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

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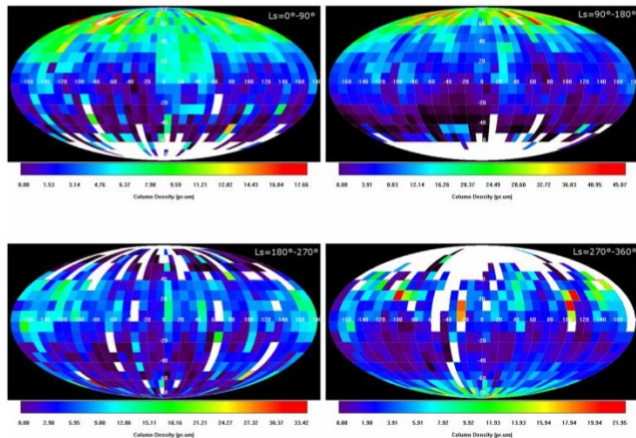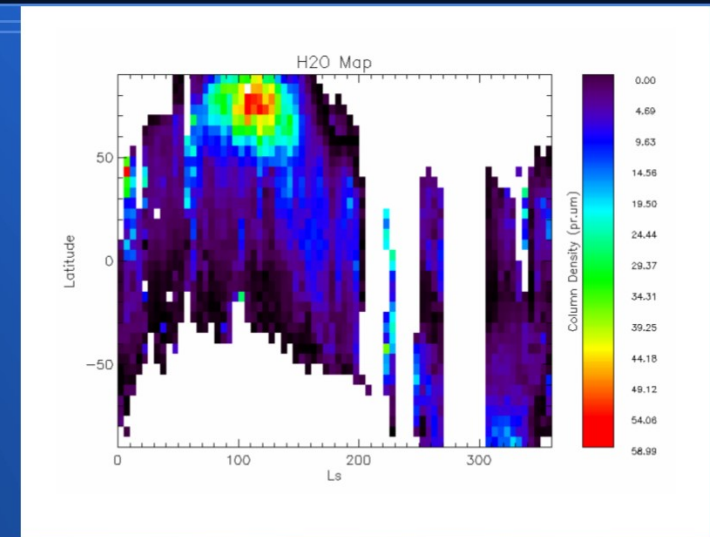
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Introduction

Although the geographical and seasonal distribution of water vapour in the Martian atmosphere was widely studied (e.g. Sindoni et al., 2011), we have only few direct measurements about its vertical distribution (e.g. Fedorova et al., 2009; Maltagliati et al., 2013).

The study of <u>the geographic distribution of water vapor</u> in the atmosphere of Mars (Sindoni et al., 2011) <u>has revealed a periodic longitudinal localization of minor gaseous species</u>.

Two peculiar cases, where we can indirectly infer about the H_2O vertical distribution, has been selected as test cases.

Credits: Sindoni et al., 2011

Development of a technique to retrieve H$_2$O vertical profiles from PFS limb measurements

- We adapted and validated three multiple-scattering radiative transfer codes based on Monte-Carlo approach optimized for limb simulations:
    1. SCATRD_OFOS (Forward MC);
    2. MYSTIC (Forward and Backward MC)
    3. JACOSPAR (Backward MC)

- We developed two codes for the retrieval of the atmospheric quantities (gaseous and aerosols content) profiles from limb geometries:
    a) An Onion-Peeling based code optimized for gaseous retrieval;
    b) A Bayesian based code (MITRA; Sindoni et al., 2013; Oliva et al., 2016) optimized for both gaseous and aerosols retrievals.

- As first attempt we applied the *(1a)* approach to a limited sample of two PFS limb scan representing two very different atmospheric conditions:
    i.   northern spring (Ls = 0°-30 °) over the near-equatorial region (10°-30°N)
    ii. southern spring (Ls = 180°-210°) over the near-polar region (50°-70°S)

# Selection of PFS limb measurements for the retrieval of H$_2$O vertical profiles

These two cases are representative of very different seasonal and geographical conditions. Differences in the vertical distribution of water vapor was inferred indirectly from the study of Martian planetary waves (Sindoni et al., 2011).

