Strong seasonal and diurnal variability of water D/H on Mars as revealed with ExoMars/NOMAD

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We present the first complete dataset of retrievals of water D/H vertical profiles derived from the Nadir and Occultation for Mars Discovery (NOMAD) instrument, onboard ExoMars Trace Gas Orbiter (TGO). NOMAD is a spectrometer operating in the spectral ranges between 0.2 and 4.3 μm onboard ExoMars TGO. NOMAD has 3 spectral channels: a solar occultation channel (SO –Solar Occultation; 2.3-4.3 μm), a second infrared channel capable of nadir, solar occultation, and limb sounding (LNO –Limb Nadir and solar Occultation; 2.3-3.8 μm), and an ultraviolet/visible channel (UVIS –UV visible, 200- 650 nm). The infrared channels (SO and LNO) have high spectral resolution ($\lambda/d\lambda$ ~10,000-20,000) provided by echelle grating in combination with an Acousto Optic Tunable Filter (AOTF) which selects diffraction orders.

Deuterated water (HDO) is primarily quantified by probing the v1 band at 3.7 μm, corresponding to the orders 118-122 of the NOMAD/SO channel. We used information from all of these orders to quantify HDO. Water is measured with NOMAD at different diffraction orders across the whole SO wavelength range. Some strong bands, such as the v1 and v3 of water at 3.7 μm (orders 166-170), allow to probe high altitudes where the atmosphere is thin, yet these bands become too optically thick at lower altitudes (<30 km). We therefore complement the water measurements by also probing weaker bands, such as the 2v2 at 3.3 μm (orders 133-136) and lines in the 3 μm region (orders 147-149). At altitudes when different orders provide similar sensitivities, we verified that the retrievals of water were consistent between the orders. This multi-order quantification strategy ensures maximum altitude coverage and self-consistency across the database.

Measurements of water vapor vertical profiles are a key diagnostic to the escape processes acting on water on Mars. Since its first scientific operation started on 21/April 2018, the ExoMars/NOMAD instrument suite has regularly conducted solar occultation measurements that are able to provide water vapor vertical profiles with unprecedented vertical resolution (< 1 km). The occultations sample the dawn and dusk terminators, allowing us to investigate diurnal changes, while the broad range of dates (April/2018 –September/2019) spans almost a full Mars year, and permits the investigations of the seasonal cycle on the D/H. For the retrieval analysis, we employed the Planetary Spectrum Generator (PSG).

Our initial analysis of two D/H profiles measured with NOMAD reveal strong variability before and after the dust storm of 2018, indicative of a strong effect of the climatology on the water cycle and isotopic signatures. In this paper, we advance these pioneering measurements to the whole planet and a broad range of seasons. Our latest results show dramatic variability of the D/H across seasons and over short time scales. The D/H is expected to vary due to the Vapor Pressure Isotope Effect (VPIE), which produces

an isotopic fractionation at condensation (e.g., cloud formation and frost/ground fog formation), yet the observed localized (in time and space) anisotropies are certainly higher than was predicted by current atmospheric models. In this presentation, we will discuss different possible scenarios that may explain this variability and will discuss how these short-term processes impact our ability to estimate water loss from atmospheric D/H measurements.

