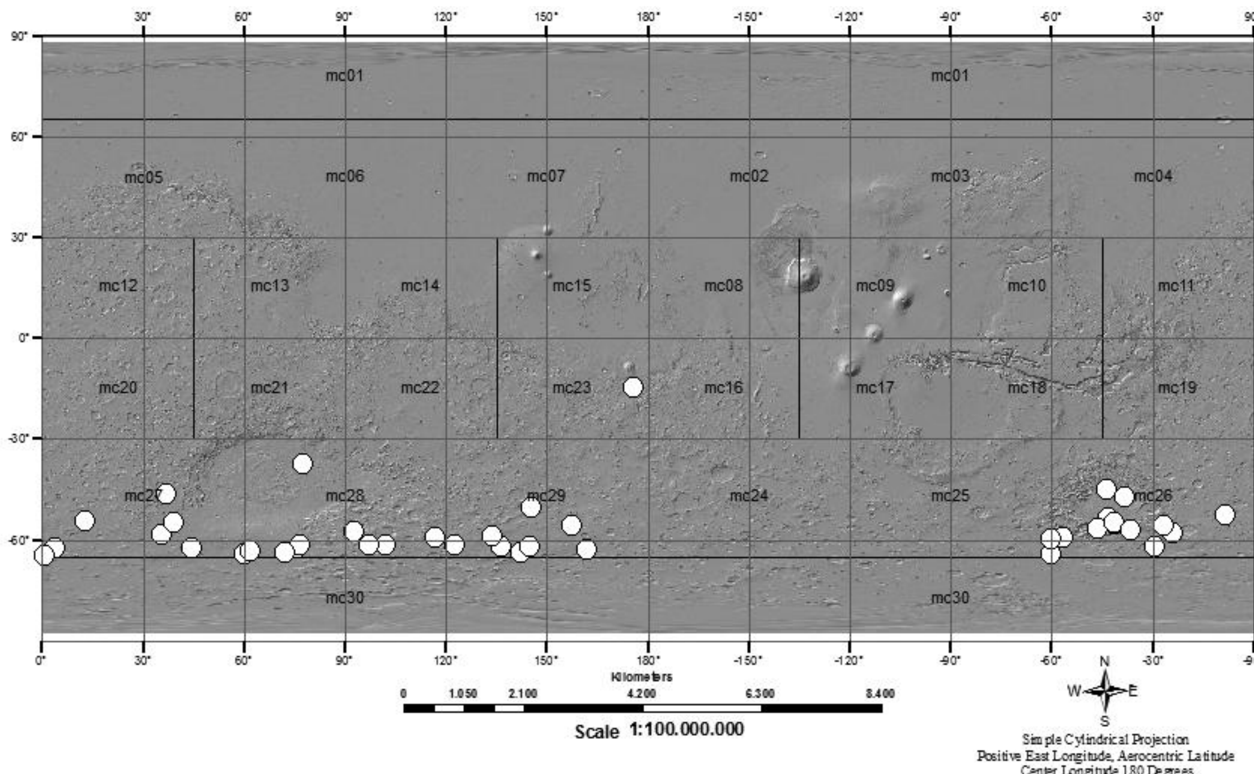

Fig. 2: Distribution of the images considered in our study on the surface of Mars in 5 quadrangles: Aeolis (MC23), Argyre (MC26), Noachis (MC27), Hellas (MC28) and Eridania (MC29). The white circles represent the center coordinates of the scenes in the initial dataset. Image credits: R.K. Hayward, K.F. Mullins, L.K. Fenton, T.M. Hare, T.N. Titus, M.C. Bourke, A. Colaprete, P.R. Christensen.

The local analysis provided by our method permits to quantitatively analyze in detail the same region in a multitemporal basis. Russell crater (54.9°S, 347.6°W) is an interesting site for dust devil tracks observation: a total of 32 images between 2007 and 2012 were processed to compute the mean albedo of the exact same region of interest (a pair of examples is provided in Figure 2). The results obtained for the whole sequence are shown in Figure 3, where circles stand for images where no dust devil tracks were observed and triangles stand for images showing those tracks. The main conclusion is that, in general, higher albedos were found during the winter seasons when most of the images have no tracks.

