FOGS AND CLOUDS ARE A POTENTIAL INDICATOR OF A LOCAL WATER SOURCE IN VALLES MARINERIS. C. W.S. Leung[1], S. C. R. Rafkin[2], D. E. Stillman[2], and A. S. McEwen[1]. [1]Lunar and Planetary Laboratory, University of Arizona, 1629 E University Blvd, Tucson, AZ, USA. 85721 (cwsleung@lpl.arizona.edu), [2]Dept. of Space Studies, Southwest Research Institute, 1050 Walnut St., Suite 300, Boulder, CO, USA. 80302

Introduction: Recurring slope lineae (RSL) are narrow (0.5-5m), low-albedo seasonal flow features on present-day Mars that extend incrementally down warm, steep slopes, fade when inactive, and reappear annually over multiple Mars years [1,2]. Over 250 candidate and confirmed RSL sites have been discovered, with ~50% of all accounted RSL sites appearing in and around Valles Marineris. [3]. RSL favor slopes with relatively warm daytime temperatures, which at times can reach peak brightness temperatures of ~250-300K [2,3]. Dry and wet origins for RSL have been suggested, but observational correlations of incremental lengthening with seasonality and surface temperature suggests some role for a volatile, for which water is in the right temperature regime [1,2]. The detection of hydrated salts at locations and seasons where RSL are active further support the hypothesis that RSL form as a result of contemporary water activity on Mars [4].

The origin of RSL as well as the mechanism by which RSL are recharged remains an open question. Hypothesis for groundwater sources of volatile include seeping water, melting shallow ice, and deeper aquifers reaching the surface at springs [1-3]. Atmospheric water recharge via perchlorate deliquence has also been proposed [5,6], provided a mechanism exists to efficiently concentrate enough water to the surface to account for the estimated RSL water budgets, which vary [3,7].

Fog Observations on Mars? Extensive recurring slope lineae activity has been detected in Valles Marineris on Mars and coincides with regions where putative water ice fogs may appear [8]. Images from the High Resolution Stereo Camera (HRSC) on Mars Express (Figure 1b) show possible morning ice fog in the Coprates Chasma region of Valles Marineris at 09:20 local time during L_s = 38°. The potential low-lying water ice fog in the image appeared exclusively inside the canyon, vertically extending only partially up the canyon walls, and does not appear over the surrounding plateaus. Fog Phenomena on Mars has also been reported in Viking Orbiter images lingering shortly after dawn in the canyons of the Noctis Labyrinthus region at the western end of Valles Marineris. However, it has also been argued that these are dust hazes rather than fogs [12].

Water ice fogs will form if the atmosphere becomes saturated. This can happen with the appropriate combination of cooling or addition of water vapor. The water ice fogs would subsequently dissipate by mid-day as the atmosphere is heated.

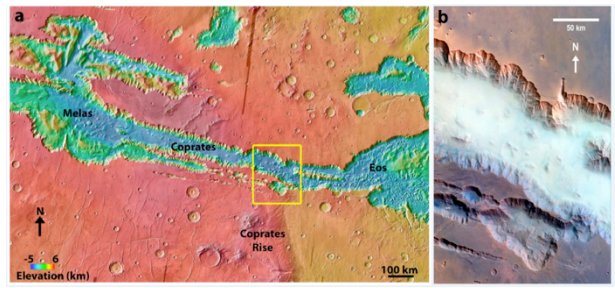

Figure 1. (a) Mars Orbiter Laser Altimeter (MOLA) topography overlain on Thermal Emission Imaging System (THEMIS) daytime infrared mosaic of central Valles Marineris. (b) Mars Express High Resolution Stereo Camera (HRSC) image H0438_0000_ND4 capturing morning ice fog in Coprates Chasma. Region correspond to yellow rectangle in panel a. [8]

If fogs are present, they may provide a clue to the water cycle within the canyon, and could elucidate the processes related to the evolution of RSL. In this study, we show that fog formation in the valley is unlikely without a local water source, and that the thermodynamic conditions in Valles Marineris do not favor the atmosphere as a primary recharge mechanism for RSL.

Atmospheric Model: Using the Mars Regional Atmospheric Modeling System [9], we investigate the atmospheric dynamics in and around Valles Marineris. The numerical model domain for our simulation is specified by four, two-way nested grids, with the last grid focused on the canyon with ~20 km horizontal grid spacing.

Discussion: Our simulation results in Valles Marineris show a curious temperature structure, where the inside of the canyon appears warmer relative to the plateaus immediately outside at all times of day (Figure 2). The main source of water in the Martian atmosphere comes from sublimation of the N. pole duing northern spring, and should be well-mixed by the time the air reaches the Valles Marineris region. Formation of water ice fogs require the surface to drop below the condensation temperature. The temperature structure suggests that if water is well mixed and fog is present within the canyon, fog and low-lying clouds should also be present on the cooler surrounding plateaus as well. This is generally not the case. **Therefore, the only way to produce fog inside the canyon is to have a local water source**.

