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 #3

General Comments: As the world's first passive microwave instrument uploaded on Chinese geostationary meteorological satellite FY-4M, it will open a new era of continuous three-dimensional observations of various key geophysical parameters under all skies. In this study, channel optimization for atmospheric temperature profile retrieval over ocean was performed based on information entropy theory, and then the retrieval was done using a Bayesian algorithm. The topic of this paper has great practical value. Although this research is based on simulation research, it is urgently needed for China's meteorological satellite operations. This new PMW sounder adds some channels never be used before, especially the hyperspectral and Y1&2 bands is uniquely available on meteorological satellites. An original study on its contribution to temperature profile retrieval is conducted in this paper.

Overall, the paper is written smoothly, and the content is organized reasonably. It is recommended for acceptance after minor revisions. Specific suggestions and comments are as follows.

Reply: We sincerely thank the reviewer for the assessment of our work and for recognizing its practical value for future FY-4M satellite applications. We also appreciate the constructive comments and suggestions, all of which have been carefully addressed in the revised manuscript.

Specific Comments:

Q1: The emphasis in the title is on the all-sky atmospheric temperature profile retrieval over ocean.

Reply: Thank you for this helpful suggestion. We agree that the title should more clearly emphasize the focus of this study on all-sky atmospheric temperature profile retrieval over ocean. Therefore, we have revised the title as follows:

A Prototype Algorithm for All-Sky Atmospheric Temperature Profile Retrieval over Ocean Based on Channel Optimization for the FY-4M Satellite

Q2: In abstract: "several high-frequency channels in the high-precision detection of atmospheric temperature profiles over ocean", gives the specific center frequency.

What is the 'true value' used for temperature profile validation?

Reply: Thanks for pointing this out. Regarding the first question, we have revised the abstract to specify the center frequencies of these high-frequency channels as follows:

especially the potential application of its unique temperature hyperspectral channels (52.6-57.3 GHz) and several high-frequency channels (380 and 424 GHz) in the high-precision detection of atmospheric temperature profiles over ocean

Regarding the second question, during the retrieval validation stage, independent test samples were randomly selected from the a priori database, and the atmospheric temperature profiles provided by ERA5 reanalysis were used as the reference truth for comparison. We have added the following clarification to the retrieval validation part of the 'Results' section in the revised manuscript:

To evaluate the retrieval performance of different channel configuration schemes in the Bayesian algorithm, 100,000 samples each for clear-sky, cloudy, and precipitating conditions were randomly selected from the a priori database to form an independent test dataset, while the remaining samples were used as the training dataset. The corresponding atmospheric temperature profiles obtained from ERA5 in the a priori database for these test samples were used as the reference truth and compared with the Bayesian retrieval results for validation.

Q3: In table 1: channel 5&6 the characteristics are the same. It is suggested to add one column to specify the purpose of each channel. Based on Table 1, provide the distribution of the weight function for all channels.

Reply: Thank you for the careful review of our manuscript. We have corrected the polarization of channel 5 in Table 1 and Table2, and added a new column to Table 1 to specify the purpose of each channel as follows:

Table 1. Channel characteristics of the FY-4M satellite.

Band	Number	Frequency (GHz)	Bandwidth (MHz)	Polarization	Design Purpose
K/Ka	1	23.8	270	V	Total water vapor sounding
	2	23.8	270	H	
	3	31.4	180	V	Surface radiation correction
	4	31.4	180	H	

