THE SEASONAL CYCLE OF METHANE AT GALE CRATER, MARS, REPLICATED WITH METHANE ADSORPTION AND DIFFUSION THROUGH THE REGOLITH. C. L. Smith[1], J. E. Moores[1], R. Gough[2], G. Martinez[3], P.-Y. Meslin[4], S. K. Atreya[3], P. R. Mahaffy[5], C. Newman[6], and C. R. Webster[7], [1]Center for Research in Earth and Space Science (CRESS), York University 4700 Keele Street, Toronto, ON Canada, chrsmith@yorku.ca, [2]University of Colorado, Boulder, [3]University of Michigan, [4]Université Paul Sabatier, IRAP, UPS, CNRS, Toulouse [5]NASA-Goddard Space Flight Center, [6]Aeolis Research, [7]California Institute of Technology-Jet Propulsion Laboratory

Introduction: There is a strong, repeating cycle of the magnitude of the background methane mixing ratio the that has been observed at Gale Crater, Mars, by the Sample Analysis at Mars (SAM-TLS) instrument on-board the Mars Science Laboratory (MSL, Curiosity) Rover (Webster et al., 2018). The measured mixing ratio has ranged between 0.23 and 0.65 ppbv (see Fig. 1) and is substantially smaller than the methane spikes measured by Webster et al. (2015) at 7 ppbv. The relative magnitude of the background methane mixing ratio cycle was not predicted by models (e.g. Meslin et al., 2011), has not been found to correlate with any environmental parameter, and no physical process has yet been able to satisfactorily explain the timing and shape of the seasonal cycle (Martinez et al., 2017). However, the background methane cycle, complete with phase lag and amplitude, can be replicated if the subsurface regolith contains a source of methane (either through micro-seepage from below or as a result of prior methane plumes) and is allowed to adsorb onto and diffuse through the regolith.

Methods: A 1-dimensional diffusive-adsorptive numerical model was produced. The atmospheric thickness was assumed to be the modeled height of the planetary boundary layer at Gale Crater as a function of season (Newman et al., 2017) and in constant contact with the top of the regolith stack. Methane is allowed to seep upwards from a constant deep source through the diffusive/adsorptive regolith. Methane is also allowed to adsorb from the base of the atmosphere to the top of the regolith stack and diffuse downwards. To simulate the loss of methane from the local area via various transport methods, methane was given a lifetime which, it should be emphasized, is not equivalent to the photolysis lifetime, rather a "residence lifetime" in the local atmosphere in contact with Gale Crater. This residence lifetime is henceforth referred to as "Effective Atmospheric Dissipation Timescale" (EADT). The seepage rate at Gale Crater can be constrained assuming adsorptive-diffusive equilibrium is currently in place.

