Dry versus wet conditions for RSL. C. Huber[1] , L. Ojha[2] and J. Wray[3], [1]Brown University, [2]Johns Hopkins, [3]Georgia Institute of Technology.

Introduction: Recurring Slope Lineae (RSL) are dynamical features that may involve running water close to the current Martian surface. However the physical processes involved and the nature of these ephemeral darkening features remain poorly constrained, leading to a debate as to their origin: (1) dry granular current versus [1] (2) wet gravity currents [2,3].

RSL growth downslope during warm seasons seems unequivocally to couple them to climatic conditions and their downhill propagation qualifies them as gravity currents sensu latto. Here we discuss the pros and cons of dry and wet models and the main challenges that each is currently facing.

The wet RSL model is challenged by arguments regarding the control of the angle of repose on their final extent, the correlation between RSL length and the amount of material involved and finally the putative source for the material involved in the gravity current. In contrast the challenges facing dry models are (1) the fading of the darkening observed after RSL activity, (2) the mass balance for granular material and (3) the observation that several RSL do not end at the rupture in slope where the slope decreases significantly below the angle of repose[4].

At this stage it is fair to say that neither dry nor wet endmember models are entirely satisfying It is however through the combination of observations with quantitative models which provide testable hypotheses and numerical constraints that we are bound to progress on this question.

Physical models: Our modeling efforts focus on wet gravity current in the very shallow subsurface (upper few cm), our goal being to develop quantitative tests for the argued weaknesses of the wet hypothesis (Fig. 1). These gravity currents take place in the porous martian soils at depth shallower than the effective capillary fringe. Currents are modeled through lubrication theory in 3-D, assuming a point source, or series of point sources upslope. These aqueous fluids, once released near the Martian surface either from atmospheric condensation (deliquescence) or by deeper confined aquifers, are unstable and evaporate at rates controlled by atmospheric conditions and diffusive transport of water molecules through the thin layer of soil that separates the flow from the surface. We use two different models for evaporation, the first assumes that the evaporation rate is linearly proportional to the depth (and by extension the thickness) of the current (MODEL 1) and the second where the evaporation rate is constant (MODEL 2).

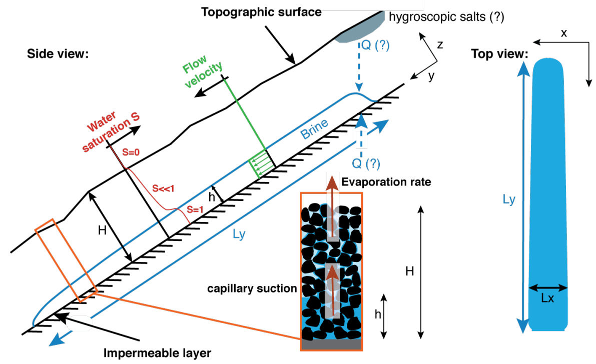

Figure 1. Schematic illustration of the wet gravity current model for RSL.

Fluid budget and constraints on chemistry: We ran 1200 numerical simulations of wet gravity currents for each evaporation model varying the rate of evaporation, slope, production rate of fluids and hydraulic conductivity of soils. In combination with scaling analysis we establish how the topology of RSL and their rate of growth imaged remotely can be used to provide sound estimates for the local evaporation rate, permeability of soils and fluid production rate for each of the 13 measured non-merging RSL we have catalogued (from mid to near equatorial latitudes).

For Model 1, we establish unequivocally the effective evaporation rate from the transient growth of the RSL. The rates are consistent to what would be expected for brines wetting a fine grain soil [5]. We can then use the steady-state (maximum) extent (length and width) of each RSL to retrieve independently the hydraulic conductivity of the soil and the production rate of fluids. Interestingly, this procedure leads to RSL lengths downslope that are significantly decorrelated from production rates for RSL. The length of RSL is controlled by the permeability of the soil, the slope angle and the evaporation rate.

The procedure for Model 2 is significantly different, because one cannot use the transient growth of RSL to unequivocally constrain the evaporation rate. The fact that evaporation rate cannot be retrieved directly from growth forces us to use Markov Chain Monte-Carlo simulations to find the best match between simulated and measured RSL and constrain permeability, evaporation rate and production rate. Interestingly, we find that both models retrieve net evaporation rates and production rates within errors of each other, i.e. the choice of evaporation model has limited effects on constraining the volume of fluids involved.

