

FIRMOS-B level2 analysis on TRANSAT and WHAFFERS campaigns using FARM and KLIMA codes



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Abstract. FIRMOS-B is a Fourier-transform infra-red (FTIR) spectroradiometer capable of measuring the atmospheric spectra between 100 and 1600 cm^{-1} . Due to its accurate measurements in the far infra-red, it was involved, as FORUM demonstrator, in the two measurement campaigns TRANSAT 2024 and WHAFFERS. In the frame of the TRANSAT 2024 campaign, in Kiruna (Sweden), FIRMOS-B was launched as a payload on the CNES CARMENCITA stratospheric gondola. During the flight, FIRMOS-B acquired several nadir spectra with the purpose of mimicking the future FORUM observations. During the ascent phase, other in-situ measurements were performed such as: vertical profiles of temperature, water vapor and cloud parameters. WHAFFERS took place in Canada in 2025. In this case FIRMOS-B acquired zenith-sky spectra at the Ottawa airport in synergy with other ground-based and airborne measurements performed by the Canadian NRC. FIRMOS-B was then moved to the Gault natural reserve to measure in synergy with FINESSE, a similar instrument employing a commercial Bruker EM27 spectrometer modified to operate in the FIR. Here, we will present the results of the retrieval codes FARM and KLIMA, retrieving level2 data from FIRMOS-B measurements acquired during the two campaigns. These codes present important differences, while KLIMA exploits a line-by-line radiative transfer model for the spectra simulation, FARM is faster and uses the direct model sigma-FORUM which exploits parametrizations based on pre-computed parameters.

TRANSAT 2024

The FIRMOS-B nadir measurements were acquired onboard the CARMENCITA gondola during the period between 26 June 2024 at 23:00UTC and 27 June 2024 at 9:30 UTC. The FIRMOS-B measurements are divided in Part1, acquired during the gondola ascent, and Part2, acquired when the gondola altitude was more stable. Three balloons (Pico-Light, CFH-Julich, NOAA-FPH) were launched during both Parts 1 and 2 for the in-situ measurement of temperature and water vapor.



Fig1: Overview of the Carmencita gondola flight. The colours represent the gondola altitude in km.

PART1

Part1 of FIRMOS-B measurements was acquired in presence of clouds. For this reason, we analysed these spectra with the FARM, taking into account the presence of ice clouds. We know about the presence of ice clouds thanks to the in-situ measurements acquired during the ascent by the NIXE instrument installed onboard the gondola.

