Retrieval studies using the Far-IR spectral measurements performed by FIRMOS-B from stratospheric balloon flights

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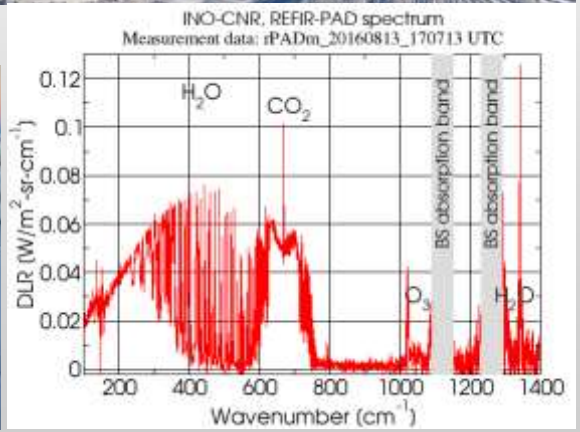
CNR-INO in support to FORUM mission preparation

Development of FIR FTS instruments and deployment from ground and from stratospheric balloons

REFIR-PAD (CNR-INO, ASI) from 2005 to date
From stratospheric balloon (30-35 km) and high-altitude sites (>3km)

FIRMOS (ESA – CNR-INO – ASI)
From high-altitude sites

FIRMOS-B (ESA – CNR-INO – ASI)
From stratospheric balloons



23 – 24 August 2022 HEMERA-3 flight from Timmins (CA)

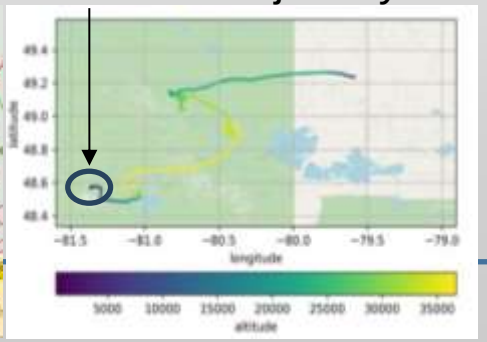
The HEMERA-3 flight was the fourth and last launch of the Strato-Science 2022 balloon campaign carried out with the CNES CARMEN gondola in August 2022 from the ASC/CSA stratospheric balloon base in Timmins (CA, 48°34'N, 81°23'W).

The flight had a few problems:

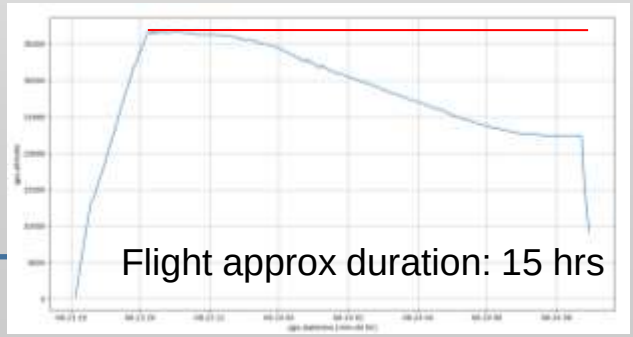
- After the initial phase, the balloon started to lose altitude, probably because of a He leak.
- As a result, the flight path was different from planned.

Planned trajectory

Real trajectory

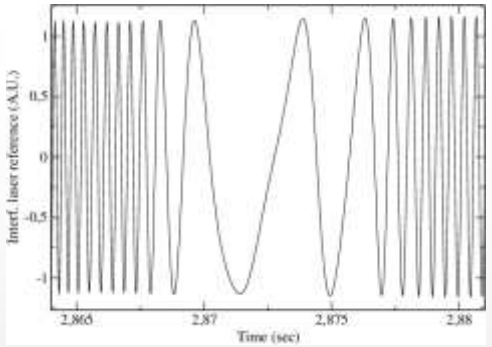


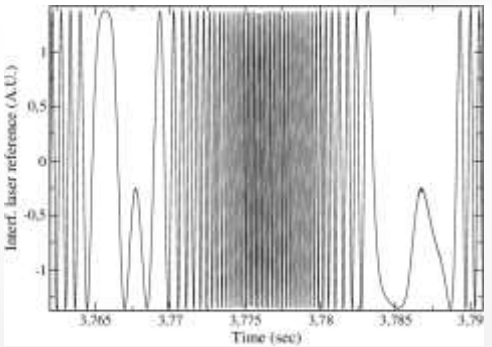
Balloon Altitude



FIRMOS-B measurements from Timmins 2022

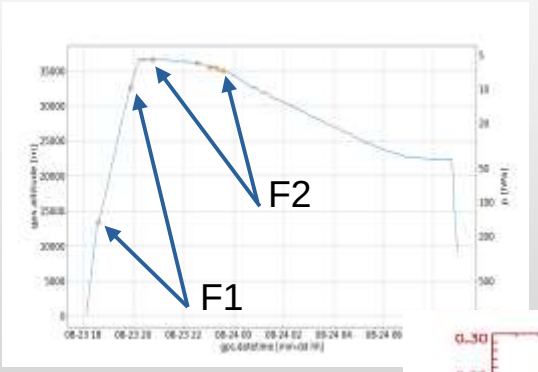
Measurements affected by a disturbance on the slide speed due to mechanical coupling with vibrations produced by the compressor of another instrument onboard of the gondola. Problem discovered just before the launch, thus it was not possible to find an effective workaround.