Ls 0-30° - Lat 10-30°		Ls 180-210° - Lat 50-70°	
Mean Tan Alt [Km]	# of Averaged Spectra	Mean Tan Alt [Km]	# of Averaged Spectra
29.10	1	38.20	1
32.93	3	57.76	7
40.86	5	64.16	23
59.83	4	67.52	34
70.61	5		

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.

Indirect clues about H₂O vertical distribution
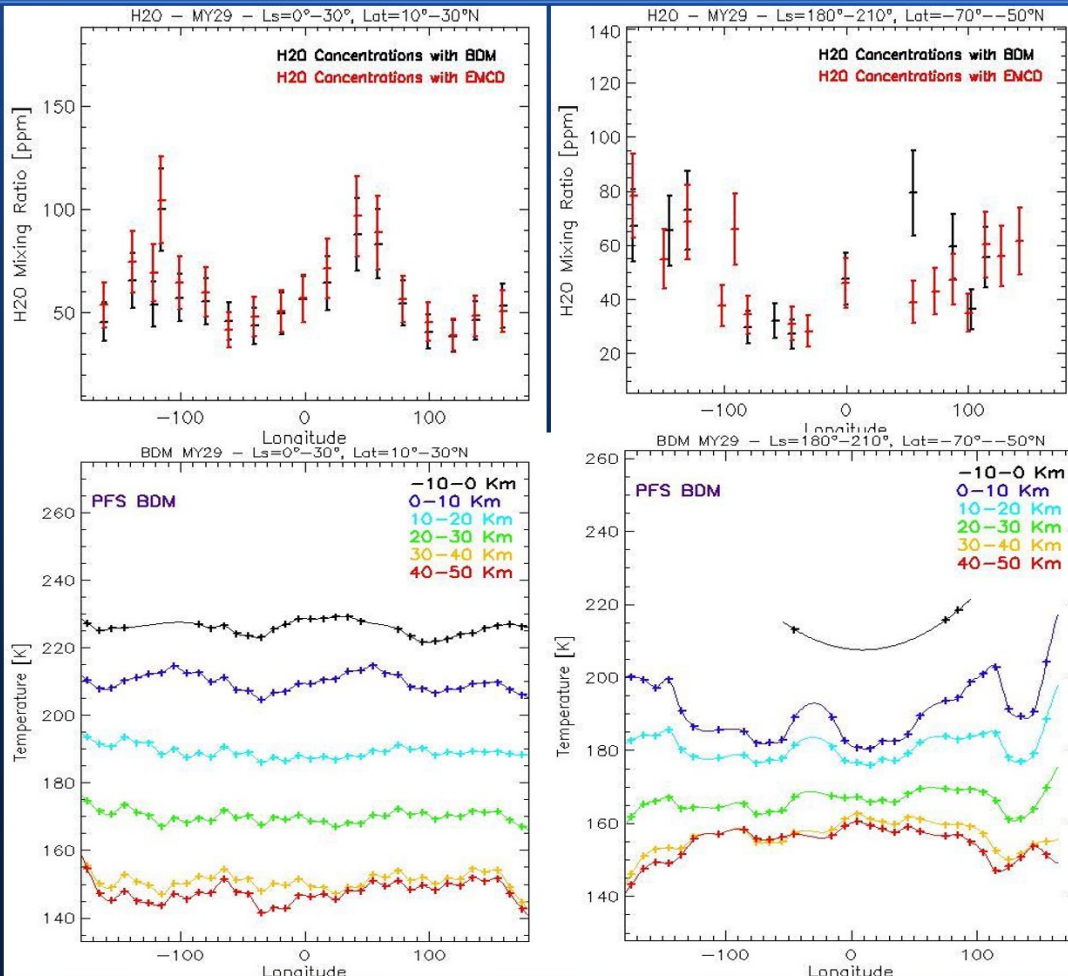
The selection of the first test cases comes from the study of H_2O wave trends where we identified two very different atmospheric conditions:

- northern spring (Ls = 0°-30 °) over the near-equatorial region (10°-30°N
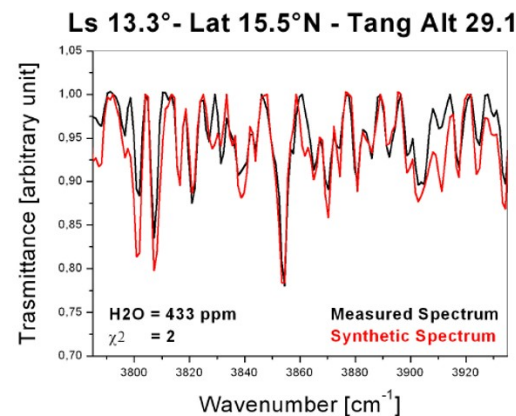- southern spring (Ls = 180°-210°) over the near-polar region (50°-70°S)

The wave phenomenon observed in H_2O longitudinal distribution finds a correlation with the temperature profiles measured by PFS LW channel.

These indirect results suggest the confinement of water vapour in the lower atmospheric layers.

Development of a technique to retrieve H₂O vertical profiles from PFS limb measurements

The retrieval code was applied to the 2.6 µm band (around 2800-2900 cm^{-1}).

The estimated uncertainty on the retrieved concentrations is about 24%.

Ls 13.3°- Lat 15.5°N - Tang Alt 29.1

