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Modeling of HDO in the Martian atmosphere

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Abstract

HDO and the D/H ratios are important species to study to understand Mars past and present climate, in particular with regards to the evolution through ages of the Matian water cycle. We present here new modeling efforts aimed at rejuvinating the representation of HDO in the LMD Mars GCM motivated by the future comparison with the new observations provided by the Atmospheric Chemistry Suite (ACS) on board the ESA/Roscosmos Trace Gas Orbiter.

1. Introduction

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 [3, 6, 8].

H and D atoms in the upper atmosphere are coming from H_2O and HDO, their sole precursor in the lower atmosphere. The lower mass of H over D atoms and the fact that H_2O is preferentially photolysed over HDO [2] explain the differential escape of these two elements. Finally, due to differences in vapor pressure for HDO and H_2O, 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 [1, 4].

2. Modeling HDO

These fractionation processes can affect the amount of HDO with latitude, longitude, altitude and with the season. In particular, previous models [7] 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 [8] also show longitudinal variations of H/D ratios which are not explained so far. It is therefore essential to model the HDO cycle and the associated processes of fractionation in a 3D general climate model (GCM).

Previous work has been done on 3D GCMs of HDO, in particular around the LMD Mars GCM [7]. 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 microphsyics that control cloud formation and thus HDO fractionation. With the TGO mission now entering its mission phase, very strong and precise constraints will be soon available to evaluate the GCM prediction capability.

3. Contribution of ACS

The Trace Gas Orbiter, part of the ExoMars mission, has now reached its operational orbit. 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.

ACS combines high resolving power (> 10,000), high accuracy (ppb level) and large spectral coverage (0.7 – 17 μm) to a large variety of observation modes [5].

Thanks to its solar occulation capabilities, ACS will be able to provide vertical profiles of HDO and H_2O from a few kilometers above the surface up to 60 km, reaching precisions up to 1 ppb. It will thus be possible to detect when the abundance of the two species decreases due to condensation, to observe the cloud formation and to measure the subsequent fractionation.

These measurements will constrain the spatial and temporal variabilities and help improve our understanding of the HDO and H_2O cycles.

We will describe here our preliminary work on the update of the HDO model in the LMD Mars GCM and will attempt first comparison with the early TGO/ACS observations.

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