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Anna A. Fedorova, Alexander V. Trokhimovskiy, Oleg I. Korablev, Denis A. Belyaev, N. I. Ignatiev, Franck Lefèvre, Franck Montmessin, Kevin Olsen, Juan Alday, Francois, Forget, et al.

CLIMATOLOGY OF CO AND O_2 ON MARS BASED ON TWO MARTIAN YEARS OF ACS TGO OCCULTATION MEASUREMENTS

A. A. Fedorova, A. Trokhimovskiy, O. Korablev, D.A. Belyaev, N. Ignatiev, *Space Research Institute (IKI), Moscow, Russia (fedorova@iki.rssi.ru),* **F. Lefèvre, F. Montmessin,** *LATMOS, Guyancourt, France,* **K. S. Olsen,** *AOPP, Department of Physics, University of Oxford, UK,* **J. Alday,** *The Open University, UK,* **F. Forget**, *Laboratoire de Meteorologie Dynamique (LMD), Paris, France*, **A. Lomakin, A. Patrakeev**, *IKI, Moscow, Russia.*

Introduction:

The molecular oxygen (O_2) and carbon oxide (CO) are minor constituents of the Martian atmosphere with the annual mean mixing ratio of (1560 ± 60 ppm) and (673 ± 2.6 ppm), respectively (Krasnopolsky, 2017). Both are non-condensable species and their mixing ratio responds to the condensation and sublimation of CO_2 from the polar caps, resulting in seasonal variations of its abundance in polar regions.

The O_2 column-averaged mixing ratio was obtained by several ground-based observations as well as by Herschel orbiting observatory. Recently, measurements of the O_2 near-surface mixing ratio by SAM on the Mars Science Laboratory Rover showed significant seasonal and interannual variability unexpected for non-condensable trace gases (Trainer et al, 2019).

The CO abundance on Mars has been measured by high-resolution ground-based spectroscopy from infrared to microwave range and by nadir observations from Mars' orbit with OMEGA and PFS/Mars-Express, CRISM/MRO and NOMAD/TGO. These observations have shown strong seasonal variations of CO, especially in high latitudes with a global average of ~800 ppmv (Bouche et al., 2021, Smith et al., 2018, 2021). In situ measurements by SAM/Curiosity resulted in an even lower value of 580 ppmv (Trainer et al., 2019).

While the global seasonal trends at least for CO are relatively well understood, the vertical distribution of these species was poorly documented before the arrival of TGO at Mars.

ACS solar occultation observations:

In 2018, the ExoMars TGO began its science phase by observing Mars' atmosphere from its orbit. The Atmospheric Chemistry Suite (ACS) (Korablev et al., 2018) can sound the vertical structure of the atmosphere in solar occultation mode. ACS includes three high-resolution infrared spectrometers: NIR (near-infrared, 0.7-1.7 ⌠m), MIR (middle infrared, 2.3-4.2 ⌠m) and TIRVIM (thermal infrared, 0.7-17 ⌠m). All three channels measure the vertical distribution of CO in three spectroscopic bands: 1.57 μm (NIR), 2.3 μm (MIR and TIRVIM) and 4.7 μm (TIRVIM). The NIR channel also provide the measurement of the O2 density at altitudes of 0-50 km based on 0.76 μm band by solar occultation.

The first CO vertical profiles were inferred from ACS MIR at altitudes 20–120 km and Ls=164–220° before and during the global dust storm (GDS) of Mars year (MY) 34. They showed a prominent depletion in the CO mixing ratio up to 100 km, pointing to the importance of CO oxidation during wetter GDS conditions (Olsen et al., 2021).

In this work we present results of the long-term monitoring of the vertical distribution of O_2 and CO for two Martian years from Ls=163° of MY34 to the Ls=180° of MY36.

Results:

We study seasonal and spatial variations of both species and their ratio during the TGO measurements as well as interannual variability.

We report the averaged mixing ratio for CO of ~950 ppm and for O_2 of~1900 ppm at altitudes 0–40 km and latitudes from 45°S to 45°N with averaged ratio O_2/CO~2.

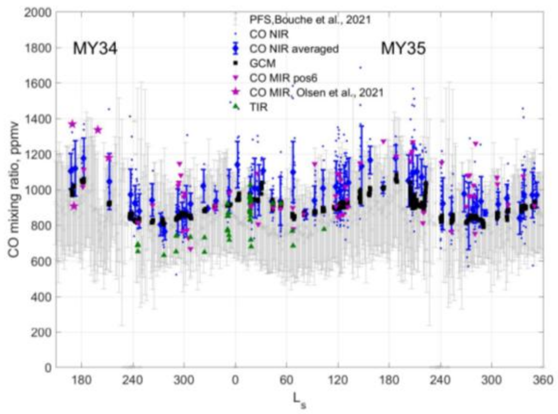

Figure 1. The averaged values of CO from ACS profiles measured within ±45° latitude range and below 35 km. Blue points, purple and green triangles are individual NIR, MIR and TIRVIM occultations, respectively. Purple stars are the results of Olsen et al., 2021 from MIR position 7 (integrated below 40 km). Blue diamonds with error bars are averages of NIR data binned within 5° of Ls. Black squares are GCM model results corresponding to the NIR averages. Grey crosses are averages of PFS data (Bouche et al., 2021). All error bars are standard deviations.

We found a strong enrichment of both species near the surface during the southern winter and spring in middle and high southern latitudes with a layer of 3000-4000 ppm (for CO) at 10–20 km corresponding to local depletion of CO_2. The GCM does not predict the enrichment in this period, both in terms of absolute value and vertical extent. This indicates that the breakup of the polar vortex enriched in CO and O_2 and the subsequent mixing with midlatitude air occur too early with the settings of the LMD GCM.

At equinoxes, both in the northern and southern spring, we found an increase of CO mixing ratio above 50 km to 3000–4000 ppmv explained by the downwelling flux of the Hadley circulation on Mars. Comparison with the general circulation chemical model has shown it tends to overestimate the intensity of this process, bringing too much CO from its region of production in the high atmosphere.

The minimum of CO observed in the southern summer in the high and middle southern latitudes has average VMRs of 700–750 ppmv in the low atmosphere and agrees well with nadir measurements by CRISM/MRO and PFS/MEX even they have a lower values of 400-700 ppmv and ~600 ppmv, respectively, in the same period. The CO profiles calculated in southern summer by the LMD GCM are in broad agreement with ACS.

The observations during the two Martian years allow us to study the interannual variability for the year with the global dust storm (MY34) and year without GDS (MY35). We observed the depletion of the CO mixing ratio at 30-40% both in the northern and southern hemispheres during the global dust storm of MY34 compared with the calm MY35. The decrease of the CO mixing ratio in MY34 can indicate the response of CO_2 production rate to the increase of water vapor abundance in the atmosphere for the same period that suggests an impact of HO_x chemistry on the CO abundance.

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