ICE CLOUDS RETRIEVAL

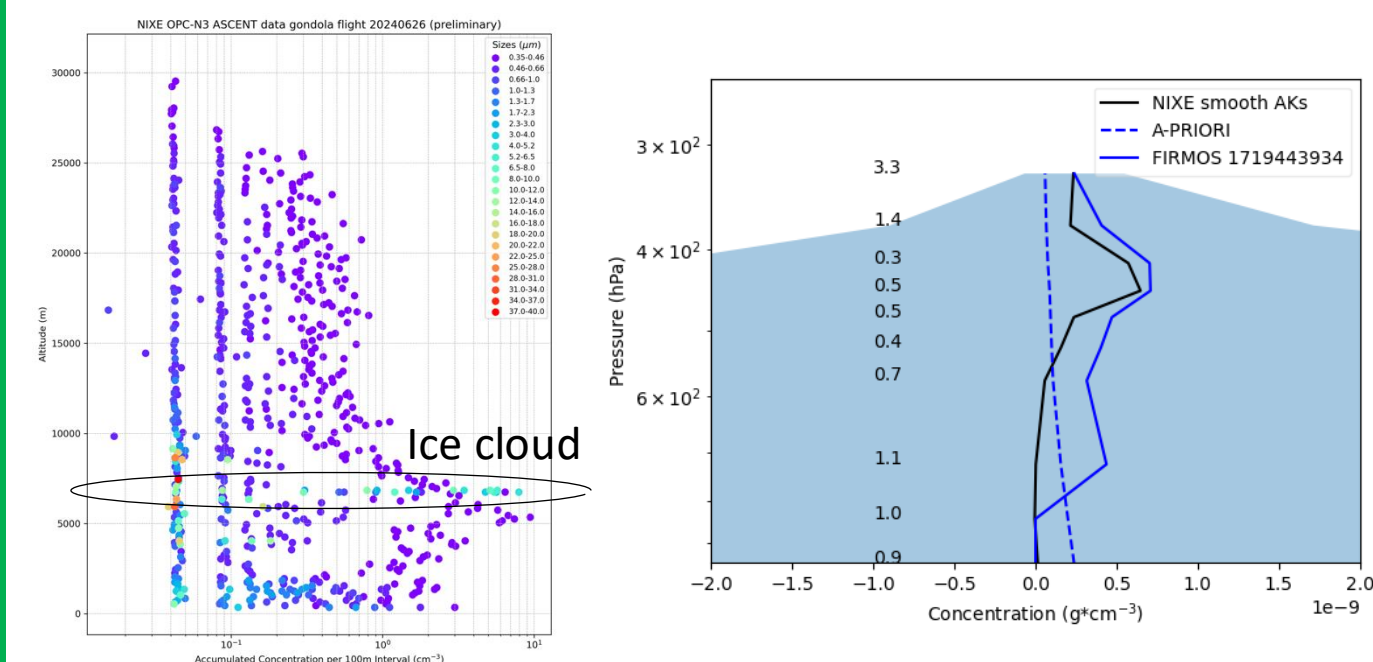


Fig2: Particle concentration measured by the NIXE-OPC during the gondola ascent for each size bin (left). Comparison between Ice Water Content (IWC) retrieved from the FIRMOS spectrum (blue) closest in time to the cloud in-situ data and the in-situ data smoothed with the retrieval Averaging Kernels (AKs) (black). The blue shadow is the retrieval error and the numbers inside the plot are the retrieval information content.

RADIATIVE CLOSURE EXPERIMENT

The in-situ cloud data allowed us to perform a radiative closure experiment. We used the NIXE data, and T, H₂O, and O₃ measured by the radiosoundings, as input for the RTM GBB-Nadir, a code capable to simulate the nadir spectra using the multiple scattering RT solver DISORT (Stamnes et al. 2000). We compared the simulated spectrum to the FIRMOS measurement closest in time to the in-situ cloud data. The time difference is a couple of minutes. The single scattering properties are computed assuming spherical particles (Mie approximation).

