Responses to Reviewers' Comments

We are sincerely grateful to the editor and reviewers for their valuable time spent on reviewing our manuscript. The comments are constructive and valuable, and we have tried our best to address the issues raised by the reviewers in revised manuscript. Please find our item-by-item response (in bold) to the comments (in black) raised by the reviewers, and the paragraphs added in the revised manuscript (in red).

Reviewer #1

General Comments: This paper conducts research on a new temperature profile retrieval method using simulated data from China's new-generation geostationary microwave satellite scheduled for launch. Channel optimization is performed based on information contribution, and an all-weather temperature profile retrieval algorithm is finally established. The proposed algorithm fully leverages the advantages of the geostationary microwave satellite and meets the requirements for rapid operational retrieval. Meanwhile, this paper intensively analyzes the improvement brought by the hyperspectral channels of the geostationary microwave satellite to temperature retrieval results, which provides valuable references for further instrument optimization research. The research outcomes possess strong practical value. Nevertheless, this study needs further elaboration on the variation characteristics of retrieval product accuracy under different weather systems. In addition, the current retrieval accuracy should be compared with existing operational retrieval methods to better clarify the application prospect of the proposed algorithm.

Reply: We thank the reviewer for the valuable time and constructive comments, which have helped us to improve our manuscript. All specific comments have been addressed item by item. In response to the two issues raised in the General Comments, we have further evaluated the retrieval performance under different weather systems by adding a typhoon case study to the 'Results' section. Further details of this case analysis are provided in our responses to the relevant specific comments below. For the second issue, we have also added a comparison with the operational FengYun-3E (FY-3E) vertical atmospheric sounding system (VASS) product. Considering the interpretation of this comparison is closely related to the limitations raised by another reviewer, we have added the following paragraph to the 'Results' section as follows:

Liu et al. (2026) reported temperature RMSEs of 3.07, 3.56, and 3.26 K for the FengYun-3E (FY-3E) vertical atmospheric sounding system (VASS) product under clear-sky, cloudy, and all-sky conditions, respectively, based on validation against radiosonde observations. The lower RMSEs obtained in the present study demonstrate the potential of the proposed algorithm. Considering the used plane-parallel MWRT model cannot fully represent three-dimensional scattering effects, however, the retrieval errors for real FY-4M observations may be larger than those indicated by the present simulation experiments. Therefore, the actual retrieval performance should be further evaluated using real on-orbit FY-4M observations in the future.

Liu, S., Xu, J., Chen, L., Liu, H., Wang, W., He, J., Zhu, S., and Shi, J.: Comprehensive validation of temperature and humidity profile retrievals from FengYun-3E, IEEE Trans. Geosci. Remote Sens., 64, 4102214, https://doi.org/10.1109/TGRS.2026.3658572, 2026.

Specific Comments:

Q1: Line 33-35: "The closer the frequency is to the center line of the oxygen absorption band, the stronger the absorption, and the higher the peak altitude of the weighting function."

I fail to understand this sentence. Is there a direct correlation between the peak height of the weighting function and strong absorption?

Reply: Thank you for raising this point. We agree that the original sentence could be misinterpreted as implying a simple direct correlation between absorption strength and the peak altitude of the weighting function. We intended to explain that, near an oxygen absorption band, channels closer to the absorption-line center generally have larger absorption coefficients and optical depths, so radiative contributions from the lower atmosphere and surface are more strongly attenuated. As a result, these channels are mainly sensitive to radiation from higher atmospheric layers, leading to higher peak altitudes of their temperature weighting functions. We have revised the sentence in the manuscript as follows:

Near an oxygen absorption band, channels closer to the center line generally have larger absorption coefficients and optical depths, so radiative contributions from the lower atmosphere and surface are more strongly attenuated. As a result, these channels are mainly sensitive to radiation from higher atmospheric layers, leading to higher peak altitudes of their temperature weighting functions (Rodgers, 2000; Aires et al., 2015).

