Temperature and CO_2 density distribution in Mars upper atmosphere from the ACS-MIR / TGO solar occultations at 2.7 μm absorption band

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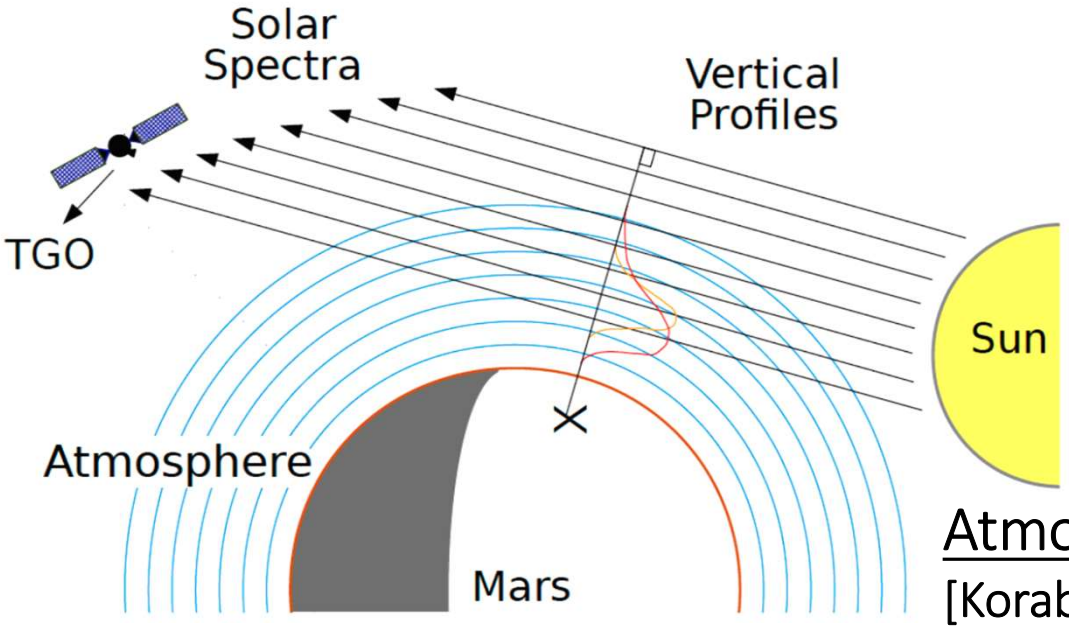
Solar occultation by ExoMars Trace Gas Orbiter (April 2018 – nowadays)



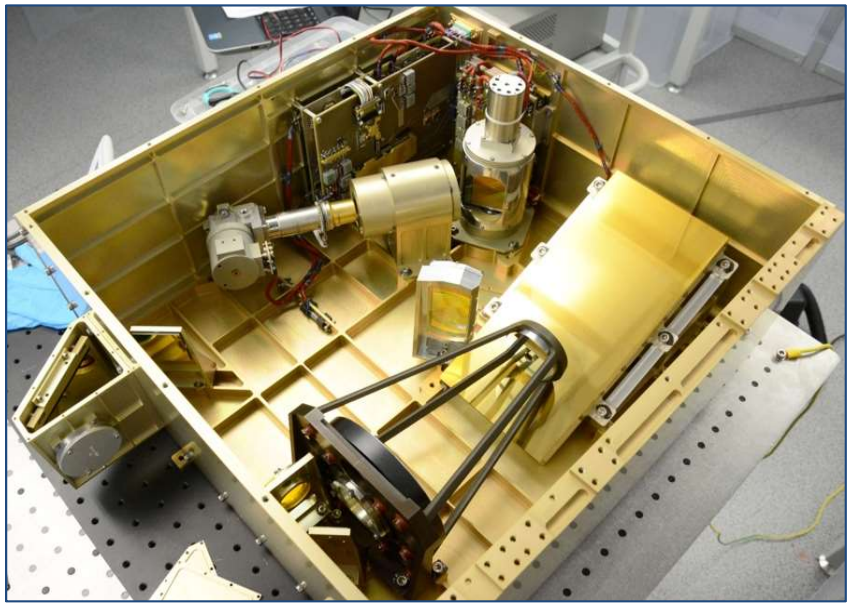
Measured atmospheric transmission spectrum:

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

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

Atmospheric Chemistry Suite (ACS)

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



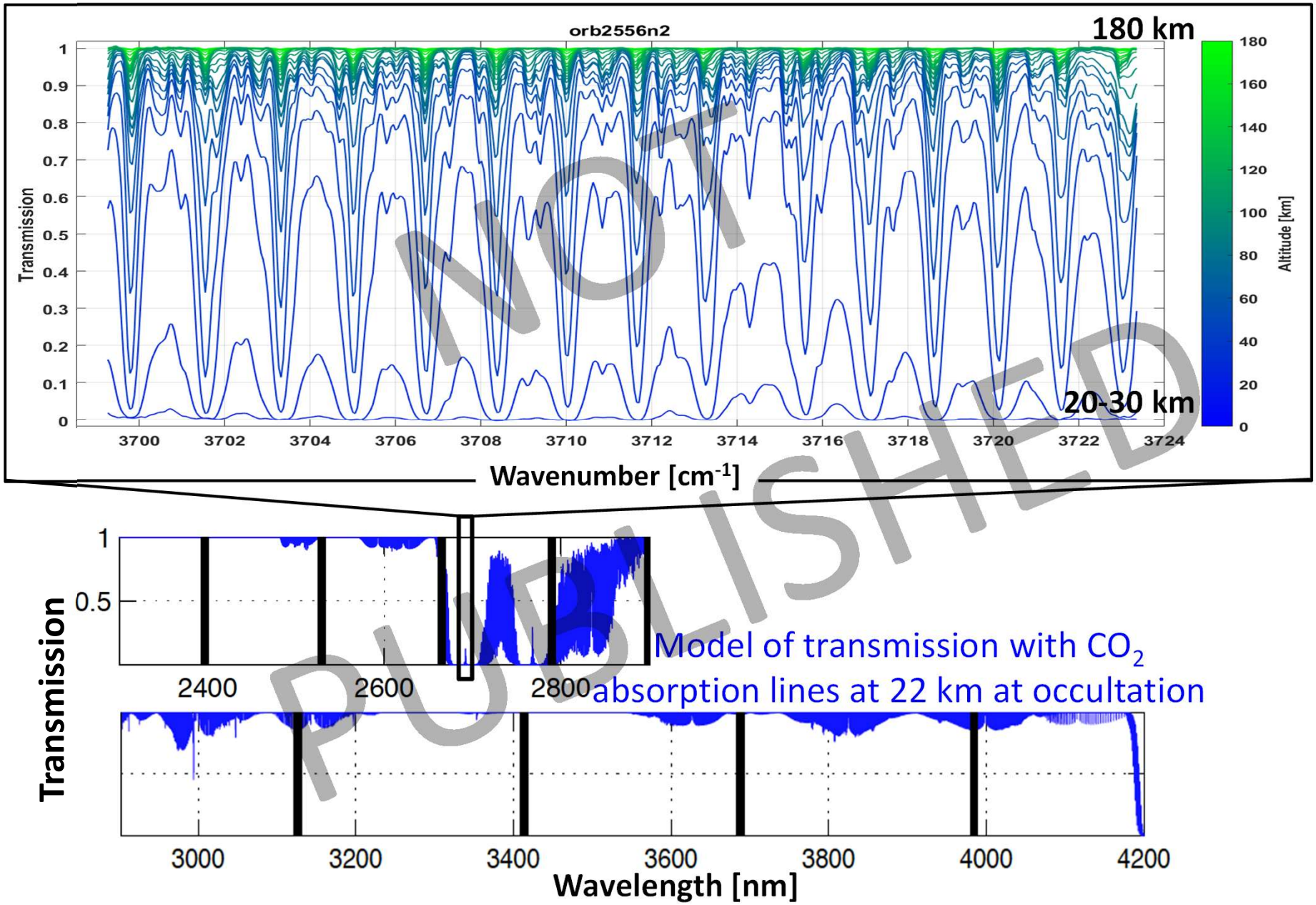
Science goals: altitude sensitive profiling of atmospheric temperature, density, minor species (CO, H_2O, HDO, CH_4 etc.)