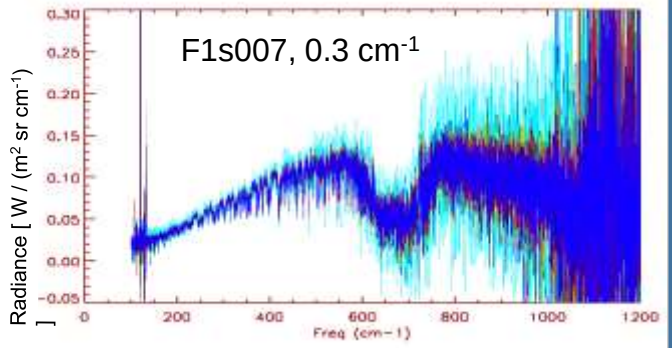




Despite this inconvenience, we were able to recover approx 12% of the measurements, that is 7 sequences:

- 2 sequences (F1) in the ascending part of the flight. These measurements are in clear sky.
- 5 sequences (F2) in the first part of the flight at ceiling altitude (~35 km). These measurements are in cloudy sky.
- Each sequence consists of more than 30 single spectra that are processed individually.

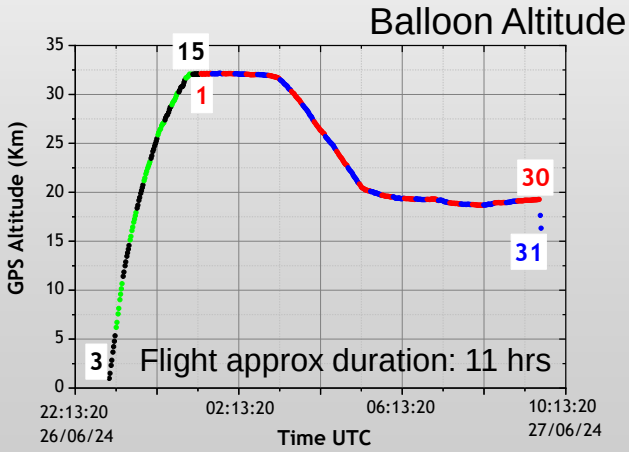


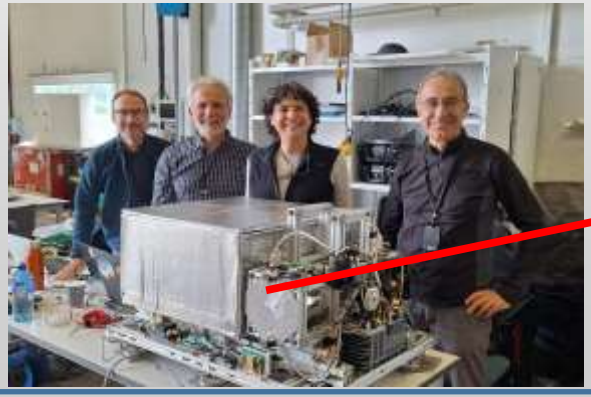


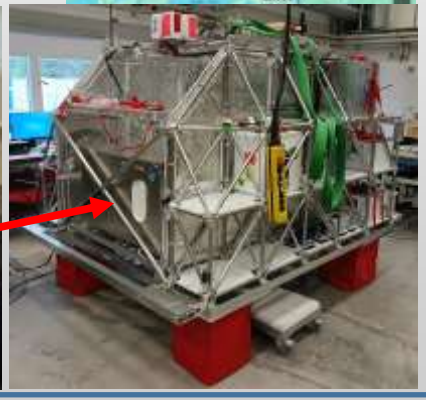
26 - 27 June 2024 ATMOSFER balloon flight from Kiruna (Sweden)

ATMOSFER (bAlloon-borne evaluaTion of atMospheric hygrOmeters and Synergistic eFforts for the prEparation of the foRum mission), was funded by CNRS / University of Reims to CNES with the goal of supporting with stratospheric measurements the improvement of the SRL of the FORUM mission.

