Volatile insight on global circulation on Mars, with implications for Mars 2020 landing sites. J. Hurowitz[1], S. Karunatillake[2], L. Kerber[3], and M. Mischna[3]. [1]Geosciences, Stony Brook University, NY 11794 (Joel.Hurowitz@stonybrook.edu), [2]G&G, LSU, LA 70803 (wk43@cornell.edu), [3]JPL and Caltech, CA 91109.

Introduction: Settle [1] posited an intriguing and testable hypothesis: that the geographic distribution of near surface sulfur deposits on Mars should be influenced by high level winds carrying aerosolized sulfuric acid droplets downwind from Tharsis Montes and Olympus Mons, following the wind flow directions in the upper atmosphere.

Several critical reasons merit an assessment of Settle's [1] hypothesis. Across most landing sites on Mars, soil chemistry appears to be remarkably homogeneous, enriched in S and Cl relative to their basalt precursors. The S/Cl ratio that we analyze in these soils is consistent with derivation from primary magmatic exhalatives.

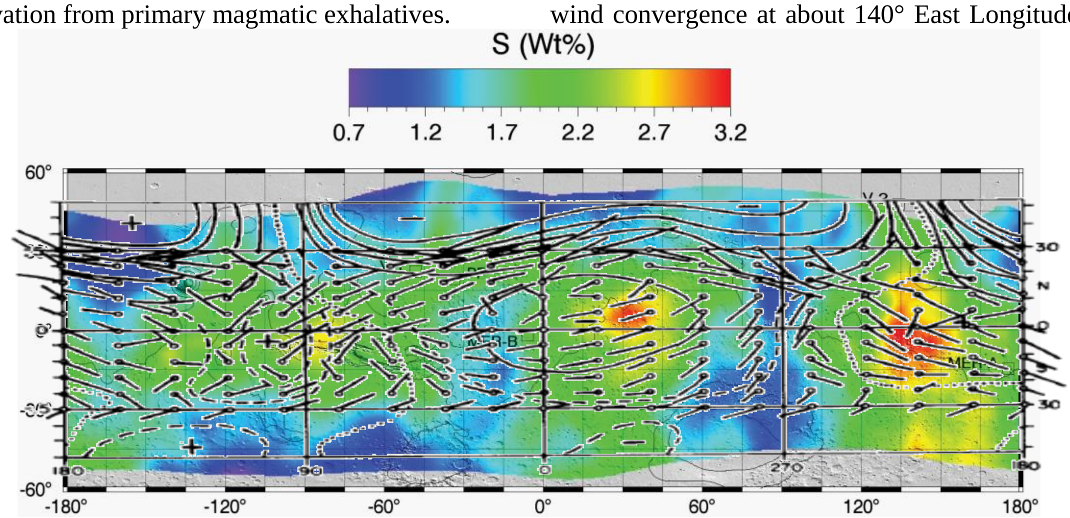


Figure 1. Overlay of the early GCM model [2] on a preliminary S mass fraction (as %) map [3]. N. hemisphere winter solstice, 1.5 mbar level wind patterns shown as an example.

Extrapolating from in situ observations, we recently concluded [4] that bulk soil chemistry on Mars shows a signature of basalt with the chemical addition of S and Cl. The chemical province that overlaps with the Radar Stealth area, as derived from Mars Odyssey Gamma and Neutron Spectroscopy (GRS), serves as a possible regional example of such trends [5]. Furthermore, we note minimal subsequent fractionation of the soil chemical composition following addition of these two elements (most likely in the form of H_2SO_4 and HCl) [4] .

The in situ and orbital geochemical observations allow us to re-state the "acid fog" hypothesis [1]. Acid aerosol droplets would precipitate from volcanic eruptions, depositing across the surface in a low water activity (a_w) environment, minimizing the remobilization of S and Cl, and preserving a basaltic bulk chemistry diluted by S and Cl. This may signify a hallmark of Amazonian water-rock interaction. We present our qualitative assessment, preliminary results, and future work here.

Qualitative assessment: We overlaid flow patterns from Webster's [2] model of upper atmospheric circulation – as also used by Settle [1] -- on a preliminary GRS sulfur map [3]. To first order, a match appears between this early Global Circulation Model (GCM) and the GRS S-distribution map (Fig. 1). The model predicts two seasonal lobes of wind directed towards the northern and southern hemispheres from a center of wind convergence at about 140° East Longitude. This overlaps with GRS-S enrichment that has strong north and south directed "lobes". Qualitatively, S-bearing aeorosols may preferentially precipitate in the center of this wind convergence zone or be carried towards the poles by the northern and southern jets. A strong circular flow pattern also exists over another S enrichment near the equator at about 30° Longitude. Furthermore, some low-S regions coincide with areas of strong regional outflow, consistent with the expectation that S would not undergo net deposition or removal in such regions. The winter solstice wind patterns show the strongest visual association. While the equinox wind pattern shows some divergence, it preserves the south directed lobe and convergence zone at 140° Longitude.

If, as suggested qualitatively, the distribution of surface S coincided with the predicted locations of fallout from upper level atmospheric circulation, a powerful constraint would arise on the source and distribution of acid volatiles on the martian surface. Moreover, this may also identify regions to avoid for a Mars 2020 landing, as latter stages of surface weathering by acidic aerosols may pervade in such locations. Accordingly, we predict that a realistic GCM simulation of S-transport and deposition will highlight areas on Mars where exhalative acid S-deposits accumulate, in turn coinciding with areas of S- and Cl-enrichment, along with S/Cl ratios similar to bulk martian soil.

