13 YEARS OF TEMPORAL FADING QUANTIFICATION IN DARK SLOPE STREAKS FROM LYCUS SULCI.

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Introduction: Slope streak is a phenomenon among the few known examples of contemporary geologic activity on Mars [1]. They are typically dark fan-shaped features which are seen on downslope regions, as steep reliefs and crater slopes [2]. Newly formed streaks are dark, and darker than other streaks in the same region [3] and it is known that the streaks tend to fade becoming lighter with time. Dark streaks provide a more obvious and discernible rate of atmospheric dust fallout and their analysis may provide clues about dust deposition and target material properties. Thus, our main objective in this paper is to present a tool that we have developed to measure, in a fully automated manner, the full pixel analyses albedo contrast between slope streaks and their neighborhood regions and, in addition, how its application to a large variety of image dataset belonging to distinct Martian regions can improve our knowledge on the formation of these streaks.

Method: *Image dataset*. The dataset is comprised of 20 regions of interest (ROIs) cropped from 14 images (4 MOC and 10 CTX), distributed on regions of Lycus Sulci. The images considered in our study are overlapping images acquired between the years 2000 and 2013. The oldest images guided the determination of the set of ROIs. Hence, the same area represented on the former image, must be represented on the other image crops, as showed in Fig. 1.

Due to the automaticity of our approach, additional and careful efforts were necessary to get a very good register between the images captured by different cameras, once our algorithm quantifies the temporal variation albedo of each individual streak.

Fading algorithm. The developed algorithm ensures that the same and exact streak is correctly identified in each multi-temporal image. The establishment of the correspondence between the same segmented object in the images along different dates is achieved through overlapping each element of the primary and older image, segmented by the method proposed in [4], on the images segmented of the following years. If there is some match between the area of the reference object (streak) and the object of the newer image, the inside streak media value (digital number) and the media value of its neighborhood is saved. Since images are acquired by diverse sensors in rather different time periods (of the day and of the season of the year), it is less prone to errors to evaluate the contrast ratio (between the albedo of each streak and its neighborhood) [5] rather than computing an absolute albedo value of the streak in each date. Fig. 2 shows an example of the output of this procedure, where the streaks observed in CTX (Fig. 2a) were first detected automatically (Fig. 2b) and then the reference object defined to perform the correspondence with the objects of the others images (Fig. 2c), finally the streak neighborhood determined (Fig. 2d). Once defined the average of digital number (DN) values (of the interior and neighborhood) of each streak, the DNs is converted into an albedo value.

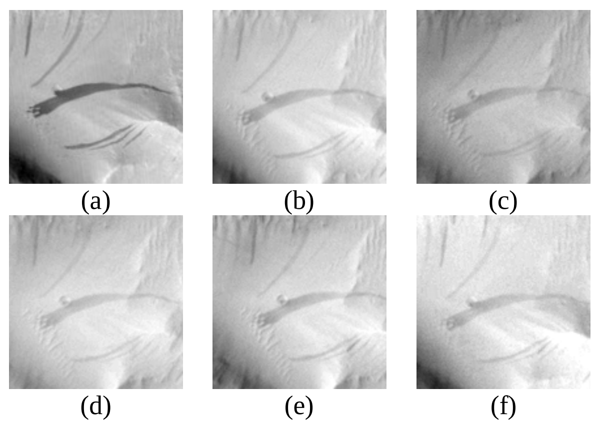
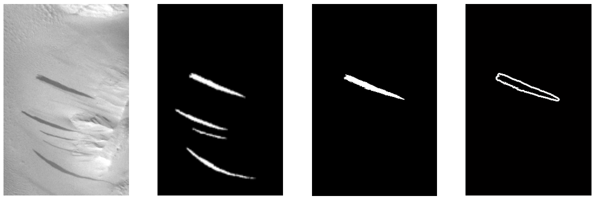


Fig. 1. *Region of interest (ROI) shown in six different images (camera, year). (a) MOC, 2000; (b) CTX, 2007; (b) CTX, 2007; (c) CTX, 2008; (d) CTX, 2010; (e) CTX, 2012; (f) CTX, 2013;*

