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Looking for the sources of methane on Mars: statistical analysis of GCM simulations

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Abstract

Recent modeling studies looking for the source of atmospheric methane detected on Mars have consisted of looking for a single emission scenario that would be in agreement with the observations. We here propose a new strategy based on a large statistical sample of possible release scenarios, with the aim of determining the best source region *in terms of probability*.

1. Introduction

Several observations of methane on Mars have been reported over the last 15 years [1 and references therein]. Given its short photochemical lifetime in the Martian atmosphere, the presence of methane points to recent activity. Looking for the potential gas sources on Mars is thus a crucial step toward a better understanding of the origin of the released gas.

Several model studies [e.g. 2, 3] demonstrated the capabilities of GCMs to understand processes forming atmospheric plumes of methane from local outgassing events, such as the plume observed in 2003 by Earth-based telescopes [4]. Nevertheless, those investigations are largely inconclusive because many combinations of release locations and release scenarios can explain observations. Indeed, such problems are weakly constrained given the sparsity of observational data. In addition, the use of release patterns (either instantaneous or continuous) in previous studies has not been supported by methane emissions on Earth. Emission patterns (strength and duration) of methane releases 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]. This information from terrestrial analogs can provide guidance for GCM simulations, so that values used are within reason for the geological systems on Mars in the vicinity of any methane detections.

2. 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. 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.

3. Application to the long high-CH_4 sequence recorded by Curiosity

In Mars year 32, the tunable laser spectrometer (TLS) of the Sample Analysis at Mars (SAM) instrument suite on the Curiosity rover recorded at Gale crater 4 successive high-CH_4 abundances spread over 60 sols [1]. This emission event will be considered in order to illustrate the capabilities of the new statistical approach. Simulations performed using the GEM-Mars GCM [6], a model already applied to study the time evolution of the gas in the atmosphere after surface release [7], will be used to form a large sample of release scenarios that will be constrained by the available CH_4 observations in order to determine the most likely source regions around Gale crater. In addition, a detailed analysis of geological features observed in the investigated area will be conducted [8]. Combining the results of the modeling and geological analyses will allow us to narrow the range of potential regions from which the detected methane originated.

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