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Study of Mars mesosphere longitudinal temperature variations from NOMAD-SO onboard ESA's TGO.

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NOMAD [1] is one of the four instruments on board ESA's Trace Gas Orbiter and consists of three channels: SO, LNO, and UVIS. The SO channel 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-optic tunable filter for the selection of the diffraction orders. SO has been 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. One diffraction order is ~25 cm^{-1}, and six diffraction orders are scanned at each occultation. The spectral resolution is ~0.15 cm^{-1}, and the signal-to-noise ratio is ~2500. The field of view varies between 1.6 km and 1.85 km, and the vertical sampling varies between 0.1 km and 1 km depending on the beta-angle of TGO. The vertical resolution of the profiles is ~2.5 km. Recently, in 2024, SO started to scan 12 diffraction orders per occultation, dividing the vertical sampling by two but improving the coverage of several species. The resulting vertical resolution is then reduced to a maximum of 50 %. The instrument function of SO was described in ref. [2].

The retrieval of CO_2 density and temperature was described in ref. [3]. The radiative transfer computations are performed with the ASIMUT software [4]. The regularisation of the profiles is carefully fine-tuned with an iterated Tikhonov method [3, 5]. This fine-tuning of the regularisation helps to better constrain some variabilities in the profiles that are, for instance, produced by tides and gravity waves. The regularisation does not add any a priori information to the retrieved profiles.

The diffraction order 132 (2966 to 2930 cm^{-1}) is used to infer the CO_2 density and temperature in the troposphere (altitudes below ~50 km), while the CO_2 density and temperature are inferred in the mesosphere (~50 to ~100 km) from diffraction orders 148 (3326 – 3353 cm^{-1}) and 149 (3348 – 3375 cm^{-1}). Previously, the retrievals in the mesosphere were done only with order 148 (3138 measurements from 2018 to 2023) for the thermosphere, but diffraction order 149 (2880 measurements from 2018 to 2023) is now added to the retrieval pipeline. Diffraction order 148 is sensitive to CO_2 density but weekly sensitive to temperature, while diffraction order 149 is highly sensitive to temperature in addition to CO_2 density. Diffraction order 165 (3708 – 3738 cm^{-1}) is used to retrieve CO_2 density and temperature in the upper thermosphere (140 – 190 km). The lower bounds of the diffraction orders are due to the saturation of the lines[3]. Nevertheless, a full profile combining GEM-Mars [6, 7] and the retrieved profiles from the diffraction orders 132 and 148 (altitudes below 100 km) is provided for the retrievals of other species whose lines are dependent on temperature.

We analysed the longitudinal variations of temperature for some profiles with very close solar longitude, local solar time, and latitude around 60°. Only non-migrating tides (non-synchronous with the relative position of the Sun) can be analysed as the set of profiles corresponds to tight ranges in local times: either 0 h, 9 h, or 15 h. The local times close to 0 h cover the Northern hemisphere in the first half year and the Southern hemisphere in the second half year. The local times close to 9 h and 15 h cover the Southern hemisphere in the first half year and the Northern hemisphere in the second half year. Some preliminary results concerning four sets of profiles in Martian year 35 where longitudinal variations could be inferred were presented in [8]. This analysis was now extended to more than fifty of those sets of profiles from Martian years 34 to 37. Amongst the results, we found an important wavenumber-1 structure at 9 h around L_S 60° and 110° in the Southern hemisphere with very similar amplitude and phase for Martian years 35 to 37. Still, we found no structure higher than 1% of the background temperature at 15 h around L_S 85° in the Southern hemisphere.

Comparisons to simulations from a GCM [6, 7] show some large differences in the amplitude of longitudinal variations in the mesosphere, especially closer to aphelion in the Southern hemisphere, showing that the dynamical processes occurring at that time might still need to be better constrained. Comparisons to the results of measurements from other instruments are ongoing to confirm those results obtained with SO.