Recurring Slope Lineae on Mars: Updated Global Survey Results

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Introduction: Recurring Slope Lineae (RSL) are dark, narrow features which extend downslope on steep (>20°), equator-facing, mid-latitude rocky slopes of Mars [1]. They are observed to form and grow during multiple warm seasons, and fade in cold seasons. Prior to this investigation, RSL had been confirmed from repeat coverage at only 7 locations ranging in latitude from 48S to 32S. Likely RSL (evidence of fading in cold seasons, but not yet observed to recur in multiple Mars years) were observed at 12 locations in the mid-latitudes. Candidate mid-latitude RSL (CMR), which have morphology and geological setting of RSL, but with no repeat imaging or without apparent changes were investigated in 12 locations. Candidate equatorial RSL (CER) (much like CMR but changes between images are observed and seasonality is unclear) were investigated at 8 locations in the equatorial region (Figure 1). Intensive monitoring of confirmed RSL sites was conducted in the most recent southern-hemisphere late spring to early fall, and we attempted to confirm additional candidates. We present results from our preliminary seach for RSL over all latitudes of Mars in images acquired during 2011 by the High Resolution Imaging Science Experiment (HiRISE)[2] onboard the Mars Reconnaissance Orbiter (MRO). Summaries of updated thermal data, geographical distribution, slope profile and other attributes (albedo, elevation, thermal inertia etc) are also presented.

	Setting & Morphology	Growth	Fading	Recurring	Unconstrained Changes	McEwen et al.	This work	Total
Confirmed	X	X	X	X		7	8	15
Likely	X	X	X			12	11	23
CMR	X					12	22	34
CER	X				X	8	7	15

Figure 1. Description of different RSL candidates and numbers observed.

Statistics on image analysis and geographical distribution: HiRISE acquired ~2000 images over all latitudes during 2011 between Mars L_s (areocentric longitude of the sun) 250-10. Out of those, 1818 images showed no signs of anything resembling RSL. Likely RSL were identified at 11 locations in the mid latitudes. CMR were observed at 22 locations, and CER at 7 locations (Figure 2). Candidate RSL (CMR and CER) could not be verified for various reasons including but not limited to: lack of repeat imaging, ambiguous identification of the features, limited resolution of an image, etc.

107 images corresponding to 15 sites showed confirmed cases of RSL. Most of these images were monitoring series of previously known RSL or RSL candidate sites. Incremental growth of RSL and fading were observed in the confirmed RSL images and recurrence was verified.

Geological Setting: RSL occur on slopes that appear geologically very recent, and are often found in “fresh” (very well-preserved) impact craters. Confirmed RSL sites are mostly mid-latitude craters with a low dust cover index (emissivity ranging from 0.96 to 0.98), thermal inertia of 98-411 $Jm^{-2}s^{-1/2}K^{-1}$, albedo 0.105 to 0.285 and elevation -5049 to 2459 m. A list of attributes observed for RSL is presented in Table 1. The values for thermal inertia, dust index and albedo represent a median around the center lat and lon of HiRISE images where RSL are observed, and therefore have some uncertainty because the RSL may not occur in the center of the image. RSL have concave topographic profiles; the starting slope is always steeper than the ending slope.The average starting slope derived from five

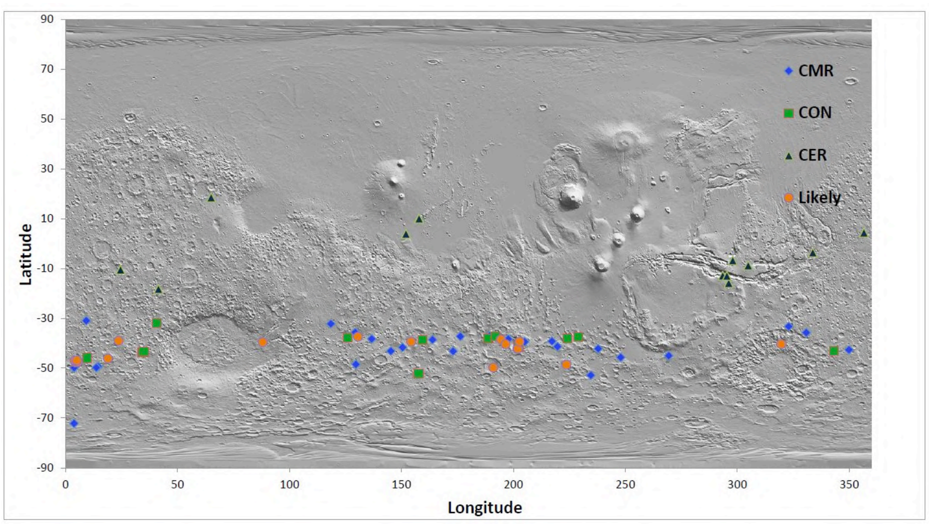

Figure 2. Geographical distribution of confirmed, CMR, CER and likely RSL.

HiRISE Digital Terrain Models (DTMs) of confirmed RSL sites is ~33°, and the ending slope has a mean of ~29°.