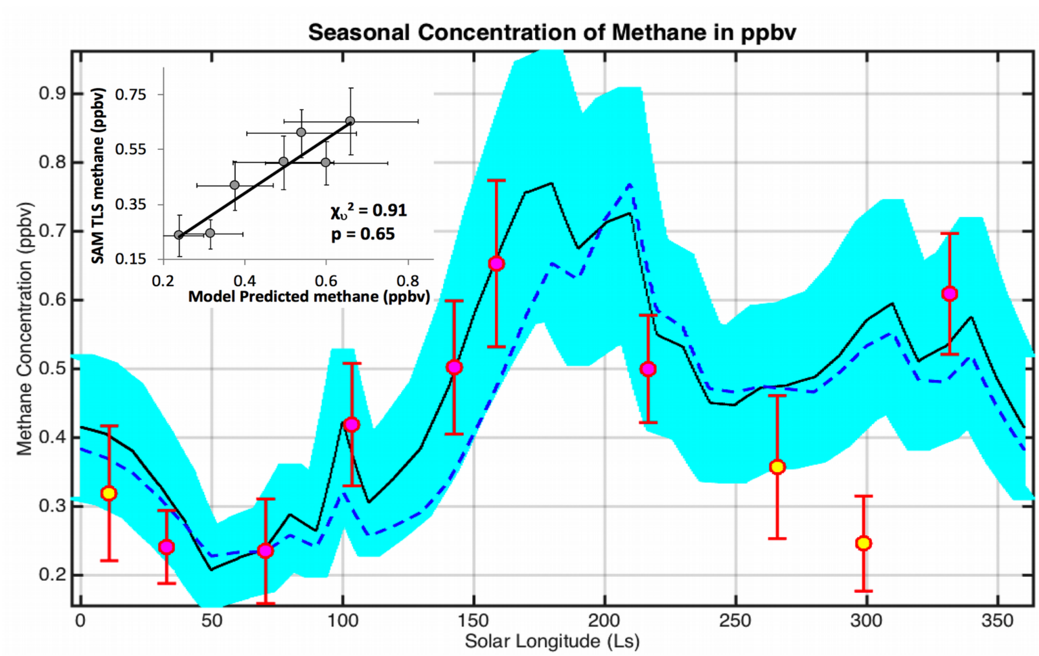

Figure 1: ... *e model*
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Results: After running the model over a wide range of input parameters, the best fit model (χ_υ^2 of 0.91) to the SAM-TLS data (filled circles) was found with subsurface seep = 2.8 × 10^{-16} kg m^{-2} s^{-1}, DAL=30 sols, ΔH = 31.5 kJ mol^{-1}, and γ/η (uptake to evaporation coefficient ratio) = 1. The results of this model are shown in Figure 1 (black line) with the uncertainties (cyan range) stemming from measured temperature uncertainties from the Rover Environmental Monitoring Station (REMS) on-board MSL (Martinez et al., 2016).

Model parameter space (EADT, γ/η, ΔH) was widely explored and satisfactory fits could be obtained for other combinations of input parameters. Figure 2 shows the results of this sensitivity analysis for EADT=30 sols. Current values for γ/η and ΔH determined from laboratory studies of Martian analogs (Gough et al., 2010) are shown by the white X and error bars on Figure 2. These values do not produce good fits to the SAM-TLS data, but good fits can be obtained by varying either one or both of the values.

We note that the lower-than-expected methane values between 250 to 300 Ls are diluted by having air enter the crater from northerly latitudes.

Conclusions: Seasonal variation in SAM-TLS data, including timing and magnitude, can be satisfactorily replicated with a diffusive-adsorptive model if sub-surface seepage is permitted through the regolith and if either the γ/η or ΔH value (or both) are allowed to vary from those determined from laboratory studies of Martian regolith analogs.

The Trace Gas Orbiter of the ExoMars mission has reported (Korablev, 2018) non-detection of methane (<0.1 ppbv) at altitudes above ~4 km. This further indicates that our interpretation of the SAM-TLS measurements within Gale crater is consistent with a surface-atmosphere interaction at the near-surface.

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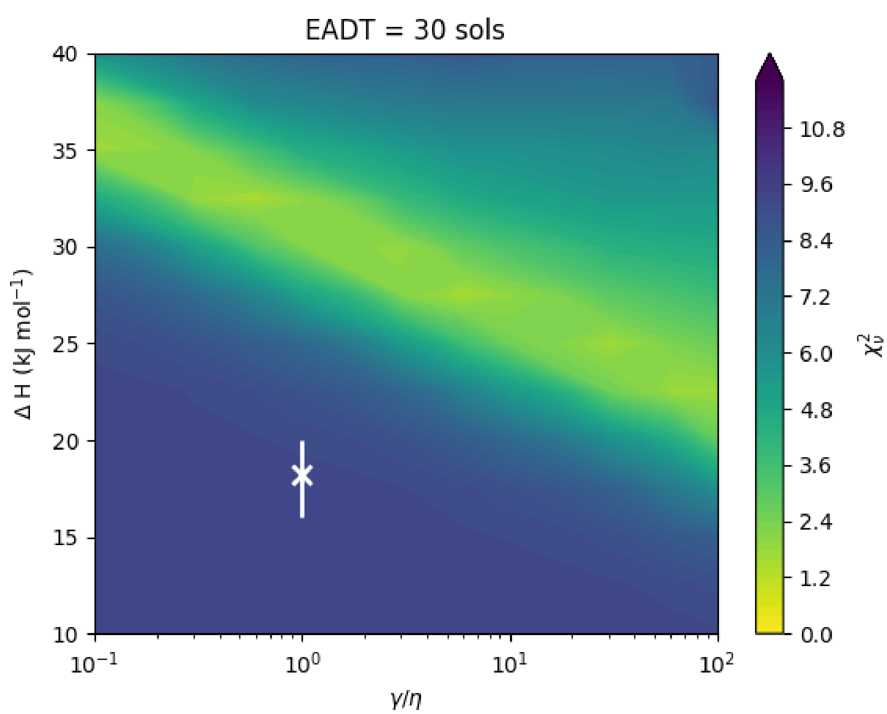

Figure 2: Model parameter sensitivity analysis.