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Mesospheric/Thermospheric temperatures and high altitude water on Mars in the MY34

Denis Belyaev et al.

Introduction

The southern spring and summer on Mars in the 34th Martian Year (MY34, Ls 180°-360°) was decorated by two dust storms: the global one (GDS) at Ls 190°-240°, and the regional one at Ls 320°-330°. Just before the onset of the GDS, the nominal ExoMars Trace Gas Orbiter mission began (April 2018) with an onboard solar occultation experiment by the spectrometric Atmospheric Chemistry Suite (ACS) [1]. The first ACS-NIR retrievals of the temperature and water mixing ratio revealed an increase the H₂O abundance up to altitudes of 80-100 km not only in the stormy events but also at the perihelion in the southern hemisphere (around Ls~270°) [2]. Moreover, as it was shown, the water supersaturation occurs even in presence of the ice clouds, while the stormy warm atmosphere rises the hygropause level [2, 3]. This phenomenon increases a capability of water escape from Mars. Simultaneous investigation from the NOMAD/TGO solar occultations demonstrated analogue results for the H₂O enhancement up to 80 km in the stormy seasons, but without the saturation estimations [4].

In this paper, we present results from more sensitive solar occultation measurements in the 2.65-2.7 μm spectral range by the middle infrared channel of ACS (ACS-MIR). The channel allows mesospheric and thermospheric retrievals of temperature and CO₂ density in parallel with the mesospheric water abundance. Our results confirm the ACS-NIR and NOMAD conclusions concerning the H₂O vapour behaviour in the second half of the MY34. We report the most humid mesosphere occurred in the perihelion season where the water enrichment was established about 5-10 ppbv at altitudes of 110-120 km. We also present the temperature and CO₂ density seasonal distribution covering the troposphere, the mesosphere and the thermosphere of Mars.

Measurements

The ACS-MIR channel is a cross-dispersion echelle spectrometer dedicated to solar occultation measurements in the 2.3-4.3 μm wavelength range [1]. The instrumental resolving power $\lambda/\Delta\lambda$ reaches ~30 000, while the altitude resolution is 1-2 km and the signal/noise ratio is about ~1000. Each occultation session covers a spectral interval with one or a few CO₂ absorption bands appropriate for the atmospheric density and temperature retrievals. In this work, we perform data analysis in the 2.65-2.7 μm spectral range, which occupies echelle diffraction orders from 221 to 224, observed simultaneously. This spectral region hosts strong CO₂ and H₂O absorption bands that are sensitive to detections of CO₂ density up to 180-190 km and H₂O density up to 120-130 km. For the MY34 the MIR dataset in the considered spectral range is made of ~100 occultation profiles in the Northern hemisphere and of ~90 in the Southern one encompassing seasonal period from Ls 165° to 355°.

Retrieval concept

The temperature and densities retrieval scheme consists of several iterations with a fitting of a forwardly modelled transmission spectrum to a measured one at each observed altitude. The model includes line-by-line calculations CO₂ and H₂O absorption cross sections depending on specified temperature and pressure. The fitting procedure is based on Jacobian matrix containing transmission derivatives on free parameters: temperature, CO₂ density and H₂O density. The clue contribution to an optimal estimation comes from the molecular cross sections derivatives on temperature; they differ significantly from line to line in the considered spectral range. Thanks to that, an independent and simultaneous retrieval of temperature and density is possible. Once the altitude profiles of these parameters are estimated at the first iteration, we calculate the atmospheric pressure profile assuming the hydrostatic equilibrium. This assumption was successfully tested by other vertical profile retrievals from the ACS data [1, 5].

The uncertainty of the retrievals is determined by the transmission errors and the Jacobian matrix for each of free parameters. This estimation allows establishing maximal altitudes with a positive detection of CO₂ and H₂O densities.

Results

ACS-MIR solar occultations in the 2.65-2.7 μm spectral range provide us with unprecedented capability to profile CO₂ density and temperature from 20 to 180 km, covering the troposphere, the mesosphere and the thermosphere of Mars. The homopause varies around ~130 km and CO₂ mixing ratio decreases from 96% to 20-40% at 180 km due to photolysis and molecular diffusion. In parallel with the same dataset, we report very high altitude water abundance, at 110-120 km, that occurred in the southern spring

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including the ODS and the perihelion in the 34th Martian Year. However, our measurements in the northern hemisphere revealed such a high H₂O enrichment only at the stormy events. Comparison of our climatology with some improvements in the Global Circulation Model for the MY34 is in progress.

Acknowledgements

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