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Searching the source location of methane detected at Gale crater using the Mars Regional Atmospheric Modeling System (MRAMS)

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The in situ 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 CH_4 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 CH_4 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 CH_4 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.

Two scenarios are considered in the context of the circulations predicted by MRAMS. The first scenario is a punctual release of CH_4 (tracer 1#) within the crater whereas in the second scenario that punctual release is outside the crater (~100 km NW rover position). In both scenarios tracer 2# is placed from 200 to 500 meters above ground level (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). The punctual release is assumed to take place near the season when the rise of concentration was first noted (Ls336).

Conclusions

As expected, Ls270 was shown to be a fast 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 just 10 hours after release.

At other seasons ~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.

The timescale of mixing in the model is on the order of sols regardless of season while in the SAM observations is on the order of 100 sols. In the second scenario (punctual methane release outside Gale crater), methane arriving rover location from outside crater is diluted by approx. 6 orders of magnitude just 12 hours after release.

Therefore, either there is a continuous release inside the crater (more likely) or there is a continuous and very large magnitude local release outside the crater. In order to test that, new experiments are being performed with continuous methane releases both inside and outside the crater.