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Martian winds drive seasonal methane variations observed by MSL-SAM

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The MSL-SAM team recently presented in situ measurements of the background methane levels in Gale Crater that exhibits a strong, repeatable seasonal variability with a mean value of 0.4 ppbv (Webster et al. 2017 AGU2017 P33F-07). The Mars Regional Atmospheric Modeling System (MRAMS) is ideally suited to study the role of local atmospheric transport and mixing in the evolution of methane from potential source locations. Clathrate hydrates could be a possible source of episodic methane releases on Mars, and are used to estimate atmospheric abundances based on reasonable surface flux rates.

In our simulations, which use tracers to quantitatively assess atmospheric transport, mixing of the crater air with external air is found to be high during all the martian year, being slightly more rapid at Ls 225-315 compared to other seasons. This result is in contrast to prior work, and we find that the crater is not isolated at any period of the year. The mixing time scale is $\sim$1 sol or less.

The model simulations further suggest that there must be a continuous release of methane to counteract atmospheric mixing, because the timescale of mixing is much shorter than the observed span of elevated methane levels. The model also indicates that the timing of MSL-SAM sample ingestion is very important, because the modeled methane abundance varies by one order of magnitude over a diurnal cycle. The crater atmospheric circulation is strongly 3-D, not just 1-D or 2-D, and any scenario describing the transport of methane must recognize this dimensionality.

Presumably, ground temperature controls the release of methane trapped in clathrates on seasonal timescales. The methane flux should be higher during warmer seasons, implying a seasonal hemispheric difference in methane background values if we assume ubiquitous release sources over the planet. During Ls 225-315, the strong northwesterly air flowing down the crater rims during nighttime originates from deep within the northern hemisphere, whereas at other seasons the origin of that external air is from locations closer to the crater or from more tropical regions. The consequence of this is that although the local methane emission in the crater may be highest during the warm Ls 225-315 season, those emissions are rapidly transported away and replaced by methane-poor air emanating from the cold northern hemisphere. In contrast, the methane flux in the crater at other seasons is similar to the flux for the source air location. In this scenario, mixing has little effect on the overall methane concentration and the concentration should be better correlated with the local ground temperature.

The origin of methane variability is an active area of research, and our colleagues on the MSL team (John E. Moores and co-authors) are working to better model adsorption on and diffusion through the regolith, as well as the impact of the depth of the boundary layer on vertical mixing.