ASSESSMENT OF RECURRING SLOPE LINEAE ACTIVITY TRIGGERING BY WIND AND DUST DEPOSITION IN HALE CRATER.

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Introduction: Recurring Slope Lineae (hereinafter RSL) are seasonal dark flows on steep slopes of Mars [1]. These movements of several meters long appear and grow downwards (more or less incrementally) and fade (partially or totally) more or less progressively. Many studies were made to understand the origin and the mechanisms of RSL, firstly investigating wet processes involving for example liquid water or brines (see an overview in [2]), and then dry processes that frequently involve dust [3, 4, 5, 6, 7, 8, 9]. Even if dry processes are now favored, they are not yet precisely understood. In particular, while some studies suggest that RSL could primarily be dust-removed features [6, 8], others argue that RSL are flows of dark sand material (e.g., [7]).

The RSL seasonality is overall close to that of the dust cycle [6]. Major RSL formations are for example observed during the dust storm season (southern hemisphere summer) at all latitudes [1, 2, 6] and more RSL are observed after global dust storms [8]. A recent study also highlighted a spatial and time correlation between northern hemisphere RSL activity and atmospheric dust [10].

Hale crater (323.48°E, 35.68°S) is a southern hemisphere site for which a specific seasonality has been found by [11]: three pulses of RSL apparition or lengthening are identified at Hale, while only two pulses have been reported for other sites. Hale crater may thus provide key information to understand the link between the RSL seasonality and the dust cycle (also characterized by three pulses [12]). Here we reanalyze HiRISE observations of Hale to characterize the activity with a dust removal/deposition point of view, trying to constrain the formation triggers (dust deposition, winds, …) and formation scenario for RSL.

Data and method: The HiRISE camera onboard Mars Reconnaissance Orbiter (MRO) has been taking high-resolution images (> 0.25 m/pixel) of the Martian surface since 2006 allowing the identification of small-scale movements such as RSL. We compare consecutive HiRISE images of two Hale crater areas (central peak) with RSL (one of which is already studied in [2]) for different Martian Years (MY). We divide the characterization of RSL activity into two kinds: periods of apparition or lengthening of RSL-like features (i.e., when the extent of dark surfaces increases) and periods of RSL fading or disappearing (i.e., when the contrast between dark surfaces and adjacent bright surfaces decreases). In the framework of the “dust-removed”