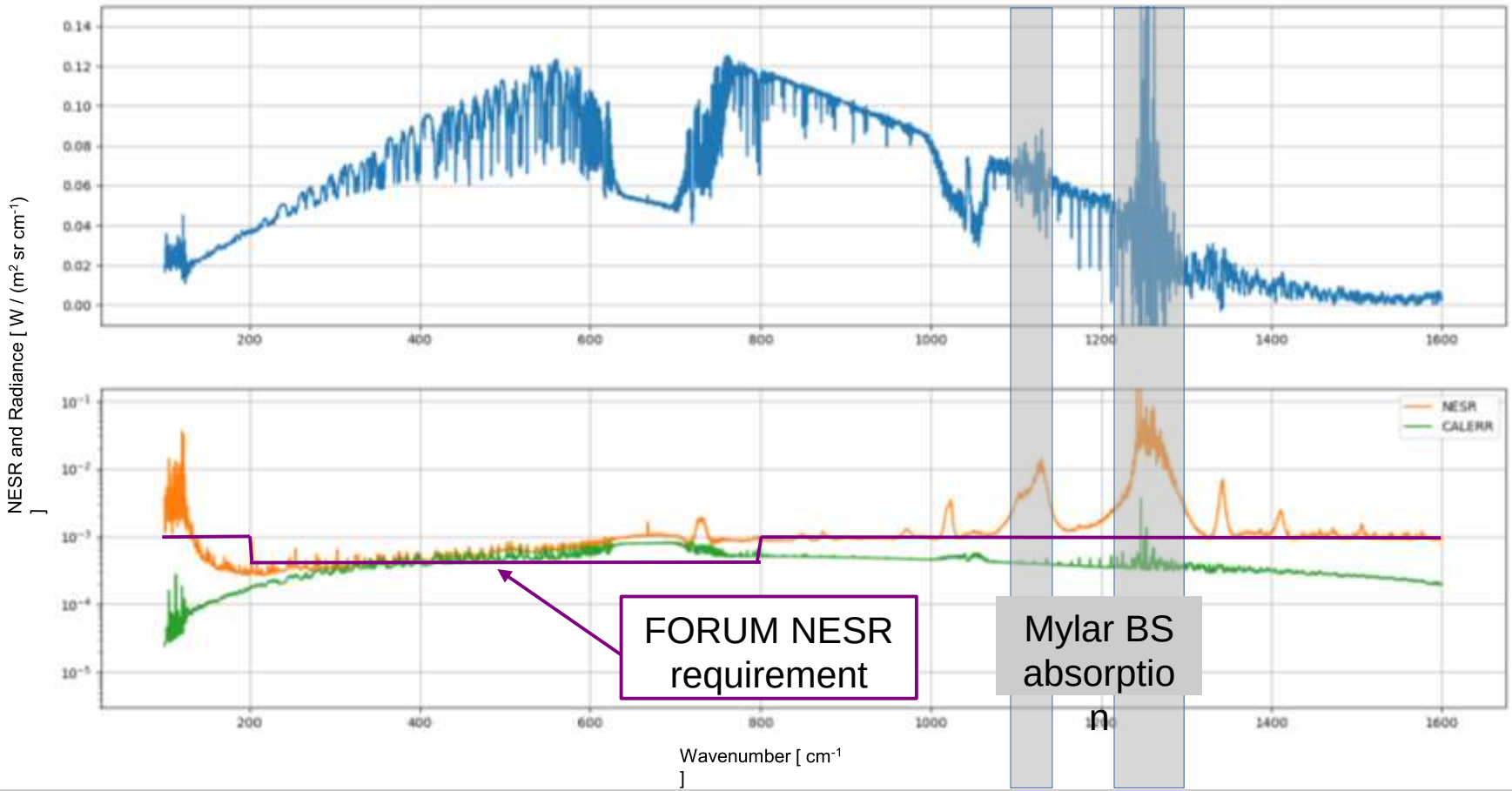
FIRMOS-B was hosted by CNES at no cost on-board of the ATMOSFER flight within the TRANSAT 2024 campaign from Kiruna.







FIRMOS-B measurements from Kiruna 2024: good NESR performance



Retrieval codes used (all based on optimal estimation)

KLIMA

- Full physics accurate model developed at CNR-IFAC
- No scattering model, only gas absorption and emission
- Can retrieve simultaneously atmospheric profiles (T, H2O, + ..) and surface properties (surface temperature and emissivity at a user defined grid)

References

- S. Del Bianco et al. Ann. Geophys., 2014. https://doi.org/10.4401/ag-6331
- Dinelli et al. Rem. Sens. 2023: https://doi.org/10.3390/rs15102532

SACR

- Simultaneous Atmosphere and Cloud Retrieval developed at CNR-INO
- Uses gas ODs computed by LBLRTM
- Models scattering with a 2-streams δ-Eddington approx
- Can retrieve simultaneously atmospheric profiles (T, H2O, + ..), cloud properties: Di, Dw, f_{ice}, OD, CTH, surface temperature

References

- Di Natale et al. JQSRT 2020. https://doi.org/10.1016/j.jqsrt.2020.106927
- Di Natale at al. AMT, 2024. https://doi.org/10.5194/amt-17-3171-2024

FARM

- FAst Retrieval Model developed at CNR-INO
- Uses the σ-IASI/F2N fast forward model (see Masiello et al. 2024)
- Can handle the synergistic retrieval (see poster S10-39).
- Can retrieve simultaneously atmospheric profiles (T, H_2O, + ..), surface properties (T and emissivity), cloud ice and water mixing ratio and effective dimension profiles.

References

- Masiello et al. JQSRT, 2024. https://doi.org/10.1016/j.jqsrt.2023.108814
- Ridolfi et al. AMT 2022. https://doi.org/10.5194/amt-15-6723-2022

Instrument Spectral Response Function (ISRF)

All retrieval codes were adapted to simulate spectral radiance measurements acquired with the following instrument spectral response function:

$$\mathrm{ISRF}(\sigma - \sigma_0) = \alpha * \mathrm{sinc}(2\pi(\sigma - \delta\sigma_0)L) + (1-\alpha) * \mathrm{sinc}^2(2\pi(\sigma - \delta\sigma_0)L)$$

with:

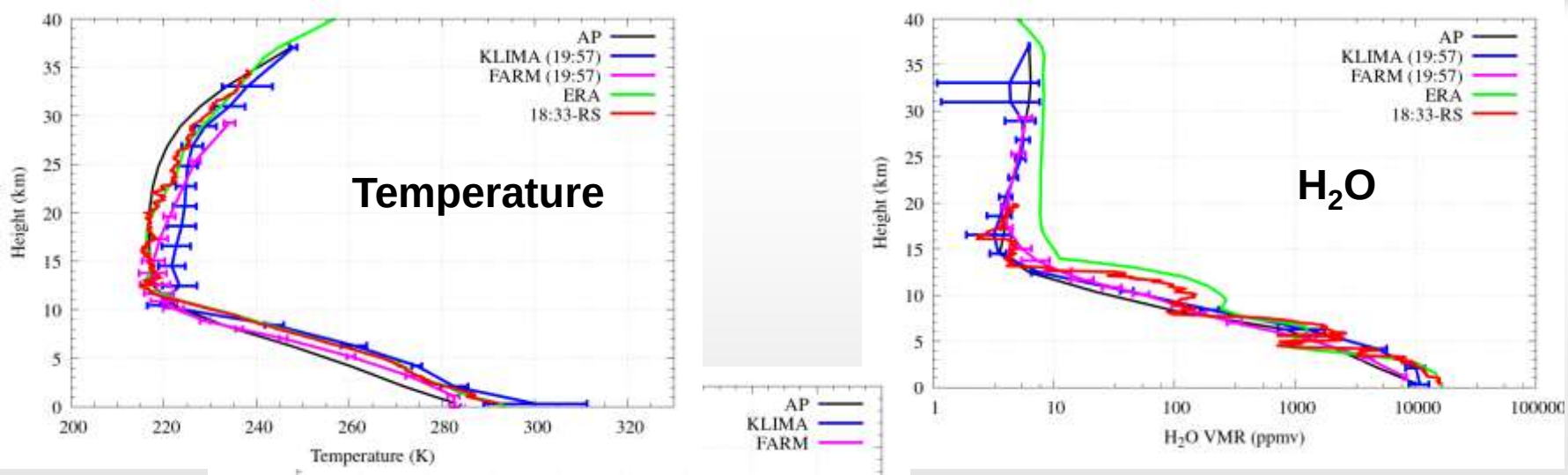
$L = MOPD = 1.67$ cm or 1 / (2 MOPD) = 0.3 cm^{-1}

