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Couplings between the lower and upper atmosphere of Mars

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1. Introduction

Over the last decade a wealth of observations has produced an unprecedented characterization of the atmospheric composition and activity from the near-surface to above the exosphere. In this overview, a synthesis of some of these observations collected will be presented. With the data at hand, it is now possible to assemble a single, coherent picture of the Martian atmosphere from the near-surface layers up until the layers interacting with the solar wind. Addressing the coupling between the lower and the upper atmosphere of Mars is central to our understanding of the key elements controlling the fate of volatiles on Mars. A focus will be made on the water vapor subliming from the seasonal and perennial ices that convert later into H atoms at higher altitude.

2. Observations

The study presented here focuses on several datasets that provide a fine characterization of the vertical distribution of some species of interest.
Water vapor profiles. The study presented in [1] reports the first monitoring of the seasonal evolution of water vapor profiles during a complete martian year. 120 profiles, obtained by Mars Express / SPICAM infrared channel, were retrieved. Northern spring-summer season and the southern spring of Mars Year (MY) 29 were covered. The seasonal evolution of water vapor mixing ratio vertical distribution reveals a strong dynamism, especially during southern spring, that is not predicted by models. The measured profiles exhibit often abrupt temporal variations and a great variety of shapes, with the frequent presence of detached layers. The water vapor vertical distribution is more reactive than expected to regional perturbations, which can propagate rapidly through the atmosphere, create abrupt water vapor and aerosol uptakes and influence the large-scale vertical evolution of these two constituents. This phenomenon has been This phenomenon has been observed several times during MY29.

2.1 Water vapor profiles.

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2.1 The polar mesospheric ozone layer

At low-to-mid latitudes, martian ozone is distributed vertically in two main layers, a near-surface layer and a layer at an altitude between 30 and 60 km [2]. In [3] evidence is reported for the existence of a previously disregarded ozone layer that emerges in the southern polar night at 40–60 km in altitude, with no counterpart observed at the north pole. Comparisons with global climate simulations for Mars indicate that this layer forms as a result of the large-scale transport of oxygen-rich air from sunlit latitudes to the poles, where the oxygen atoms recombine to form ozone during the polar night. However, transport-driven ozone formation is counteracted by the destruction of ozone by reactions with hydrogen radicals, whose concentrations vary seasonally on Mars, reflecting seasonal variations of water vapour. The observed dichotomy between the ozone layers of the two poles, with a significantly richer layer in the southern hemisphere, can be explained by the interplay of these mechanisms.

These observations imply that oxygen and hydrogen radicals can be carried from pole-to-pole thanks to planetary scale flows. In particular, models indicate that hydrogen can populate the upper branches of the solsticial Hadley cell, reaching altitudes >100 km [2]; to then access the deep polar night. The enhanced population of H and O atoms at such altitude is a consequence the large-scale transport an of the presence of exposed water vapor molecules in the sunlit regions of mars.

2.2 Hydrogen corona variability

An order-of-magnitude change in the Martian hydrogen escape rate in 2007, inconsistent with established models for the source of escaping hydrogen was reported in [4], supported by joint observations of the Hubble Space Telescope. This result was obtained from the analysis of 121.6 nm (hydrogen Lyman-α) airglow observations by SPICAM over the second half of 2007. The enhanced escape rates that were observed may be due to lower atmospheric heating and overturn during the 2007 (Mars Year 28) global dust storm, suggesting that hydrogen escape from Mars during dust storms may dominate loss of the planet's water inventory.

3. Discussion

The joint monitoring of H2O and O3 total abundances has confirmed the suspected role of OH and H as oxidants;

The characterization of H2O vertical distribution revealed unexpected amounts of water above 30 km where it can be photodissociated into H and OH;

The detection of ozone as discrete layers lying above the pole provides a nearly-direct evidence of the deep (up to 100 km) transport of H atoms;

The seasonal evolution of H above the exobase, as retrieved from limb staring modes, has revealed a behavior of H contradicting the canonical view of a upper reservoir of H seasonally disconnected from its precursor, water vapor in the lower atmosphere: the H corona shows similar seasonal variability as H_2O in the lower layers, suggesting a tighter connection between the two.

Based on the ensemble of these evidences, the following scenario unfolds: the communication between the well-mixed lower atmosphere and the outer layers where atoms (H in particular) can freely escape is more direct and much faster than anticipated. Escape processes for water need to be re-evaluated in light of this consideration. The Martian atmosphere appears as one single coherent system which is able to react on short timescales.

Acknowledgements

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