EPSC Abstracts
Vol. 6, EPSC-DPS2011-1127, 2011
EPSC-DPS Joint Meeting 2011

Observations of water vapor and supersaturation in the Mars atmosphere from the Mars Express mission

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Abstract

This presentation provides a summary of the main discoveries made by Mars Express instruments involving the Martian water cycle. Results from the monitoring of the annual and diurnal variations of atmospheric water vapor will be presented. Particular attention will be given to the retrievals of H_2O vertical distribution and the discovery of the frequent presence of water supersaturation in the Martian atmosphere.

1. Introduction

Observation of water vapor has always been a prime objective of space missions towards Mars since its first detection [12]. The Viking [3] and MGS [11] spacecrafts unveiled the presence of a water cycle on the planet possessing a clear seasonal dependence with little interannual variability. The water cycle on Mars is dominated by the sublimation/condensation process from the polar caps, especially the northern one which is the main source of atmospheric water during the year. Several other factors act as sources or sinks for water vapor, though. Sorption processes from the regolith layer, transport from global and local circulation, and water ice clouds all participate actively to the water cycle. Their relative importance, however, is still not well constrained, due to the difficulty of disentangling the mutual feedbacks and to the lack of dedicated measurements.

1.1 Mars Express

A new look at the water cycle has been provided by the ESA mission Mars Express. Simultaneous H_2O observations are routinely performed by the MEx spectrometers, OMEGA, SPICAM and PFS, that possess complementary characteristics. The combined dataset covers more than 4 Martian years. Mars Express allows also the exploitation of other important diagnostics neglected up to now (mainly because of technical limitations). OMEGA high spatial resolution permits the investigation of the regional water cycle. The solar occultation mode of SPICAM is able to map for the first time the seasonal, spatial and interannual variations of the vertical distribution of water vapor in the atmosphere, an important missing piece for the understanding of the water cycle. Observations of water vapor are complemented by surface analysis of ices [5] and soil hydration [4], performed mainly by OMEGA, and by other atmospheric species involved in the water cycle, as ozone [6] and CO [10], from SPICAM and PFS.

2. Results

All the instruments on Mars Express agree that the atmosphere of Mars is drier than previously thought. Both MAWD/Viking and MGS/TES found a maximum of 100 pr. µm during the northern summer, whereas a value between 50 – 70 pr. µm was measured by MEx [8]. The four Mars Express datasets are in good qualitative and quantitative agreement (Figure 1). The reanalysis of TES [Smith, private communication] and MAWD [2] confirmed this result, that has far-reaching consequences on the Martian climate as a whole.

The results on the diurnal variability and on the connected topic of the regolith impact on the water cycle are less clear-cut, due to the fact that the integrated amount of column density is not the best diagnostics for this kind of analysis. Both OMEGA and PFS-LW suggest that the diurnal exchange of water between the atmosphere and the regolith layer is limited within 5 pr. µm. This contradicts some in-situ observations that retrieve variations of ~ 10 pr. µm. Atmospheric circulation seems to be the dominant contribution to the spatial distribution of water, not only at large scale but also at mesoscale level, at least in some regions as Tharsis [7].

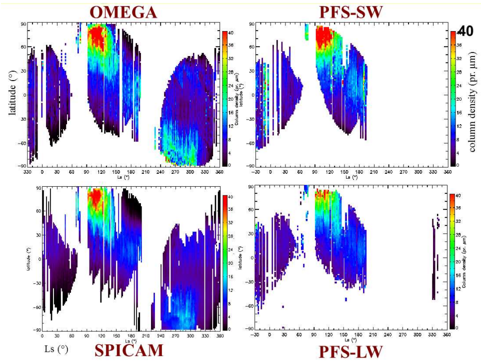

Figure 1: comparison of the annual trend of water vapor abundance as observed by the three MEx instruments (see [7] for the references to the individual retrievals).

2.1 Vertical profile and supersaturation

Before Mars Express, only few direct observations of the H_2O vertical distribution existed, with limited spatial and temporal coverage [9], and knowledge of it relied almost exclusively on GCM results. The SPICAM dataset includes more than 400 solar occultations spanning 3 Martian years (up to May 2011) from which the simultaneous vertical profiles of water vapor, carbon dioxide, and near-IR dust extinction can be extracted. First results were published in [1]. The H_2O profiles from the analyzed occultation campaigns exhibit significant discrepancies with the predictions of the LMD-GCM, used as reference (Figure 2).

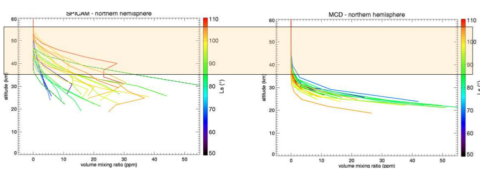

Figure 2: comparison between the profiles retrieved on the northern hemisphere by SPICAM (left) and the LMD-GCM results (right) for the first occultation campaign of MY29, that covers northern spring-summer. Southern hemisphere is analogous. Color indicates Ls.

Not only the observations show a variety of shapes not present in the GCM, but the latter constantly underestimates the H_2O mixing ratio at mid-atmosphere, between 30 and 50 km. Computation of the saturation state of the atmosphere shows that the water in excess is often supersaturated. In fact, more than 50% of the sample exhibits a degree of supersaturation, up to a saturation ratio of 10 in some orbits. The supersaturation of water vapor on Mars is the likely consequence of processes related to the complex cloud microphysics, as the removal of condensation nuclei due to scavenging effects. The importance of water ice clouds and the connection between the water and dust cycles is shown also by other discoveries, as the frequent presence of a layer enriched in water vapor below a detached aerosol layer, probably generated by water deposition

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