H2O = 433 ppm
χ^2 = 2
Measured Spectrum
Synthetic Spectrum

Ls 0-30° - Lat 10-30°N

Ls 180-210° - Lat 50-70°S

The H_2O band treatment (continuum definition, normalization, etc.) is described in details in Sindoni et al., 2011.

During the northern spring on the near equatorial regions, the atmosphere above 35 Km is relatively wet.

On the contrary, during the southern spring the atmosphere near the south polar region becomes extremely dry above 60 Km (~ 25 ppm).
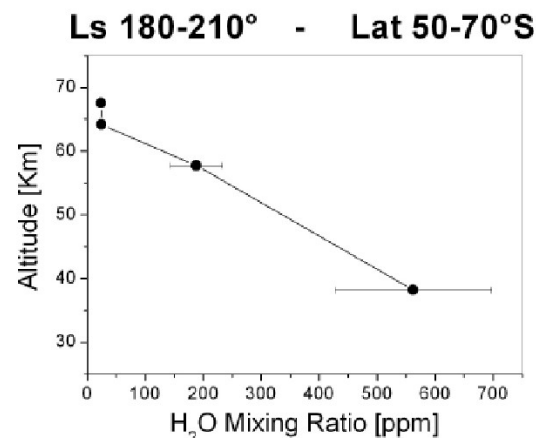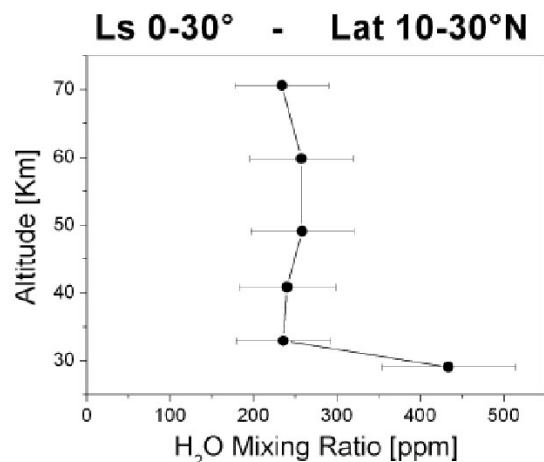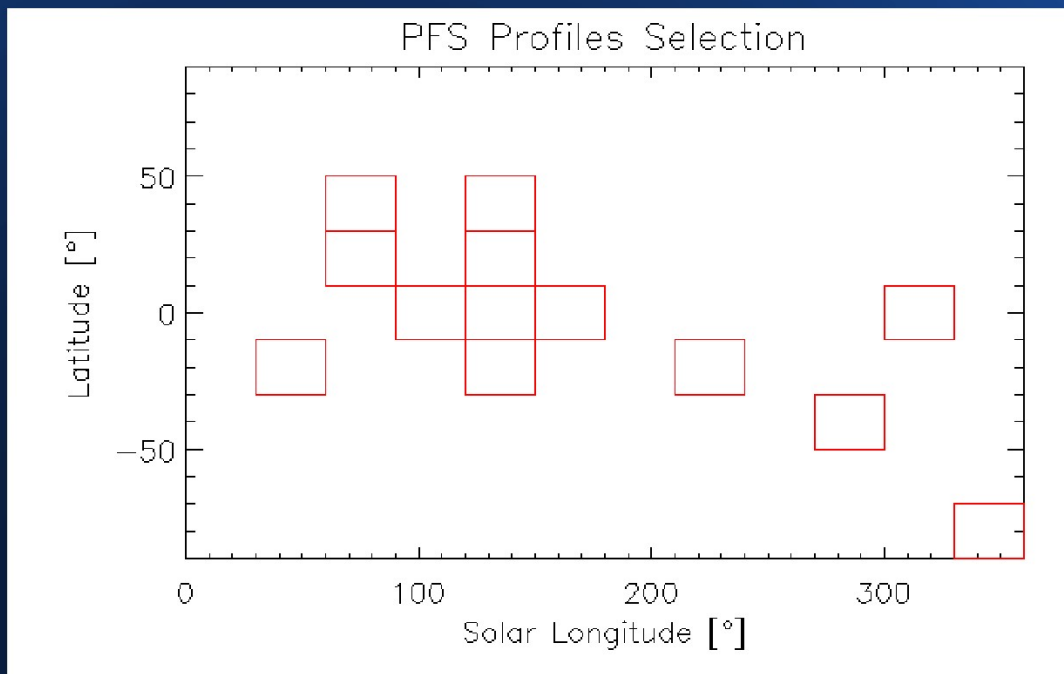
Development of a technique to retrieve H_2O vertical profiles from PFS limb measurements

