QUANTITATIVE MAPPING AND EVALUATION OF WET AND DRY FORMATION MECHANISMS OF RECURRING SLOPE LINEAE (RSL) IN GARNI CRATER, VALLES MARINERIS, MARS. D. E. Stillman[1], B. D. Bue[2], K. L. Wagstaff[2], K.M. Primm[1], T. I. Michaels[3], and R. E. Grimm[1], [1]Dept. of Space Studies, Southwest Research Institute, 1050 Walnut St #300, Boulder, CO 80302 (dstillman@boulder.swri.edu), [2]Jet Propulsion Laboratory, California Institute of Technology, [3]SETI Institute

Overview: RSL are narrow (0.5–5 m) low-albedo features that incrementally lengthen down steep slopes during warm seasons. As hundreds of RSL can exist within a single HiRISE image, we developed the Mapping and Automated Analysis of RSL (MAARSL) system to reduce the effort involved in manually mapping each RSL in each image. MAARSL analyzes a set of orthorectified HiRISE images and Digital Elevation Map (DEM) to detect candidate RSL, compute descriptive statistics, and characterize changes over time. The results of MAARSL are then used to evaluate dry and wet RSL formation mechanisms.

Background: Garni crater (11.516°S, 290.308°E) has a diameter of 2.4-km and is on the floor of Melas Chasma. This crater is of great interest as it possesses large RSL on slopes facing different directions depending on the season. Additionally, two slope slumps have also been imaged within the crater. HiRISE has acquired 37 images of the crater. The first 22 images have been orthorectified to a DEM and cover MY31 L_s 133.0° to MY32 L_s 323.7°. The last of the 37 images was acquired MY34 L_s 357.5° with five images covering the period after the MY34 global-encircling dust storm. Thus, we use the orthoimages to quantitatively map RSL locations, while the remaining images will be qualitatively investigated for interannual changes and how RSL were affected by the MY34 dust storm.

MAARSL first creates an illumination model [1] that generates a shaded relief of the DEM with respect to the subsolar azimuth and incidence angle associated with each HiRISE image. MAARSL then compares the modeled values of intensity to the observed values. Observed intensities that are less than the modeled intensities are deemed candidate RSL. An interactive GUI is applied to allow fast filtering of spurious RSL candidates. However, it is also possible for MAARSL to fail to detect some candidates. Therefore, we also used a final manual editing pass to allow the addition of any missing RSL pixels.

MAARSL Results and Analysis: We mapped ~3,000 RSL in 22 orthoimages. As RSL vary greatly in size, we characterize RSL activity in terms of total darkened area as a function of seasonality and slope orientation.

Our most significant findings are:

1) Interannual variations were common for the areal extent of RSL on many slope orientations between MY31 and MY32 and were even more significant in MY33 and MY34 before the dust storm.

2) After the MY34 dust storm, RSL formed on every intercardinal and cardinal slope-facing direction. MAARSL data from MY31 and MY32 suggests that RSL would have normally formed on only three of the eight slope orientations. Additionally, numerous RSL tributaries are detected.

3) MAARSL results demonstrated that RSL lengthening and fading occur concurrently on the same slopes and even on the same RSL (**Fig. 1&2**).

4) The correlation of RSL darkened area with the theoretical maximum of shortwave insolation per sol (E_{max}) and the threshold value of E_{max} needed to start RSL lengthening differs depending on the slope-facing direction. The correlation of RSL lengthening and E_{max} shows that NE-, N-, and NW-facing RSL are correlated with increasing E_{max}. Interestingly, RSL in Chryse and Acidalia Planitiae (CAP) also lengthen during increasing E_{max} [2]. CAP RSL and NE-, N-, and NW-facing Garni crater RSL also have similar seasonalities and are responding to similar insolation and dust opacities. However, S- and SW-facing RSL are correlated with both increasing and decreasing E_{max}. Additionally, RSL in the southern mid-latitudes (SML) also lengthen during increasing and decreasing E_{max}, have similar seasonalities, and are responding to similar insolation and dust opacities as S- and SW-facing Garni Crater RSL [3].

5) The slope slump fading rate is consistent with the fading rates of RSL.

6) Slope angles calculated at the resolution of the DEM (1 m) show that many RSL start and/or terminate on slopes that are below the 28° minimum angle of repose of martian sand dunes [4]. For example ~25% of RSL terminate on slopes <28°. Note that dry sand typically has an angle of repose of 34°, with non-spherical grain shapes increasing the angle. Additionally, many RSL and the mapped slope slumps show significant portions at angles that are below the angle of repose. Our findings contradict the greater-than-angle-of-repose measurements that were calculated by low-pass filtering of the DEM at 20 m [5,6], but are similar to the unsmoothed (1 m) findings of *Teblot et al*. [7].

Discussion of Formation Mechanisms: Overall, dry dusty flows can explain recharge and fading via atmospheric dust deposition, darkening by the removal of dust, high activity after the MY34 dust storm, and the lack of measurable material being transported as dust can be blown away. However, no existing model can reproduce a triggering mechanism that allows dust flows to increase in size and overprint the existing topography over hundreds of sols. Additionally, if the low slope angles measured are not artifacts, then RSL cannot be dry unless those mechanisms can also impart the necessary momentum to continue to flow through these below-angle-of-repose slopes.