Preliminary results: Given the regional focus of our work, we use geochemical maps derived from GRS. This involves the latest data derivation on 05/28/2010, corresponding to cumulative spectra across the life span of the GRS suite. For preliminary insight, we employ 0.5°×0.5° bin sizes, even though formal analyses will use 10°×10° maps, corresponding to the effective spatial resolution limit of the three chemical maps in focus: Cl, H, and S.

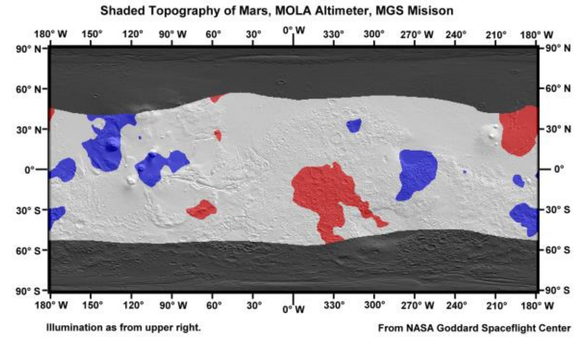
Our method employs the chemical province delineation approach used in Eq. 1 by Karunatillake et al. [5]. We require the corresponding test parameter's magnitude to exceed unity when identifying bins of interest, approximating 84% confidence in directional deviation from the global average of a given compositional variable. Places of spatially continguous bins that exceed the roughly 4 – 5° of arc radius intrinsic GRS spatial resolution confer an even higher significance to deviations.

While this preliminary analysis uses the standard arithmetic mean and standard deviation equations, formal analyses will use Eq. 7 by Karunatillake et al. [6] to compute the mean and Eq. 11 to compute the standard deviation. These introduce weighting to account for the areal distortion that results from equi-rectangular (i.e., simple cylindrical or plate-caree) projections.

As also supported by recent work [7], in situ soil shows a bimodality in S/Cl mass ratios. The surficial material tends to range between 1.8 - 3.6, while the bulk subsurface soil ranges between 4 - 5. Gamma spectral observations, as consistent with decimeter scale depth sensitivity, also show S/Cl ratios in the 4 - 5 range across most of the martian surface. Consequently, we sub-sample the observed global distributions of total Cl and S content, by excluding pixels with anomalously high and low S/Cl mass ratios from the regional bulk soil (Fig. 2).

We next identify regions unusually high in the total S and Cl content at 68%, 87%, and 95% confidence on a bin basis (Fig. 3). Each of these thresholds, if generating contiguous areas exceeding the intrinsic GRS resolution, amount to total spatial confidence exceeding 95%. Such areas may signify recent accumulations of S and Cl from atmospheric processes, assuming of course, unremarkable geomorphology. Given the relatively arid atmospheric conditions in recent martian geology, these are also less likely to be exploration-worthy for Mars 2020 from a habitability perspective.

Figure 2. Gamma-derived regions of anomalous S/Cl



ratios, identified in red (i.e., high) and blue (i.e., low), overlain on a shaded topography map of Mars. We exclude these regions from our analysis for the reasons described in the text.

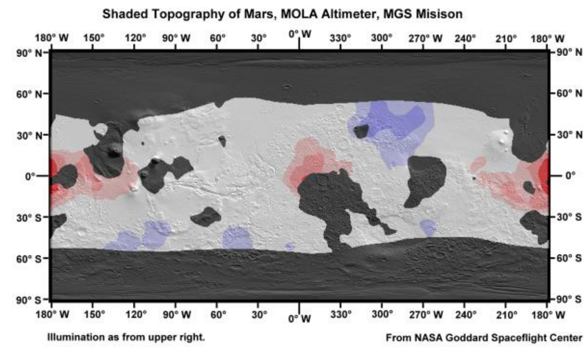


Figure 3. Gamma-derived regions of total S and Cl content enrichment (i.e., deepening red hue at 68%, 87%, and 95% confidence), and depletion (blues), overlain on a shaded topography map of Mars. This excludes the S/Cl anomalies (Fig. 2).

Future work: Our qualitative analysis and preliminary results collectively motivate an analytical comparison with GCM predictions for S aerosol transport in the upper martian atmosphere. We expect our upcoming work to validate the hypothesis.

References: [1] M. Settle, *J. Geophys. Res.*, vol. 84, no. B14, pp. 8343 – 8353, 1979. [2] P. J. Webster, Icarus, vol. 649, pp. 626–649, 1977. [3] P. L. King and S. M. McLennan, *Elements*, vol. 6, no. 2, pp. 107–112, 2010. [4] J. A. Hurowitz and W. W. Fischer, *Geochim. Cosmochim. Acta*, vol. 127, pp. 25–38, 2014. [5] S. Karunatillake et al., *J. Geophys. Res.*, vol. 114, no. E12, p. E12001, Dec. 2009. [6] S. Karunatillake et al., *J. Sci. Comput.*, vol. 46, no. 3, pp. 439–451, Aug. 2011. [7] S. Karunatillake et al., *Icarus*, vol. 226, no. 2, pp. 1438–1446, Nov. 2013.