THERMAL STRUCTURE AND WATER CLIMATOLOGY OF THE MARTIAN MIDDLE-UPPER ATMOSPHERE FROM ACS/TGO SPECTROSCOPY

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Introduction:

The thermal structure of the middle (50-100 km) and upper (above 100 km) atmosphere of Mars holds key information relevant for climate modeling, atmospheric escape, understanding the impact of solar activity, as well as planning spacecraft maneuvers. The altitude range of 80-130 km hosts the layers of mesopause, the coldest atmospheric zone, and homopause, where the atmosphere is no longer uniformly mixed [1]. Moreover, water vapour molecules above ~80 km, when rises so highly [2-4], are effectively exposed by photolysis from the solar radiation that leads to H and O atoms escape.

In this paper, we report highly sensitive measurements of the vertical distribution of temperature, CO_2 and H_2O densities as measured by the Atmospheric Chemistry Suite (ACS) on board ExoMars Trace Gas Orbiter (TGO) in the regime of solar occultation [5]. The middle-IR channel (ACS-MIR) has been performing the experiment since April 2018 in the spectral range from 2.3 to 4.2 μm with the resolving power exceeding 25 000. In the occultation mode, the instrument senses CO_2 absorption band around 2.7 μm in an extremely broad altitude range, from 20 to 180 km, covering the troposphere, the mesosphere and the thermosphere of Mars. In parallel, the strong H_2O band at 2.66-2.67 μm is also observed for the first time up to 120 km.

In the paper, we discuss our scheme of the temperature and CO_2, H_2O density retrievals [4, 6] validating with atmospheric models and with simultaneous measurements by ACS-NIR below 100 km [2]. The climatology is provided by the seasonal and latitude coverage of observations that includes about 600 vertical profiles spreading over 1.5 Martian Years (MY), from the middle of MY 34 to the end of MY 35. The dataset allows observing seasonal and latitudinal variations of the thermal structure at the dawn and dusk terminators. Temperature and pressure conditions for H_2O and CO_2 saturation are analyzed as well.

Results of observations:

Our measurements cover several Martian seasons containing the second half of MY 34 and the entire MY 35, which correspond to ACS MIR observations from May 2018 to January 2021. The selected data set comprises 308 occultation sessions in the Northern Hemisphere and 301 sessions in the Southern Hemisphere, encompassing seasonal periods from L_S = 180° to L_S = 356° in MY 35. We highlight several key points of our observations:

- Seasonal variability of the Martian temperature and CO_2 density is observed at altitudes from 20 to 180 km [6].
- The mesopause altitude rises from 70-90 km in the high latitudes of winter to 130-150 km in the summer season for both hemispheres [6].
- The homopause altitude varies from 80 km at aphelion to 110 km at perihelion in the MY 34 and 35, and it depends on dust activity [6].
- For the first time, water relative abundances are reported in a previously unexplored altitude range: from 100 to 120 km [4].
- Both the global dust storm in MY 34 and the two perihelion seasons (MY34, 35) reveal 10–50 parts of H_2O per million by volume (ppmv) at 100–120 km. At the same time, it does not exceed 2 ppmv during aphelion of MY 35 [4].
- High altitude H_2O super saturation conditions (>10) occur at 80-110 km every perihelion season. For CO_2, the condensation episodically occurs at aphelion Polar Regions in troposphere altitudes.

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