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Temperature and CO₂ density distribution in Mars upper atmosphere from the ACS-MIR / TGO solar occultations at 2.7 μm absorption band

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and Miguel Lopez-Valverde (4)
and ACS team

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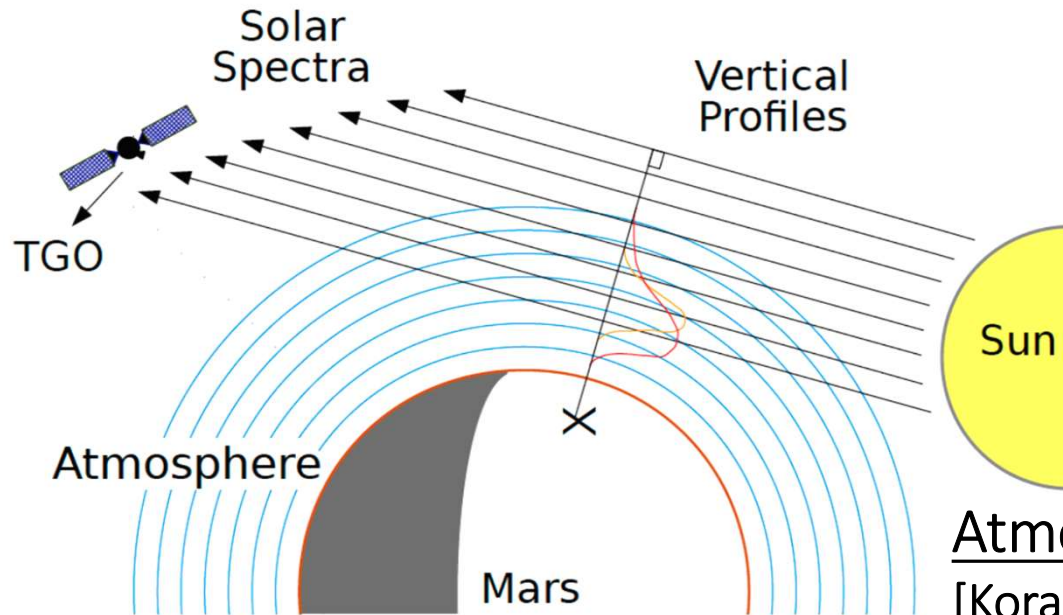
(3) University of Oxford

(4) IAA, Granada, Spain

EGU 2020 (remotely), 4-8 May 2020, Virtual World



Solar occultation by ExoMars Trace Gas Orbiter (April 2018 – nowadays)



Measured atmospheric transmission spectrum:

$$J_A(\nu, z) = \frac{F(\nu, z)}{F_0(\nu)}$$

$F_0(\nu)$ – pure solar spectrum;

$F_0(\nu, z)$ – solar spectrum, transmitted through atmosphere at tangent altitude z .

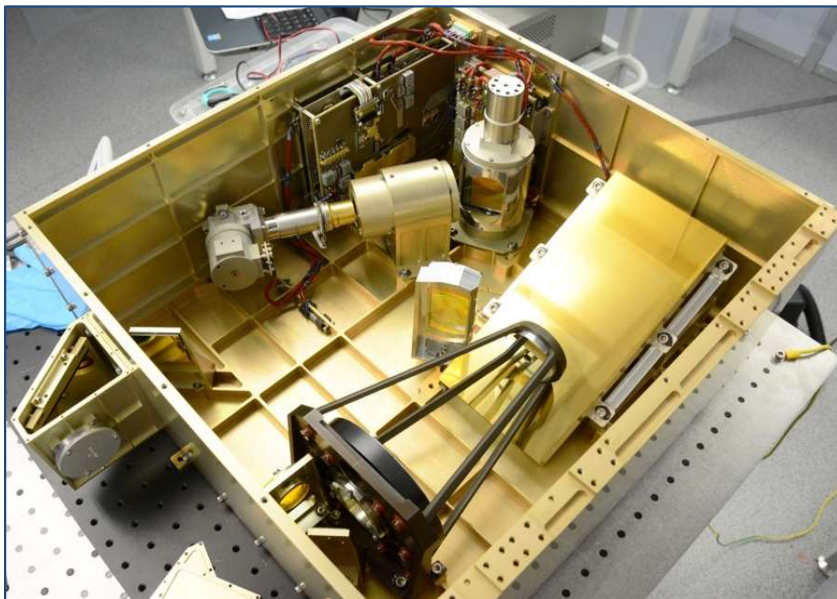
Atmospheric Chemistry Suite (ACS)

[Korablev et al., 2018, Sp. Sci. Rev.]

