Evaluation of MSL-SAM martian methane detections with the Mars Regional Atmospheric Modeling System (MRAMS)

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Introduction: The in situ detection of methane at martian Gale crater by Mars Science Laboratory Curiosity rover TLS-SAM instrument has garnered significant attention because of the implications for the potential of indigenous Martian organisms [1]. In the absence of a yet-to-be-confirmed rapid destruction mechanism, the photochemical lifetime of methane is on the order of several centuries. This is much longer than the atmospheric mixing time scale, and thus the gas should tend to be well mixed except when near a source or shortly after an episodic release. The observed spike of 7.2 parts per billion by volume (ppbv) from the background of <1 ppbv, and then the return to the putative background level in 47 sols is, therefore, curious. The reported background values from SAM have a mean value of 0.69 ± 0.25 (ppbv) following a pattern with a minimum value in the end of the austral autumn and a maximum value in the end of the austral winter.

Experiment configuration: The Mars Regional Atmospheric Modeling System (MRAMS) [2] is ideally suited for study the transport and mixing of methane from specified source locations using tracers, and to test whether methane releases inside or outside of Gale crater are consistent with SAM observations. In order to characterize seasonal mixing changes throughout the Martian year, simulations were conducted at Ls = 90º and Ls = 270º. And additional simulation was conducted at Ls = 155º, in order to mimick Mumma et al. 2009 methane detections. Several modeling scenarios were configured, including instantaneous and continuous releases both inside the crater, outside but near the crater, and outside but far away from the crater. Four different scenarios were considered for this research: punctual methane release inside Gale crater, punctual methane release outside -100km NW- crater, continuous methane release outside -100km NW- crater and continuous methane release inside crater. In the punctual releases scenarios, experiments were designed injecting four tracers into the model to simulate the transport of methane and to understand the mixing of air inside and outside the crater. Tracer #1 mimics methane release and the other three tracers are placed in different elevations (vertical discriminator), due to the three dimensional nature of mixing and transport. In this two first scenarios, tracer #2 is placed from 200 to 500 meters AGL inside Gale crater, tracer #3 from 500 to 2,000 meters AGL inside Gale crater, and tracer #4 elsewhere (outside and above Gale crater, see Figure 1). In the continuous release scenarios, MRAMS code was modified to mimick different clathrates continuous emissions. In these experiments, CH4 flux rate from ground is 2 kg m-2 s-1 [3] and it is not predictive, that is, the flux knob can be adjusted in order to get a proportional answer.

Conclusions: (a) Simulations indicate that there must be a steady-state release to counteract atmospheric mixing, because the timescales of mixing are ~1 sol during all seasons [Figure 1], which is much faster than previously estimated [4]. (b) Duration of CH4 peak detected by SAM is 100 sols (assuming no high frequency variations) [1], so then there should be a steady-state release inside the crater to counteract mixing, or there should be a very large magnitude and size steady-state release outside the crater. (c) It is difficult to reconcile the SAM peak methane detections with the atmospheric transport and mixing predicted by MRAMS. The only plausible scenarios, although highly unlikely, that are consistent with the model results (0-1.2ppbv) and the SAM background low methane observations, are those where the rover is very close to a localized steady-state release [Figure 2] or where the source region spans a broad latitudinal range and under the condition that such releases are globally rare in space and time [Figure 4]. (d) If we multiply flux, increase release area or move it closer to rover (or all of previous) in our initial conditions, we would get CH4 values that SAM should be capable to detect doesn't matter where it comes from. (e) Timing is important for SAM measurements (high daily variability with peaks in all scenarios) [Figure 3]. (f) Steady-state release inside or close to Gale show very localized CH4 in contrast with Mumma et al.

detection. (g) In the steady experiments mimicking M09 detection release area, only 12 times lower CH4 values detected by SAM are modeled around MSL. Although Ls155 is the season of the M09 peak CH4 detection, the highest value in the M09 modeled scenario (0.6 ppbv) is reached in Ls270 [Figure 4]. (h) Atmospheric circulation is strongly 3-D [4], not just 2-D, so in order to constrain a source air mass location is important to take into account vertical motion instead of just horizontal wind speed and direction.

Figure 1: Punctual methane released outside crater is diluted by approx. 6 orders of magnitude after just 12 hours when arriving to rover location.