Aires, F., Prigent, C., Orlandi, E., Milz, M., Eriksson, P., Crewell, S., Lin, C.-C., and Kangas, V.: Microwave hyperspectral measurements for temperature and humidity atmospheric profiling from satellite: the clear-sky case, J. Geophys. Res. Atmos., 120, 11334-11351, https://doi.org/10.1002/2015JD023331, 2015.

Rodgers, C. D.: Inverse methods for atmospheric sounding: Theory and practice, World Scientific, Singapore, https://doi.org/10.1142/3171, 2000.

Q2: All figures are relatively blurry, which affects the analysis of the results. It is recommended to adjust the figure types.

Reply: We sincerely apologize for the insufficient resolution of the figures in the original manuscript. In the revised manuscript, all figures have been regenerated and replaced with high-quality versions. All revised figures have a resolution of 300 dpi. In addition, we enlarged the font sizes of the axis labels, legends, color bars, and annotations to ensure that all information is clear.

Q3: Line 135-137: “the Global Precipitation Measurement (GPM) Microwave Imager (GMI) Level 1C-R Version 05 TB product (Wentz and Draper, 2016) and GMI Level 2 retrieval product (Version 07) derived via the Goddard profiling algorithm (GPROF) (Kummerow et al., 2015).”

Specific descriptions should be provided to illustrate the applications of these two datasets; otherwise, the introduction of the two datasets will appear abrupt.

Reply: We appreciate this helpful comment. The following description has been added to the revised manuscript:

Specifically, ERA5 was used to obtain atmospheric temperature, relative humidity, pressure, SST, and WS; the GMI L1C-R product provides observed TBs served as the observation vector in the subsequent one-dimensional variational (1D-Var) adjustment; and the GPROF L2 product supplies hydrometeor profiles, including CLWC, RWC, and IWC, as part of the a priori state vector, together with auxiliary precipitation information such as SPR.

Q4: Line 158-159: “Sa and Sy denote the error covariance matrices of and, respectively, with off-diagonal elements set to zero.”

How are these errors defined in this study? Is it static or dynamically variable? The authors are suggested to discuss these issues.

Reply: Thank you very much for pointing this out. We agree that the description of S_a and S_y in the original manuscript was insufficient. We have added the following description to the revised manuscript:

$\boldsymbol{S_a}$ and $\boldsymbol{S_y}$ denote the background error covariance matrix and the observation error covariance matrix, respectively. In this study, both matrices were prescribed as static matrices. The standard deviations in $\boldsymbol{S_a}$ were specified according to the type of state variable. For hydrometeor contents, the standard deviation was set to 0.2 after the logarithmic transformation (base 10). For surface emissivity, the standard deviation was set to 0.5 after the inverse hyperbolic tangent (arctanh) transformation. $\boldsymbol{S_y}$ was calculated from the instrument noise of each GMI channel (Wu et al., 2026; Yin and Liu, 2017). Although error correlations may exist among different state variables and vertical layers, both matrices were treated as diagonal matrices to improve computational efficiency and numerical stability.

Wu, B., Li, X., Wang, Y., Fan, X., Zhang, P., Chen, L., and Fu, Y.: A prototype precipitation retrieval algorithm for passive microwave observations from the FY-3G satellite, J. Remote Sens., 6, 1057, https://doi.org/10.34133/remotesensing.1057, 2026.

Yin, M. and Liu, G.: Developing an a priori database for passive microwave snow water retrievals over ocean, J. Geophys. Res. Atmos., 122, 12960-12981, https://doi.org/10.1002/2017JD027636, 2017.

Q5: Line 162-164: “In this study, the observation vector includes TBs from nearly all GMI channels, except for the horizontally polarized channels at 89 GHz and 166 GHz.”

Does this mean that these two channels will no longer be used in subsequent retrieval processes? If so, what are the reasons?

