SEARCHING FOR THE MOST PROBABLE SOURCE LOCATIONS OF THE METHANE DETECTED BY CURIOSITY AND PFS IN MID-JUNE 2013.
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Introduction: The observations of methane on Mars over the last 15 years have been highly controversial. The detection of 15.5 ± 2.5 ppbv of methane above Gale Crater on 16 June 2013, by the Planetary Fourier Spectrometer (PFS) onboard Mars Express was recently reported [1]. This detection was recorded one day after the observation of a spike (5.78 ± 2.27 ppbv) by Curiosity and constitutes the first independent confirmation of the presence of methane on Mars. In this context, we developed a statistical approach of GCM simulations of methane emissions to search for the most probable source locations of the gas detected by the two instruments.

Previous model studies: Several model studies [e.g. 2, 3] demonstrated the capabilities of GCMs to understand processes forming atmospheric plumes of methane (e.g., the plume observed in 2003 by Earth-based telescopes [4]) from local outgassing events. Nevertheless, those investigations are largely inconclusive because many combinations of release locations and release scenarios can explain the observations. Indeed, such problems are weakly constrained given the sparsity of observational data. In addition, the release patterns (either instantaneous or continuous) used in previous studies are not supported by patterns of methane emission (strength and duration) on Earth, which are known from various types of terrestrial analogs, including faulted areas, springs, mud volcanoes, and areas with diffuse low levels of gas release called microseepage [5]. The information from terrestrial analogs can provide guidance for GCM simulations [6, 7], so that values used are within reason for the geological systems on Mars in the vicinity of any methane detections.

Statistical analysis of release experiments: In this context, instead of supporting the available CH_4 observations with one consistent numerical experiment, we developed an innovative statistical approach considering a large number of realistic release scenarios and applied a statistical analysis to this sample [1]. Such a study is made possible taking advantage of the additivity of tracers. Methane emission events can be viewed as a sequence of stochastic gas fluxes generated by combining tracers released successively and scaled randomly in order to mimic the time variability of typical methane seepage observed on Earth. Hence, a probability can be attributed to the given emission site in terms of the ratio between the number of scenarios consistent with the observations and the size of the statistically representative sample. As a result, comparing the probabilities associated with all potential emission sites within a predetermined region indicates the most plausible sites from the standpoint of the atmospheric circulation.

Application to the release event detected by Curiosity and PFS in Mid-June 2013: A preliminary analysis of the observations (including upper limits) recorded by PFS and Curiosity in a 14-sol time window suggests strongly that the two instruments detected the same CH_4 release event, which took place over a few sols and most likely outside Gale Crater.

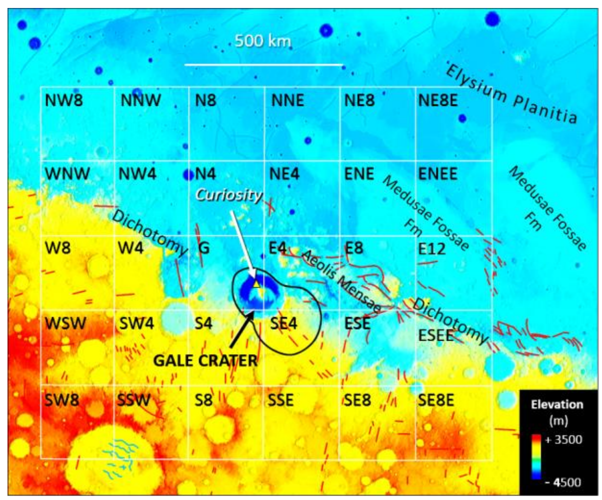

Figure 1. Location map and regional setting [1]. The black outline around Gale Crater is the envelope of PFS footprints. The yellow triangle shows the location of the Curiosity rover. The white grid shows the area of interest from atmospheric modelling. Each block is considered as a potential source of methane.

Simulations performed using the GEM-Mars GCM [8], a model already applied to study the time evolution of methane in the atmosphere after surface release [9], was used to form a large sample of release scenarios that was constrained by the available observational data in order to determine the most likely source regions around Gale Crater. 30 model grid cells within a

24°×20° area centered at Gale Crater were considered as potential emission sites (see Fig. 1).