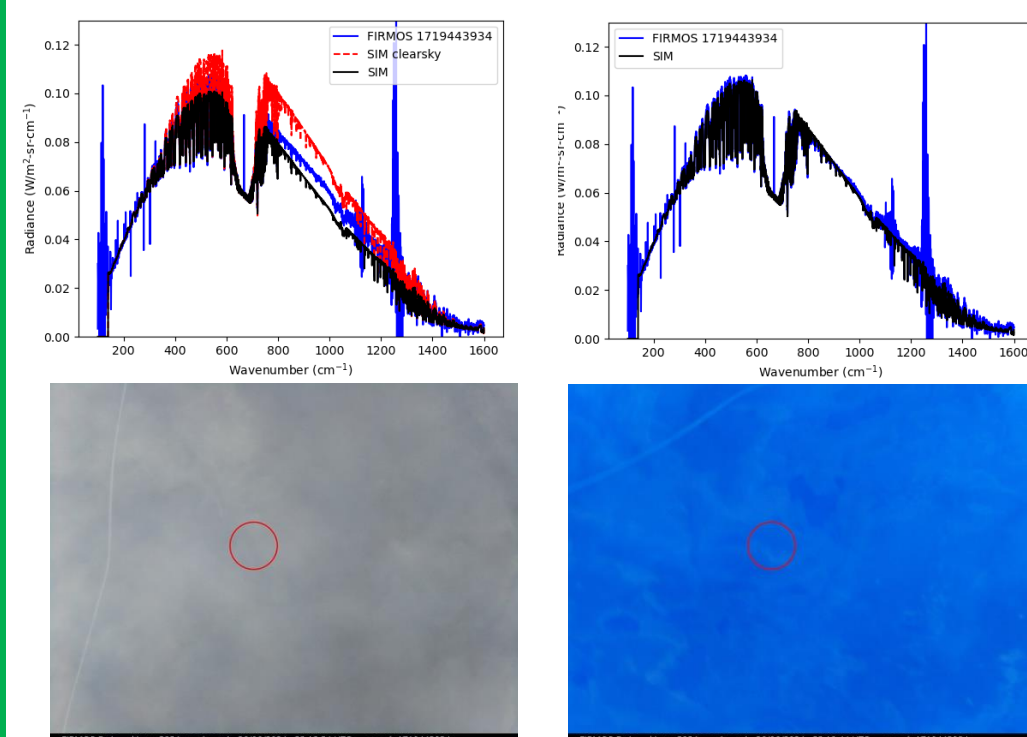


Fig3: In the left panel, measured (blue) vs simulated spectra (cloudy in black and clear-sky in red). In the right panel, the simulated spectrum (black) is a linear combination of clear-sky and cloudy simulated spectra (2/3 cloudy and 1/3 clear).

Fig4: FIRMOS camera at the beginning (left) and the end (right, after 1 minute) of the acquisition of the considered spectrum. Cloud coverage shows an important variability.

CONCLUSIONS

- The retrieved ice cloud is similar to the one measured in-situ.
- The radiative closure experiment presents difficult conditions due to high cloud variability during the acquisition of a spectrum. The results improve when we linearly combine clear and cloudy simulations. In the future, we will take into account the ice particle shapes.
- The retrieved T and H₂O profiles are very similar to the ones measured in-situ.
- From the quality assessment performed on the WHAFFERS FIRMOS-B dataset, we see that the calibration error curve and the NESR are well reproduced by the average and standard deviation of the residuals, respectively. The frequency shift and FOV are stable with time and present expected values.

PART2

Part2 of FIRMOS-B measurements was acquired in clear-sky conditions. Hence, we analysed these spectra with FARM, without considering clouds.

