Retrieval of Water Vapour Vertical Profiles in the Martian Atmosphere using PFS/MEX data

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Introduction: Although the geographical and seasonal distribution of water vapour in the Martian atmosphere was widely studied [4,9,12], we have only few direct measurements about its vertical distribution [1,5]. Indeed, other indirect information about it come from nadir data [10] and GCM models [7]. The reason for the lack in the knowledge of minor species vertical distribution lies in the scarcity of stable algorithms able to retrieve the gaseous concentrations by limb measurements. The difficulty in modelling the radiative transfer for limb geometries is caused by the multiple scattering treatment, which becomes very important in the visible and near-infrared ranges if the atmosphere contains dust and/or water ice aerosols particles (the typical case of Mars).

We developed a stable algorithm for the retrieval of minor atmospheric species by limb measurements, based on the statistical Monte-Carlo modelling, with particular attention on the scattering treatment. The retrieval code was applied to a selected set of PFS/MEX measurements and so it provided important suggestions about the H_2O vertical distribution in the Martian atmosphere.

Retrieval Method: Our code for the retrieval of the atmospheric composition can exploit two techniques: 1) the onion-peeling and 2) the Bayesian data inversion [8] approaches. The latter uses the Gauss-Newton iterative procedure to minimize the χ^2 function. The synthetic spectrum takes into account the multiple scattering, both by molecules and particles, and it is computed using a true spherical model [11], which is based on the statistical Monte-Carlo approach [2,6,13]. Finally, the convergence criterion takes into account the χ^2 minimization.

We used the H_2O absorption band at 2.6 μm (3780-3950 cm^{-1}) for the retrieval of its vertical abundances.

Dataset: The PFS/SWC (Short Wavelength Channel) [3] dataset used for this work covers more than three Martian years. We divided it in bins of 30° in Solar Longitude (Ls) x 20° in Latitude in order to highlight the seasonal and geographical differences in the vertical distribution of water vapour. Then, we averaged spectra in tangent altitude bins of 30 Km, from the surface to 80 Km, and by shifting by 10 Km in the tangent altitude of limb measurements from an average to the next one. This approach improves the SNR and the vertical coverage.

Results and Conclusions: Our results confirm the expected confinement of water vapour in the boundary layer of the Martian atmosphere. They also suggest a large seasonal and geographical variability in its vertical distribution. In particular, during the northern spring on the near equatorial regions, the atmosphere above 35 Km is relatively wet, having a water vapor concentration higher than its mean global and annual average value. On the contrary, during the southern spring the atmosphere near the south polar region becomes extremely dry above 60 Km, reaching almost the minimum quantity we detected in the Martian atmosphere. The explanation of this behaviour lies in the dynamical processes that occur in the Martian atmosphere and which drive the global circulation.

The results we report demonstrate the capability of our code to retrieve vertical profiles of water vapor concentrations from PFS/MEX limb measurements. Moreover, this work will be useful in future data processing of both PFS and other instruments on board current and future missions, as NOMAD aboard the ExoMars spacecraft.

References:

[1] Clancy, R.T., et al. **Icarus** *293*, p. 132-156, 2017.
[2] Emde, C. and Mayer, B., (2007). **Atmos. Chem. Phys.**, *7*:2259-2270, 2007.
[3] Formisano, V. **Planet. Space Sci**. *53*, 963-974, 2004.
[4] Fouchet, T. et al.. **Icarus**, 190, 32-49, 2007.
[5] Maltagliati, L., et al. **Icarus** *223*, p. 942-962., 2013.
[6] Mayer, B. **European Physical Journal Conferences.**, *1*:75-99, 2009.

[7] Navarro, T.M., et al. **J. Geophys. Res.** *119*, p. 1479-1495, 2014.
[8] Rodgers, C. D. *Inverse Methods for Atmospheric Sounding*. **World Scientific**, 2000.
[9] Sindoni, G., et al. **Planetary and Space Science**, Volume *59*, Issue 2-3, p. 149-162, 2011a.
[10] Sindoni, G., et al. **EPSC-DPS Joint Meeting 2011**, Vol. *6*, EPSC-DPS2011-768, 2011b.
[11] Sindoni, G., et al. **European Planetary Science Congress**, 2013.
[12] Smith, M.D.. **J. Geophys. Res**.*107*, 251, 2002.
[13] Vasilyev, A. V. et al. **Conf. to forty years French-Russian coop. in space science, session - Planetary studies and future missions, IKI**, 2006.

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