From each of them, a series of 30-min-long methane pulses was applied for a total duration of 5 sols. Exploiting the linear additivity of the methane tracers, the tracers were linearly combined by random numbers to produce release scenarios composed of stochastic fluxes. A total of 10^6 different combinations were generated for each of the 30 considered release sites. For these patterns, the initial times and durations of emission were also generated randomly. As a result, the constructed episodic emission scenarios last from 30 minutes to 5 sols. The large number (10^6) of emission scenarios considered in each of the model grid cells forms a statistically representative sample of all of the possible release scenarios from a specific site.

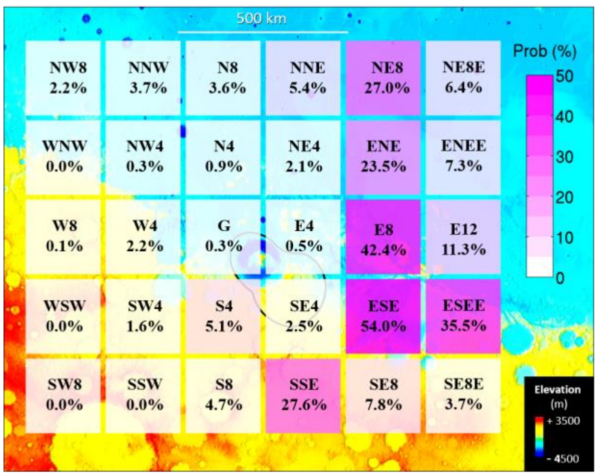

Figure 2. Probabilities estimated for the 30 emission sites [1]. For each grid cell, the probability of being a source location is defined as the number of release scenarios consistent with the observations divided by the sample size.

The simulated scenarios were then compared with the observational constraints. The result of the statistical analysis is shown in a probability map (see Fig. 2). Sites to the north, west and south-west of Gale Crater have no significant probability of being source locations. Sites to the east and south-east of Gale Crater yield the highest probabilities as source locations, especially blocks E8 and ESE, with probabilities of 42.4% and 54.0%, respectively, meaning that about half of all the generated emission patterns released from these sites can reproduce the available set of observations. The total mass of methane released from E8 (ESE) in 95% of scenarios fitting the observations is 1,170–2,740 tons (1,590–4,050 tons), which corresponds to an enhancement of ~0.1–0.3 ppbv (0.2–0.4 ppbv) to the global mean mixing ratio, after the gas is well mixed around the planet. These abundances can be considered as upper limits for the mass released, given the coarse resolution of the GCM.

A geological analysis of the area covered by the 30 blocks was independently conducted to search for structures that could be associated with methane release. This analysis points to a source in the same region east of Gale Crater, where faults of Aeolis Mensae may extend into proposed shallow ice of the Medusae Fossae Formation (MFF) and episodically release gas trapped below or within the ice (see Fig. 3).

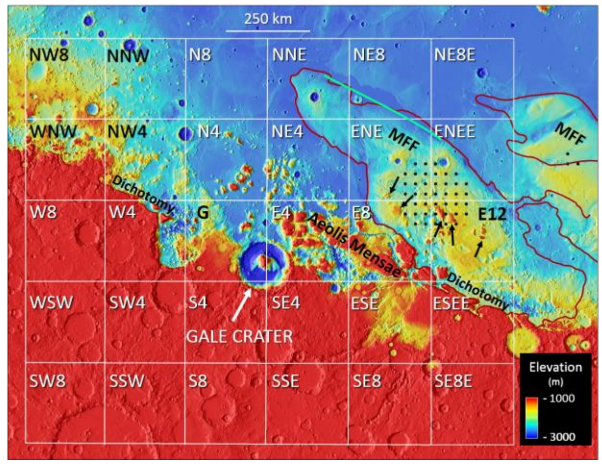

Figure 3. Geological context of grid blocks [1]. Black dots represent sites with water-equivalent hydrogen > 26%. The dark red line shows the outline of the lower member of the MFF. The green line shows aligned knobs. Black arrows highlight Aeolis Mensae outcrops within the MFF. The yellow triangle is the Curiosity rover location.

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