EPSC Abstracts
Vol. 13, EPSC-DPS2019-771-2, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Understanding the water cycle above the north polar cap on Mars using MRO CRISM retrievals of water vapor

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Abstract

The north polar cap (NPC) on Mars is the major reservoir of atmospheric water (H_2O) currently on Mars. The retrieval and monitoring of atmospheric water vapor abundance are crucial for tracking the cycle of water above the NPC. The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) aboard the Mars Reconnaissance Orbiter (MRO) has provided a wealth of data covering the time period between 2006 and 2016. The retrievals of water vapor column abundances over this extended period of time were performed over both ice-free and water ice covered surfaces, extending the coverage of the water vapor maps to include the permanent cap.

1. Introduction

The importance of monitoring water vapor abundances and their spatial and temporal variation is to understand the non-uniformity of water sublimation across the north polar cap, and to look for interannual dependences.

Previous retrievals of water vapor from orbiters around Mars included using the Mars Atmospheric Water Detector (MAWD) onboard the Viking Orbiter. The north polar region (latitudes 60˚N to 90˚N) was observed [1] during northern spring and summer in 1977 and 1978, corresponding to Mars Year (MY) 13. Water vapor results show amounts in excess of 100 precipitable microns (pr-µm) at regions surrounding the permanent cap, at Ls=110˚, presenting a great deal of structure in the water vapor distribution.

Using the Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES), water vapor abundance maps in Mars' north polar regions during spring and summer seasons were produced [2,3]. TES and MAWD retrievals share broad similarities, including the timing of the maximum water vapor abundances during the summer time, and the low abundances in the winter hemisphere. However, for the same location and season (L_s ~ 90˚ - 135˚), the water abundance levels retrieved using MAWD are twice as great as those retrieved using TES data. Updated retrievals of water vapor over the polar regions including the seasonal frost and the permanent ice cap were later reported [3] and show peak abundances over the permanent cap reaching 80 ± 15 pr-µm.

2. Observations and Method

CRISM provided a wealth of data that extend over 5+ Martian years. These observations include ~5,300 observations at latitudes higher than 60˚N. The retrieval process is iterative, and it shares similar assumptions as described in previous works [4,5]. At first, we define the continuum around the water vapor band at 1368 nm in the observed CRISM spectrum in order to establish the contrast between the continuum and the center of the water vapor band, therefore extracting the water abundance (Fig. 1). Aerosol extinction (scattering and absorption) is included in the retrieval process, and the fundamental idea is to vary the water vapor abundances until a best fit is achieved between the modeled and the observed spectrum as returned by CRISM. As shown in Figure 1, the wide spectral absorption around 1500 nm belonging to water ice on the surface of Mars affects the channels to the right in the water vapor band at ~ 1360 nm.

We corrected for the presence of surface ice in two stages. At first, the continuum at 1421 nm is calculated by applying the correlation between the continuum levels (I/F) at 1329 nm and 1421 nm from using ~ 1100 CRISM spectra with no surface ice. During the second stage, the channels that are affected by the presence of surface ice are excluded from the fit.

3. Results

For most of the observed years, the onset of the water sublimation occurs around L_s=30°, whereas the peak of the summertime maximum occurs between L_s=110° and 120° for all the observed years, except for MY30 where it occurred earlier between L_s=100° and 110° (Fig. 2c). The maximum column abundance values around the summertime maximum vary between the observed Mars years, with the difference reaching a factor of 1.5 between MY 32 (70 ± 17 pr-µm) and MY 29 (45 ± 10 pr-µm) (Fig. 2c). Later in the season, the water vapor is transported equatorward, and by L_s = 180° at the end of the water deposition period, the water abundance decreases to levels below 10 pr-µm.

The general behavior of water vapor is similar over ice-free (Fig. 2a) and ice-covered surfaces (Fig. 2b), but lower values of water vapor over ice-covered regions are observed during early spring, followed by a sharp increase during early summer, when the ice-covered regions exhibit rapid sublimation [6]. The retrieved values of water vapor abundance reach 90 ± 22 pr-µm over the newly exposed water ice from the permanent cap, as compared to 60 ± 15 pr-µm over the ice-free surfaces that do not extend to the permanent cap. Away from the period around summer time maximum, modest interannual variability in the water vapor abundance is observed within the 25% uncertainty.

4. Figures

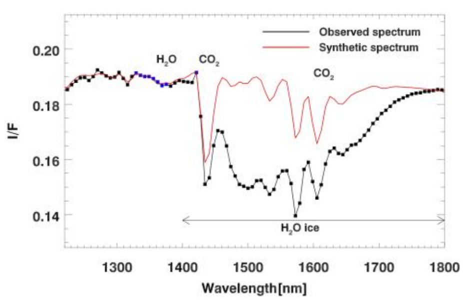

Figure 1: The portion of the CRISM spectrum of FRT0000ABD0 as observed over surface ice [6]. The H_2O surface ice band is indicated between 1400 nm and 1800 nm. The best fit spectrum (red) of the atmospheric water and CO_2 is compared against the CRISM observation (black) taken during northern spring at L_s = 69°, and the retrieved value for the atmospheric water abundance is 9 pr-µm. The channels used in computing the fit of the water vapor band around 1360 nm are shown in blue.

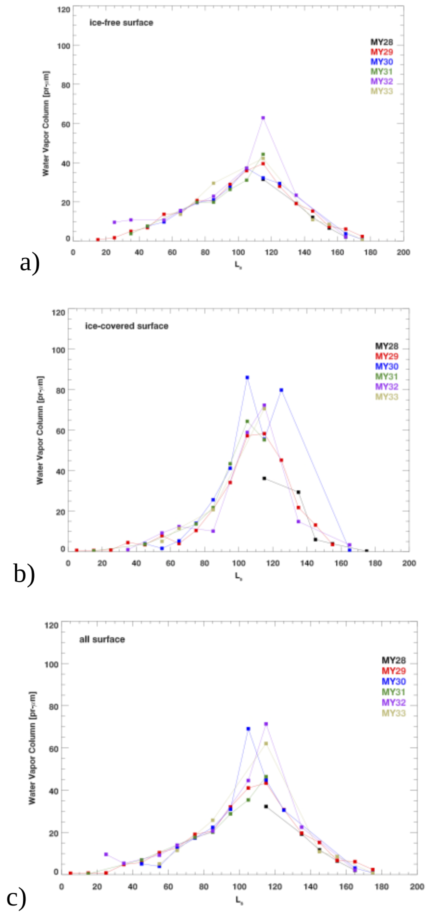

Figure 2: Latitudinally averaged (60°N - 87°N) atmospheric water vapor column abundance (pr-µm) over the north polar region during northern spring and summer for the 5+ Martian years as observed by CRISM [6]. Panel a represents the retrievals over ice-free surfaces. Panel b represents the retrievals over surfaces that are covered with water ice, and panel c represents the combined retrievals over the north polar region, for both surfaces.

References

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