In this response letter, our responses are labeled in blue. Revised sentences in the updated manuscript are shown in *italic purple text*. All line numbers correspond to the revised manuscript with tracked changes, where deletions are shown in red and additions are shown in blue.

General comment:

This is an excellent paper which describes a genuine scientific experiment using collocated hyperspectral infrared and microwave atmospheric soundings for retrieval of its thermodynamic states. The approach and methodologies applied to the experiment appear sound, and the presentation of the retrieval results is clear. There is some lack of clarity/rigor in the presentation details of the experiment methodologies and of the measurement parameters/conditions. Those aspects are commented below for improving further the quality of the paper. Minor editorial comments are listed at the end.

We thank Dr. Lin for the suggestions and comments, which greatly improved the clarity and quality of our manuscript.

Comments for improving the lack of clarity/rigor in the presentation details of the experiment methodologies and of the measurement parameters/conditions:

Lines 72 – 82: 2 Field campaigns

> It would be good, for the readability, to summarise the field campaigns in a table format together with relevant information such as the dates, locations, experiment configurations (geometry & polarization), wind condition, additional in-situ measurements, etc.

We have included a table describing the basic information of the field campaign, as well as the data collected and used in this retrieval analysis.

Table 1. Summary of the field campaign.

Date	11 February 2023
Location	Ottawa International Airport (latitude: 45.32°, longitude: -75.66°), Ottawa, Canada
Radiosonde	One radiosonde sounding between 14:22:53-15:26:22 UTC.
HiSRAMS	HiSRAMS was mounted on a research aircraft, providing zenith-pointing measurements before take-off and after landing, and both zenith-pointing and nadir-pointing measurements at various altitudes. In this study, we primarily use single-polarized zenith-pointing measurements from the ground and nadir-pointing measurements taken at 6.8 km altitude.
AERI	AERI was positioned on the ground, providing continuous zenith-pointing downwelling longwave radiance measurements.

Lines 83 – 133: Figures S1, S2, ..., S7

> Figures S1, S2, .., S7 are mentioned in the text, but are nowhere to be found. It is not understandable whether they are referring to those of a specific reference paper. Please clarify!

Figures S1 to S7 are provided in the supplemental document, which can be accessed at https://doi.org/10.5194/egusphere-2024-1045-supplement.

Lines 115 – 121: ERA5 re-analysis dataset

> The description of the re-analysis dataset used as the a priori dataset should be improved. For instance, why is it necessary to have a historical Februaries dataset from 1944 to 2022? Do the 9 grid boxes correspond to 3x3 boxes with the center box containing the Ottawa Airport? In which of the boxes is the campaign instrumentation located? A map with the campaign location, ERA5 grids and flight path would be helpful for the readers.

We aim to incorporate a variety of possibilities to form the *a priori* dataset. At the same time, we want to exclude the seasonal cycle from the *a priori* dataset. Therefore, we use the historical February dataset from 1944 to 2022, sourced from ERA5, to construct the *a priori* dataset. We have revised the sentence on Lines 133-134: *"This setup was designed to capture the temporal and spatial variability of atmospheric state variables near the measurement site."*.

Yes, the 9 grid boxes correspond to a 3x3 arrangement, with the center box containing Ottawa International Airport, where all instruments were located to collect the data used in the retrieval analysis. We have revised the sentences on Lines 92-94: *"A summary of the FC2023 field campaign is provided in Table 1, and all data used in the retrieval analysis were collected at Ottawa International Airport, Ottawa, Canada."* and on Lines 131-133: *"Hourly-mean profiles from Februarys between 1944 and 2022 were extracted from ERA5 across a 3x3 grid of nine boxes, with the center box including Ottawa International Airport (latitude: 45.32°, longitude: -75.66°), where real measurements were collected."*.

Line 170: Eq. 9

> As K can be negative (Figs. 6d & 6e), wouldn't it better to use |K| in Eq. 9?

We have revised the definition of **SNR** and have updated Figure 3 and Figure 6. We have included one sentence on Lines 206-208: *"To avoid negative **SNR** due to negative **K** values, which indicate how the measurements increase or decrease in response to increases in the state variables, we take the absolute values of **K** in the formula."*.

$S_{e,diag}$ can in general be improved by averaging of independent measurement samples, limited by the Allan variance of the instrumentation. Please explain how the instrumentation data have been averaged for achieving the optimum $S_{e,diag}$.

For the AERI observations, $\mathbf{S_{e,diag}}$ is determined by the noise equivalent spectral radiance. Based on a simple sensitivity test, the information content for temperature and water vapor from AERI measurements is primarily limited by **K**, rather than by $\mathbf{S_{e,diag}}$ (see Table R1-1). This indicates that averaging independent measurement samples will not significantly improve the retrieval performance of temperature and water vapor from AERI measurements.