Reply: Thank you for pointing out this unclear statement. The exclusion of the horizontally polarized channels at 89 and 166 GHz was only applied to the 1D-Var adjustment step for constructing the a priori database, and these channels were still considered in the subsequent FY-4M channel optimization and Bayesian retrieval. As shown later in Table 2, the corresponding FY-4M channels at 89.0 and 165.5 GHz are both retained in the final recommended channel configuration. We have added the following clarification to the revised manuscript:

It should be noted that this exclusion applies only to the GMI observation vector used in the 1D-Var adjustment of the a priori database and does not preclude the corresponding FY-4M frequency channels from being considered in the subsequent channel selection and retrieval experiments.

Q6: Figure 3: The interpretation of Figure 3 is unclear. Does the black straight line represent the mean profile? What do the error bars stand for?

Reply: We have added these details to the legend of Fig. 3 and revised the caption of it as follows:

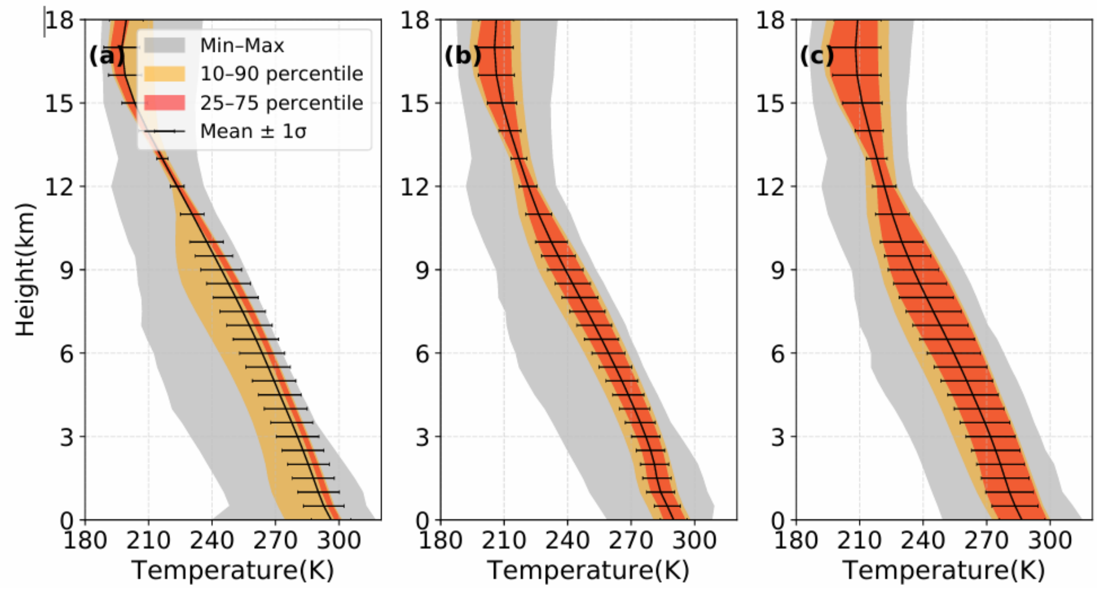

Figure 3. Temperature profiles used for IC analysis over the ocean under (a) clear-sky, (b) cloudy, and (c) precipitating conditions. The grey, yellow, and orange shading indicates the min-max, 10th-90th, and 25th-75th percentile ranges, respectively. The solid black line denotes the mean profile calculated from all samples under each weather condition, and the error bars represent the corresponding standard deviation.

Q7: Line 270: "with the findings of Aires et al. (Kangas et al., 2015)"

The citation format adopted in this manuscript is unconventional, and revision is recommended.

Reply: We apologize for the incorrect citation format in the original manuscript. This citation has been corrected in the revised manuscript. Also, we have carefully checked and revised all in-text citations and reference entries throughout the manuscript to ensure their consistency with the journal requirements.

Q8: Line 339-340: "the temperature bias profiles for different channel configuration schemes are generally distributed around the zero line, with root mean square error (RMSE) below 1 K."

