QUANTIFYING RECURRING SLOPE LINEAE IN SPACE AND TIME. E. I. Schaefer[1], A. S. McEwen[1], S. Mattson[1], and L. Ojha[2], [1]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721 (schaefer@lpl.arizona.edu), [2]School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA 30332-0340.

Introduction: Recurring slope lineae (RSL) are flow-like features found on some martian slopes that may indicate the presence of liquid water on or near the surface [1,2]. RSL

- are narrow (0.5-5 m) and relatively dark [1,2]
- form on steep slopes (25-40°), often below bedrock outcrops [1,2]
- occur primarily in the southern midlatitudes [1,2] and in the tropics near Valles Marineris, with one additional confirmed site in the northern midlatitudes [3]
- form and extend incrementally downhill on slopes that often face the sun (e.g., equator-facing slopes in local spring/summer), quickly fade as the season changes, and form again in a future year [1,2]

Slopes that host active RSL are measured to have afternoon brightness temperatures of ~250-300 K [2,3] as measured by the Thermal Emission Imaging System [4]. Although a “dry” mechanism might yet explain RSL formation, briny flow on or very near the surface is more consistent with current observations, especially the apparent temperature dependence, incremental growth, and rapid fading [3]. Nonetheless, the source for such liquid is unclear [3].

In this investigation, we quantify RSL and their behavior in detail for the first time. Such measurements can significantly enhance and supplement qualitative observations. In addition, these observations will provide necessary constraints to proposed RSL mechanisms as these are explored via laboratory work [e.g., 5,6], modeling, and terrestrial analogs [e.g., 7].

As a first step, we are comprehensively documenting RSL evolution in Tivat crater (45.93° S, 9.53° E) in Noachis Terra using data from the High Resolution Imaging Science Experiment (HiRISE) [8] aboard the Mars Reconnaissance Orbiter. This site has 20 HiRISE images from three Mars years (29-31). In particular, the average revisit interval is just 18 sols for the RSL active season of late MY 30. With ~100 RSL, the site has enough features for statistical analysis but not so many that comprehensive mapping is impractical.

Methods: We have generated a high-resolution Digital Terrain Model (DTM) [9] from HiRISE images ESP_012991_1335 and ESP_013624_1335 and have coregistered and orthorectified all 20 HiRISE images to this DTM.

Mapping RSL presents several complications. In some cases, poorly developed RSL can be difficult to distinguish from shadows or perennial discolorations. For this reason, we treat HiRISE image ESP_021628_1335 (Ls 250.6) as a baseline image by assuming it has no RSL. This image is the earliest spring image we have for Tivat, and it does lack any obvious or well developed RSL. However, additional complications remain:

- The width of RSL is near the HiRISE resolution limit of ~1 m.
- Because the RSL mechanism is unknown, it cannot be relied upon to resolve mapping ambiguities, such as whether small discontinuities in RSL are real or merely superficial.
- Revisit intervals are of a few weeks or more but RSL can change significantly over shorter timescales.

To address these complications, we collect ancillary data while mapping RSL so that we can simulate different plausible interpretations of their extents and inter-image behavior. This in turn allows us to quantify the influence of specific assumptions and limitations on our measurements. Example interpretation differences include:

- inclusion/exclusion of individual low contrast features
- inclusion/exclusion of individual features that are frequently obscured by shadows or boulders
- inclusion/exclusion of inferred (e.g., sub-resolution) links between RSL
- liberal vs. conservative estimates of individual RSL growth where in-line features have coalesced between HiRISE images

For efficiency, reproducibility, and consistency, we convert mapped RSL polygons to linear representations (“skeletons”) using an adaptation of the medial axis transform, a rigorous concept in mathematics for which fast and robust algorithms have been developed [10]. This conversion allows us to make linear measurements such as length and growth rate.

