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.

This is a well written paper. The analysis is thorough and supports the conclusions made. The presentation quality is good. The authors first conduct AERI and HiSRAMS retrievals for ground-based observations of clear sky only, which compares the capability of the two instruments in terms of information content on temperature and water vapor. Then they demonstrate a joint retrieval between ground-based AERI and air-borne HiSRAMS clear sky and show the benefit of combining the two instruments. I don't think this paper delivers new science, but it does present a retrieval algorithm for atmospheric temperature and water vapor sounding from IR and MW. I have the following comments for authors to consider:

We thank the reviewer for the valuable comments that improve the quality of our manuscript. We have revised the manuscript accordingly.

In terms of the new science in our manuscript, our intention is to introduce the role and ability of new technology in hyperspectral microwave instruments to retrieve temperature and water vapor vertical profiles. HiSRAMS is one of the first developed hyperspectral microwave radiometer. We have included a sentence on Lines 72-73: *"With the development of HiSRAMS, we aim to demonstrate the capabilities of new technology in hyperspectral microwave instruments for retrieving temperature and water vapor vertical profiles under both clear-sky and all-sky conditions."*.

1. The value of this paper is on combining air-borne microwave and ground-based infrared sounding measurements, not much on whether or not the MW and IR combined could provide a better "all-sky" retrievals. I think it is better to point this out in your title, abstract, and literature survey, and center them on your major findings.

As one of the first hyperspectral microwave radiometers developed, the HiSRAMS instrument has provided some of the earliest data ever obtained in this study. While the strength of microwave radiometers lies in their ability to penetrate clouds, thus enhancing all-sky temperature and water vapor profiling, it is crucial first to evaluate the instrument under well-controlled conditions. Therefore, we have chosen to conduct initial tests in clear-sky environments to showcase the capabilities and significance of this new hyperspectral microwave technology. It's worth noting that ground-based, airborne, and combined hyperspectral infrared and microwave measurements each offer unique benefits due to their distinct geometric configurations.

In order to make it clearer, we have revised the sentences on Lines 12-17 in the abstract: *"In contrast to infrared radiometry, microwave radiometry can penetrate clouds, making it a valuable tool for all-sky thermodynamic retrievals. Recent advancements have led to the fabrication of a hyperspectral microwave radiometer: the High Spectral Resolution Airborne Microwave Sounder (HiSRAMS). This study utilizes HiSRAMS to retrieve atmospheric temperature and water vapor profiles under clear-sky conditions; this is an initial assessment of one of the first hyperspectral microwave radiometers, comparing the results to those from an infrared hyperspectrometer, the Atmospheric Emitted Radiance Interferometer (AERI)."*.

2. The retrieved profiles agree with the radiosonde surprisingly well, but clear differences with the first guess can be seen. Are these results all for a single case? How does the algorithm perform in general? It is hard to reach conclusions based on a single case.

Yes, the retrievals are all based on a single case. We have revised the sentence in the Conclusions and discussion section on Lines 514-517: *"Additionally, the retrieval comparison in this study relies on limited samples from a single campaign* ***which only provides one case study for each retrieval configuration****, thus bounding the usefulness of the error statistics and comprehensiveness of this assessment. Specifically,* ***only a single radiosonde*** *was launched during the field campaign, which may have induced temporal and spatial variability in the truth profile."*.

We have not yet developed an Observing System Simulation Experiment (OSSE) for retrievals based on "sandwich" measurements. However, OSSEs and operational retrievals for single HiSRAMS and AERI measurements have been well studied, with results similar to ours (Bliankinshtein et al., 2019; Bliankinshtein et al., 2023; Turner et al., 2014; Turner et al., 2018; Loveless, 2021). Operational retrieval algorithms for HiSRAMS and AERI under all-sky conditions are currently in development.

Bliankinshtein, N., Gabriel, P., Huang, Y., Wolde, M., Olvhammar, S., Emrich, A., Kores, M., and Midthassel, R.: Airborne Measurements of Polarized Hyperspectral Microwave Radiances to Increase the Accuracy of Temperature and Water Vapor Retrievals: an Information Content Analysis, AGU Fall Meeting, 2019.

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.

Loveless, D. M.: Developing a Synergy Between Space-based Infrared Sounders and the Ground-based Atmospheric Emitted Radiance Interferometer (AERI) to Improve

Thermodynamic Profiling of the Planetary Boundary Layer, The University of Wisconsin-Madison, 2021.

Turner, D. D. and Blumberg, W. G.: Improvements to the AERIoe thermodynamic profile retrieval algorithm, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 12, 1339-1354, 2018.

Turner, D. D. and Löhnert, U.: Information content and uncertainties in thermodynamic profiles and liquid cloud properties retrieved from the ground-based Atmospheric Emitted Radiance Interferometer (AERI), Journal of Applied Meteorology and Climatology, 53, 752-771, 2014.

3. The retrieval bias around the sharp vertical features is very large, which is due to the lack of vertical resolution. This could be demonstrated by calculating the bias by comparing retrievals with the radiosondes that are vertically smoothed by the averaging kernel. Perhaps it is more interesting to ask what kind of instrument designs could resolve such feature, new channels, lower measurement error, etc.