Science goals: altitude sensitive profiling of atmospheric temperature, density, minor species (CO, H₂O, HDO, CH₄ etc.)

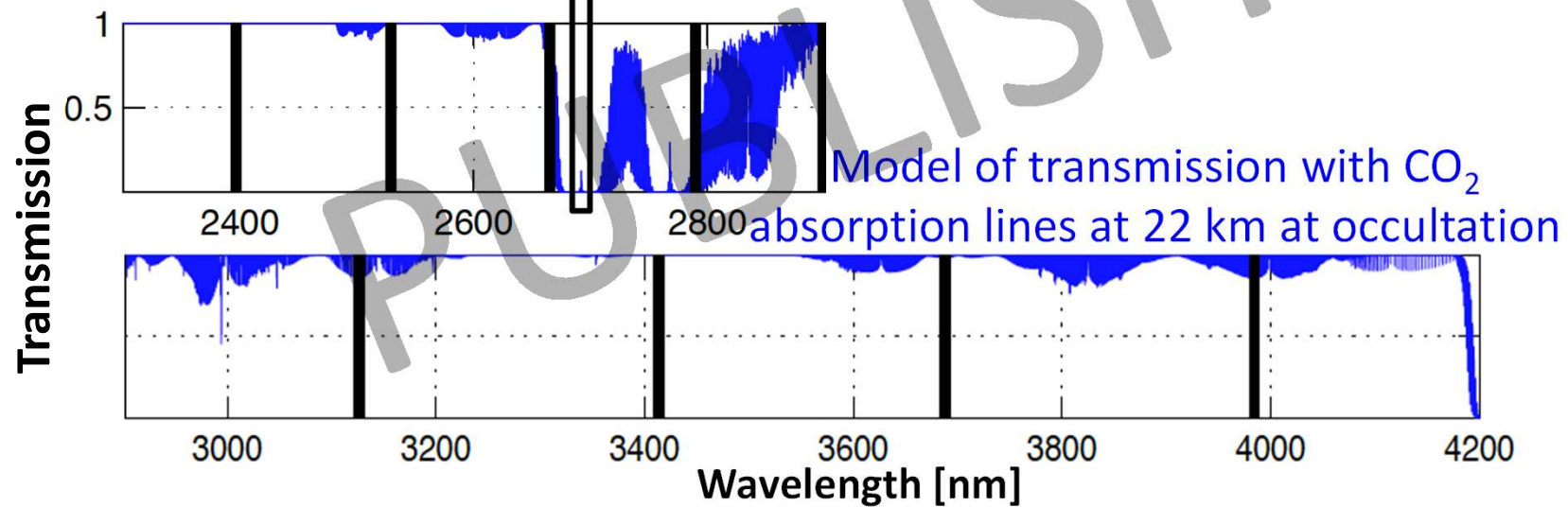
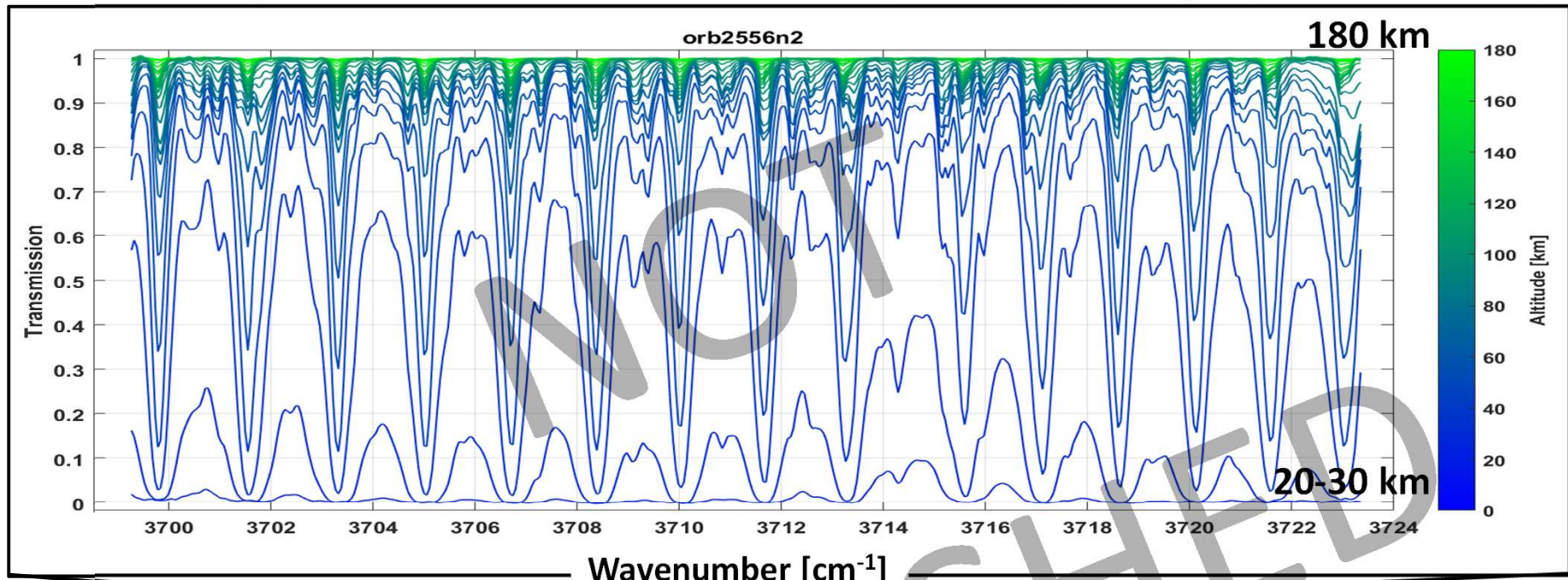
ACS-MIR channel:

- Echelle spectrometer
- Cross-dispersion system
- Spectral range 2.3 – 4.2 μm
- Resolving power $\lambda/\Delta\lambda \sim 30\,000$
- FOV: $0.23^\circ \times 0.02^\circ$ (0.2-2 km)



CO₂ spectroscopy around 2.7 μm

Transmission spectra measured at one occultation in spectral range ~2.7 μm (echelle order 221)



Concept of temperature and density retrievals from transmission spectra

$$J(z) = \exp\left[-\int \left(\sigma_{CO_2}(T, p)n_{CO_2}(z) + \sigma_{H_2O}(T, p)n_{H_2O}(z) + 5F_{SMOW}\sigma_{HDO}(T, p)n_{H_2O}(z)\right) dz - \tau_{aer}\right]$$

$J(z)$ - transmission, $\sigma(T, p)$ - CO_2 and H_2O absorption cross sections, n - CO_2 and H_2O number densities, $F_{SMOW} = 1.3 \cdot 10^{-4}$, τ_{aer} - aerosol slant opacity.

1) Spectroscopic database HITRAN 2016 for $\sigma(T, p)$ and CO_2 broadening for H_2O lines [Gordon et al., 2017; Gamache et al., 2016; Devi et al., 2017];

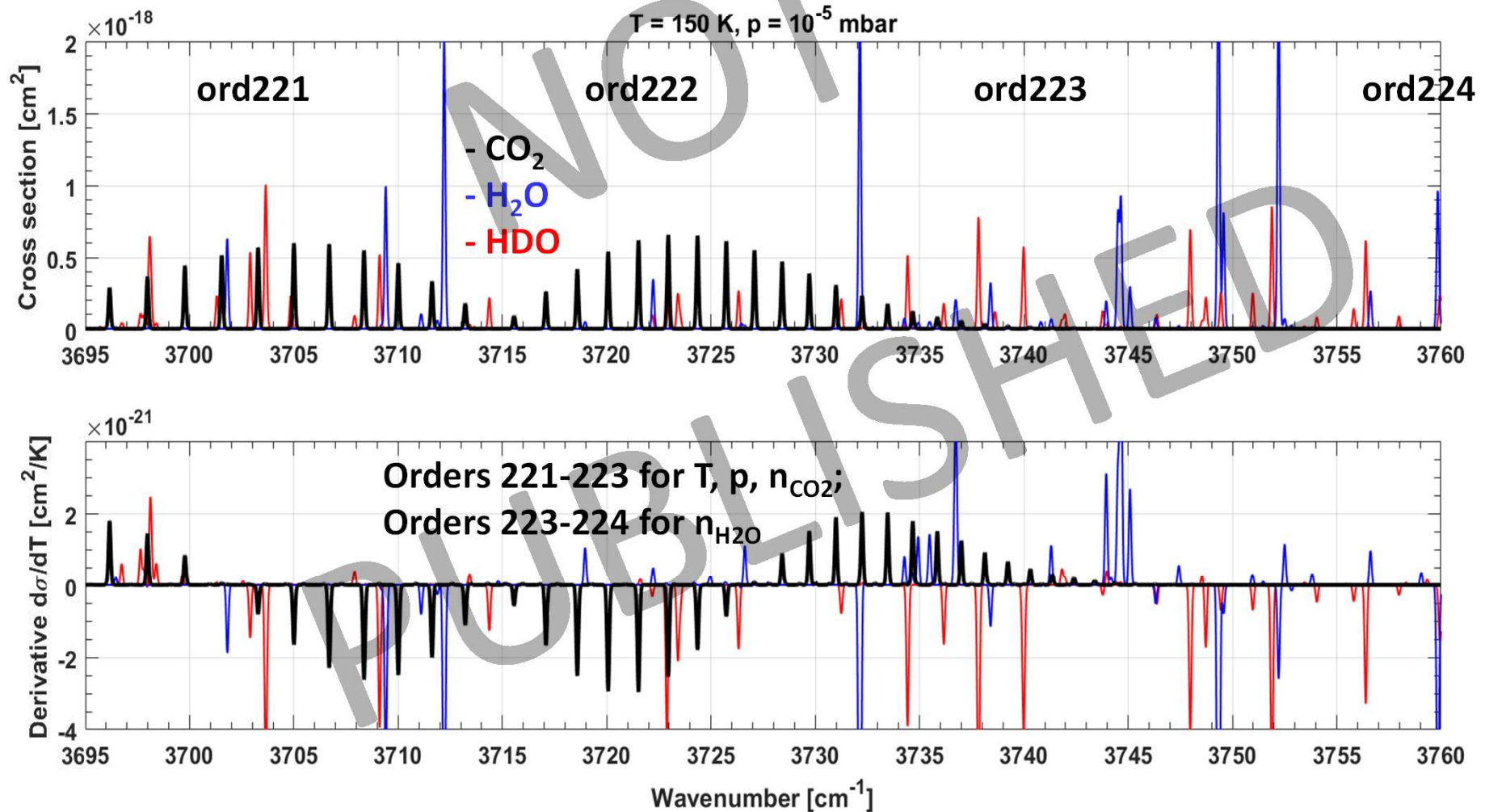
2) 1st guess for (T, p) , n_{CO_2} and n_{H_2O} profiles from the MCD5.3 (climatology);

3) Direct retrievals of $T(z)$, n_{CO_2} and n_{H_2O} at a multi iteration scheme while hydrostatic pressure: $p(z) = p_o \exp\left(-\int \frac{m(z)g(z)}{kT(z)} dz\right)$