Results and Discussion: Although the algorithms to simulate interpretation differences and their effects are not yet complete, we have begun mapping. Current results therefore reflect just one interpretation and are reported in Table 1 for the three images that have been mapped so far, plus the baseline. We will continue mapping the remaining 16 images and then expand mapping to other sites. We will then compare these results with mapping results of possible analogs and to expected values based on the predictions of proposed RSL models.

ESP_013624_1335, taken in MY 29 at Ls 290.3, records the maximum RSL extent of any HiRISE image of the site. The next image, ESP_021628_1335 from MY 30 at Ls 250.6, is our baseline image and interpreted to have no RSL. 11 sols later, at Ls 257.8, 13 well developed RSL have appeared with a typical length of 56 m, implying an observed growth (downslope propagation) rate of ~5 m/sol. Note that instantaneous growth rates could be very different from this number if RSL are only active during a portion of the day and/or formed late in the interval between these two HiRISE images. Five of these earliest formed RSL continue to grow between this image and the next, ESP_022195_1335 at Ls 278.5, 32 sols later. However, their observed growth rate, ~1.6 m/sol, is much smaller for this interval. This growth rate is also smaller than the median observed growth rate of all RSL that grew during that interval, ~2.5 m/sol, which includes 93 RSL that formed during the interval.

Although some of these sample sizes are small, these observations are consistent with qualitative observations of images that have not yet been mapped. Such observations suggest that individual RSL grow most quickly early in their life cycles, then progressively slow and ultimately stop. In a few cases, RSL seem to repeat this life cycle within a single active season; in at least one such case, this seems to be triggered by the confluence of a new RSL into an existing trunk. These observations hint that RSL terminations may be determined by a limited supply rather than a shallowing slope alone. If true, this has implications for models of RSL evolution and also removes a possible obstacle to relating RSL to streaks that form on the avalanching slopes of dunes [3], for which a shallowing slope cannot be invoked to explain the position of the termini. We will explore this and other possible relationships as this investigation continues.

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References: [1] Ojha L. et al. (2011) *LPSC 42,* Abstract #2101. [2] McEwen A. S. et al. (2011) *Science, 333,* 740-743. [3] McEwen A. S. et al. (2014) *Nature Geoscience, 7,* 53-58. [4] Christensen, P. R. et al. (2004) *Space Sci. Rev., 110,* 85-130. [5] Chevrier V. F. and Rivera-Valentin, E. G. (2012) *Geophys. Res. Lett., 39,* L21202. [6] Masse M. et al (2012) *LPSC 43,* Abstract #1856. [7] Levy, J.S. (2012) *Icarus, 219,* 1-4. [8] McEwen A. S. et al. (2007) *JGR, 112,* E05S02. [9] Kirk R. L. et al. (2008) *JGR, 113,* E00A24. [10] .T. W. Brandt and V. H. Algazi (1992) *CVGIP: Image Understanding, 55,* 329-337.

Table 1

	MY 29	MY 30		
	Ls 290.3[1]	Ls 250.6[2]	Ls 257.8[3]	Ls 278.5[4]
Δ sol		**+607**	**+11**	**+32**
number of RSL				
total:	98	0	13	106
areal extent (m^2)				
total:	10,221	*N/A*	661	3,674
RSL lengths (m)				
total:	13,506	*N/A*	741	4945
mean:	169	*N/A*	57	47
median:	61	*N/A*	55	23
width of each RSL (m)				
mean:	1.06	*N/A*	0.98	0.95
3D length weighed mean:	1.32	*N/A*	1.21	1.10
median:	0.97	*N/A*	0.93	0.92
growth rate (m/sol)				
mean per extended RSL:	--	*N/A*	--	3.49
median per extended RSL:	--	*N/A*	--	2.48
mean per inherited RSL:	--	*N/A*	--	1.61
mean all RSL:	--	*N/A*	5.04	1.04

[1]ESP_013624_1335
[2]ESP_021628_1335 (baseline)
[3]ESP_021773_1335
[4]ESP_022195_1335