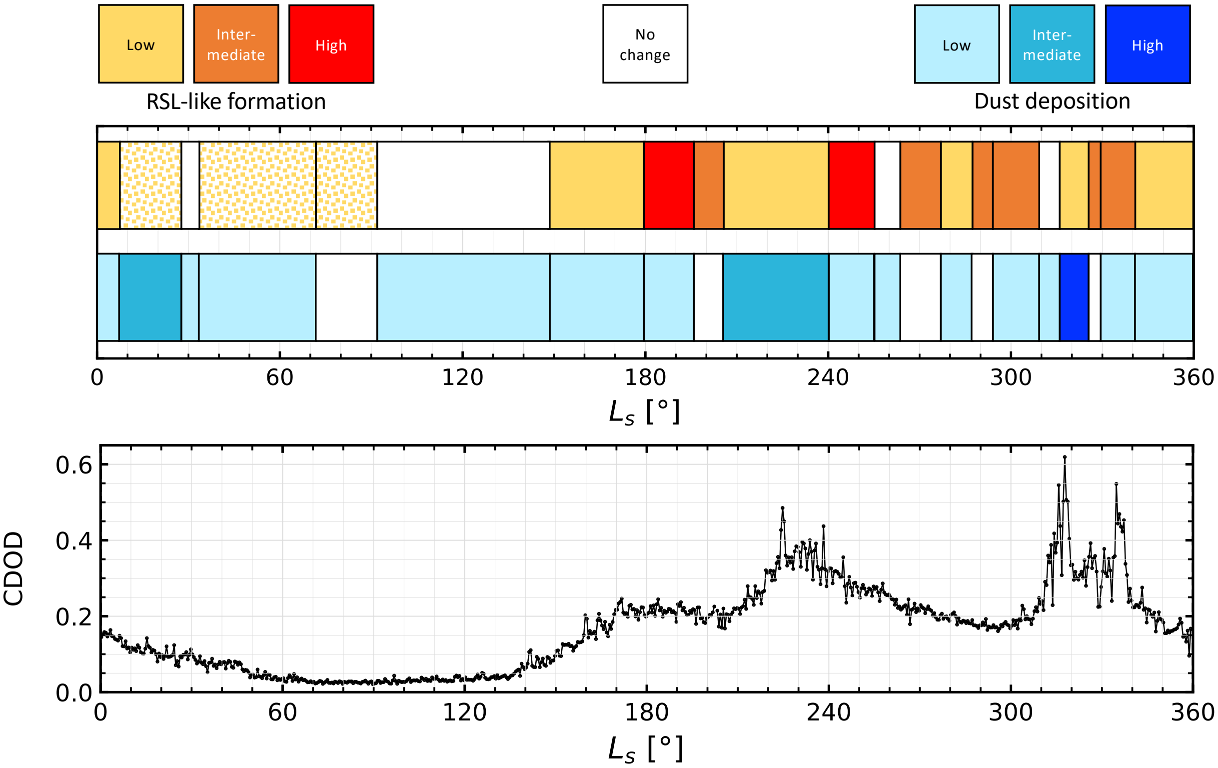

Figure 1: Summary of RSL activity timing in Hale crater (two areas of the central peak) compared to atmospheric dust time variations. (Top) RSL-like formation and dust deposition activity from HiRISE observations of MY 31, 32 and 33 summarized in one Martian year. Note: small colored cubes (yellow) are periods where formation features are observed at only one of the two sites. (Bottom) Time variations of the CDOD normalized in pressure [13] above Hale crater averaged over MY 31, 32 and 33.

hypothesis for RSL, these two periods correspond respectively to dust removal and deposition periods. Note that some periods of RSL contrast decrease may in fact correspond to regional dust removal, and not dust deposition, as suggested by [5]. Each of those has 3 levels of intensity: low, intermediate, and high. We then compare this activity timeline to atmospheric dust at Hale using 9.3 µm Column Dust Optical Depths (hereinafter CDOD) [13] (MCS/MRO measurements) from the same Martian years as the HiRISE observations.

Results and discussions: At top of Figure 1, we summarize the activity for MY 31, 32, and 33 by distinguishing the RSL formation features (1st row) and dust deposition (2nd row) for all slope orientations. Overall, we can notice that the two first pulses of RSL formations and lengthenings defined in [11] correspond to high formation levels (L_s 180-205° and 240-255°), while the third one seems to be less intense and corresponds to an intermediate formation level from L_s 325° to 340°.

During the "clear atmosphere season" (L_s ~ 0-150°), characterized by a large decrease of the CDOD (see bottom of Figure 1), lower winds and therefore higher dust fallout, we noticed different levels of dust deposition but also some RSL lengthenings and/or few apparitions (low level), notably from two consecutive HiRISE images between L_s 72° and 92°. Note that RSL formation near the southern hemisphere winter solstice has not been previously reported at Hale crater, and that this is poorly compatible with water-related mechanisms requiring high temperatures.

At the beginning of the dust storm season (L_s ~ 150-200°), corresponding to a first increase of the CDOD, there is a high RSL formation level (1st pulse) corresponding to many apparitions (more or less long). This type of formation can be reminiscent of avalanches that suddenly roll down a part of the slope, which seems to be triggered by the combination of surface dust availability (important due to dust accumulation during the clear atmosphere season) and stronger winds (beginning of the storm season).

Then, we noticed a second period of high RSL formation level (L_s~240-255°, 2nd pulse), including many apparitions and lengthenings. We can note that this pulse does not correspond to a local peak in CDOD. This period is also preceded by dust deposition (corresponding to a CDOD peak) at an intermediate level.

As for the two first pulses, there is an important surface dust deposition (L_s~315-325°) preceding the 3rd pulse. Dust deposition and then RSL pulse correspond to two successive CDOD peaks during the southern hemisphere summer. RSL formations are less important than other pulses, which may imply that the end of the dust storm season corresponds to a decreasing wind activity and/or a lower amount of remaining available dust.

Conclusion: We have analyzed RSL activity at Hale crater with a dust deposition/removal viewpoint. At first order, we find again the three southern hemisphere spring/summer pulses of activity discovered by [11], and we also have identified an RSL formation event occurring near the winter solstice. In more detail, we notice that there are dust depositions before each pulse. Dust deposition corresponds to a long decrease of CDOD (1st pulse) or to local peaks (2nd and 3rd pulse). This may imply that dust deposition at RSL locations can occur as both progressive fallout or rapid transport associated with storms. This also implies that a certain surface dust deposition seems to be necessary to have a significant level of RSL formation. We also observe that the availability of dust does not seem to be always sufficient to trigger RSL formation: local increase in atmospheric dust, which could be related to increased wind activity, seems to be required (1st pulse) or seems to favor RSL formation (3rd pulse). We can propose an RSL formation scenario consistent with these observations. If there is enough surface dust deposition, a dry avalanche-type formation can be observed (possibly initiated by winds). With less dust deposition or slope unfavorable conditions (not allowing avalanche), the RSL lengthen downward more incrementally (as for the 3rd pulse) under the action of winds. This proposed scenario elaborated using Hale observational constraints will be tested, improved and confirmed with similar analyses performed at other RSL sites.

Acknowledgments: HiRISE observations are freely available on the HiRISE website at https://hirise.lpl.arizona.edu, and 9.3 µm column dust optical depth are freely available at http://www-mars.lmd.jussieu.fr/mars/dust_climatology/.

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