Constraining the MSL-SAM Methane Detected Source Location Through Mars Regional Atmospheric Modeling System (MRAMS)

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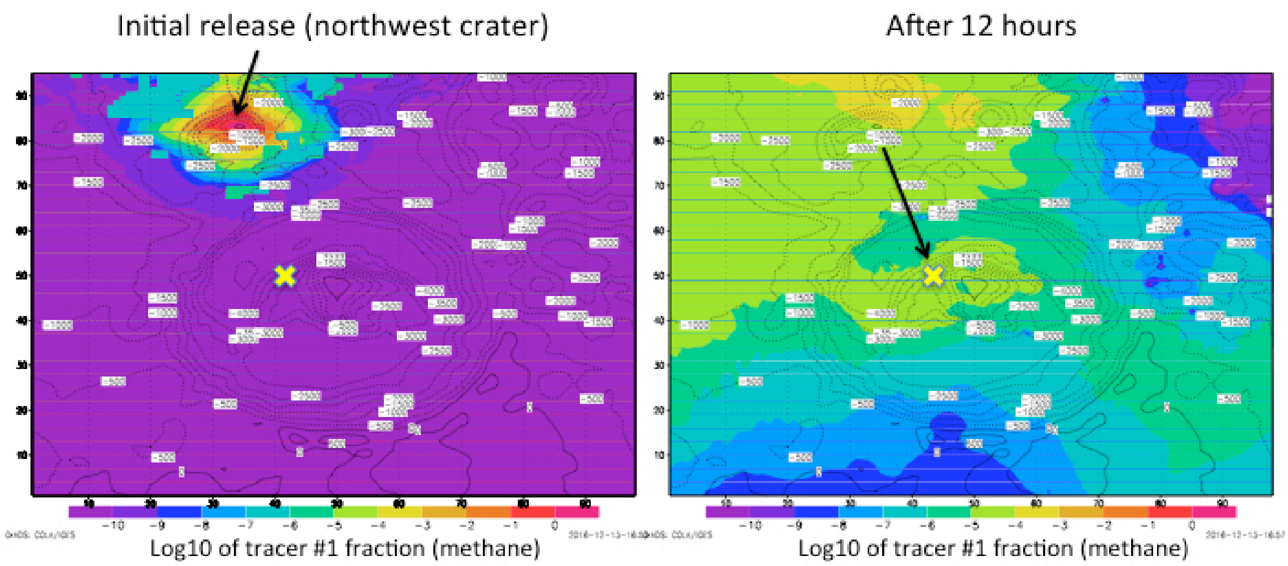
The detection of methane by SAM instrument has garnered significant attention. There are many major unresolved questions regarding this detection: 1) Where is the release location? 2) How spatially extensive is the release? 3) For how long is CH4 released? In an effort to better address the potential mixing and remaining questions, atmospheric circulation studies of Gale Crater were performed with MRAMS mesoscale model, ideally suited for this investigation. The model was focused on rover locations using nested grids with a spacing of 330 meters on the innermost grid that is centered over the detection site. In order to characterize seasonal mixing changes throughout the Martian year, simulations were conducted at Ls0, 90, 180 and 270. The rise in CH4 concentration was reported to start around Ls336, peaked shortly after Ls82, and then dropped to background prior to Ls103. The aim of this work is to establish the amount of mixing during all seasons and to test whether CH4 releases inside or outside of Gale crater are consistent with SAM observations. The 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. Two scenarios are considered in the context of the circulations predicted by MRAMS. The first scenario is a punctual release of CH4 (tracer #1) within the crater whereas in the second scenario that punctual release is outside the crater (100km NW). In both scenarios the methane release is punctual instead of continuous and 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).

Conclusions

In both scenarios, the release is assumed to take place near the season when the rise of concentration was first noted (Ls336). This is a transitional time at Gale Crater, when the flushing winds are giving way to a rapid mixing scenario but slower compared to Ls270. As expected, Ls270 was shown to be a faster mixing season when air within and outside the crater was well mixed by strong, flushing, northerly flow and large amplitude breaking mountain waves: air flowing downslope (buoyancy and dynamical forcing) at night penetrate all the way to the surface. In the experiments, all inside mass is gone from crater after just 10 hours. At other seasons only ~50% of inside mass stays in crater after 10 hours and simulations indicate that the air flowing down the crater rims does not easily make it to the crater floor. Instead, the air encounters very cold and stable air pooled in the bottom of the crater, which forces the air to glide right over the colder, more dense air below. Thus, the mixing of near surface crater air with the external environment in these seasons is potentially rapid but slower than Ls270. Timescale of mixing in MRAMS model is on the order of 1 sol regardless of season, much faster than previously estimated. Duration of CH4 peak observed by SAM is ~100 sols (assuming no high frequency variations). In the second scenario (puntual methane release outside Gale crater), methane arriving rover location from outside crater is diluted by approx. 6 orders of magnitude after just 12 hours. Therefore, either there is a continuous release inside the crater (more likely) to counteract mixing, or the methane is widely distributed so that mixing doesn’t matter, or a local release outside the crater have to be continuous and very large magnitude (unlikely). In order to test that, new experiments are being performed with continuous methane releases both inside and outside the crater. The calculations of methane fluxes will be made for clathrates at different depths and formed from a gas phase containing 90%, 50% and 10% of CH_4. Also, back trajectory calculations will be used to determine origin of air at rover location as a function of time.

Keywords: Mars, Mars Atmosphere, Mars Atmosphere modeling, methane detection on Mars, Curiosity rover

Dispersion of a local methane release upstream of the crater



Methane tracer diluted by ~6 orders of magnitude inside crater after 12 hours, regardless of the season.
1 part per billion (ppb) of methane at MSL requires 1 part per mil of methane at release site!

Rover location

