THERMAL PROPERTIES OF RECURRING SLOPE LINEAE IN COPRATES CHASMA. C. Millot[1], C. Quantin-Nataf[1], C. Leyrat[2], L. Lozac'h[1], F. Millet[1], [1] Laboratoire de Géologie de Lyon Terre, Planètes, Environnement, Université de Lyon, 2 rue Raphaël Dubois 69622 Villeurbanne Cedex, France. [2] Observatoire de Paris, 61 avenue de l'Observatoire 75014 Paris, France.

Introduction: Recurring Slope Lineae (RSL) are dark features that occur, incrementally grow and fade every year on warm and steep slopes at the surface of Mars [1]. This phenomenon has been interpreted as an evidence for the presence of a volatile, possibly water, which has risen new issues on Mars modern habitability [1] [2]. However, the source for a volatile such as liquid water has not been identified yet. Dry mechanism has been also proposed [3] as an alternative explanation. As RSL occur every year at the warmer period, temperature seems to be the key parameter to understand RSL formation. To date, very few studies have been conducted to estimate spatial temperature variations at high resolution. In the present study, we aim to analyze the thermal behavior of the surface and subsurface of RSL location at high spatial resolution over a full seasonal thermal cycle. We focus on RSL locations in Valles Marineris, as it is the region of Mars with the highest density of known RSL on Mars. The observation of Valles Marineris RSL is well documented, in particular in the south wall of Coprates Chasma [4]. We use numerical thermal model to provide constraints on temperature range at which RSL occur every year in the south wall of Coprates Chasma. These estimations help us to understand surface and subsurface temperature distributions during the diurnal and seasonal cycle.

Methods: We first collect Digital Terrain Model (DTM) from the High Resolution Imaging Science Experiment (HiRISE) [5] camera at 1 m/pixel on RSL locations in Coprates Chasma identified in [4]. We then use HiRISE images to map individual RSL under Geographic Information System (GIS) environment (ArcGIS/ESRI). We use these RSL contours to extract their high resolution topography from HiRISE DTMs. We then estimate the solar flux for each pixel of each RSL DTM. From the topographic values, we extract the slope and orientation on every pixel using the 3D analyst extension of ArcGIS software. The results are then implemented in an IDL program developed by C. Leyrat [6] which uses SPICE libraries to compute solar flux with great precision [7]. Calculations are realized for a complete year, with fifty iterations a day to cover the diurnal cycle as well as the seasonal cycle. Hence, we compute the solar flux taking into account local topography and solar longitude. At last, solar flux values are included in MARSTHERM program [8] and temperature calculations are performed solving the energy balance at the surface for every location, including the effect of CO_2 condensation-sublimation cycle [8]. We consider heat transfer processes in subsurface, solving the equation for conduction of heat in 1D along the vertical depth direction axis, including the effect of the atmosphere and considering heat reemission by the planetary surface. The energy balance is solved for every pixel at any time iteration. The program runs for five Martian years to allow convergence. The model output is the temperature variations at several depths, for every pixel and for any time in the year.

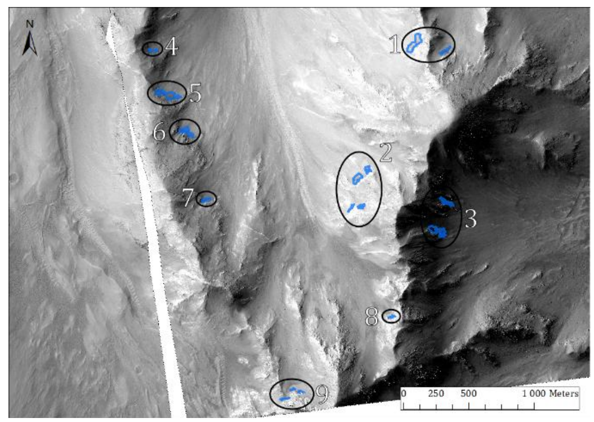

Figure 1: Map of the RSL with their IDs we analyzed here. The image displayed in background is the HiRISE image ESP_024993_1670 (NASA/JPL/University of Arizona).

Results: We perform several computations over multiple years on RSL features displayed in the figure 1. For each HiRISE pixel, the model outputs: surface temperatures and subsurface temperature at ~10 cm, 30 cm, 1 m, 3 m and 5 m below the surface. Two cases of thermal inertia, which describes the response of the considered medium to temperature variations, have been tested: 200 or 400 $J.m^{-2}.s^{-1/2}.K^{-1}$. These two endmembers correspond respectively to thermal inertia of fine (hundreds of µm) or coarse (few mm) sand [9]. Figure 2 displays the surface temperatures and subsurface temperatures at 7 cm computed with MARSTHERM program [8]. Temperature spatially varies because of orientation and slope variations. At 7 cm, cooler temperatures are due to the night low temperatures; heat conduction to depth depends on surface temperature and physical properties of the medium. Our results reveal that the diurnal cycle at the surface range from 170 K before the sunrise to 290 K in the early afternoon. The maximum and minimum temperature can be shifted in time depending on the orientation of the RSLs. For instance, east-facing slopes are heated before west-facing slope during the diurnal cycle. Seasonal cycle presents a global warming between L_S = 300° and L_S = 80° and a cooling after L_S = 130°.