σ = wavenumber (cm^{-1})

$\alpha = \Omega\,(\sigma - \delta\sigma_0)L/2$ Ω = instrument solid angle aperture (sr), retrieval parameter

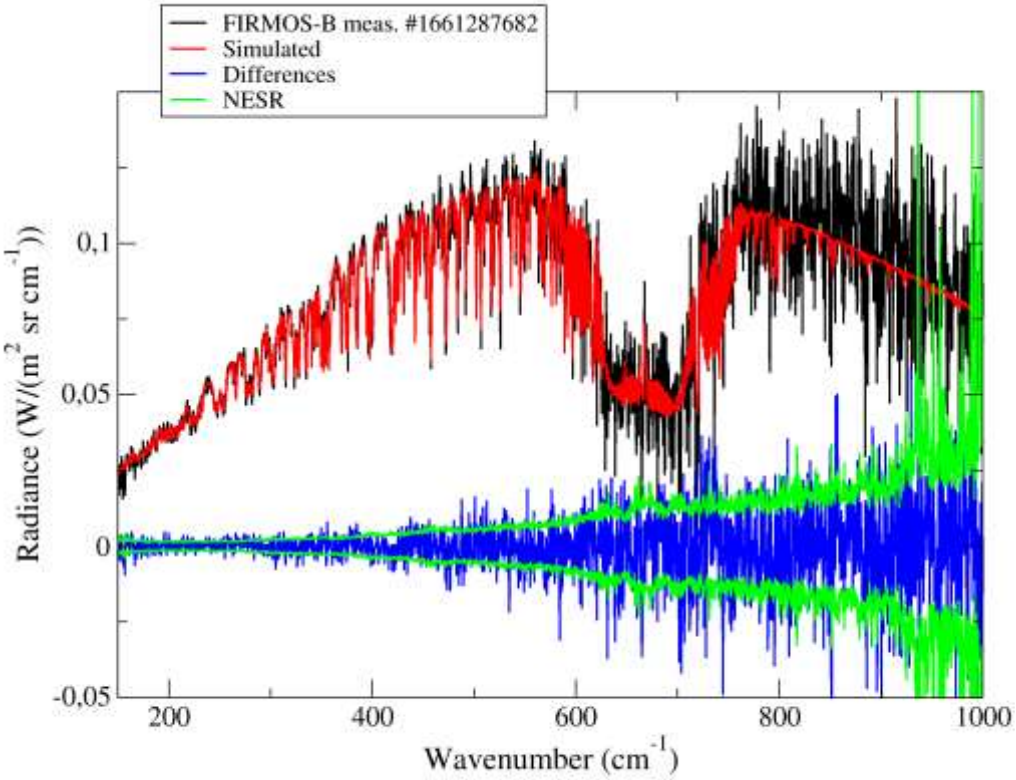
$\delta = (1 + \epsilon * 10^{-6})$ where ϵ (ppm) is a wavenumber-stretching retrieval parameter

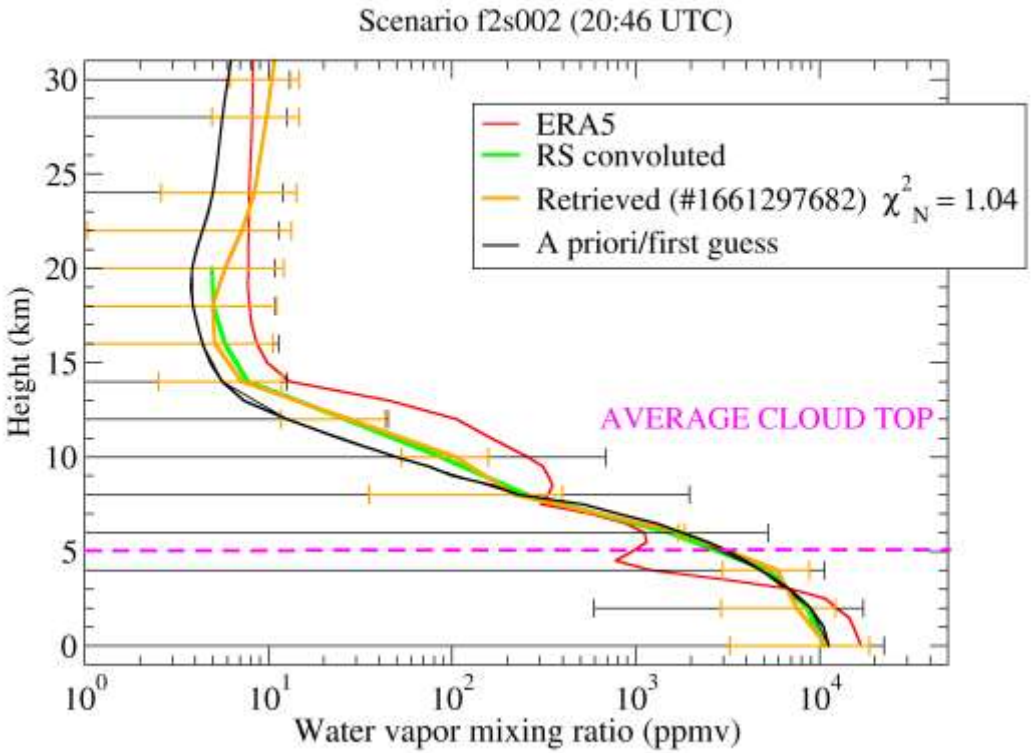
Timmins 2022: clear scene F1 s007, KLIMA and FARM retrievals