If the study only focuses on typhoon-affected areas, can the temperature retrieval still achieve such accuracy? The authors are suggested to discuss these points to further clarify the application scenarios of the proposed method.

Reply: We fully agree with the reviewer that the application in typhoon-affected areas should be further discussed. We have added a typhoon case study to the 'Results' section of the revised manuscript to further evaluate the retrieval performance under an extreme weather condition:

To further evaluate the retrieval performance under extreme weather conditions, moreover, the simulation results of Typhoon Doksuri at 25 July 2023 were used for a representative case study. The typhoon atmospheric fields were first simulated using the Weather Research and Forecasting (WRF) model, and treated as the reference truth. The corresponding FY-4M channel brightness temperatures were then calculated using the MWRT model and used as the input observations for the retrieval evaluation. As in the preceding simulation experiments, Gaussian random noise with a mean of 0 K and a standard deviation of 0.5 K was also added to represent instrumental noise. Fig. 9 shows the spatial distributions of the reference and retrieved temperature fields at 850, 500, and 250 hPa. Overall, the retrieved temperature fields reproduce the main spatial patterns of the reference fields at the three pressure levels. The warm-core structure near the typhoon center is clearly captured and the surrounding horizontal temperature gradients are also reasonably represented.
Fig. 10 further shows vertical profiles of temperature retrieval errors for different channel configuration schemes in the typhoon case. Except for the NHC90 scheme, the biases of the other schemes are still generally distributed around 0 K, with RMSE values below 1 K at most vertical levels. This indicates that the proposed retrieval algorithm can maintain good performance even under strong convective weather conditions such as typhoons. Consistent with the results discussed above, the AC schemes generally show higher retrieval accuracy than the NHC schemes, with smaller RMSE values. This further highlights the important contribution of the hyperspectral channels to atmospheric temperature profile retrievals.

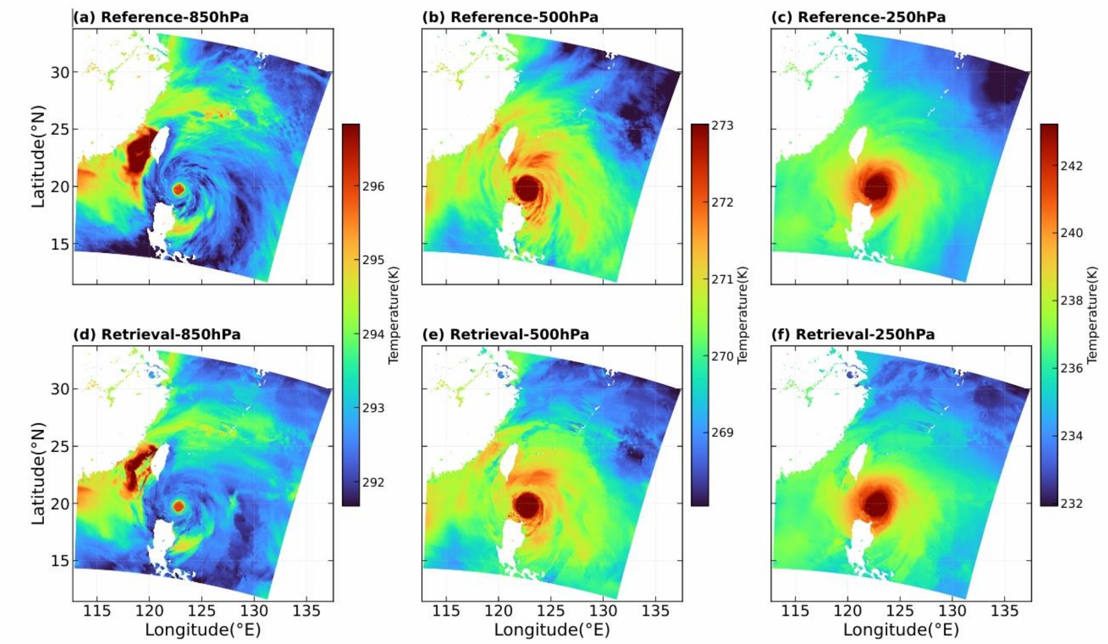

Figure 9. Spatial distributions of the simulated temperature fields by the WRF model (upper row) , and retrieved temperature fields (bottom row) at different pressure levels (from left to right: 850 hPa, 500 hPa, and 250 hPa) for the Typhoon Doksuri case at 25 July 2023.