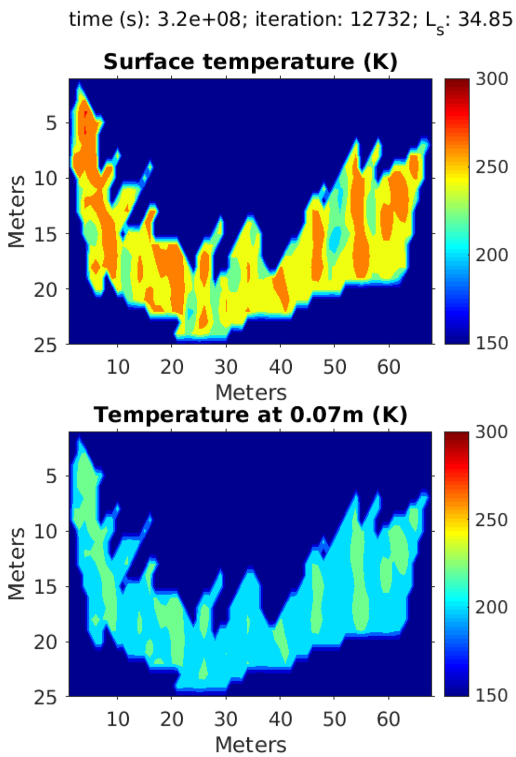

Figure 2: Surface and subsurface temperature maps (K) computed from MARSTHERM program for RSL4. Solar longitude, ephemerid time and iteration are indicated for these maps. Thermal inertia is set to 400 $J.m^{-2}.s^{-1/2}.K^{-1}$.

Figure 3 shows the temperature distribution over all the pixels included in the RSL4 area. The mean slope orientation is NE. According to the RSL activity highlighted in [4], RSL4 appears around solar longitude L_S = 320°, grows and starts to fade at L_S = 150° until complete fading around L_S = 180°. Diurnal cycle is not taken into account in this representation, as we keep the maximum temperature value for every day in a complete year. Our results show that the RSL occurrence corresponds to a sharp increase in temperatures and fades when temperatures decrease, as previously observed [1] [2]. At the time the RSL starts to fade, a part of about 5% of the pixels displays temperatures below 259 K (yellow solid line in figure 2).

Discussion and perspectives: The range of temperature we have calculated is typical of the phase transition temperature for Mg or Na-perchlorates [10]. Moreover, they have been detected in RSL [11]. Thus, this result is consistent with an activity involving salts deliquescence (from solid to liquid by atmospheric water absorption).

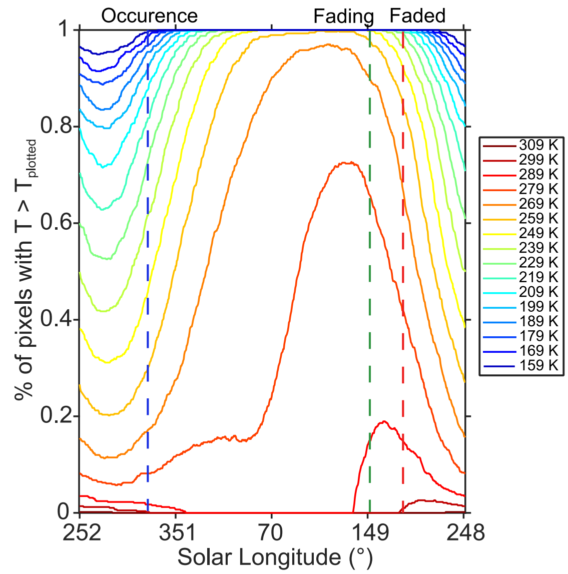

Figure 3: Seasonal variability in temperature values distribution for RSL4. The temperature maximum is extracted every day to get rid of diurnal cycle. Dashed lines highlight the RSL activity in this region according to supplementary data from Stillman et al. [6] for NW facing slopes (Blue is occurrence; Green is fading and Red is faded). Color scale represents the temperature in Kelvin. For instance, at solar longitude L_S = 70°, ~95% of the pixels have a temperature above 259 K, and ~90% have a temperature above 269 K.

However, we have no clue if relative humidity allows this kind of process in Coprates Chasma. To further decipher the origin of RSL, our method will be applied to most of the RSL features. Moreover, as temperature gradients have involvement in dry mechanism proposed in [3], computations may be performed for temporal and spatial gradients.

References: [1] McEwen A. et al. (2011) *Science, 333 (6043)*, 740-743. [2] McEwen A. et al. (2014) *Nature Geoscience, 7 (1)*, 53-58. [3] Schmidt F. et al. (2017) *Nature Geoscience, 10 (4)*, 270-273. [4] Stillman D. E. et al. (2017) *Icarus, 285*, 195-210. [5] McEwen A. et al. (2007) *JGR: Planets, 112 (E5)*. [6] Leyrat C. et al. (2016) *Icarus, 268*, 50-55. [7] Acton C. H. (1996) *Planetary and Space Science, 44 (1)*, 65-70. [8] Clifford S. M. and Bartels C. J. (1986) *LPSXVII*, 142-143. [9] Piqueux S. and Christensen P.R. (2011) *JGR, 116 (E07004)*. [10] Gough R. et al. (2014) *Icarus, 233*, 316-327. [11] Ojha L. et al. (2015) *Nature Geoscience, 8*, 826-832.