Timmins 2022: SACR results for a cloudy scenario in F2 s002

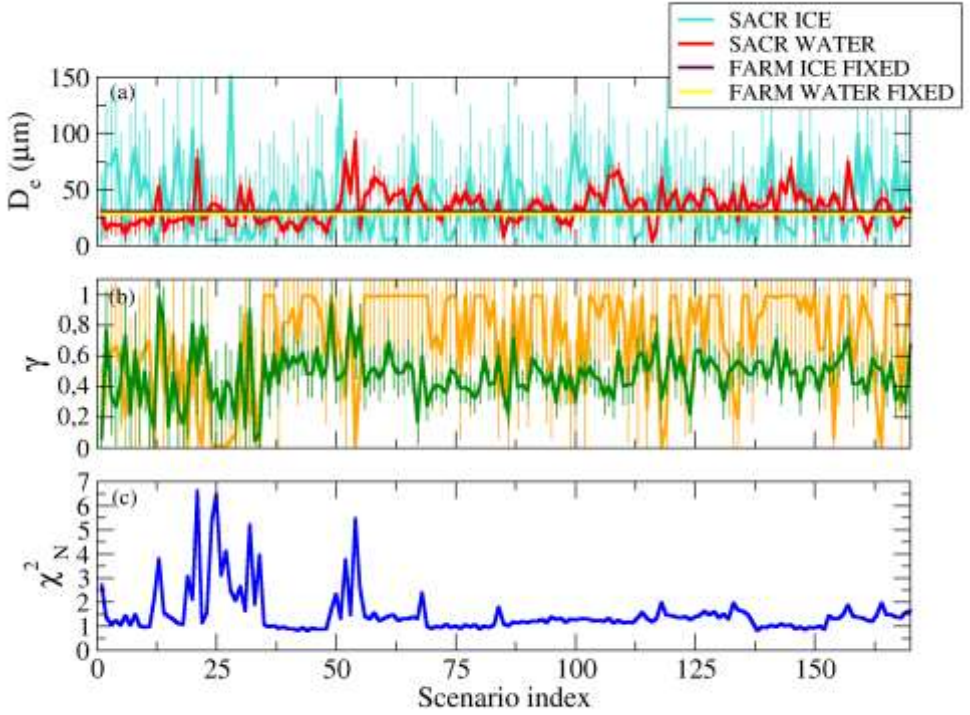
Residuals of the fit and retrieved water vapour profile for F2 s002, spectrum #1661297682