We applied Eq. R2-1 to smooth the retrieved temperature and water vapor profiles, and the updated retrieval bias figures are shown in Figures R2-1 and R2-2. To some extent, the sharp vertical features have been reduced. However, relatively sharp biases, primarily caused by fine vertical features, are still present. To accurately display the biases and avoid confusion, we have decided to retain the original Figures 8 and 13. The error analysis using the smoothed profiles has been included in the Supplementary Information.

We agree that understanding what kinds of instrument designs could resolve such features is important. Based on the OSSE for HiSRAMS-only measurements (Bliankinshtein et al., 2019), the microwave absorption characteristics already limit the information we can obtain from the atmosphere. In other words, regardless of how high the spectral resolution, how wide the spectral range, or how low the measurement error within a reasonable setup, the information content from a hyperspectral microwave radiometer cannot be significantly increased. A more detailed analysis of combining microwave and infrared hyperspectral radiometers warrants further investigation in the future.

$$\boldsymbol{x}_{truth}^{smoothed} = \boldsymbol{A}(\boldsymbol{x}_{truth} - \boldsymbol{x}_a) + \boldsymbol{x}_a \qquad \text{Eq. R2-1}$$

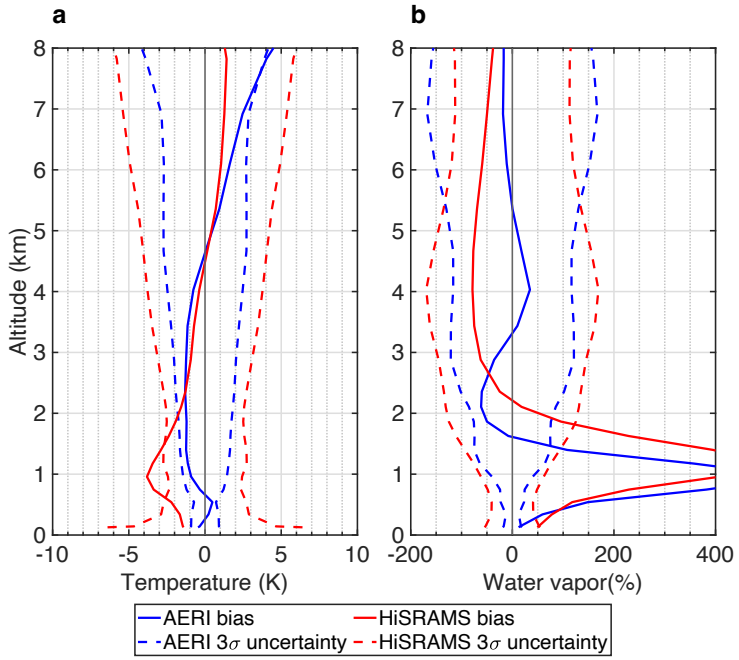

Figure R2-1: Comparison of retrieval bias and uncertainty in ground-based retrievals for (a) temperature and (b) water vapor. The truths used to determine the bias are smoothed using Eq. R2-1.

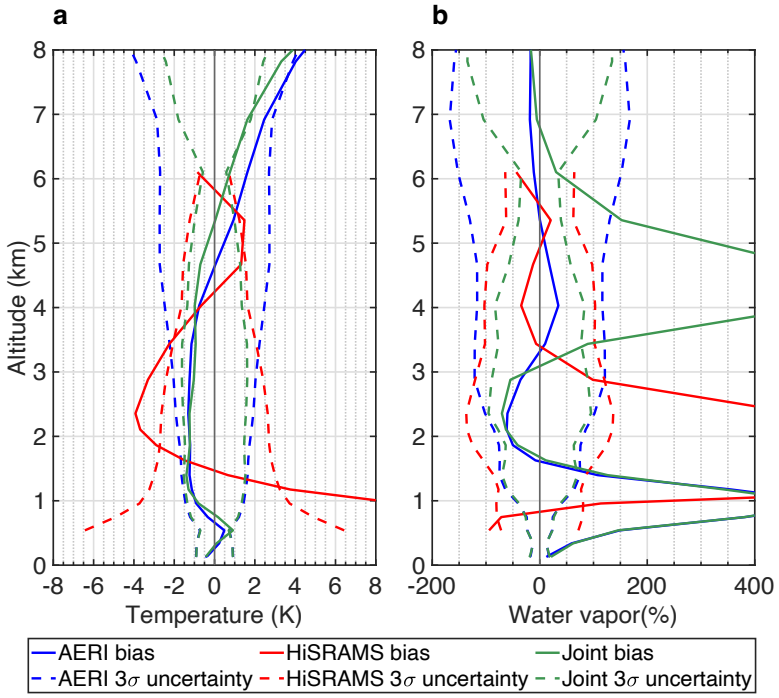

Figure R2-2: Comparison of retrieval bias and uncertainty in joint retrievals for (a) temperature and (b) water vapor. The truths used to determine the bias are smoothed using Eq. R2-1.

Bliankinshtein, N., Gabriel, P., Huang, Y., Wolde, M., Olvhammar, S., Emrich, A., Kores, M., and Midthassel, R.: Airborne Measurements of Polarized Hyperspectral Microwave Radiances to Increase the Accuracy of Temperature and Water Vapor Retrievals: an Information Content Analysis, AGU Fall Meeting, 2019.