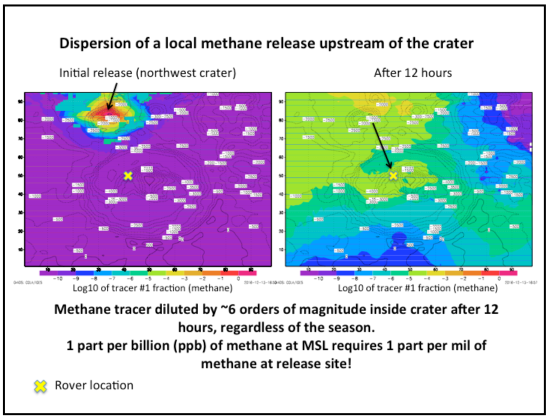


Figure 2: Nine sols timeseries of MRAMS_CH4 abundance at steady-steate source location inside Gale crater.

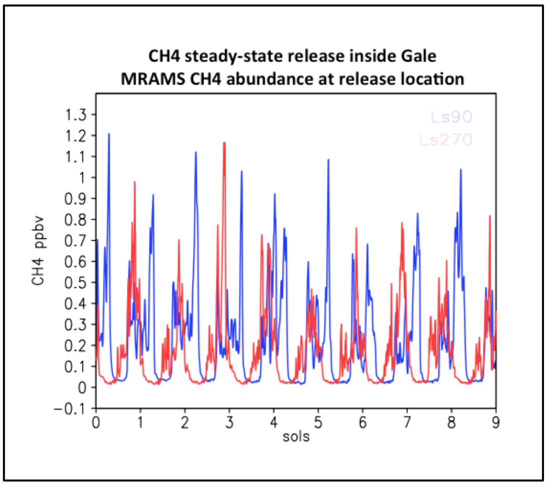


Figure 3: Two sols timeseries of MRAMS_CH4 abundance at MSL location. MRAMS_CH4 was release in different locations (NW-NE-SW-SE) outside Gale crater.

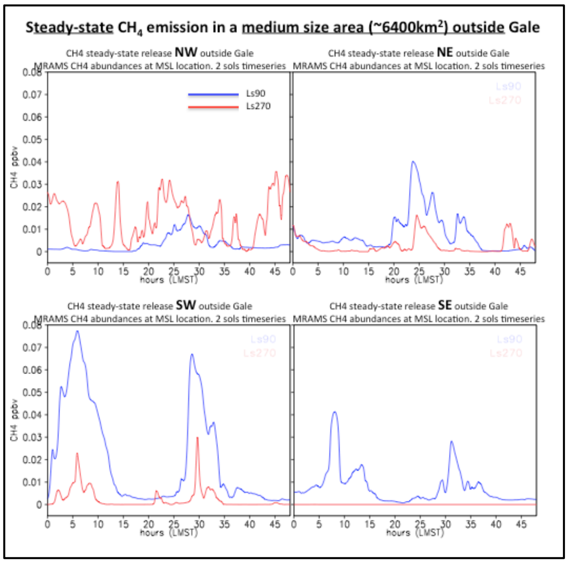
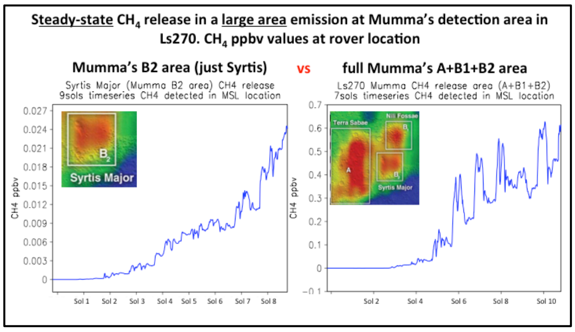


Figure 4: Ten sols timeseries of MRAMS_CH4 abundance at MSL location. MRAMS_CH4 was release in Mumma detection area (Terra Sabae+Nili Fossae+Syrtis). Also included for comparison MRAMS_CH4 released just in the Mumma detection Syrtis area plot



References: [1] Webster, C.R. et al. Science, 2015; [2] Rafkin S.C.R. et al., Icarus, 2001; [3] Gloesener et al. 6th MAMO conference, 2017; [4] Pla-Garcia et al, Icarus 2016.

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