Atmospheric water vapour from the PFS/Mars Express observations

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Introduction:

As the history of water on Mars is of fundamental importance to understand the Red Planet the first observations of water vapour from a spacecraft were already made by the IRTM instrument on *Mariner 9*. But the first global and seasonal coverage of H_2O distribution was generated by the *Viking* orbiters (MAWD instrument) in the late 1970's (see Fig. 1).

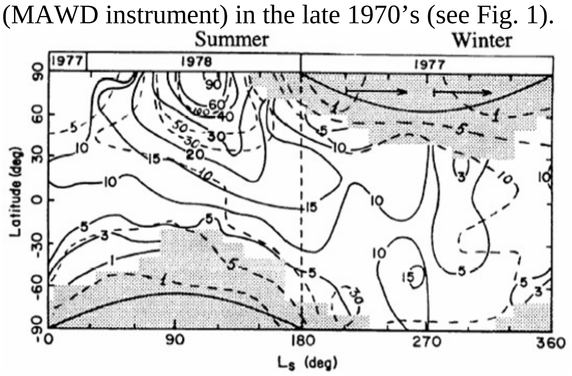

Figure 1: The development of water vapour in the atmosphere for one year (solid lines) starting from spring at L_S=0°. A strong maximum is seen around L_S=90° close to the North pole [2].

From these measurements it was visible that the gas seems to be the most variable minor constituent in the Martian atmosphere with variations reaching a factor of 10 in the course of a Martian year. These changes are governed by three main reservoirs *[3]*:

1) the condensation and sublimation on the polar caps, especially the Northern cap
2) the exchange with regolith and surface frost
3) advective transport in the air by the general circulation

The PFS instrument:

Since the successful insertion of the European *Mars Express* spacecraft into Mars' orbit the Planetary Fourier Spectrometer (PFS) has delivered several thousands of spectra. The PFS instrument is an infrared Fourier spectrometer with two channels *[1]*. The long-wavelength channel (LW) observes the thermal spectrum emitted by Mars both in daytime and nighttime at wavelengths between 5.5 µm and 50 µm. The short-wavelength channel (SW) covers the spectrum from 1.2 to 5.5 µm by utilizing reflected solar light. Therefore it delivers useful spectra only during daytime and appropriate observational phase angles. The spectral resolution of PFS is in the unapodized mode 1.3 cm^{-1}, the spatial resolution is up to 8 km (15 km) for SW (LW) for a single spectrum. One of the main goals of PFS is to study trace gases, including H_2O, in the Martian atmosphere.

Procedure of column density retrieval:

To determine the amount of water vapour in the atmosphere over a selected area up to 15 spectra have to be averaged. This measure reduces the noise but in turn decreases the spatial resolution. For the retrieval the strong H_2O band at 2.56 µm is chosen because it is not influenced by the thermal structure of the atmosphere.

Fig. 2 shows an example of an averaged PFS spectrum in SW (green) with the fitted theoretical spectrum (black) which is made up of water and CO2 lines (blue and black lines). Additionally the solar spectrum is displayed in red to explain features which are seen in the reflected solar light.

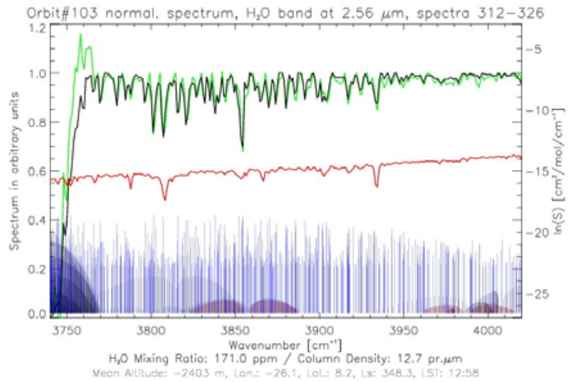

Figure 2: A sample averaged spectrum (average of 15 PFS spectra from orbit 103) and the fitted synthetic spectrum.

Results:

For a look at the period around Northern spring equinox on Mars the calibrated SW spectra up to orbit 422 have been analyzed. In Fig. 3 the retrieved H_2O column densities are plotted over the albedo map of Mars. The average amount of water vapour in the atmosphere lies between 8 and 15 precipitable micrometers (pr. µm) with extreme values in regions like Arabia Terra or the tall volcanoes such as Olympus Mons. The processed observing period covers the seasons from L_S=330° to L_S=36°.