Table R1-1 The impact of $\mathbf{S_{e,diag}}$ on the information content using AERI measurements

$\mathbf{S_{e,diag}}$ scaling factor	DFS for temperature	DFS for water vapor
0.2	10.82	4.83
1	9.52	4.22
5	8.32	3.58

For the HiSRAMS observations, the instrument and model uncertainty that form $\mathbf{S_{e,diag}}$ are defined in Liu et al., 2024: "For HiSRAMS measurements, if multiple individual measurements are averaged, the standard deviation of any individual measurements during the whole observational period is considered to be the uncertainty of the HiSRAMS-averaged measurements, which is applied to HiSRAMS ground measurements in FC2021 and FC2022 and flight measurements in FC2023. If only the individual observed spectrum is available, i.e., FC2023 HiSRAMS ground measurements, its uncertainty is determined by taking into account the radiometric noise characterized by the noise-equivalent differential temperature, calibration load imperfections, detector nonlinearity error, and instrument drift (Bliankinshtein et al., 2023a).". HiSRAMS sensor development took into account the trade-off between spectral resolution, temporal/spatial resolution of measurement and noise level, such that instrument integration time is compliant with Allan variance and reasonable for sensor on a moving platform, while keeping the hyperspectral resolution of 6.1 MHz. Sensitivity tests involving scaling (i.e., inflating or reducing) the matrix indicate that $\mathbf{S_e}$ is not the primary controlling factor of retrieval information content; instead, **K** is (Bliankinshtein et al., 2023).

Liu, L., Bliankinshtein, N., Huang, Y., Gyakum, J. R., Gabriel, P. M., Xu, S., and Wolde, M.: Radiative closure tests of collocated hyperspectral microwave and infrared radiometers, Atmospheric Measurement Techniques, 17, 2219-2233, 2024.

Bliankinshtein, N., Liu, L., Gabriel, P., Xu, S., Bala, K., Wolde, M., Huang, Y., Auriacombe, O., Krus, M., and Angevain, J.-C.: Airborne validation of HiSRAMS atmospheric soundings, IGARSS IEEE International Geoscience and Remote Sensing Symposium, 4372-4375, 2023.

Lines 213 – 214: Radiosonde data

How well are the collocation of the radiosonde measurements with respect to the AERI/HiSRAMS profile?

A single radiosonde was launched at Ottawa International Airport between 14:22:53 and 15:26:22 UTC. The balloon's trajectory is illustrated in Figure 2 from Liu et al. (2024). Since the radiosonde profile was obtained in slightly over one hour, the temporal variability of the profiles is expected to be minimal. However, the spatial variability of the profiles could lead to relatively large errors. We have included this discussion in the Conclusions and discussion section on Lines 516-517: *"Specifically, only a single radiosonde was launched during the field campaign, which may have induced temporal and spatial variability in the truth profile."*.

Liu, L., Bliankinshtein, N., Huang, Y., Gyakum, J. R., Gabriel, P. M., Xu, S., and Wolde, M.: Radiative closure tests of collocated hyperspectral microwave and infrared radiometers, Atmospheric Measurement Techniques, 17, 2219-2233, 2024.

Lines 334 – 336: "... we adopt an elevated surface boundary condition at altitude of 429 m ..."

Please include a short explanation how the land surface emissivity is artificially reduced during the retrieval.

We have included two sentences on Lines 375-377: *"Instead of developing a land surface emissivity model to simulate the surface boundary condition, we employ the HiSRAMS observed brightness temperature at 429 m as the "surface" (lower boundary condition). This approach accounts for both the surface emission and the atmospheric effects below 429 m."*.

Lines 428 – 429: "The temperature and water ... ~~decrease~~ **increase** with distances away ... in single instrument retrievals **due to the increasing atmospheric attenuation**.

Done.

<u>Editorial comments:</u>

Figures 2, 5, 10 & 12: Please expand the horizontal axis for a better visualization of the different retrieved profiles.

We have updated Figures 2, 5, 10, and 12.

Line 50: "However, recent advancements in ~~microwave~~ **digital** Fast Fourier ~~Transfer~~ **Transform** (FFT) ~~filter~~ **spectrometer** techniques have led to the development of ..."

Corrected.

Line 87: "The AERI forward model **which** we adopt is ...

Done.

Line 118: "The vertical coordinate ~~we~~ adopted in ..."

Done.

Line 224: “However, it is noted in **Figure 2** that AERI exhibits a more pronounced ...”

Done.

Line 504: “...European Space Agency (ESA contract 4000123417/NL/LA) for **the** HiSRAMS **development and permission for its use**, and ...”

Done.