Calculating the albedo. The conversion of NDs into an estimated Lambert Albedo, for CTX images, is done through the division of radiance factor by the cosine of the solar incidence angle. The radiance factor I/F is achieved using the *scaling factor* (SF) and *Offset* values (both contained in the label of the images) as follows: I/F=DNxSF-Offset. For the conversion of the NDs from MOC images, we use the radiometric equation presented in ISIS 3 application documentation, as follows: $r = ((dn\text{-}z\text{+}off/a\text{-}g)/ex\text{-}d)$; where r is the is the average signal being generated at the focal plane, z is the fixed zero offset, off is the commanded variable offset, dc is the dark current term, g is the gain-dependent offset, a is the commanded system gain (where minimum gain is 1 and all other gains are >1) and ex is the exposure time in milliseconds. The reflectance value is the multiplication of *r* and *iof* (radiance factor). All the parameters mentioned are provided in CUB file, of each image, provided by the ISIS application.



(a) (b) (c) (d)

Fig. 2. *Sequence developed to compute the slope streaks albedo contrast. Image CTX B10_013642_206*

Temporal fading quantification: The contrast ratio of 34 slope streaks from Lycus Sulci was calculated between the years of 2000 to 2013 (as the contrast ratio tends to 1 the brighter the streak is). According to the multi-temporal images availability of the ROIs, some of them contain up to seven years of information while the ones with less information cover about three years.

The 34 streaks showed an average change in contrast ratio (on-streak and off-streak albedo values) of 0,009169 per Earth year (Ey^{-1}). Analyzing the streaks fading individually, we noted a big variation between each slope streak. While the quickest streak fading showed a contrast ratio of 0,755545 in 2000 and 0,941300 in 2013, what represents a change contrast ratio of 0,014289 Ey^{-1} (red line in Fig. 3), the contrast ratio of the slowest streak fading is 0,919339 in 2000 and 0,963043 in 2013, a change contrast ratio of 0,003362 Ey^{-1} (blue line in Fig. 3).

In a global evaluation throughout these 13 years of analysis, all the 34 slope streaks faded. However, during some short periods we observed a slight reversal to darkening, and then brightening over again as shown in portions of the curves of the three examples presented in Fig. 3.

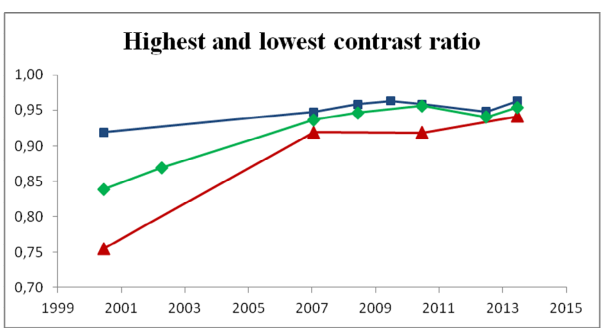


Fig. 3. *Variation of contrast ratio of tree slope streaks examples analyzed in Lycus Sulci region.*

Conclusions: Slope streaks with lower contrast ratio (darker streaks) showed the highest values of change per year. It indicates that the brightening process is not linear. In the current observations, the fading process (or change of contrast ratio per year) is much larger in darker streaks (streaks with a contrast ratio lower than 0,80) and it is getting light over the years. The slight darkening observed in all the 34 streaks supports that there are more dynamic aspects involved than a simple streak fading like, for example, a streak reactivation as suggested in [6]. Additionally, the lack of a relationship between increase and decrease of the change contrast ratio for streaks from the same location may indicate a more dynamic aspect of the process that supposed until now.

The full pixel analyses of the streaks and neighborhoods and the albedo transformation provided by our method ensure a whole set of reliable data. However, we should be cautious and to not state that the fading process at Lycus Sulci is representative of the whole in Mars. For that purpose we need to analyse much more sites that would help establishing a relationship for fading and maybe to validate the idea of reactivation. We have already selected more regions with similar temporal scales to, in a next step, verify if the 13 years of temporal fading observed at Lycus Sulci is similar to the other Martian locations.

References:

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