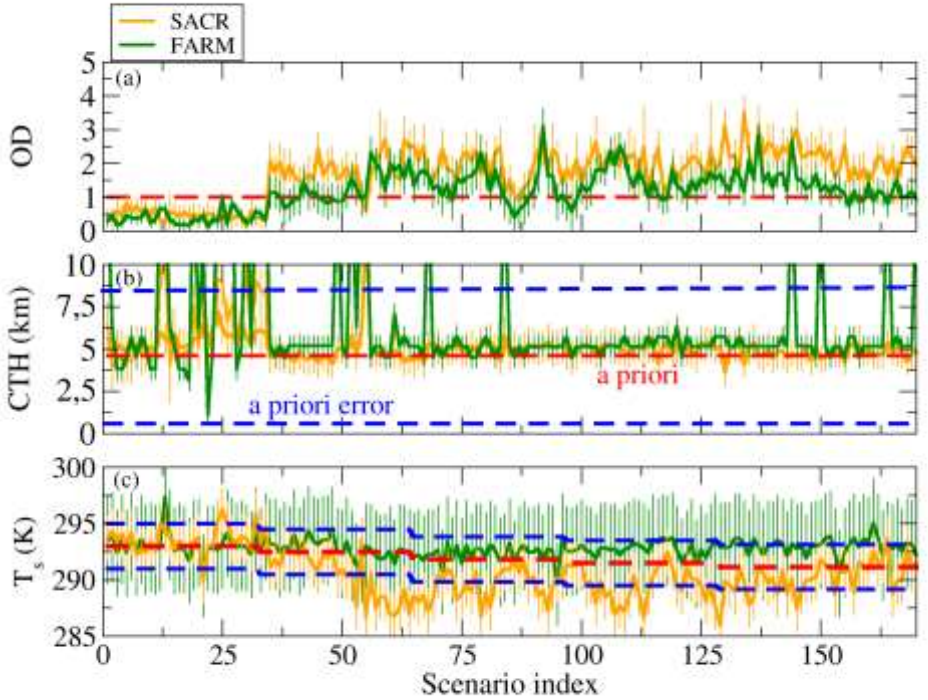




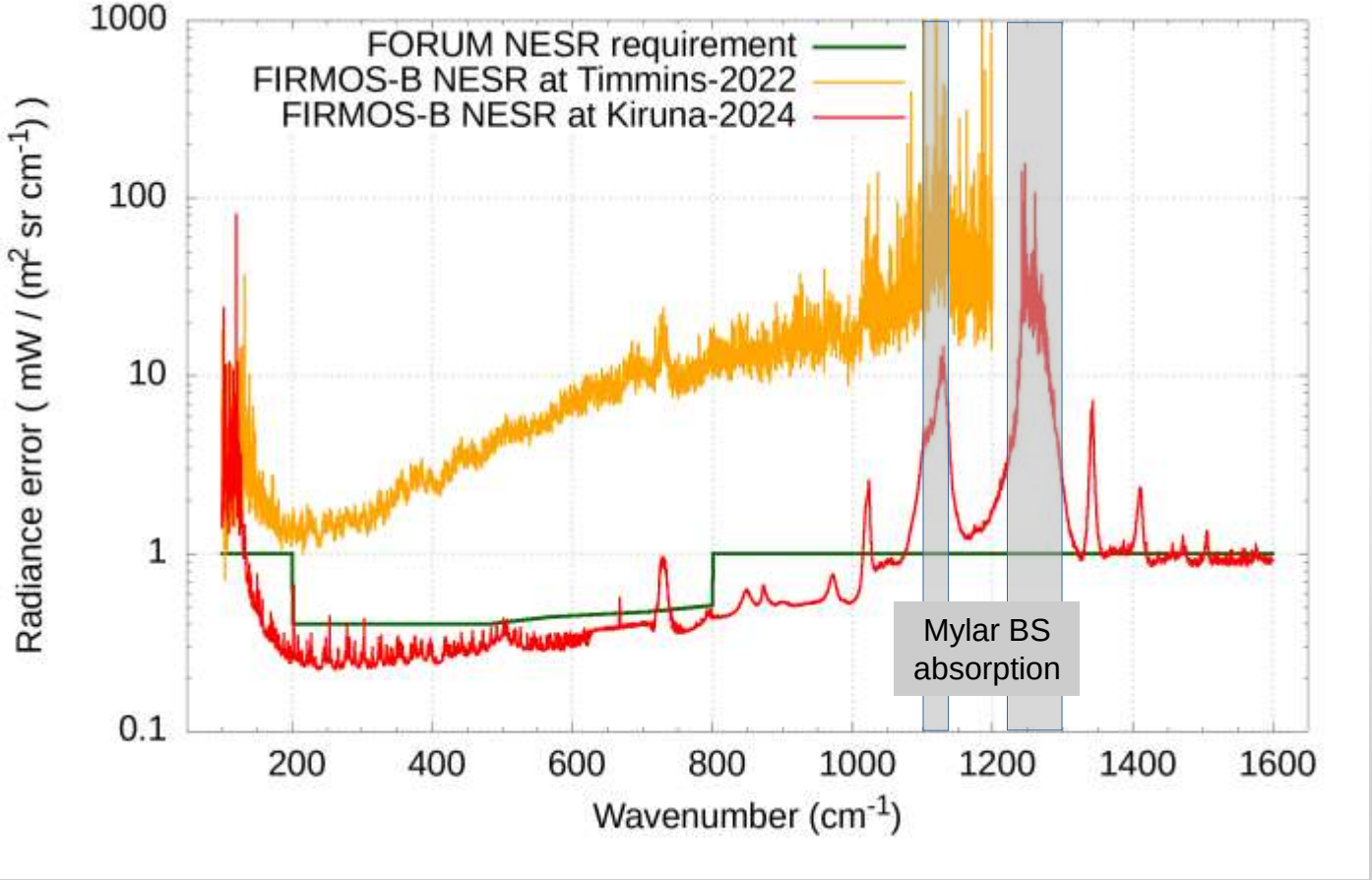
Timmins 2022: results for cloudy scenes F2 s00* SACR and FARM

Cloud parameters, Ts and normalized χ^2





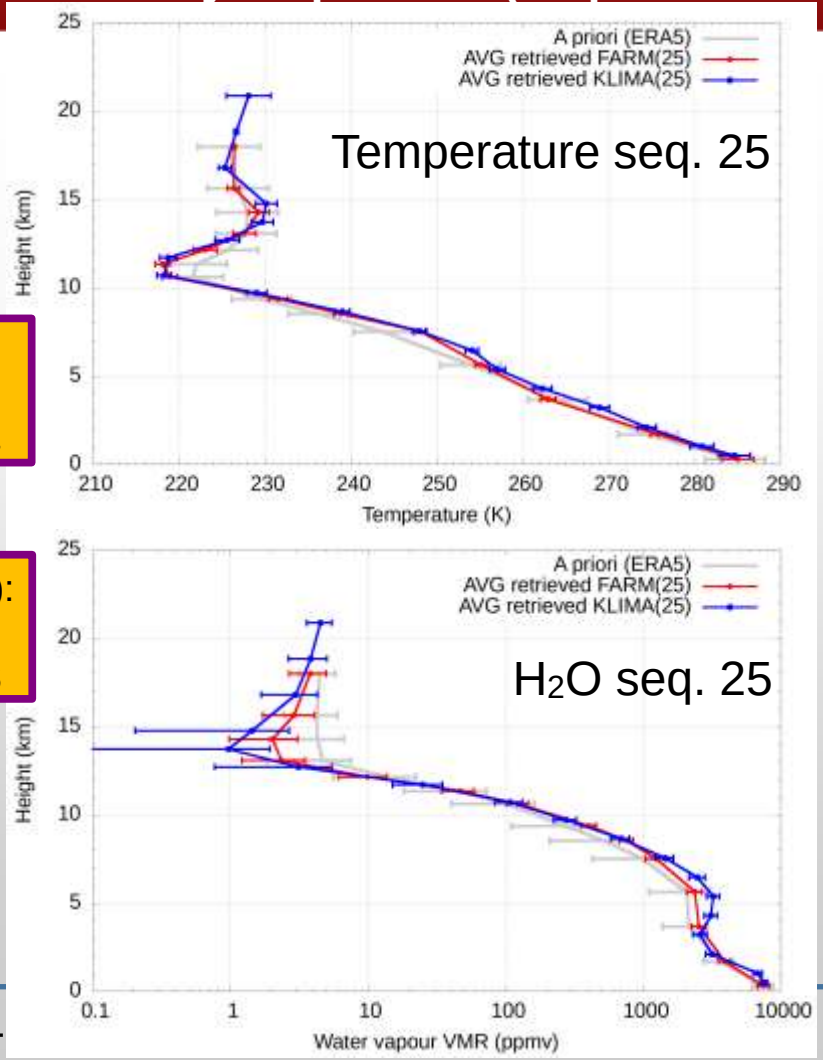
FIRMOS-B NESR performance: Timmins 2022 vs Kiruna 2024 (individual spectra)