Concept of temperature and density retrievals from transmission spectra

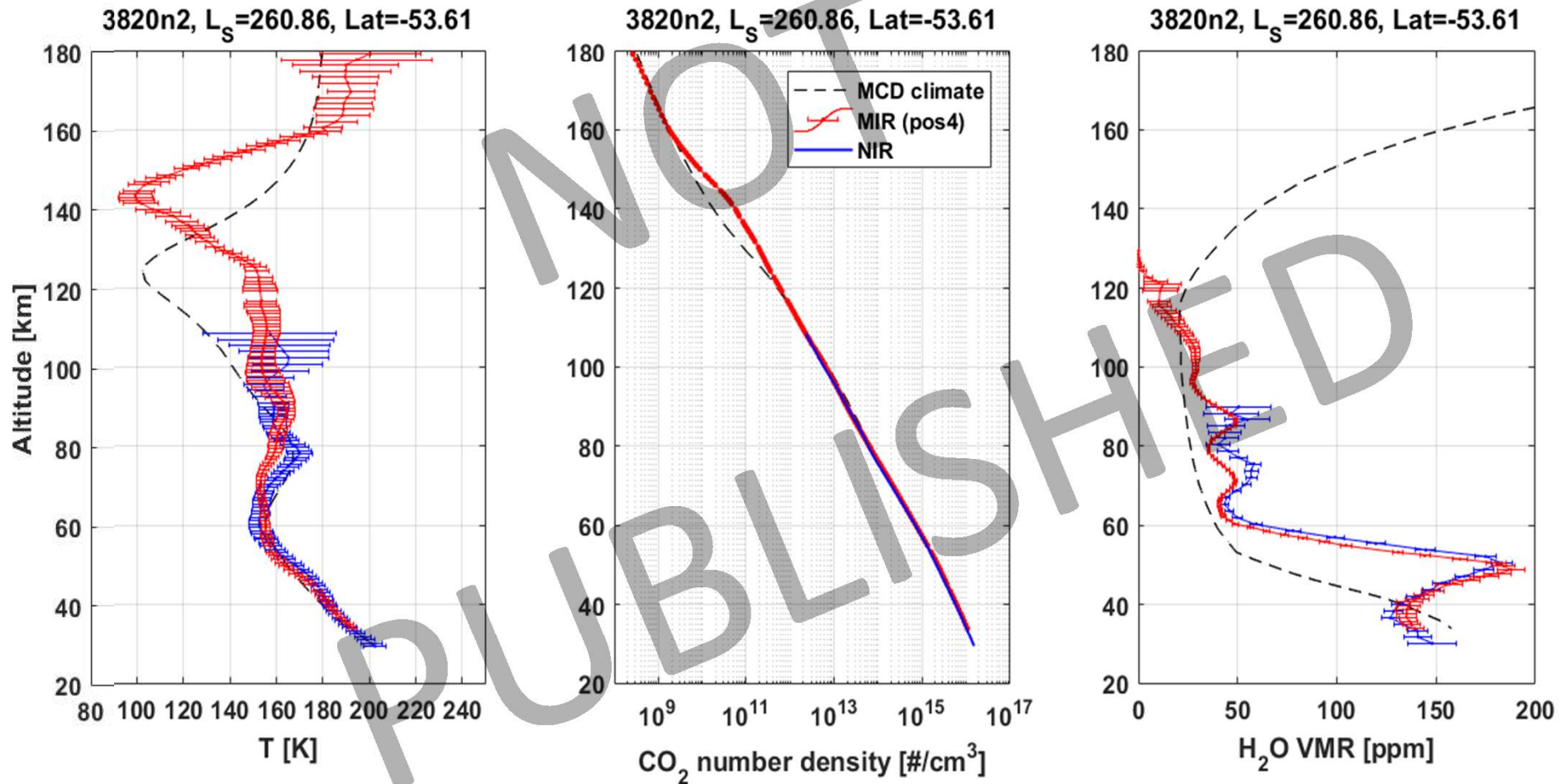
4) Use Levenberg-Marquardt algorithm with an Jacobian based on cross-section derivatives $d\sigma/dT$:

CO_2 , H_2O and HDO spectroscopy at 2.65-2.7 μm range (MIR echelle orders from 221 to 224)



Example of one profile retrievals (average of orders 221, 222, 223):