In later orbits during the Northern summer also the sublimating polar ice into atmospheric water is detected (cf. Fig. 5).

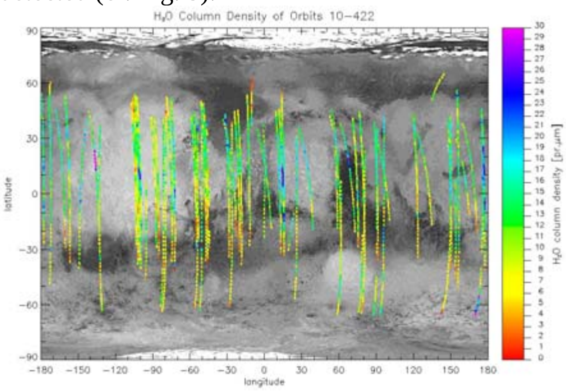

Figure 3: The water vapour column density (given in pr. µm) over the albedo map of Mars. The measurements were taken during the orbits 10 – 422.

One interesting fact to note is a weak correlation of the water vapour column density with the albedo of the Martian surface (see Fig. 4). This might be a hint towards an expected interaction between the atmospheric water and the Martian regolith which is known to keep large amounts of adsorbed water *[3]*.

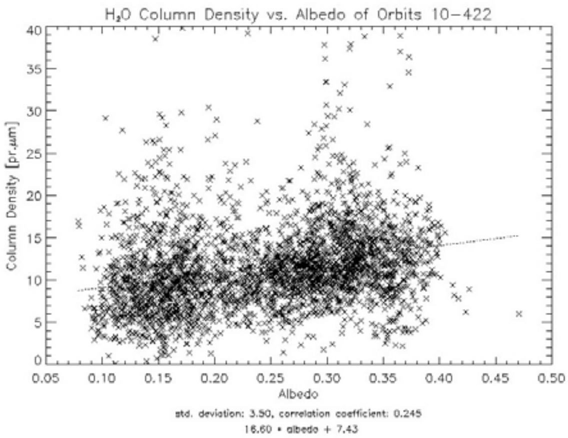

Figure 4: The atmospheric H_2O (scaled to 6.1 mbar) versus the measured albedo. A weak correlation with a correlation factor in the order of 0.25 is visible.

Comparisons and future work:

The comparisons of the results from three different teams working on PFS SW data show a very good agreement in most of the compared orbits. As an example the retrieved H_2O column density for orbit 1023 is shown in Fig. 5. Now it will be interesting to see the comparison between different instruments on *Mars Express*.

Also during its extended mission the *Mars Express* spacecraft will observe the planet throughout its seasons. The PFS data will contribute significantly to the understanding of the atmosphere and the water cycle on Mars, its interaction with the soil and finally the climate history of the Red Planet.

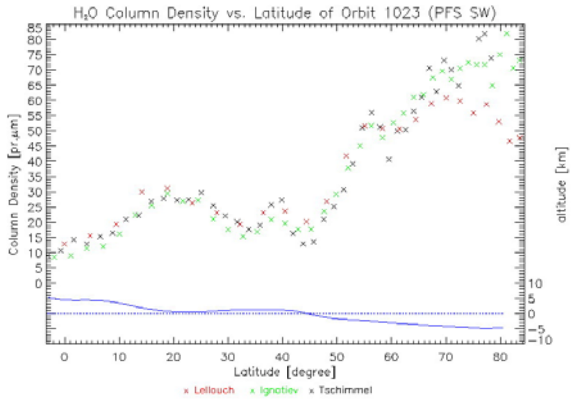

Figure 5: The results for orbit 1023 of three different PFS SW workgroups (black: M. Tschimmel, green: N.I. Ignatiev, red: E. Lellouch) showing the retrieved column density versus latitude. The blue line denotes the altitude of the Martian surface (given by MOLA data).

References:

[1] Formisano, V. et al.: P&SS, Vol. 53, Iss. 10 (2005)

[2] Jakosky, B.M., C.B. Farmer: The seasonal and global behavior of water vapor in the Mars atmosphere - Complete global results of the Viking Atmospheric Water Detector experiment, JGR, Vol. 87 (1982)

[3] Titov, D.V.: Adv. Space Res., Vol. 29, No. 2 (2002)