THE WATER CONTENT OF RECURRING SLOPE LINEAE ON MARS. C. S. Edwards[1] & S. Piqueux[2]; [1]United States Geological Survey, Astrogeology Science Center, Flagstaff, AZ, cedwards@usgs.gov; [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

Introduction

Evidence for ancient flowing water on the surface of Mars is widespread and varied [1-3], but present day liquid water may only be transient, briny, and confined to limited areas where solar insolation and temperatures are maximal [4-6]. In particular, Recurring Slope Linea (RSL observed on warm Martian slopes (Fig. 1) are meter-scale seasonally recurring dark flow-like features [7-9], potentially associated with liquid water. Other hypotheses for the formation of these features have been proposed, including dry granular flows and seasonal oscillations of near-surface adsorbed water [7].

Numerical models, laboratory work, and Antarctic analogues corroborate the liquid water-brine hypothesis for these flows [4, 11, 12]. The seasonality of RSL is also not consistent with recurring granular flows or absorption of atmospheric vapor [7, 9], as RSL are most active during low atmospheric water vapor seasons [13]. For these reasons, the liquid water-brine hypothesis is favored by the community and is adopted as a testable formation mechanism in this study. So far, the direct spectral signature of water (liquid or solid) has not been identified in RSL, supporting the hypothesis that these features involve small amounts of liquid [7, 14, 15]. Placing quantitative constraints on the water content of RSL would greatly help understanding their formation mechanism, but is difficult and to-date has only been limited to morphological observations and models[5].

Methods

In this study, we quantify the amount of water associated with RSL using nighttime surface temperature data from THEMIS analyzed in conjunction with (near)surface heat transfer numerical modeling [16] incorporating predicted thermophysical properties of wet regolith under Martian pressure/temperature conditions. Seasonal temperature variations between RSL-dense terrains compared to nearby dry regolith is used as the pixel-to-pixel calibration of THEMIS is <~1K (NEΔT @ 180K) and minimized the effects of a variable an difficult-to-remove atmosphere. This temperature difference between dry regolith and RSL dense terrains is shown in Fig. 2 in the form of a surface temperature difference, hereafter ΔT.

For this work, we focus on constraining the water content of RSL in a well characterized RSL-bearing region in Valles Marineris on the walls of an unnamed crater [9], where extensive daytime and nighttime THEMIS, HiRISE, and Context Imager (CTX) coverage already exists. In addition to having been previously characterized in detail [9], this area is suitable for further thermal analysis with THEMIS as it displays: 1) limited bedrock outcrops at the origination of the RSL, avoiding anisothermal behaviors with the finer slope materials ; 2) high density of RSL terrain versus dry slope material (up to 88%, typically >40% of a THEMIS pixel) maximizing wet regolith signal versus nearby dry material; 3) an extensive areal region, encompassing multiple THEMIS 100 meter pixels (Fig. 1); and 4) multi year seasonal THEMIS coverage (Fig. 2, data from individual years are not explicitly required as RSL occur in the same general regions year to year [7]). THEMIS surface temperature observations of the crater in Valles Marineris span the full Martian Year, including times when RSL are actively growing, during minor growth, fading, or not active (Fig. 2).

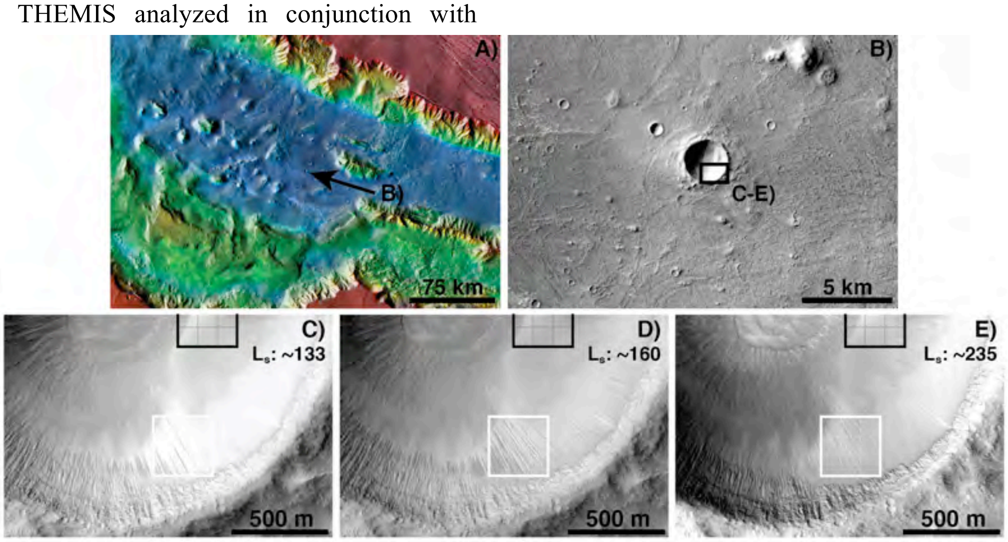

Fig. 1. Observations of the RSL containing crater in Valles Marineris centered at ~290.3˚E, 11.5˚S[9]. A) Colorized MOLA elevation[10] overlain on the THEMIS daytime temperature global mosaic B) CTX image C-E) HiRISE observations spanning L_s ~133 to 235 showing the generalized RSL progression in the region (Fig. 2) and locations of THEMIS observations