ACS-MIR channel:

- Echelle spectrometer
- Cross-dispersion system
- Spectral range 2.3 – 4.2 μm
- Resolving power $\lambda/\Delta\lambda$ ~ 30 000
- FOV: 0.23°×0.02° (0.2-2 km)

CO_2 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, *σ(T,p)* – CO_2 and H_2O absorption cross sections, n – CO_2 and H_2O number densities, $F_{SMOW}=1.3 \bullet 10^{-4}$, τ_{aer} – aerosol slant opacity.

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

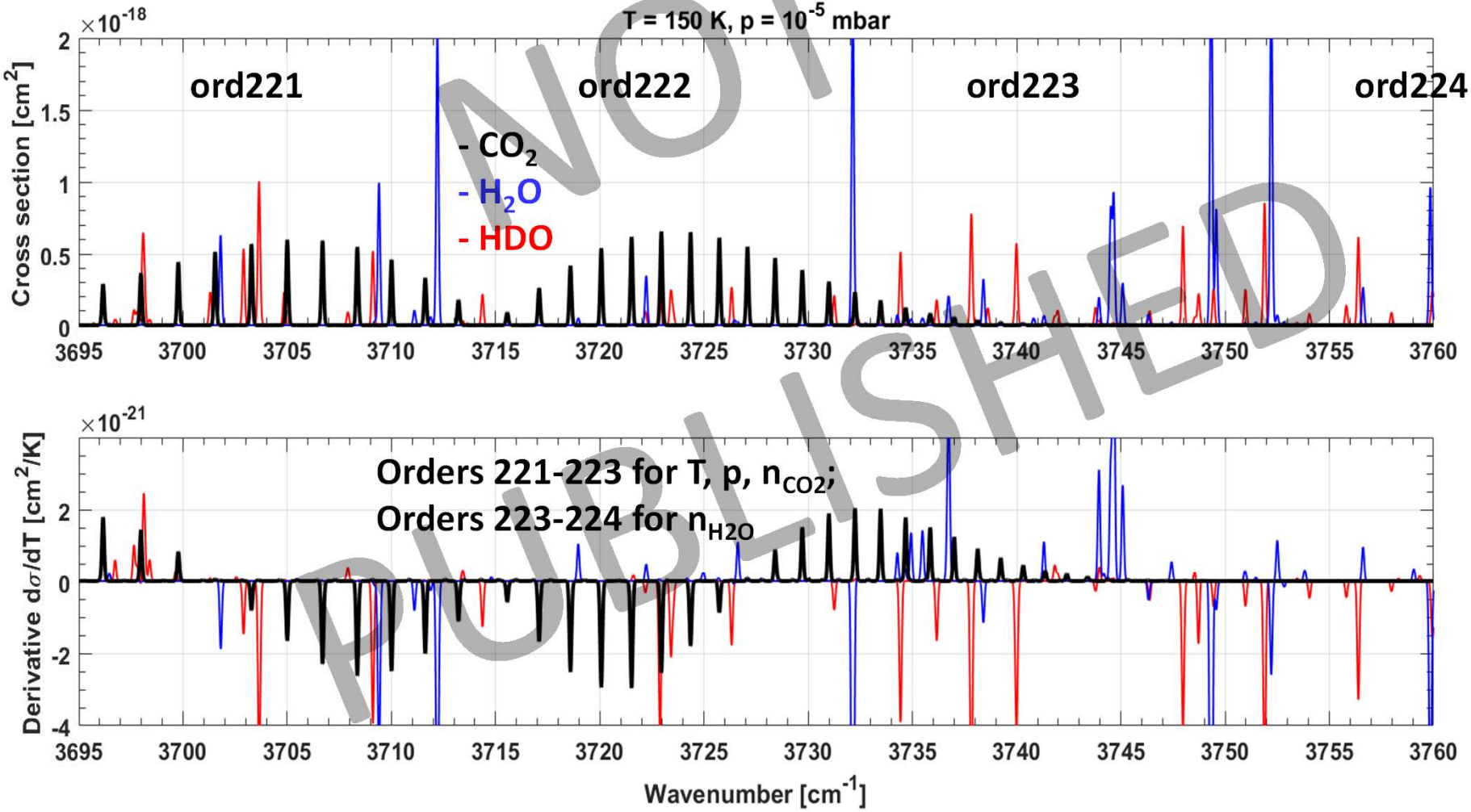
2) 1st guess for (T, p), n_{CO2} and n_{H2O} profiles from the MCD5.3 (climatology);