RSL mostly form on equator- and west- or east-facing slopes. Pole-facing slopes receive less radiance from the sun, which might explain why RSL are less abundant there. RSL on east facing slopes are observed less often than west-facing slopes, which may be due to an observational bias as HiRISE acquires images at approximately 3:30 PM local time, casting shadows from the west. RSL sometimes occur on slopes covered by many small channels. The shape, size and the distribution of RSL at some of these locations remains almost unchanged (Figure 3), between multiple years. This could be because their flow is being controlled by small (few meters wide) channels that are not resolved by HiRISE, or the source of RSL between multiple years is the same.

Table 1.

Attributes	RSL
TES albedo[3]	(0.105-0.285)
Dust index[4]	(0.96-0.98)
Thermal inertia[5]	98-411
Width	Up to 5 m
Slope aspect preferences	Mostly equator facing, but S, E and W facing observed too
Latitudes; Longitudes	Confirmed RSL: 30-60 S.
Formation L_s	L_s 240-20
Fading timescale	Months
Associated with rocks	Yes
Associated with channels	Yes
Abundance on a slope	Up to thousands
Regional mineralogy	Variable
Formation events	Incremental growth of each feature
Yearly recurrence	Yes

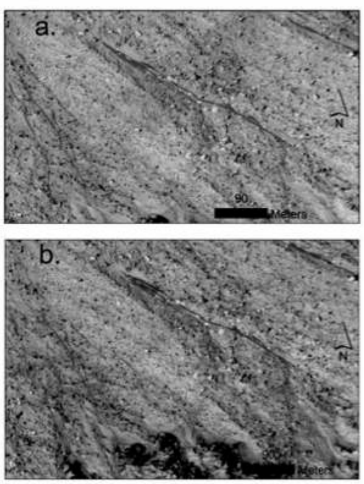

Figure 3. (a). HiRISE observation ESP_0014011_1315, (Ls: 308.34, acquired 07/23/2009) showing RSL on a NW facing slope in Raga Crater. (b). ESP_022437_1315, (Ls: 290.119, 05/10/2011) showing RSL on the same location. Downhill is to the upper left.

The geologic settings of all confirmed RSL have some features in common: a bedrock exposure, steep rocky slope (mostly equator facing), and bright fans. The arrows in Figure 4 point to these features. The bright fans over which RSL flow may be a product of deposition caused by RSL over multiple years, perhaps salt-rich deposits.

Possible Formation Mechanisms: Table 1 lists properties of RSL. The strong seasonal, latitudinal, and slope aspect distribution suggests that RSL require relatively warm temperatures. Maximum brightness temperatures derived from Thermal Emission Imaging System (THEMIS) brightness temperature (BTR) images of confirmed RSL locations (Ls 250-360) lie in the range of 250-300K [1]. However, temperature alone cannot explain the formation of these features. From our investigation, we observed more than 200 locations in the mid-northern to mid-southern latitudes that presented setting favorable to RSL (i.e., steep slopes, equator facing slopes, bedrock exposure, relatively fresh, boulders on the slope, etc.), but without signs of RSL. Equatorial regions get just as warm as mid-southern equator facing slopes but there are no confirmed case of RSL (Elorza crater has the best candidates, but further monitoring is needed). Volatiles on the surface or sub-surface, possibly brines, might be playing a crucial role on the formation of RSL.

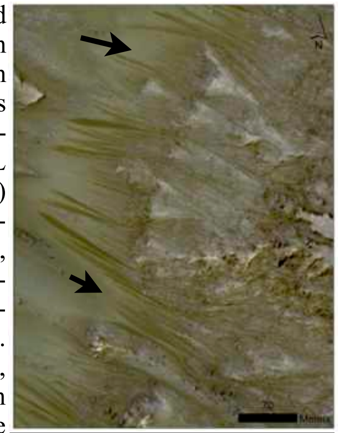

Figure 4. ESP_022689_1380 (enhanced RGB) (LS:302) showing RSL emanating from bedrock exposures on a steep rocky slope over bright smooth fans. Arrows pointing to bright smooth fans.

Future Work: HiRISE successfully monitored many RSL sites this southern summer which helped us determine which candidate RSL are in fact confirmed RSL. New DTMs of RSL and non-RSL sites are necessary to understand if there is an obvious difference in slopes between them. Orthorectification of THEMIS BTR images to high resolution HiRISE DTMs is also necessary to decrease the uncertainty in the estimates of temperature under which RSL form. Although Compact Reconnaissance Imaging Spectrometer for Mars CRISM cannot resolve individual flows because of its resolution (18m/pix), it may resolve the bright fans or show changes over time. Laboratory spectral experiments will help us understand the kind of spectral signature shown by a dry vs a wet briny surface which may also help us understand why even at places densely covered by RSL, CRISM hasn't detected any liquid water[6].

References: [1]McEwen et al. (2011) Science. [2]McEwen at al. (2007) J. Geophys. Res. [3]Christensen et al. (2001) J. Geophys. Res.[4]Ruff, S.W., and P.R. Christensen (2002) J. Geophys. Res.[5] Putzig, N. E., Mellon, M. T. (2007) Icarus.[6]Masse et al (this conference).