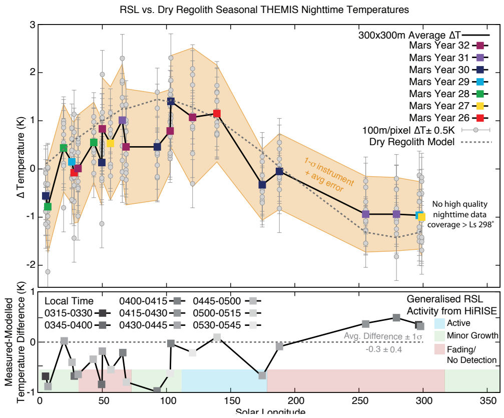

Fig. 2 *ΔT vs L_s for all THEMIS nighttime band 4 & 9 integrated temperature images covering the crater in Fig. 1. (Top) Data from all Mars years are shown as different color points on the black line. Average data are from two 300x300m regions on the most active RSL location (Fig. 1, white box) and nearby dry regolith location (Fig. 1, black box). All temperatures are referenced to the dry regolith, including the individual, 100m/pixel data. The estimated error in the measurement accounting for the 1-σ standard deviation of the average 3x3 pixel (~300x300m) box and ~0.5K relative uncertainty of THEMIS measurements (orange). The grey dashed line is a model temperature curve simulating the dry regolith temperature variations expected from subtracting the model temperatures of different azimuths on and off the RSL locations in Fig. 1. This model accounts for variations in individual image local time, Ls, on/off RSL albedo (0.168; 0.152 respectively), slope and azimuth of each locations (30˚, 305; 30˚, 290˚ respectively), and THEMIS derived dry regolith inertia (230 J K^{-1} m^{-2} $s^{-1/2}$). (Bottom) The difference between the THEMIS measured and dry-regolith model ΔT is shown, Local time is shown as grayscale points.*

Results and Implications

Water (solid/liquid) has a significant effect on the thermophysical properties of particulate regolith by increasing the bulk thermal conductivity, specific heat, and density, resulting in high thermal inertias and unique diurnal/seasonal temperature signatures. For this reason, surface temperatures and their seasonal variations are sensitive to small amounts of pore-filling water and represent an ideal measurable quantity to characterize the water content of RSL.

Over multiple years of monitoring with THEMIS nighttime data, no distinct thermal signal between wet (i.e. RSL bearing) and dry (i.e. nearby non RSL bearing) terrains is detected (Fig. 2) within the instrument detection limits (~1K), regardless of season. Numerical modeling of wet regolith under martian conditions of temperature and pressure indicates that terrains containing at least ~50 kg of water per m^3 of regolith, or roughly 0.5-3 wt% (depending on wet layer thickness) should have such a distinct thermal behavior. We conclude that the RSL-bearing terrains must be mm thin and contain ~50 kg of water per m^3 of regolith, or roughly 3 wt% at most, or have any thickness but contain <6 kg of water per m^3 of regolith.

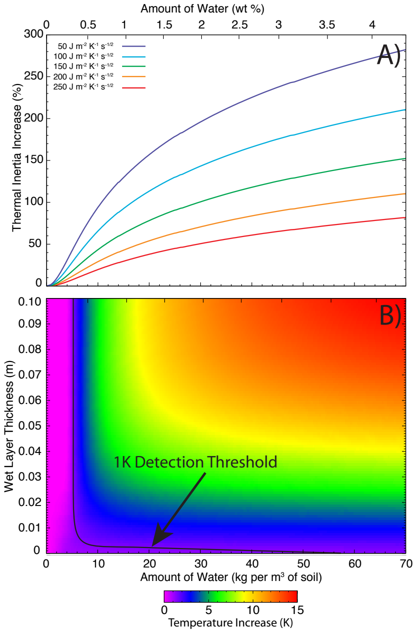

Fig. 3. *A) Thermal inertia increase (in %) versus amount of interstitial liquid water for five particle sizes consisting of 20 μm, 40μm, 100 μm, 240 μm, and 400 μm (50, 100, 150, 200, and 250 J K^{-1} m^{-2} $s^{-1/2}$, respectively). B) Modeled nighttime (0449 local time, 174 L_s) ΔT as a function of the wet layer thickness (Y axis) and amount of water (X axis).*

This result is consistent with the morphological modeling of [5] and is also consistent with expected seasonal albedo changes from wetting followed by freezing of small amounts of pore filling water [14]. The lack of a visible/near-infrared spectral signature attributable to water, as a fluid, solid, or in mineral structures [15], is also consistent with our results, as such low wt %s would likely have a small spectral contribution. The lack of spectral detection of cementing salts (expected to build up over time), coupled with the local thermal inertia values (i.e. ~230 J m^{-2} K^{-1} $s^{-1/2}$, only consistent with fine uncemented regolith) and high peak daytime temperatures (well above 273K), lead us to conclude the RSL in this area are associated with fresh water [6]. Irrespective of salinity, these flows experience diurnal/seasonal freeze/thaw and/or complete evaporation/sublimation cycles that may hinder their habitability.

References

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