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Observations of carbon monoxide (CO) by the Atmospheric Chemistry Suite (ACS) on board the Trace Gas Orbiter

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Abstract

The Atmospheric Chemistry Suite (ACS) of three spectrometers started its scientific operations in April 2018 on board the Exomars 2016 Trace Gas Orbiter (TGO). This paper will present the first observations by ACS of the vertical distribution of carbon monoxide (CO) in the atmosphere of Mars.

1. CO in the atmosphere of Mars

Carbon monoxide (CO) is formed in the atmosphere of Mars through the photolysis of CO_2 at wavelengths shorter than 200 nm:

$$CO_2 + h\nu \rightarrow CO + O \qquad (1)$$

Since the 1970s and the classic papers of [1, 2] it has been known that OH and the trace amounts of odd-hydrogen species (HO_x) produced by H_2O degradation represent the main loss of CO and can efficiently recycle CO_2 from its photodissociation product:

$$CO + OH \rightarrow CO_2 + H \qquad (2)$$

CO is therefore an important tracer of the catalytic chemistry that explains the remarkable stability of the Mars quasi-pure atmosphere of CO_2.

The photochemical lifetime of CO is estimated from reaction (2) to 5 terrestrial years [3]. This long lifetime does not authorize chemical variations of CO with local time or even at the seasonal timescale. Yet, observations show a pronounced seasonal cycle of the CO mixing ratio at high latitudes [4,5]. This phenomenon is not of chemical origin but a response to the condensation–sublimation cycle of CO_2 to and from the seasonal ice caps, which leads to enrichment–depletion of all non-condensable gases in polar regions. Thus, CO is also a good tracer of such processes and of atmospheric dynamics in general.

In terms of absolute amounts, previous measurements of Martian CO carried out from space or from the Earth indicate values of 700-1100 ppmv averaged over the atmospheric column [4,5]. Those abundances have historically been a challenge and remain unsolved for chemical models, which typically underestimate CO by a factor 2 to 8 [3]. The fact that such a basic problem persists after decades of research may be indicative that an important process is missing or largely inaccurate in our understanding of the Mars photochemical system.

To date, only column-averaged amounts of CO have been measured on Mars and no measurements of the vertical distribution of CO have been published. Vertical profiles of CO will be provided for the first time by the instruments on board the Trace Gas Orbiter.

2. The Atmospheric Chemistry Suite (ACS)

The Atmospheric Chemistry Suite (ACS) package is an element of the Russian contribution to the ESA-Roscosmos ExoMars 2016 Trace Gas Orbiter (TGO) mission [6]. ACS consists of three separate infrared spectrometers, sharing common mechanical, electrical, and thermal interfaces.

Among the three spectrometers of ACS, the mid-infrared channel (MIR) is a cross-dispersion echelle instrument dedicated to solar occultation measurements in the 2.2-4.4 μm range and achieves a resolving power of > 50000. With its unprecedented sensitivity and its spectral range that covers the 2.3 μm band of CO, MIR is well suited to retrieve accurate vertical profiles of CO from 10 km to about 140 km. In low dust conditions, we anticipate a sensitivity to CO of about 5 ppmv, i.e. less than 1% of the mean mixing ratio of CO on Mars. Measurements of the CO vertical distribution will also be possible with the thermal infrared (TIRVIM) channel of ACS, a Fourier-transform spectrometer encompassing the spectral range 1.7-17 μm. TIRVIM covers the strong CO band at 4.7 μm, which should allow the retrieval of accurate CO profiles in solar occultation mode, despite a lesser spectral resolution than MIR.

3. First observations of CO

The first vertical profiles of CO obtained by solar occultation from the MIR and TIRVIM channels of ACS, not retrieved yet at the time of writing, will be presented in this talk. They will be analysed in the context of Mars atmospheric dynamics and photochemistry. We will also present comparisons with three-dimensional simulations of Mars CO carried out with the LMD global climate model with photochemistry.

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