Wet versus dry?: The quantitative models discussed here for wet currents can however address some of the issues raised recently by Dundas et al (2017) regarding the wet origin of RSL. The three foremost challenges brought forward by these authors are the correlation with RSL termination with repose angle, the origin and supply of aqueous fluids and the fact that RSL terminating on similar slopes but with strong constrast in length would involve widely different fluid volumes. The validity of the last argument does not stand in light of our quantitative analysis, as we see that RSL length is either not (MODEL 1) or not uniquely (MODEL 2) correlated with fluid production. While Dundas et al. showed that RSL (at 10 different RSL site) tend to terminate at or near the angle of repose, it is unclear if this is a unequivocally true for all RSL sites. There are RSL observed to extend beyond the angle of repost at sites like Tivat and Juventae chasma (Fig. 2).. Finally, the amount of water trapped in the soils from our models is consistent with the small fractions that would be admissible from thermal inertia measurements [6].

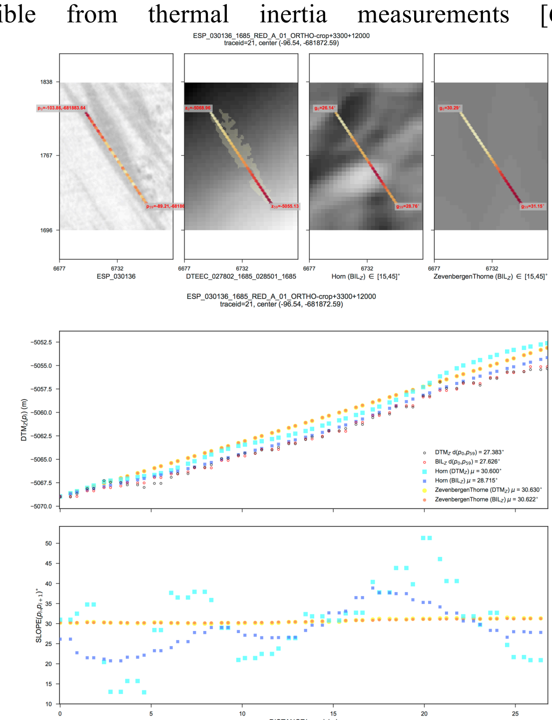

Figure 2. Slope profiles for selected RSL. Figure and computations courtesy of David Stillman.

The main challenge for wet RSL is the source and long term stability of water (either atmospheric or groundwater). From a mass balance perspective, each RSL involves in general less or about 1m^3 of brine over the warm season, which is to say it is not likely to deplete rapidly a decent size shallow groundwater reservoir. The nature of the source and confining layer that caps it to allow the source to be perched at high elevation is more difficult to explain. In some cases [7], a shallow permafrost-type layer, where the pressure of the overlain aquifer can be elevated through cycles of freezing and thawing can be invoked. However, this explanation is less plausible for RSL observed at low latitude. In summary, wet gravity currents can explain the growth rate and aspect ratio of RSL within consistent bounds for evaporation rates for brines and soil permeability (and also invoking small amounts of fluids only). Finally, wet gravity current below the surface would lead to minimal mass wasting for sand and would therefore explain why this repeting process is not leading to measurable topographic changes.

The case for dry granular currents has not been tested extensively through the development of predictable quantitative models. It remains unclear if the aspect ratio and rates of growth of RSL calculated within that framework could match those observed. However, it alleviates the main concern for the source and conditions under which fluids have to be brought or deposited onto the surface. Outside of the problem of seasonality, dry models are faced with addressing three different challenges. These are namely the explanations for the fading rate of RSL (dust deposition), the cases where RSL propagate past the typical dynamic angle of repose predicted and the lack of apparent mass wasting (problem of sand recirculation from lows to highs). As posited by Dundas et al[1] it is possible that local winds deposit dust over the tracks (fading) and could carry some sediment upslope to balance the process. However, it is not clear why recirculation of the sediments does not involve darkening when material is eroded from the bottom end of the RSL and moved back upslope, as it does when the granular gravity current takes place.

Even if the present study is unable to provide a definite answer for the origin of RSL it constrains significantly the most relevant questions to study in the future, it develops a quantitative framework for rigorous hypothesis testing and addresses some recently voiced issues regarding the role of water in RSL.

Acknowledgements: We thank David Stillman for letting us use the slope profiles shown in Fig. 2.

References:

[1] Dundas C. et al. (2017), *Nat. Geo*, 10, 903-907. [2] Ojah L. et al. (2015), *Nat. Geo*., 8, 829-832. [3] Grimm R. et al. (2014), *Icarus*, 233, 316-327. [4] Stillman D. et al. (2017), *AGU Fall Meeting*. [5] Hudson T. et al. (2007), JGR,112, 1-27. [5] Edwards C. and Piqueux S. (2016), *GRL*, 43,8912-8919. [6] Grimm R. et al. (2017), *LPSC XLVIII*, 2695.