We extended the dataset of selected PFS vertical profiles also to other bins. The selection criteria are:

- A good SNR (> 1 erg/(s cm^{-1} cm2)) in the H_2O band for at least one spectrum of the limb scan;
- The absence of atmospheric water ice clouds (Ice Cloud Index > 0.8)

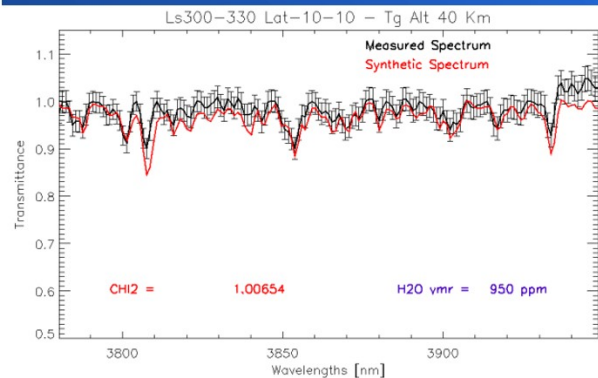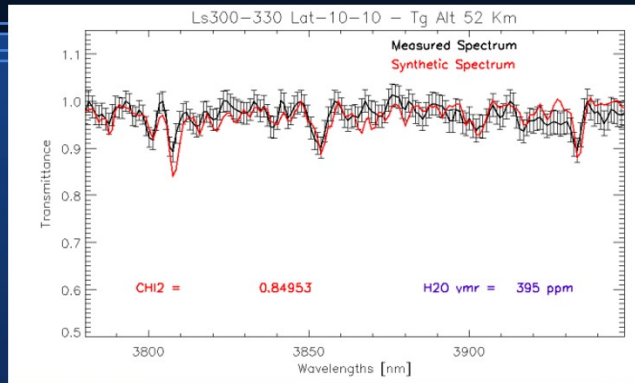This selected dataset was analyzed with the latest and more accurated code based on the approach *(2b)*:

2) MYSTIC (backward Monte Carlo)
b) MITRA retrieval code (Bayesian approach)

H₂O vertical profiles from PFS limb measurements
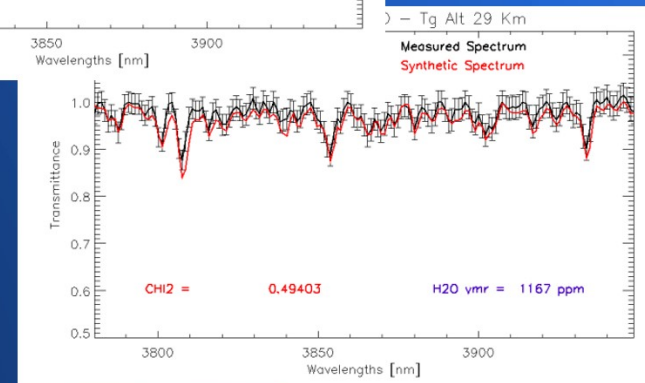

Tg Alt
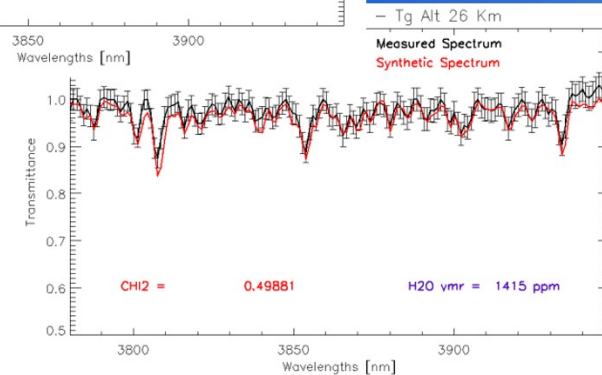52 Km

Tg Alt
40 Km

Tg Alt
29 Km

Tg Alt
26 Km

The inversion algorithm was applied two times:
1. On the continuum of the radiance spectra for the limb scan to estimate the dust properties (density and size);
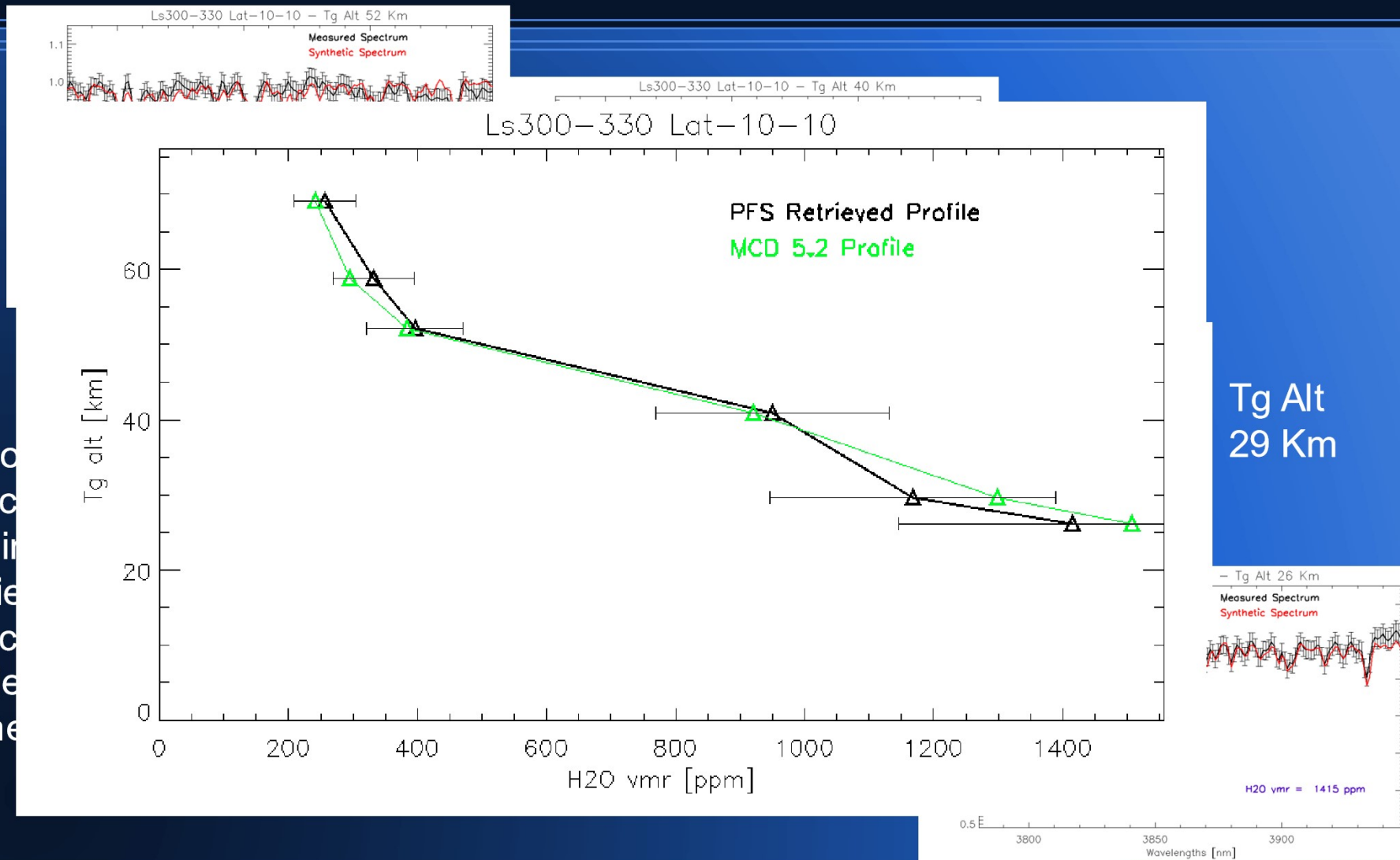2. On the continuum normalized spectra for the retrieval of the water vapour content fixing the dust properties as retrieved in step 1.