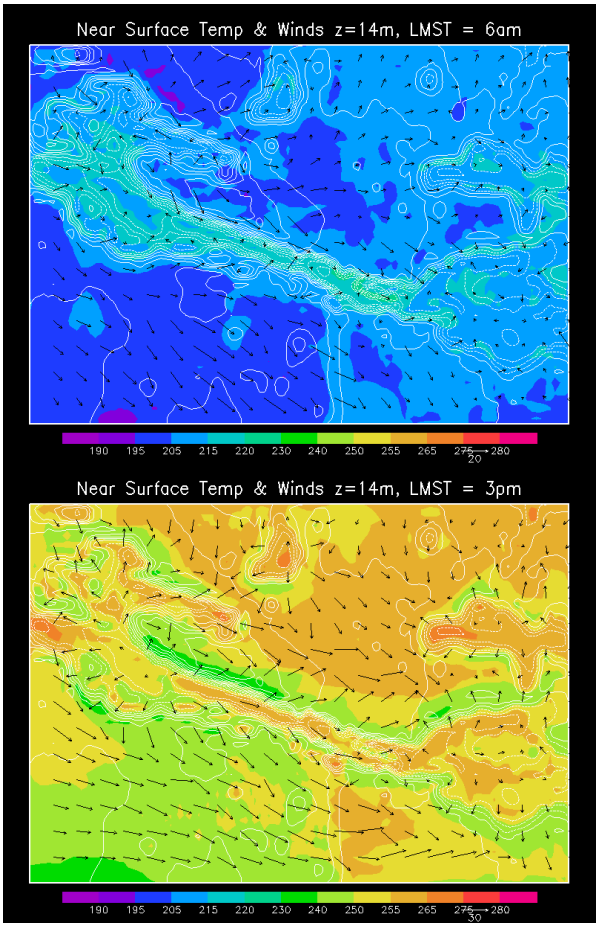

Figure 2. Diurnal near-surface temperatures (z=14m above ground) & horizontal wind circulation at 06:00 and 15:00 LT during L_s = 45°. Black arrows show instantaneous zonal & meridional averaged wind vectors indicating magnitude and direction of the circulation in the vicinity of the canyon. Plots show inner-most model grid domain covering a similar region as shown in Figure 1a.

RSL may contribute to this atmospheric water through evaporation, or the RSL may simply be a surface marker of a larger near-surface reservoir of water that can act as a source.

Using the modeled temperatures in Valles Marineris, we calculated the corresponding saturation vapor pressures and saturation mixing ratios to determine the amount of water vapor in the air at saturation (Figure 3). Based on potential fog observations inside the canyon, if we assume the plateau is just sub-saturated, and the canyon bottom is just saturated, the resulting difference in mixing ratios represents the minimum amount of vapor required for the atmosphere to be saturated, and for the potential formation of fog in Valles Marineris.

The Martian atmospheric column abundance is ~10 precipitable microns [pr-µm] on average [10] and presents a major challenge for an atmospheric origin of volatiles to support the estimated water volumes of RSL [3].

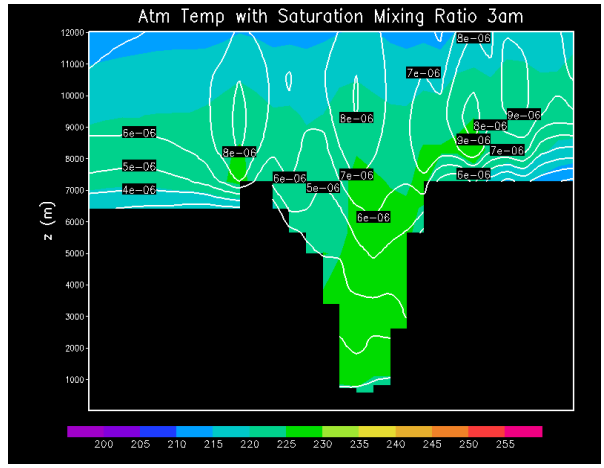

Figure 3. Cross sectional plot of the diurnal variations in atmospheric temperature (shaded) and saturation mixing ratio (contour) at 03:00 LT during L_s = 45° in Coprates Chasma.

RSL appear to be most active on warm slopes [1,2]. High temperatures typically correspond to higher evaporation rates and lower relative humidity in the atmosphere, and may present further challenges for water to be extracted efficiently from the atmosphere. Peak normalized water vapor column abundances of 10-15 pr-µm at ~Ls= 210-240° in Valles Marineris is a poor match to observed peak RSL activity in the region, and no correlation between seasonal variation in the atmospheric water vapor column abundance and RSL activity has been found [2].

Conclusions: If nocturnal clouds and fogs are present in Valles Marineris and not on the surrounding terrain, the modeled atmospheric thermal field points to an active source of water in the canyon. This source may be related to the water source for RSL and bolsters the hypothesis for a subsurface water reservoir. An atmospheric origin of water for RSL via deliquescence on salt requires an effective mechanism to trap water over small areas to support the estimated volumes of water in RSL [3,11]. No such mechanism has been identified. However, there is still evidence that the atmosphere exerts control on the formation and activity of RSL through thermal effects.

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