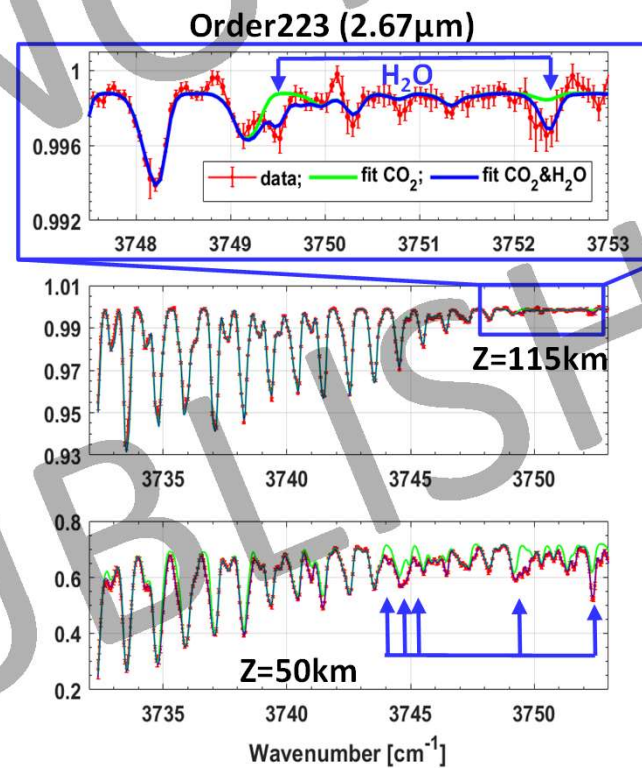
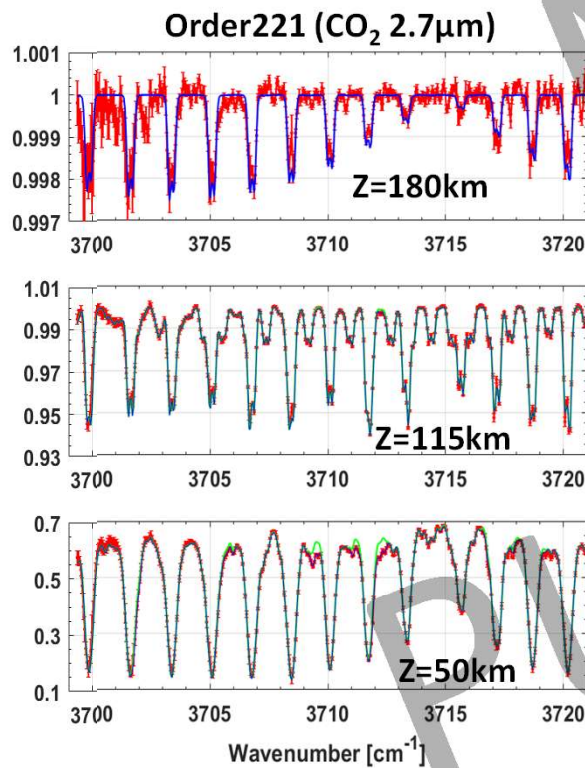
- sensitivity to CO₂ absorption up to 180 km;
- sensitivity to very high water abundance (1-10 ppm at 110-120 km)



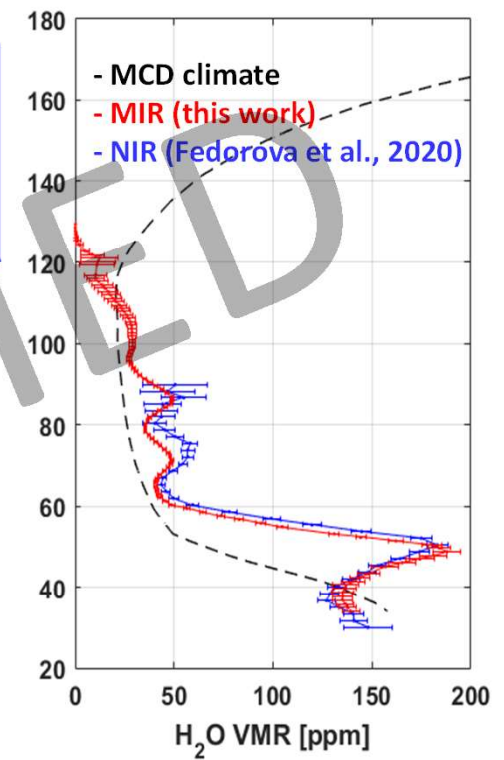
- MCD climatology; - MIR (this work); - NIR (Fedorova et al., 2020, SCIENCE)

