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Mesospheric and thermospheric carbon dioxide and temperature profiles from NOMAD-SO onboard TGO.

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NOMAD [1] is regularly scanning the atmosphere of Mars from the troposphere to the upper thermosphere since the beginning of the science operations of the Trace Gas Orbiter on April 21, 2018. This work focus on retrievals of CO_2 density and temperature in the mesosphere and the thermosphere which are both regions of high interest. The latter is the region where atmospheric escape occurs while the mesosphere is the place of many atmospheric phenomena such as gravity waves, large amplitudes tides, temperature inversion and sometimes temperature lower than the limit for CO_2 condensation. Those atmospheric phenomena can be constrained by the atmospheric temperature.

The NOMAD-SO channel (SO in the following) is dedicated to solar occultation measurements and thus probes the Martian terminator. SO is an infrared spectrometer (2.3-4.3 μm) composed of an echelle grating with an acousto-optical tunable filter for the selection of the diffraction orders (hereafter simply called orders).

This work combines the datasets from two orders: 148 and 165 convenient to probe, respectively, Mars mesosphere and thermosphere. We derived 2400 profiles for order 165 in Martian years (MYs) 34 to 36 spanning altitudes between 140 and 180 km as well as 1200 profiles for order 148 in MY 35 and 36 spanning an altitude range between 60 and 100 km. The higher bounds of the profiles are set when the lines are enough thick to retrieve density values that are at least six times higher than the noise. The lower bounds are due to saturation of the lines, i.e. when the absorption lines are so thick that their curves of growth are no more a linear function of the CO_2 density.

The retrievals are performed with the ASIMUT radiative transfer code [2] and the profiles are regularized with a Tikhonov method [3]. The regularization is further fine-tuned with the expected error estimation [4]. The temperature profiles are derived from the CO_2 density profiles with the hydrostatic equilibrium equation and the ideal gas law. The uncertainties are on average 10 K and

2 K at, respectively, the top and bottom of the profiles. The vertical resolution of the profiles is around 2.5 km.

Twenty percent of the profiles in the mesosphere contain a strong warm layer, i.e. temperature values that are 20 K higher than the background temperature. The warm layer is present at dawn in both hemispheres as well as at dusk in the Northern hemisphere but it is absent at dusk in the Southern atmosphere. In the mesospheric dataset, we also report the presence of six temperature profiles containing temperatures lower than the temperature limit for CO_2 condensation.

Analyzing the longitudinal variations of temperature for some profiles with very close solar longitude, local solar time and latitude around 60°, we found remaining wavenumber-1 and wavenumber-3 components with respectively 10% and 5% of the background temperature.

The retrieved values in the mesosphere are compared with data from the GEM-Mars general circulation model [5, 6] simulated for NOMAD-SO occultations. The comparisons are in good agreement except in the Southern hemisphere before aphelion where the temperature minimum is lower in SO data. The Northern hemisphere after perihelion have also different values where the warm layers are more important in SO data. Comparisons are ongoing with measurements from other instruments such as MAVEN-EUVM [7] for the thermosphere and MRO-MCS [8] for the mesosphere. The comparisons are in good agreement considering the differences in geometry and time.

The NOMAD-SO dataset of the thermosphere contains profiles from April 21, 2018, a bit before the global dust storm (GDS) that encircled Mars until the end of June 2018. Compared to MY 35 and 36, we notice a clear increase in the density in the thermosphere starting at Ls 185°. A comparison between the temperatures in the mesosphere and the thermosphere will be presented, we see a higher temperature at dusk than at dawn in the thermosphere and no specific trend in the mesosphere. In the thermosphere at dusk, the temperature is higher at the equator than at the poles, with the opposite at dawn. In the mesosphere, the temperature values are lower at the equator than at the poles. In conclusion, the temperature variations in the mesosphere and thermosphere at the terminator have similar seasonal trends but different diurnal and latitudinal trends.

References : [1] Vandaele et al., (2015), PSS ; [2] Vandaele et al., (2008), JGR (Planets) ; [3] Quémerais et al., (2006), JGR (Planets) ; [4] Xu et al., (2016), JQSRT ; [5] Daerden et al. (2022), JGR (Planets) ; [6] Neary et al. (2020), GRL ; [7] Thiemann et al., (2018), JGR (Planets) ; [8] Kleinböhl et al., (2009) , JGR (Planets).