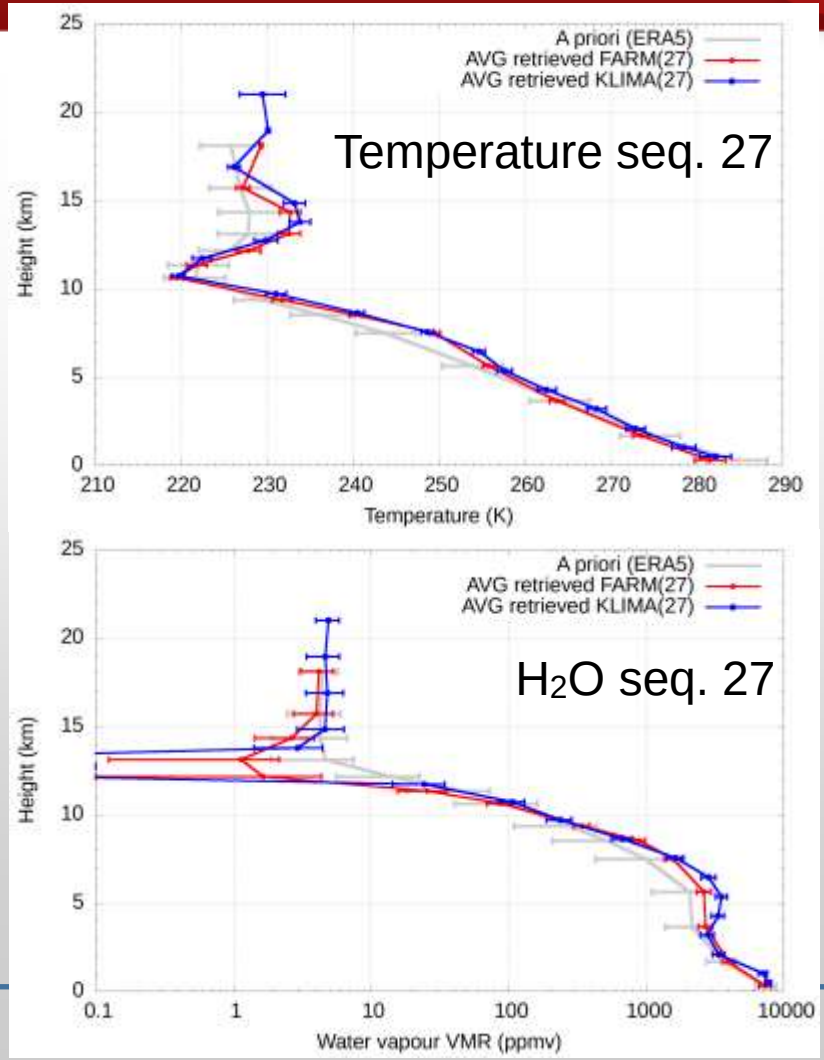


Kiruna 2024: KLIMA and FARM average retrieved profiles from individual spectra of two different clear-sky sequences (seq. 25 and 27)