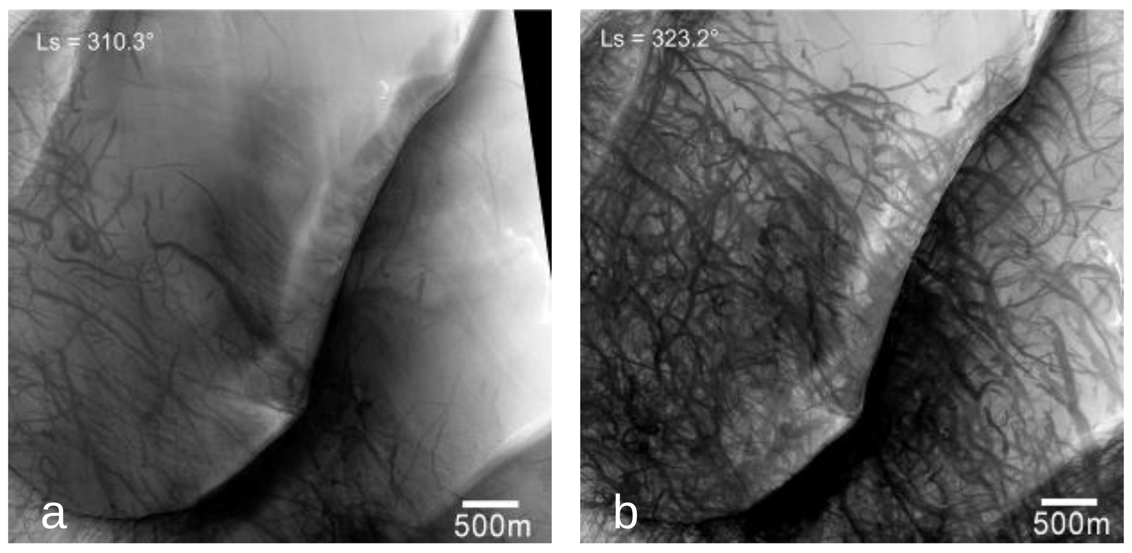

Fig. 2: Examples of changes in dust devil tracks in Russell crater on HiRISE images: (a) PSP_005238_1255, 08/Sept/2007; (b) PSP_005528_1255, 01/Oct/2007 [Image credits: NASA/JPL/University of Arizona].

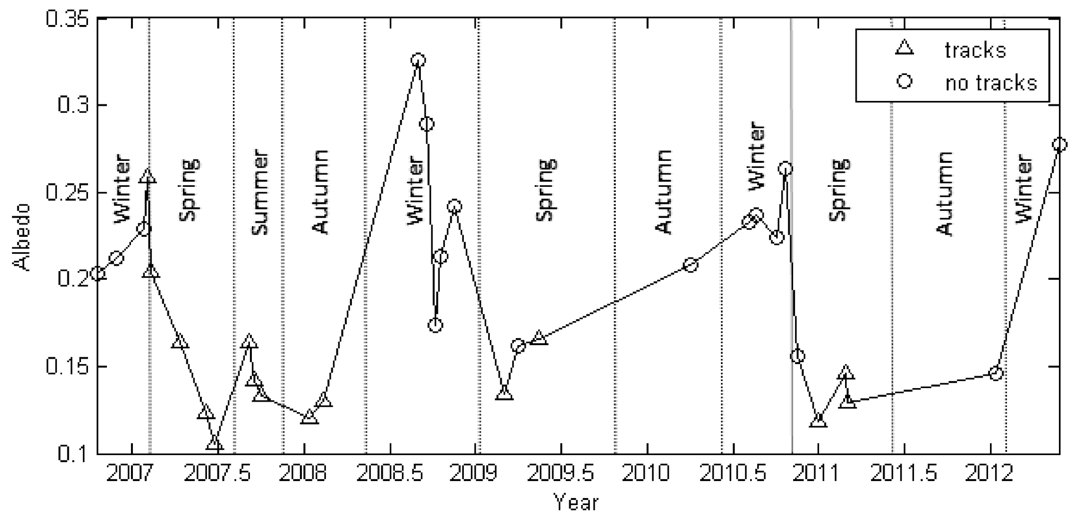

Fig. 3: Temporal analysis of the albedo in a region of Russell crater (the vertical dotted lines are used to group images belonging to the same season and do not represent, therefore, the whole length of seasons).

Conclusions

A set of 107 HiRISE images with tracks previouslly detected by an automated method was processed to calculate the albedo of the tracks and the albedo of the their neighborhood region. Albedo contrast may be used to infer the relative width of the dust coat between regions.
A temporal analysis was carried out in a region of Russell crater. For an isolated region, the variation in albedo along time may indicate the presence of dark features like dust devil tracks.

References

[1] Statella et al. (2012) *PSS*, 70, 46-58. [2] Bell et al. (2006) *JGR*, 111, E02S03. [3] Eliason et al. (2007) [4] Whelley et al. (2006) *JGR* 111, E10003. [5] Verba et al., *JGR*, 115, E09002.

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