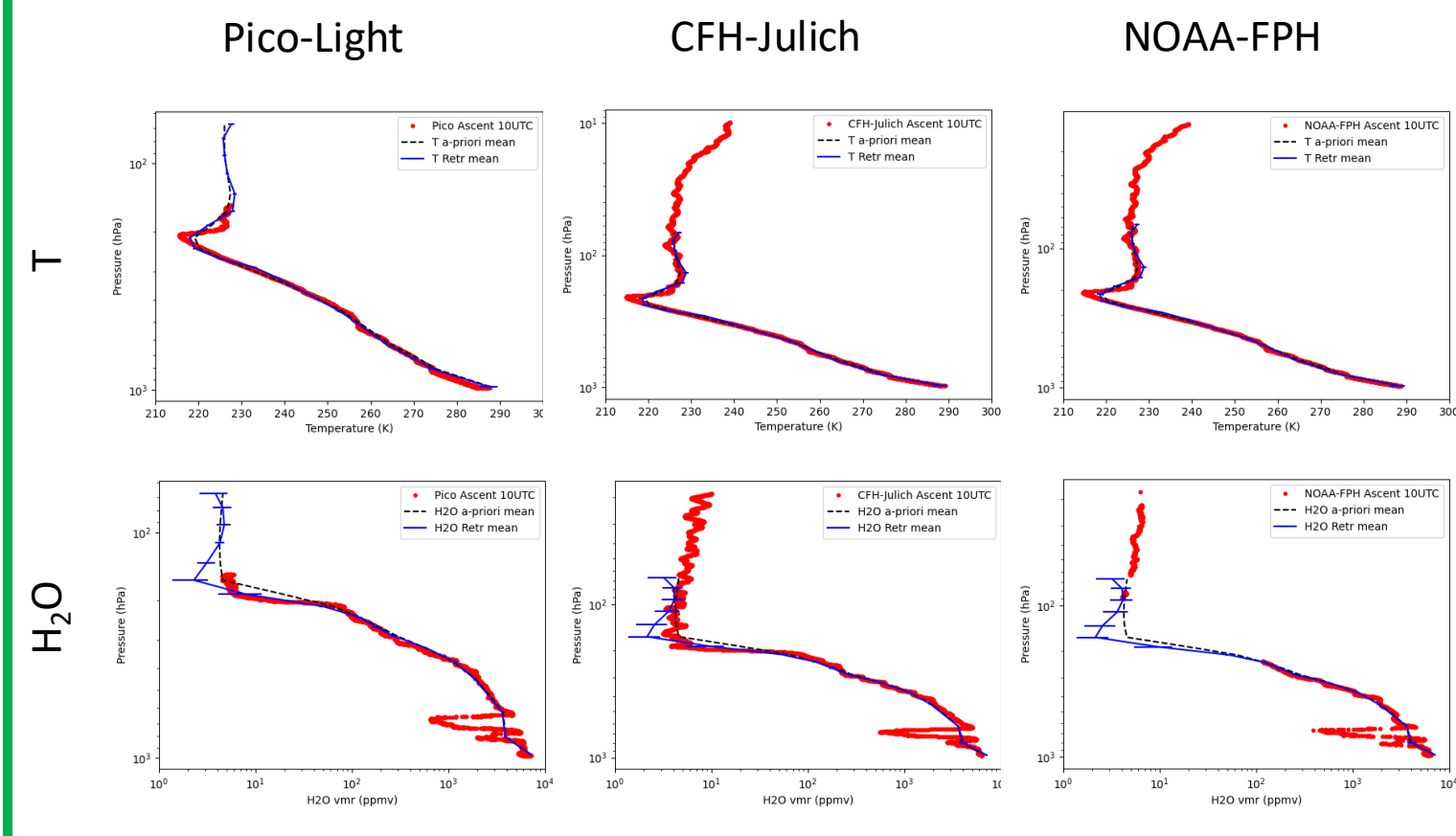


Fig5: Temperature (up) and water vapor (down) profiles retrieved by FARM from FIRMOS-B nadir spectra (blue) compared to the in-situ data acquired by Pico-Light, CFH-Julich and NOAA-FPH during the radiosoundings ascent. The FIRMOS profile (blue) in each plot is an average of all the retrieved profiles during the balloon ascent. The blue bars represent the standard deviations.

WHAFFERS 2025

The WHAFFERS campaign took place in Canada during January and February 2025. During this period, FIRMOS measured zenith-sky spectra in both Ottawa and Gault. At this stage, we used the FARM and KLIMA codes to assess the quality data by retrieving instrumental parameters.

