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Remarkably Widespread RSL Activity Following the Great Martian Dust Storm of 2018

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Abstract

Following the great 2018 dust storm (or planet-encircling dust event, PEDE), MRO/HiRISE has seen many more candidate RSL than in typical Mars years. They have been imaged at >300 unique locations from August of 2018 to May of 2019, about half of them at locations where RSL have not been seen previously (Figure 1). They are present on most steep, rocky slopes in the southern middle latitudes in southern summer of Mars Year (MY) 34, rather than ~40% [1]. RSL have been present over a wider range of latitude, slope aspect, and Ls (areocentric longitude of the sun) than in prior years. These RSL sites show evidence for recent dust deposition: obscuration of relatively dark areas, overall brighter and redder surface than in prior years, and dust devil tracks. These post-PEDE RSL observations could be explained by flow of freshly deposited dust down steep slopes [2]. If this is the case, then the otherwise puzzling recurrence and year-to-year variability of RSL activity are now explained.

1. Introduction

Recurring Slope Lineae (RSL) are relatively dark flows on steep slopes with low albedos (minimal dust cover), typically originating at bedrock outcrops [3, 4]. Individual linea are up to a few meters wide and up to 1.5 km long. The lineae grow incrementally over a period of several months, usually during the warmest time of year for the particular latitude and slope aspect, and then fade (and typically disappear) when inactive. RSL recur in multiple years (by definition) over the same slopes, with varying degrees of interannual variability. Hundreds of individual lineae may be present over a local site, and thousands in a single HiRISE image, and there are about 1,000 likely RSL sites in spite of limited coverage by HiRISE [1, 3-7].

RSL are common in (1) the southern middle latitudes where they are most active in southern summer on equator-facing slopes, (2) the equatorial regions where activity is usually timed to when the local slope receives the most insolation, and (3) in the northern mid-latitudes with activity in northern spring and summer [5]. They are often associated with pristine small gullies that are otherwise rare on equatorial slopes [4, 6]. RSL are classified as "fully confirmed" when incremental or gradual growth, fading, and yearly recurrence have all been observed [4]. They are called "partially confirmed" when either incremental growth or recurrence has been observed, or "candidate" when they resemble RSL in single images but changes have not been observed other than fading.

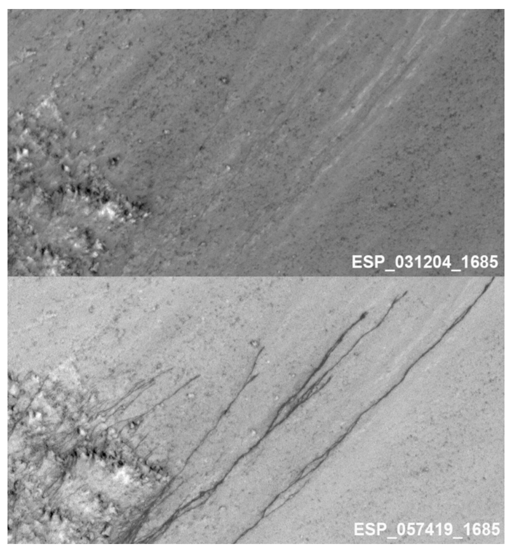

Fig. 1: RSL abundant after 2018 PEDE (bottom, Ls 276°) but absent in a prior year at about the same season (top, Ls 288°).

2. Post-PEDE Observations

Correlations between RSL activity and dust storms have been noted [3-7]. In particular there seemed to be more abundant RSL in 2007 following the MY28

PEDE. However, since the unique temporal behavior of RSL had not been recognized in 2007, we had no "before" images at any of these locations and images in later years often did not show RSL, so they were not confirmed. The 2018 PEDE provided the opportunity to systematically monitor RSL activity in relation to dust storms. In addition, HiRISE has an ongoing campaign of imaging gullies for changes [8], mostly on pole-facing slopes where RSL are not typically found. In late 2018-early 2019 we usually do see RSL on the steep east- and west-facing slopes of pole-facing gullies and alcoves. We have also seen many new RSL in images targeted for reasons other than monitoring slope processes. As a result, we collected a total of >400 images containing candidate RSL from August 20-December 28 of 2018, in >300 unique locations. About half of these are confirmed or partially confirmed RSL sites.

3. Testing RSL Hypotheses

The 2018 PEDE was in its decay phase by August, but dust opacities remained quite high, obscuring small-scale surface features. We did identify some RSL during this decay phase, which provided an important hypothesis test. In a series of experiments, [9] showed that illumination can cause dust to erupt at low atmospheric pressures. For this mechanism to work on Mars, an area must be strongly insolated for some time and then rapidly shadowed, inducing a strong transient temperature profile in the subsurface [10]. However, this mechanism cannot operate during times of high atmospheric opacity, when shadows are only slightly darker than illuminated areas. The presence of active RSL during the decay phase seems to be a challenge for this mechanism.

The PEDE provided another hypothesis test. The increased RSL presence after the MY28 PEDE could be explained either as an effect of dust deposition on the ground, or from the environmental effects of the dusty air (colder days and warmer nights). We re-imaged locations where RSL were unusually abundant in MY28, and found that only some sites had abundant RSL in 2018. The distinction seems to be the presence or absence of recently deposited surface dust. Active sites show evidence for recent dust deposition (reduced albedo contrast, dust devil tracks, higher reflectivity and redder color than in prior years with similar illumination). This indicates that dust on the surface is they key variable, since atmospheric dust opacity was high over all of these sites. Furthermore, enhanced RSL activity has persisted long after atmospheric dust opacities returned to seasonal levels.

4. How Do RSL Form?

Melting of shallow ice is unlikely, because the ice should be long gone from these warm locations. Groundwater seepage is problematic at many locations where RSL originate at topographic high points. Deliquescence likely happens on Mars, but produces tiny amounts of liquid. A dry granular flow model [11] avoids the problem of explaining the origin of significant water, but the yearly recurrence is not explained in most locations. The recurrence of RSL has been difficult to explain in all of the models discussed above: RSL activity is depleting something, either water, salt, or small grains, which must be replenished for recurrence. If RSL are flows of recently deposited dust, then the problem is solved: Dust fallout from the atmosphere replenishes the flowing material.

How can dust flow? Tiny particles should be highly cohesive. However, atmospheric transport and suspension of dust causes electrification [12], which in turn creates clumps of dust [13]. These clumps might behave like granular flows on sufficiently steep slopes.

5. Summary and Conclusions

Mars has performed a remarkable experiment via the 2018 great dust storm. The most straightforward interpretation is that RSL are primarily dust flows [2, 14].

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