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ABOUT THE SPATIAL AND TEMPORAL VARIABILITY OF METHANE IN THE MARTIAN ATMOSPHERE

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1. Introduction

After the definition of an upper limit for methane in the Martian atmosphere [1] [2], in the last few years several authors reported the detection of a very small amount of methane [3], [4], [5], [6]. Such a claim gave rise to a wide debate also because of the possible implications of such a discovery. In fact, due to the relatively short lifetime of the methane molecule in the Martian environment (about 350 years, [7]), its presence means that it is probably currently produced on the planet and hence it would be necessary to understand its production process. Suggested hypotheses are basically linked either to geothermal or biological activities [8], [9], [10], [11], [12] and, in both cases, our perspective of the planet evolution would require a major revision [13]. It is worthwhile to note that all the reported observations have been made in the spectral region of the strongest methane feature (at 3018 cm^{-1}), while the only observation made of the second strongest methane band (at 1306 cm^{-1}) yielded the upper limit given by Maguire [1]. Recently Fonti and Marzo [14] obtained the first spatial/temporal map of the Martian methane, tracing such band in a very large number of spectra, greatly increasing the confidence about the presence of methane in the atmosphere of Mars.

2. Method of Analysis

The analysis has been performed using the infrared spectra collected by the Thermal Emission Spectrometer (TES) on board of Mars Global Surveyor (MGS) [15]. In principle, its spectral resolution (6.25 or 12.5 cm^{-1}), should not be sufficient for the detection of such a narrow feature, but a careful verification, through an experimental and a computational approach, has shown that the 1306 cm^{-1} methane band is detectable by this spectrometer, averaging a few thousand spectra. The analysis has been performed on about 3,000,000 TES spectra covering the region between 60º S and 60º N in latitude. Temporally they are centred at each equinox and solstice for each of the three Martian Years (MY) considered. In addition they have been collected during the warmest part of the Martian day and in nadir configuration. During MY24/25 and 26/27 MGS/TES operated mainly in the low resolution mode (12.5 cm^{-1}) while in MY25/26 in high resolution mode (6.25 cm^{-1}). In order to deal efficiently with such a large quantity of data, each spatial/temporal slice has been explored by means of the cluster analysis approach described and extensively validated by Marzo et al. [16], [17]. Using such approach it has been possible to selectively average tens of thousand of spectra and to group them on the base of the presence of the absorption feature at 1306 cm^{-1}.

3. Discussion

The methane abundances for each temporal slice have been evaluated, taking into account both the number of spectra grouped into the cluster associated with the methane band and the depth of such band in the corresponding average spectrum. The method of analysis used, together with the full spatial coverage of Mars, provided by TES over a considerably long time span, allowed to effectively the spatial distribution and the temporal evolution of methane in the Martian atmosphere over three Martian Years (MY). The spatial distribution of methane resulted to be far from uniform with some regions of higher concentration and, at the same time, locations with concentration of methane close to zero. In particular, three broad regions, where the methane amount is systematically higher, were found: Tharsis, Arabia Terrae, and Elysium. On the other hand, the temporal evolution of the methane abundance, revealed large variations not only in the global amount but also in the spatial distribution. Such variations seem to follow a seasonal cycle and are different from one year to the other. The observed annual cycle suggests a methane lifetime of ~0.6 years [6], much shorter than previously suggested based on photochemical processes (~350 years) [4], [7], posing intriguing questions concerning the possible methane sinks as well as its sources. Results from Fonti and Marzo [14] reveal an interesting consistency with those from other authors [3], [4], [5], [6], although the different temporal and spatial scales prevented a full comparison so far. Future work includes further validation via a more focused comparison with previous studies, and possibly extending Fonti and Marzo's [14] spatial and/or temporal coverage by processing additional MGS/TES data.

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