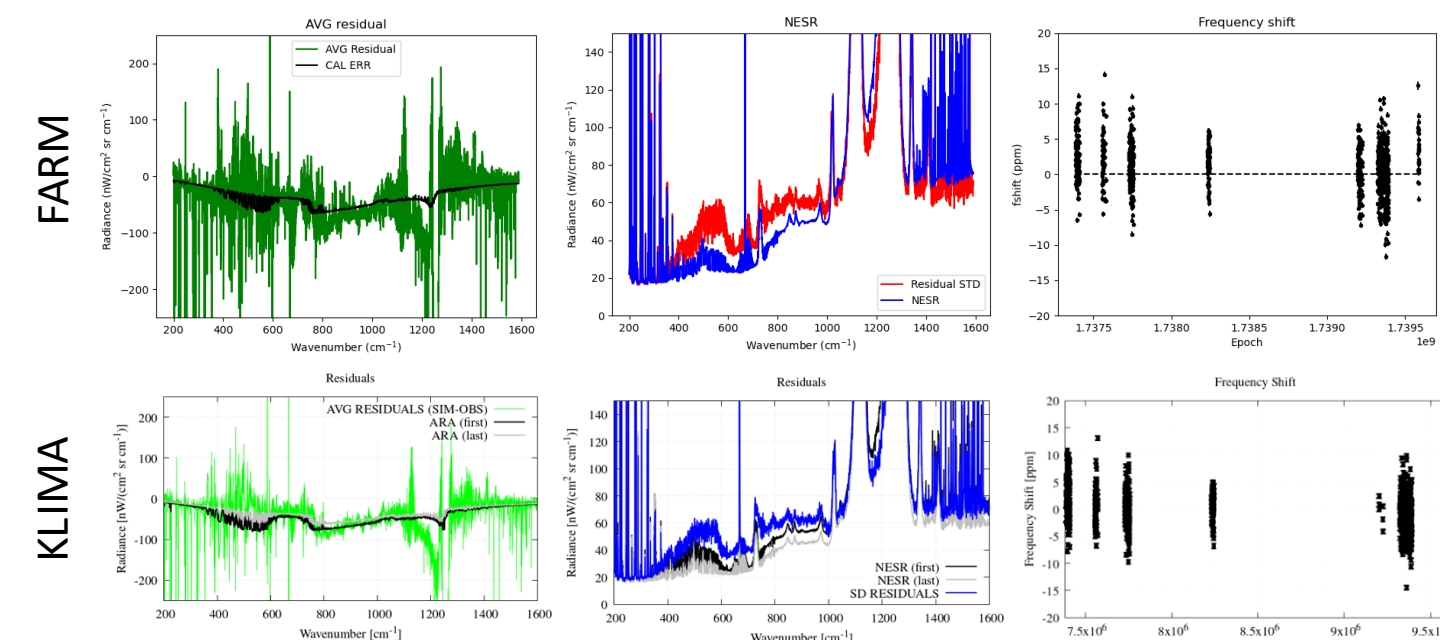


Fig6: Average residuals (green) vs calibration error (black) in the left. Estimated NESR vs the standard deviations of the residuals in the middle. Retrieved frequency shift in the right.

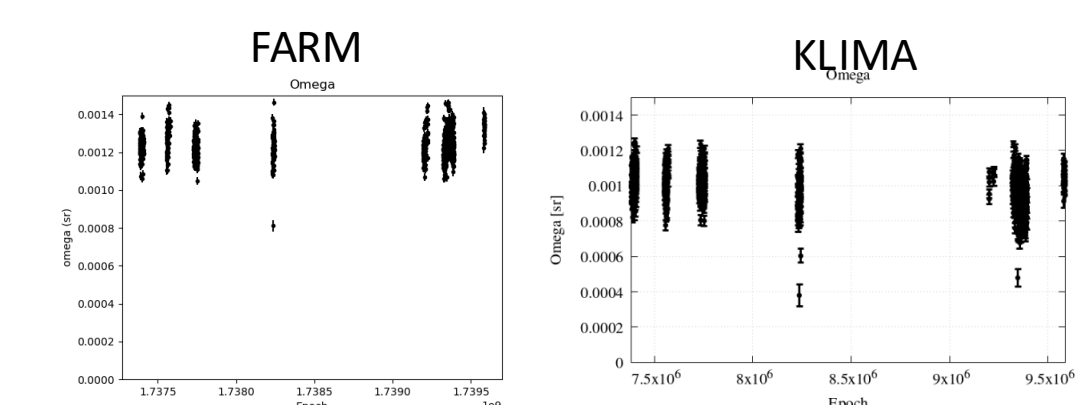


Fig7: Omega parameter (instrument FOV) retrieved by FARM (left) and KLIMA (right).