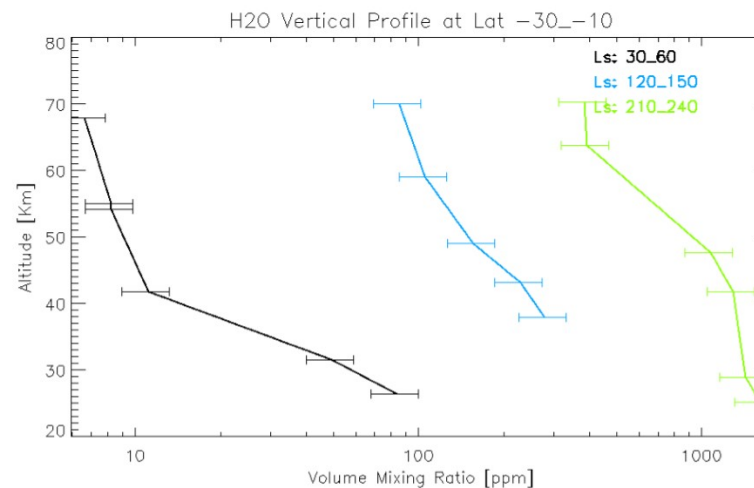# H₂O vertical profiles from PFS limb measurements
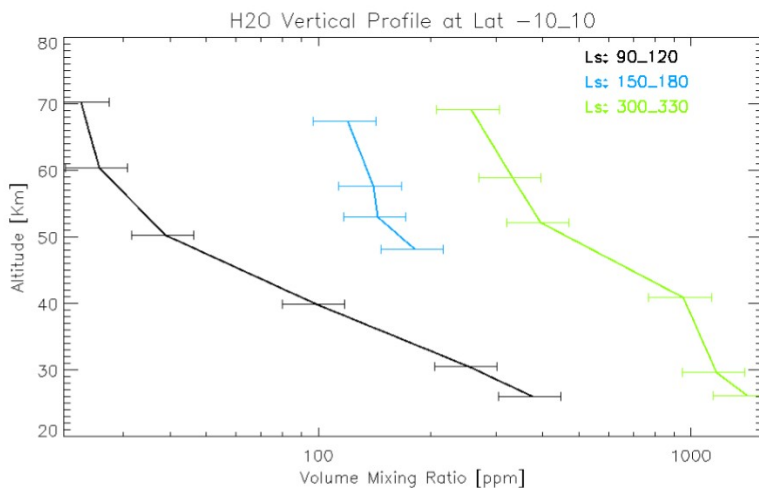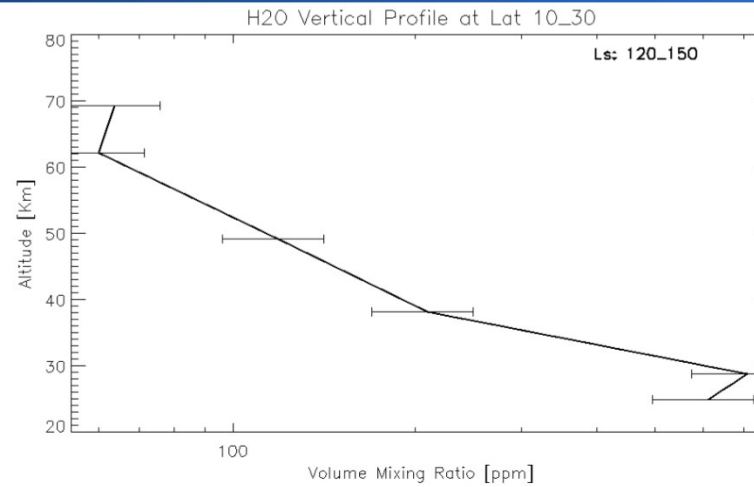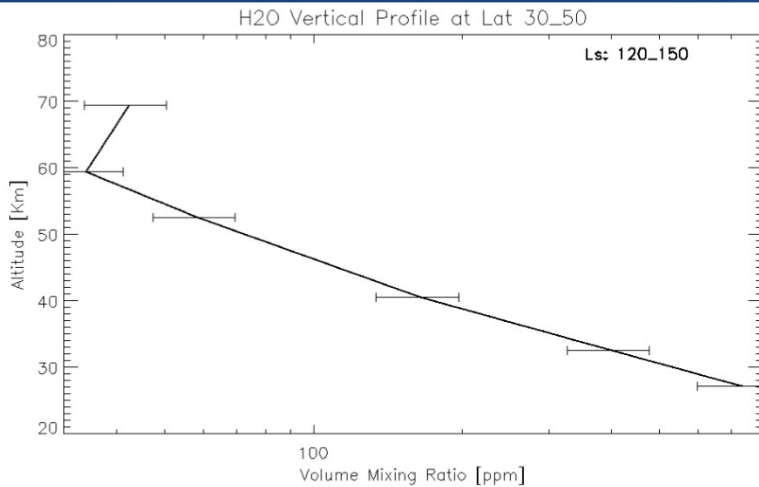
Tg Alt
52 Km

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Tg Alt
29 Km

H₂O vertical profiles from PFS limb measurements

Water vapour vertical profiles as retrieved by PFS/MEX. Profiles at different latitudinal stripes are shown: 30-50°N (top-left panel), 10-30°N (top-right panel), 10°N-10°S (bottom-left panel) and 10°-30°S (bottom-right panel). Colors represent different solar longitudes for each latitudinal stripe.

H$_2$O vertical profiles from PFS limb measurements
Conclusions

- This study has been performed within the UPWARDS project;

- The results we reported demonstrate the capability of our code to retrieve vertical profiles of water vapor concentrations from PFS/MEX limb measurements;

- We confirmed the expected confinement of water vapour in the lower layers of the Martian atmosphere;

- These new results, even if they should be regarded as preliminary, will provide a more specific and unprecedented insight on the water vapor stratification in the Martian Atmosphere, improving the current knowledge in the field;

- 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.

THANK YOU…!!!