MASS BALANCE CONSTRAINTS ON THE SUSTAINABILITY OF MARS' RECURRENT SLOPE LINEAE (RSL): SHOULD RSL BE AN ASTROBIOLOGY PRIORITY? Edwin S. Kite[1,2], [1]Caltech MC 150-21, Geological and Planetary Sciences (ekite@caltech.edu) [2]O.K. Earl Fellow.

Summary: Recurrent Slope Lineae (RSL) are the best evidence yet found for active water flows on Mars, but it is not clear if a self-consistent water source mechanism exists [1]. Supposing water is obtained either from the present-day atmosphere or from hydrated minerals in bedrock, then there must be a large flux of salt into RSL source regions. If flow rates in water tracks in the Antarctic Dry Valleys are a reference point, salt depletion in the near surface will exceed replenishment by photochemistry or dust deposition. Either (a) salt is resupplied by bedrock breakdown and/or wicking from deeper in the subsurface, requiring rapid (mm/yr) bedrock retreat, (b) each RSL is not close to steady state and will shut down when upslope salt is locally depleted ($<<10^3$ yr), or (c) RSL are dry.

Water source mechanisms: RSL are rare features associated with steep bedrock outcrops, almost always with boulder-shedding cliffs, and peak temperatures around water's melting point. A groundwater source is disfavored by RSL found rimming high mesas. 3 confirmed RSL sites are active in the warm season near the equator [2], where surface water ice should not be stable. Late melting of seasonal water frost is disfavored by the aspect-independence of some RSL. Excitement about the discovery of RSL was tempered by the lack of spectroscopic confirmation of water and of a physical model for the water source. However, at least two plausible water source hypotheses do exist: **(1) Chloride salts deliquesce** at times of relatively high humidity, flowing to produce streaks similar to those seen in the Antarctic Dry Valleys [3]. Humidities high enough for chloride-salt deliquescence are predicted to occur near sunrise and sunset by the Mars Climate Database [4]. An estimate of water uptake rate Q is $Q = V\,C_D\,W$ where $V \sim 10^1$ m/s is wind speed, $C_D \sim 3 \times 10^{-3}$ is a surface exchange coefficient, and $W \sim 3 \times 10^{-5}$ kg/m^3 is water vapor concentration in the atmosphere. These optimistic parameter choices supply ~0.1 kg/m2/sol H_2O which might be enough for flow. A key difference from the Dry Valleys is that the salinity of Mars flows would be (roughly) 20% by weight. The corresponding salt flux is $O(1)$ kg/m^2/yr (10% duty cycle), too high to be balanced by dry-deposition. The alternative salt source is be the substrate (rock or soil). The main difficulty with (1) is that W is small.

(2) Feedback between evaporite dewatering, steep slopes, volume changes, rapid erosion, and small seasonal flows: Consider a parcel of ancient, hydrated salt that is being exhumed by lateral cliff retreat. Far from the surface, the salt does not dehydrate; kinetics are slow at mean annual temperature [e.g., 5, 6]. Close to the surface, temperatures can seasonally rise above the point of incongruent melting (~275K for meridianiite) [7], releasing water/brine that forms RSL. Temperature-sensitive melting and dehydration reactions tend to produce volume changes, fragmenting the rock (e.g., [8]). For example, the reaction $MgSO_4{\cdot}11H_2O \rightarrow MgSO_4{\cdot}7H_2O + 4H_2O$ is accompanied by a 4% volume expansion [7]. Fragmentation leads to mass wasting and cliff retreat, exposing fresh material. In the next warm season, that fresh material will also release water/brine. So long as exhumation outpaces dehydration, the cycle can continue - unzipping the cliff/steep slope. A serious problem with option (2) is that any water released by incongruent melting might simply sublimate into the atmosphere.

Discussion: Neither mechanism is entirely satisfactory, but both are testable. To maintain rapid rock retreat rates, aeolian processes must remove debris from the foot of the slope as fast as it is produced. mm/yr retreat rates suggest a correlation between steep slopes, boulder falls, and RSL, and they are in the range where a long baseline of HiRISE observations might allow CosiCORR detection of enhanced mass wasting. (2) predicts that flows should always start at rocks (because fine-grained material has already dehydrated). By contrast (1) predicts that flows can start on talus. (2) predicts active mass wasting from non-evaporite caprock with a mass flux proportionate to water release. (1) predicts flow occurring in the early morning and late afternoon, with enhanced vapor concentrations (fog?) near RSL, while (2) predicts movement near the middle of the day. These might be discriminated by looking for changes in IR/R/BG reflectance as a function of time-of-day.

Need for rapid rock retreat: It is hard to avoid the need for a high flux of salt from the substrate (rock or soil). Deliquescent salt approaches the liquid state from the `salt side' of the phase diagram, so its saltiness is the eutectic value or greater. RSL flow moves salt downslope. (If slope winds have the net effect of blowing salt back up to the top of the slope, then anabatic winds are stronger than katabatic winds, which would be unexpected based on theory and on observations of bedform-terrain interactions elsewhere on Mars.) Required rock retreat rates > km/Myr imply that RSL do not persist over geologic timescales. Otherwise the required mass wasting would grossly alter the shape of host craters. (A recent paper by Chevrier and Rivera-Valentin [9] also concludes that a recharge mechanism is needed to sustain RSL; otherwise they are transient features).

Should RSL be an astrobiology priority?: Both these mechanisms assume that RSL are disconnected from any wider liquid water reservoir, an assumption that is strongly supported by orbiter and lander data. If this is correct, what does their isolation, high salinity, brief intervals of activity, and brief duration mean for the prospects of life in RSL? *Thought experiment:* Imagine sterilizing an RSL-bearing slope, transporting it intact to a sealed warehouse, and cycling it repeatedly between the wet and dry states. It is unreasonable to expect that life would originate under these conditions, so the case for life in RSL rests on colonization of RSL by biological materials from 'background Mars' (soil, or evaporite rocks). Because both soil and evaporitic rocks will be studied by current or planned missions, the case for sending an additional astrobiology mission to RSL relies on the assumptions that (i) biological materials exist in background Mars materials, but below the detection threshold of current or foreseeable instruments; (ii) the RSL environment amplifies the concentration of biological materials to a level above the detection threshold. Is this a strong case?

Acknowledgements: Discussions with Paul Hayne and Joe Levy provided new ideas.

References: [1] McEwen et al. (2011) *Science,* 333, 740-743. [2] McEwen et al. (2012) *AGU Fall Mtg.* P21C-1857. [3] Levy (2012) *Icarus*, 219, 1-4 [4] Mars Climate Database v4.3 [5] Wang, A., et al. (2012), *LPSC 43*, 2172 [6] Lu, Y., Wang, A. (2012), *AGU Fall Mtg.* P24B-03 [7] Peterson & R. Wang (2006), *Geology*, 34, 957-960. [8] Balboni, E., et al. (2010), *Environ. Earth Sci.* doi:10.1007/s12665-010-0774-1. [9] Chevrier V.F. & Rivera-Valentin, E.G. (2012), *GRL*, 39, L21202.