3) Direct retrievals of T(z), n_{CO2} and n_{H2O} 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

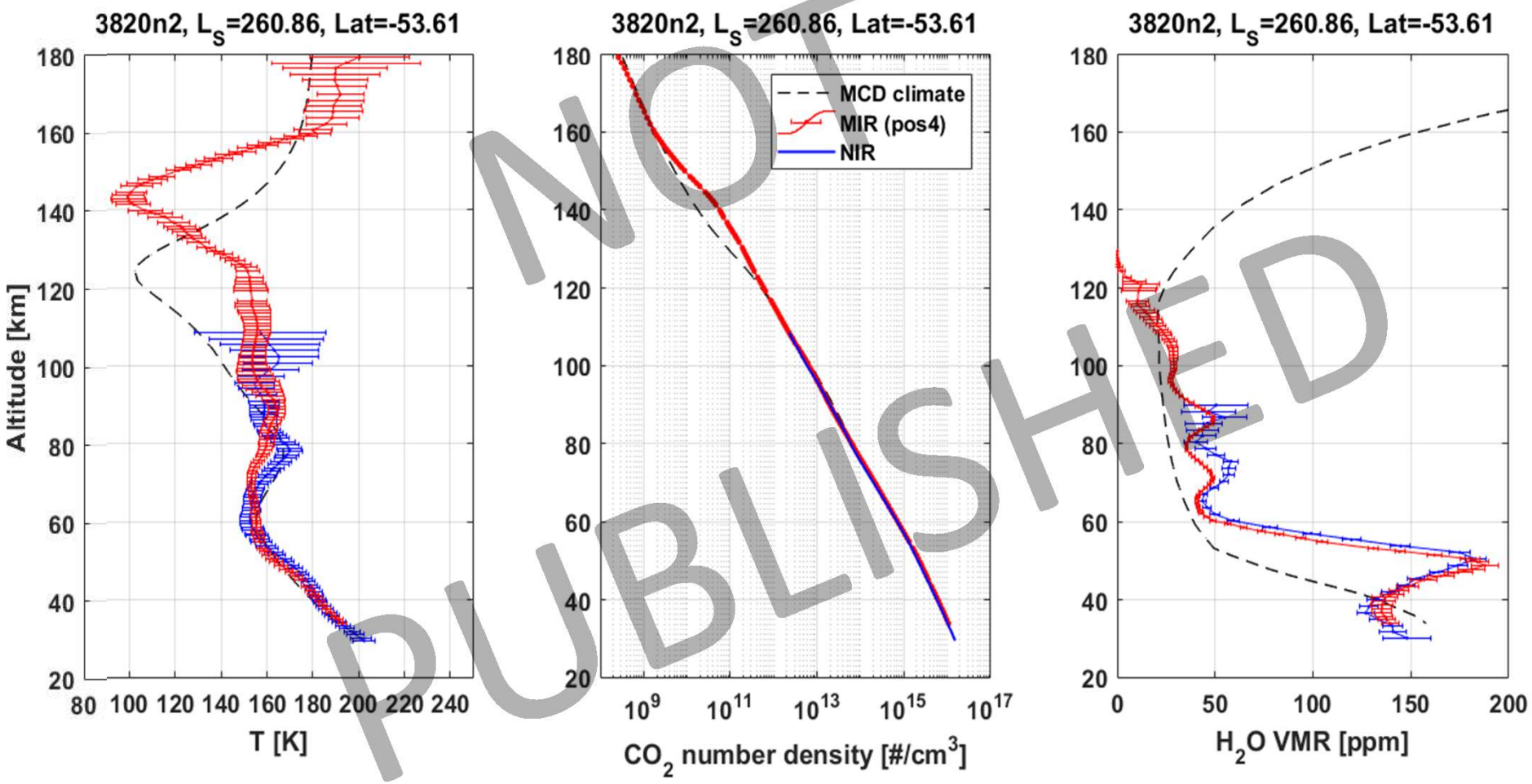
4) Use Levenberg-Marquardt algorithm with an Jacobian based on cross-section derivatives dσ/dT:

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 CO_2 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)

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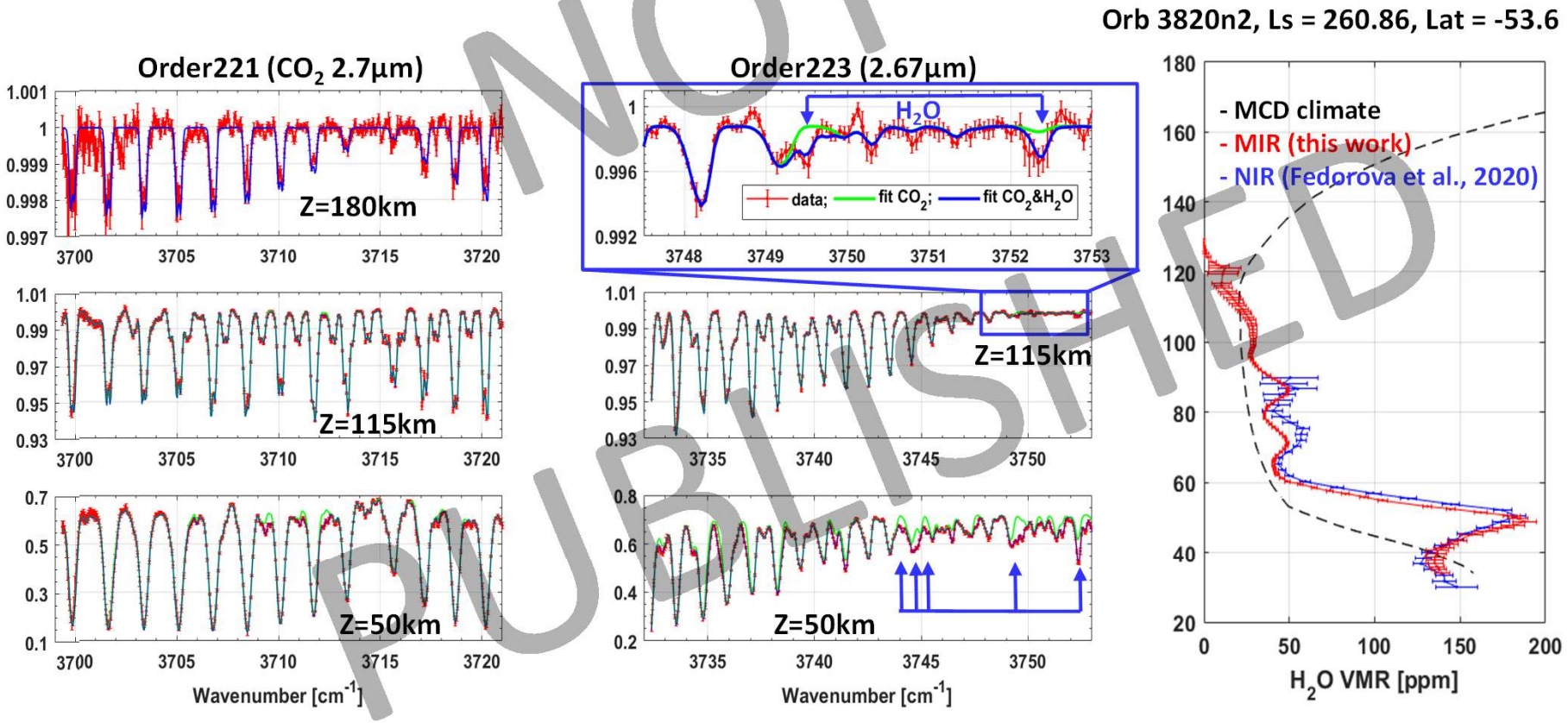
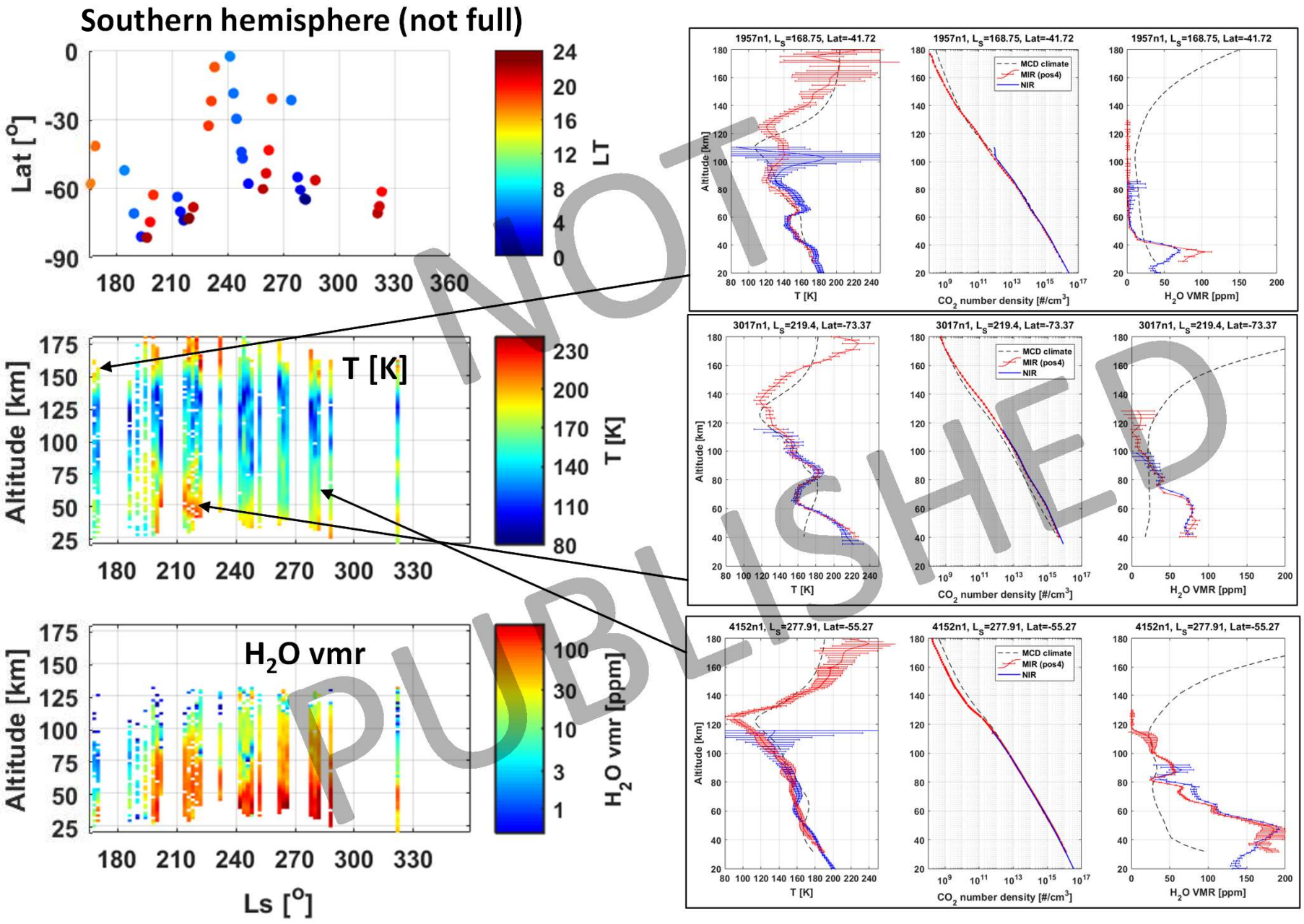


Profiles variability with Martian seasons in MY34 (Ls from 165)



Summary

1) After recent transmission improvements for ACS-MIR spectra new temperature, CO_2 and H_2O 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 H_2O 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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