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Temperature Profiles from TGO Solar Occultation Data. Retrieval Methods and Cross-validation between NOMAD & ACS

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The characterization of the thermal structure of the Martian atmosphere with unprecedented vertical resolution is one of the goals of the ESA and Roscosmos Exomars Trace Gas Orbiter (TGO) [1]. This can be achieved with two solar occultation instruments, NOMAD [2] and ACS [3], whose ultimate goal is to sound the temperature and density from the Mars' lowermost atmospheric layers up to the thermosphere. Both instruments are synergistic and complementary, and in particular, the NOMAD SO channel and the NIR and MIR spectrometers of the ACS instrument exploit a number of strong CO₂ ro-vibrational bands in the near-IR.

At the IAA we have developed a retrieval suite common for the NOMAD/SO and the ACS/MIR channels, comprising: (a) a cleaning/pre-processing module to build vertical profiles of calibrated transmittances which computes and corrects for residual calibration and instrumental effects like spectral shifts, bending of the continuum and variations in the instrument line shape; (b) a state-of-the-art retrieval scheme designed originally for Earth atmospheric remote sensing [4,5,6] and applied to Mars [7], in order to derive simultaneous density and temperature profiles in a global fit approach and allowing for hydrostatic adjustments during the internal iteration. Our first analysis of the NOMAD SO channel focused at altitudes below 100 km and on the first year of TGO operations, from April 2018 to March 2019 (second half or "perihelion" season of MY34), and revealed very interesting results [8]. The thermal structure is strongly affected by the MY34 global dust storm at all altitudes, a cold mesosphere (in comparison to global climate models) was found during the post-GDS period, and wavy structures at mesospheric altitudes in the morning terminator seem to reveal very strong thermal tides at low-mid latitudes.

Other data-cleaning and retrieval methods have been applied by other NOMAD and ACS teams following different approaches. Some of them do not apply a global fit but a sequential single-altitude inversion, and the handling of the instrument systematic uncertainties is handled in different ways during the inversion. Both NOMAD and ACS instrument teams have already obtained very valuable

and unique results up to the mesosphere and thermosphere, capturing latitudinal and longitudinal variations, as well as local time, seasonal and dust effects and wave patterns and impacts [9,10,11,12]. Still, and a cross-validation exercise between all these results is very necessary. First steps in this direction were performed previously, but with a limited amount of data, revealing a good overall agreement. A recent ISSI project gave a new push to their cross-validation and this work is partially motivated by this project. Preliminary results indicate some systematic differences between retrieval results, particularly in the upper troposphere and lower mesosphere.

One of the difficulties associated to sampling a very large altitude range with a single instrument, as we are tackling with TGO solar occultation observations, is the large range of opacities along the line of sight that need to be handled. This implies the use of different diffraction orders and/or spectral lines of very different strengths. In addition, spectral saturation of those CO₂ ro-vibrational lines need to be avoided, if they are going to be used in combination with weaker CO₂ lines. Although in principle there is no theoretical limitation to combine spectral lines, effects from inhomogeneities along the line-of-sight may appear. This can be specially important in cases like atmospheric thermal inversions, where the largest differences between NOMAD and ACS are observed. In this study we propose the use of micro spectral windows to isolate the spectral lines and their associated altitude ranges in order to combine the different CO₂ lines in an optimal way. This approach has been applied to both NOMAD/SO and ACS/MIR retrievals and we will show and discuss the impact of this strategy.

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