Example of one profile retrievals (average of orders 221, 222, 223):

- sensitivity to CO₂ absorption up to 180 km;
- sensitivity to very high water abundance (1-10 ppm at 110-120 km)

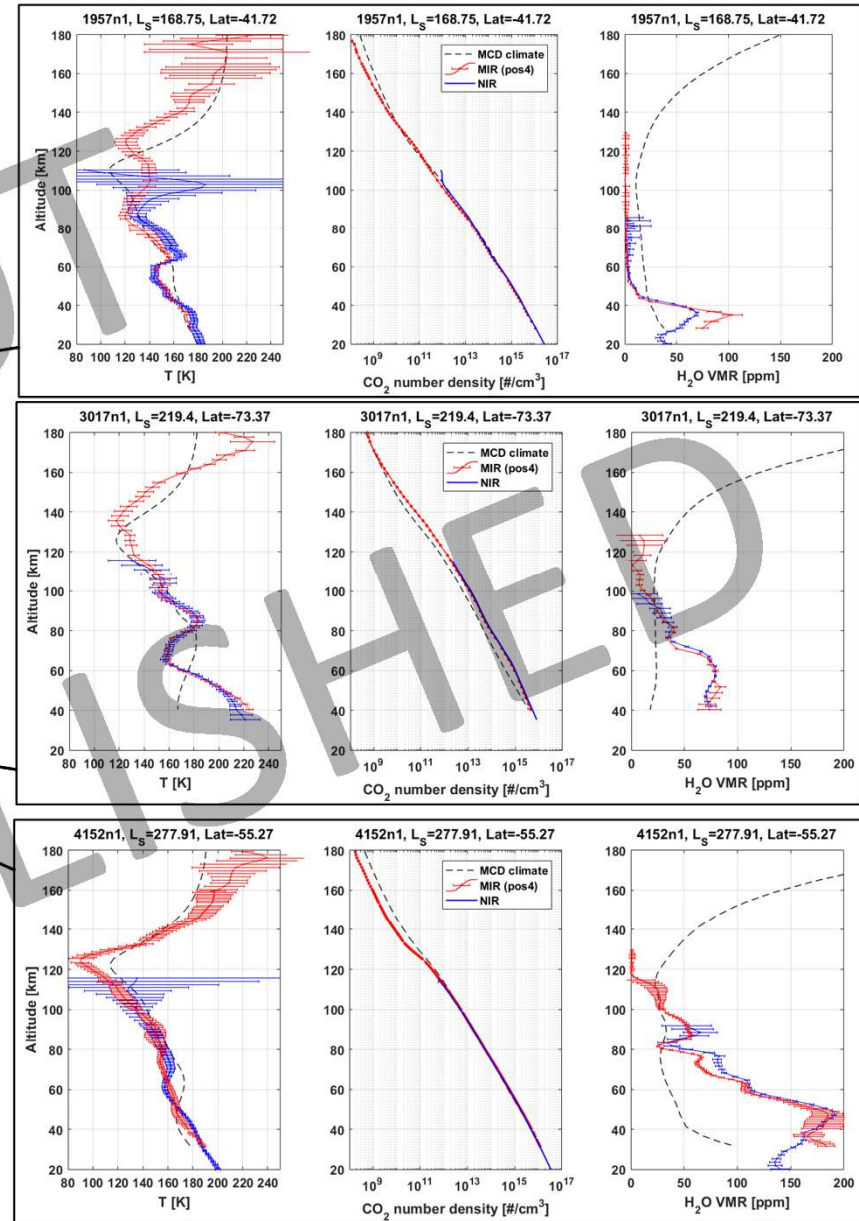
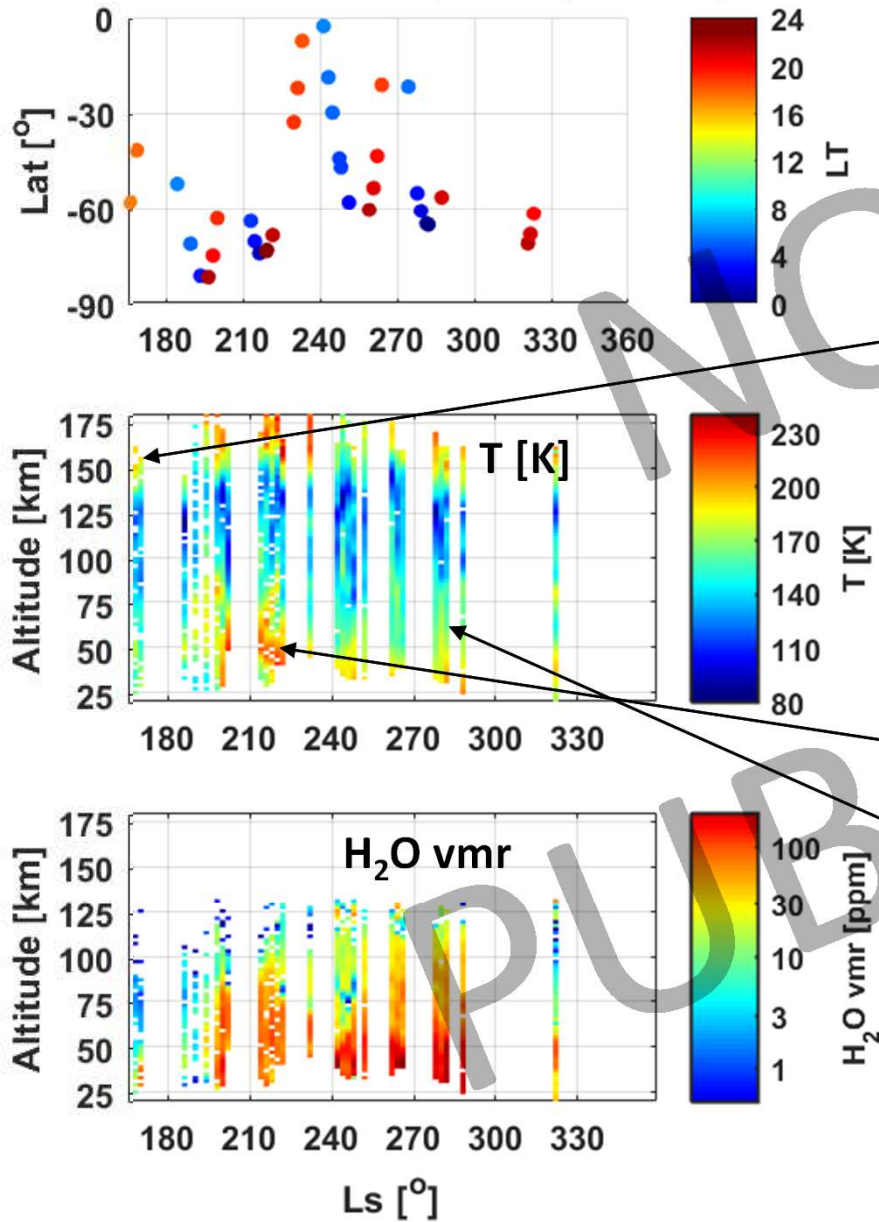


Orb 3820n2, Ls = 260.86, Lat = -53.6



Profiles variability with Martian seasons in MY34 (Ls from 165)

Southern hemisphere (not full)



Summary

- 1) After recent transmission improvements for ACS-MIR spectra new temperature, CO₂ and H₂O density retrievals in the mesosphere/thermosphere are in good progress at 2.65-2.7 μm from 20 to 180 km of altitude;
- 2) Good coincidence with ACS-NIR (Fedorova et al., 2020) retrievals below 100 km;
- 3) Abundance of 1-10 ppm H₂O vmr at 110-120 km on perihelion Southern hemisphere, MY34.
- 4) Mesospheric+thermospheric comparison with IUVS/MAVEN and with GCM MY34 is needed.
- 5) ~350 calibrated occultations at Southern and Northern hemispheres are ready for farther retrievals in MY34 and MY35.

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