Overall, briny shallow subsurface flows are consistent with below-angle-of-repose slopes and concurrent lengthening and fading. Arguments can also be made to suggest why interannual variability exists, why correlations and threshold of the E_{max} vary between different slope orientations, how slope slumps can fade at the same rate as RSL, and why so many RSL exist after a dust storm. However, the most significant problem with briny RSL flows is accessing a sufficient source of briny water and removing excess salt from the regolith.

Conclusions: More complex RSL formation models are needed to fit the complex observed behavior and a better understanding of DEMs is needed to determine whether the scree slope on which RSL form on are below or above the angle of repose. Lastly, while RSL sites have been imaged repeatedly by HiRISE, additional images are needed preferably with fewer than 55 sols between overlapping images to continue mapping how RSL behave.

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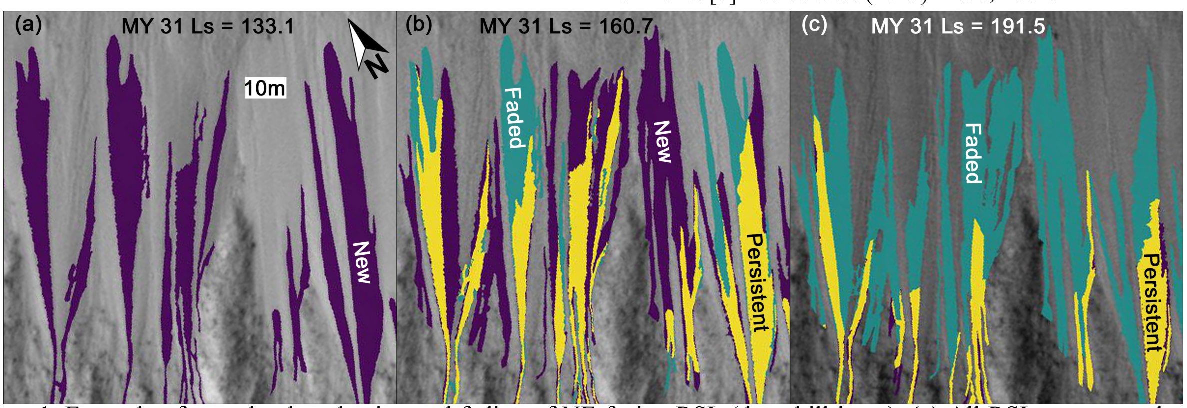

Figure 1. Example of complex lengthening and fading of NE-facing RSL (downhill is up). **(a)** All RSL are mapped new since this was the first HiRISE image of Garni crater. **(b)** RSL activity is significant with a large amount of newly darkened area (lengthening) and a lesser but significant faded area. **(c)** The majority of RSL have faded or continue to persistent.

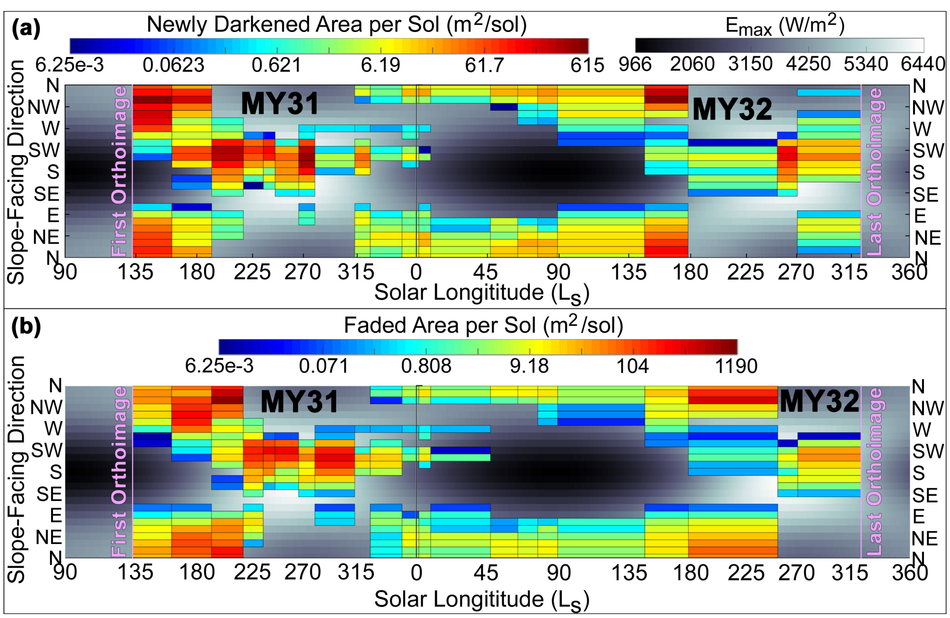

Figure 2. Color-coded **(a)** newly darkened area per sol, and **(b)** faded area per sol at the L_s of each orthoimage as a function of slope orientation (absence of color indicates change is below threshold). To enhance detail, colorscales are logarithmic. Each is overlaid on top of the grayscale shaded (values given above **(a)**) theoretical maximum shortwave insolation per sol (E_{max}).