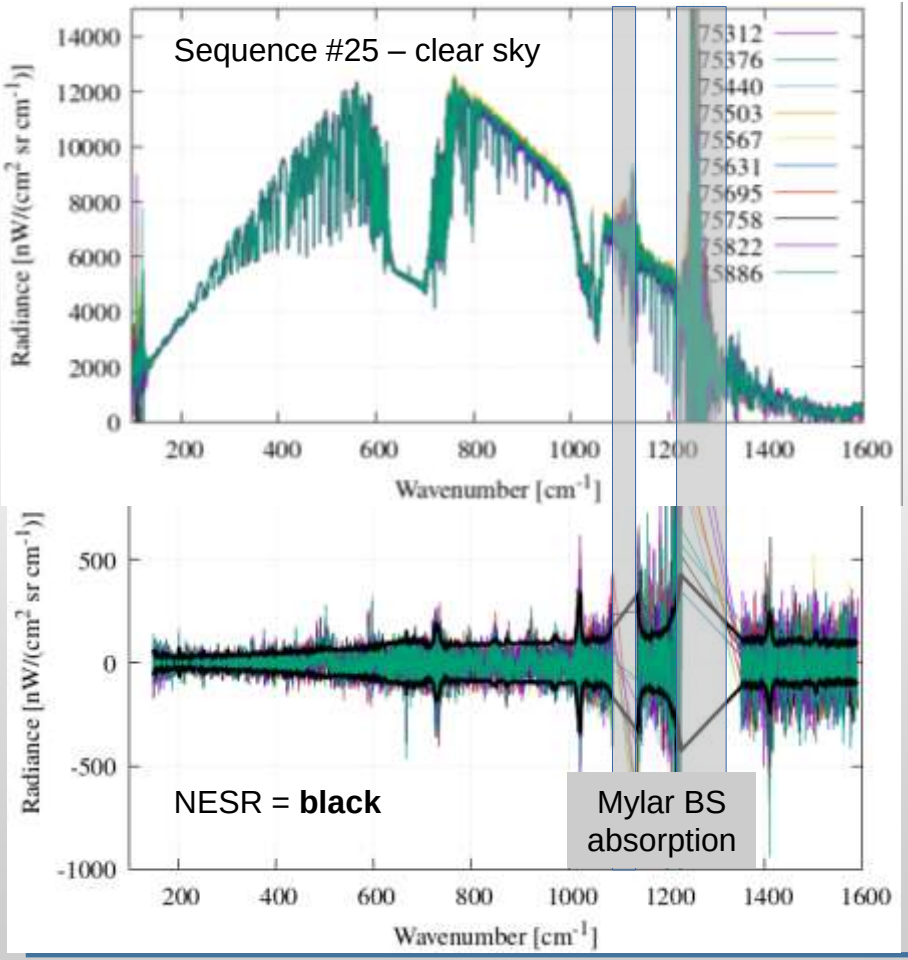
N_DoF(T):
Total = 9
in UTLS = 4

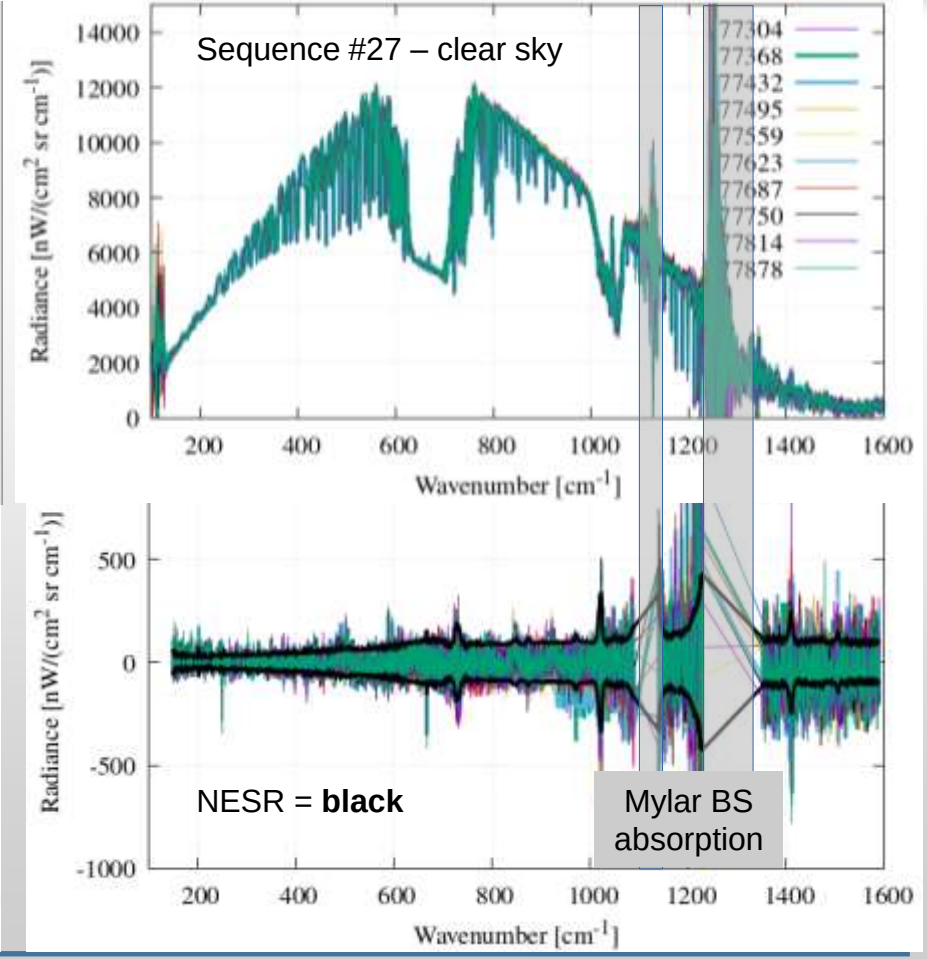
N_DoF(H_2O):
Total = 5
in UTLS = 3





Kiruna 2024: KLIMA residuals of the fit of spectra in sequences 25 and 27 (clear-sky)





Conclusion and future perspectives

- T and H2O profiles retrieved from FIRMOS-B measurements acquired in the Timmins 2022 campaign generally agree well with local radiosoundings, and we get a good fit of the spectra.
- Comparisons with radiosoundings during the Kiruna 2024 campaign are still to be done.
- The retrieved surface emissivity is quite variable from measurement to measurement, even within the same sequence of spectra. Spectral features of the surface emissivity, however, are visible. We still need to understand if these are real or an instrument artifact.
- The Chou-Tang scaling scheme implemented in σ-IASI/F2N within FARM reproduces quite well the cloud-parameters retrieved with SACR that is based on the 2-streams δ-Eddington approximation.
- We plan to repeat the cloudy retrievals with a new version of FARM that is able to retrieve only few cloud parameters: CTH, CBH, OD and D_e.
- Synergistic (joint) retrievals from real matching measurements. This would be a check of the possibility to exploit the future synergy of FORUM and IASI-NG measurements.
- Contact me to apply for the new research position for graduated students at INO:

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https://fts.fi.ino.it/~marco/