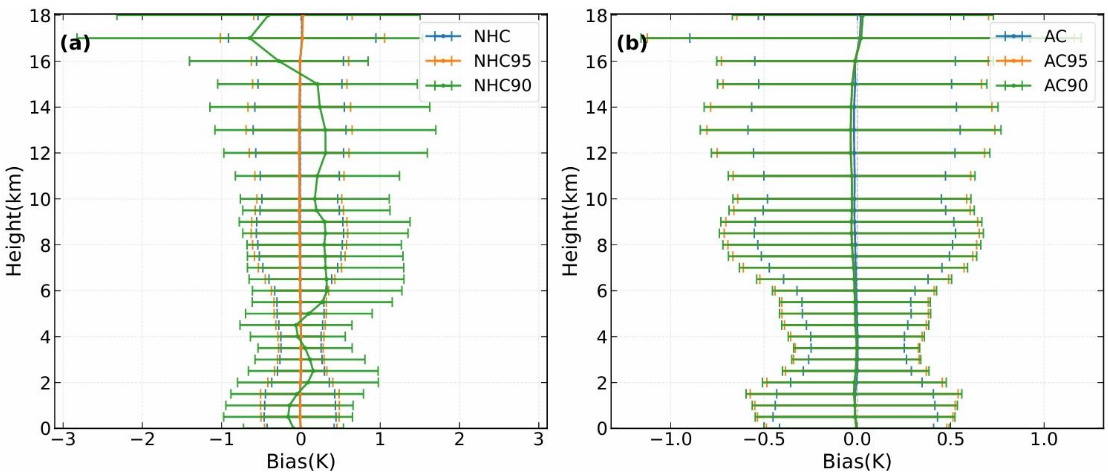

Figure 10. The statistical results of temperature profile retrieval errors for the typhoon case with (a) only non-hyperspectral channels and (b) all channels including hyperspectral channels. Error bars indicate RMSE.

Q9: Line 346-347: “the RMSE values of NHC95 and NHC90 increase by approximately 19% and 47% relative to the full NHC set, respectively. Especially”

Does the value of the optimal channel selection method mainly lie in cloudy and rainy conditions? Is it because the eliminated channels would introduce more errors under cloudy and precipitation circumstances?

Reply: Thanks for pointing this out. The value of the channel selection method does not mainly lie in cloudy and precipitating conditions. Rather, it provides a balance between retrieval accuracy and computational efficiency under different weather conditions including clear-sky. The eliminated channels were excluded mainly because their incremental information contribution was relatively small under the current channel configuration. Of course, under cloudy and precipitating conditions, hydrometeor absorption and scattering can make the temperature sensitivity and brightness temperature interpretation of some channels more complex. The excluded channels might also be linked to the factor that they aren't helpful for separating cloud and rain signals during temperature retrieval.

Q10: Figure 8: The biggest challenge of retrieval research based on simulated data lies in the inability to reasonably take instrumental errors into account. Will the retrieval errors in this study be affected by instrumental observation errors? The authors are suggested to discuss this issue.

Reply: We appreciate this suggestion. The instrument noise had already been included in our retrieval experiments, but this was not clearly described in the original manuscript. We have clarified it in the revised manuscript:

To simulate instrumental noise, Gaussian random noise with a mean of 0 K and a standard deviation of 0.5 K was added to the simulated brightness temperatures of all FY-4M channels.