Modeling of HDO in the Martian atmosphere

Loïc Rossi1, Franck Montmessin1, François Forget2, Ehouarn Millour2, Kevin Olsen4, Margaux Vals2, Anna Fedorova3, Alexander Trokhimovskiy3, and Oleg Korablev3

1LATMOS, Guyancourt, France (loic.rossi@latmos.ipsl.fr)
2Laboratoire de Météorologie Dynamique (LMD), Paris, France
3Space Research Institute (IKI), Moscow, Russia
4Department of Physics, University of Oxford, UK

Mars is known to have had a significant liquid water reservoir on the surface and the D/H ratio is an important tool to estimate the abundance of the early water reservoir on Mars and its evolution with time. The D/H ratio is a measure of the ratio of the current exchangeable water reservoir to the initial exchangeable water reservoir. Many observations from the ground have shown that the current ratio is five times that of the reference in Earth’s oceans (Encrenaz et al. 2018, Krasnopolsky et al. 2015, Villanueva et al. 2015).

H and D atoms in the upper atmosphere are coming from H2O and HDO, their sole precursor in the lower atmosphere. The lower mass of H over D atoms and the fact that H2O is preferentially photolysed over HDO (Cheng et al. 1999) explain the differential escape of these two elements. Finally, due to differences in vapor pressure for HDO and H2O, the solid phase of water is enriched in deuterium compared to the vapor phase. This effect is known as the Vapor Pressure Isotope Effect (VPIE) and can reduce the D/H ratio above the condensation level to values as low as 10% of the D/H ratio near the surface (Bertaux et al. 2001, Fouchet et al. 2000).

These fractionation processes can affect the amount of HDO with latitude, longitude, altitude and with the season. In particular, previous models (Montmessin et al. 2005) have shown that an isotopic gradient should appear between the cold regions where condensation occurs and the warmer regions. This leads to a latitudinal gradient of D/H (with variations greater than a factor of 5) between the warm and moist summer hemisphere and the cold and dry winter hemisphere. Yet some observations (Villanueva et al. 2015, Khayat et al. 2019) also show longitudinal variations of H/D ratios which are not explained so far.

Previous work has been done on modeling HDO using 3D GCMs, in particular around the IPSL Mars GCM (Montmessin et al. 2005). Since the GCM has considerably evolved since this first HDO introduction in the modeled water cycle, a reappraisal of HDO predictions is needed to account for the detailed microphysics that control cloud formation and thus HDO fractionation.

The Trace Gas Orbiter, part of the ExoMars mission, is currently in orbit around Mars. Onboard is the Atmospheric Chemistry Suite, a set of spectrometers designed to study the atmosphere of
Mars with a specific focus on trace gases such as methane. With TGO now in its mission phase, very strong and precise constraints will be soon available to evaluate the GCM prediction capability.

We will describe here our work on the update of the HDO model in the IPSL Mars GCM and will attempt first comparison with the early TGO/ACS observations, in particular in the context of the global dust storm of 2018.