V	5	50.3	180	V	Atmospheric temperature profile sounding
	6	50.3	180	H	
	7	51.76	400	H	
	8	52.8	400	H	
	9	53.246±0.08	2*140	H	
	10	53.596±0.115	2*170	H	
	11	53.948±0.081	2*142	H	
	12	54.4	400	H	
	13	54.94	400	H	
	14	55.5	330	H	
	15	57.290334(f0)	330	H	
	16	f0±0.217	2*78	H	
	17	f0±0.322±0.048	4*36	H	
	18	f0±0.322±0.022	4*16	H	
	19	f0±0.322±0.01	4*8	H	
	20	f0±0.322±0.0045	4*3	H	
Hyperspectral	21-32	52.6-55	200	V	Hyperspectral atmospheric temperature profile sounding
	33-109	55-57.3	30	V	
W	110	89.0	3000	V	Surface radiation correction and ice cloud detection
F	111	118.75±0.08	2*20	H	Atmospheric temperature and humidity profile sounding
	112	118.75±0.2	2*100	H	
	113	118.75±0.3	2*165	H	
	114	118.75±0.8	2*200	H	
	115	118.75±1.1	2*200	H	
	116	118.75±2.5	2*200	H	
	117	118.75±3.0	2*1000	H	
	118	118.75±5.0	2*2000	H	
G	119	165.5	3000	V	Quasi-window channel
	120	183.31±11	2*2000	H	Mid-level atmospheric humidity profile sounding and ice cloud detection
	121	183.31±7	2*2000	H	
	122	183.31±4.5	2*2000	H	
	123	183.31±3	2*1000	H	
	124	183.31±1.8	2*1000	H	
	125	183.31±1	2*500	H	
J	126	229	2000	V	Experimental ice cloud remote sensing
Y1	127	380.197±18	2*2000	H	Atmospheric humidity profile sounding
	128	380.197±9	2*2000	H	
	129	380.197±1.5	2*500	H	
	130	380.197±0.4	2*200	H	
Y2	131	424.763±4	2*1000	H	Middle- and upper-level atmospheric temperature profile sounding
	132	424.763±1.5	2*600	H	
	133	424.763±1	2*400	H	
	134	424.763±0.6	2*200	H	
	135	424.763±0.3	2*100	H	

Regarding the second question, the temperature-sensitivity distributions of all channels have already been presented in the form of temperature Jacobians in Fig. 4 for the non-hyperspectral channels and Fig. 5 for the hyperspectral channels. To avoid redundant presentation, we therefore did not provide separate weighting-function distributions. Also, FY-4M contains 135 channels, presenting the weighting function of each channel individually would make the figure difficult to read.

Q4: Line 138"… within the full-disk coverage of FY-4M, resulting in approximately 200 million collocated samples", in this paper you just use the samples over ocean according Line 108-109, right? If it is true, the later prior probability distributions of Bayesian and so on will be explained over ocean.

Is this database newly developed by this paper or already exist? The aim of section Line 151-169 is to adjust the retrieved GPROF hydrometeor products, if this work is not be done by this paper, suggest deletion。

Reply: Thank you for your valuable comment. We have clarified in the revised manuscript that the collocated samples used for the subsequent analysis and retrieval experiments are oceanic samples:

Here ERA5 gridded data were matched to GMI pixels using a nearest-neighbor approach within the full-disk coverage of the FY-4M satellite, resulting in approximately 200 million collocated oceanic samples for the subsequent analysis and retrieval experiments.

Regarding the second question, the a priori database construction and the 1D-Var adjustment procedure were performed following Wu et al. (2026). Therefore, following the reviewer's suggestion, we have removed the detailed description of Eq. (2) from the revised manuscript:

The minimization of the cost function was performed following Wu et al. (2026).

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.

Q5: Line 158: $\boldsymbol{S_a}$ is the error covariance matrices of $\boldsymbol{x_a}$ state vector, state variables are correlated, so it is a non-diagonal matrix with non-zero off-diagonal elements.

Reply: Thanks for pointing this out. We fully agree that correlations may exist among different state variables and vertical layers in the real atmosphere, and therefore the background error covariance matrix $\boldsymbol{S_a}$ may contain non-zero

off-diagonal elements. In this study, however, following Yin and Liu (2017), $\boldsymbol{S_a}$ was simplified as a static diagonal matrix in the 1D-Var adjustment. This simplification reduces the computational cost of matrix inversion and improves numerical stability. In response to this comment and related comments from other reviewers, we have revised the description of $\boldsymbol{S_a}$ and $\boldsymbol{S_y}$ in the revised manuscript as follows:

$\boldsymbol{S_a}$ 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.

Q6: In Equ.(5) what is the meaning of $\boldsymbol{A}$ and $\boldsymbol{B}$?

Reply: We appreciate this suggestion. The meanings of $\boldsymbol{A}$ and $\boldsymbol{B}$ are consistent with their definitions in the preceding equation. We have added the following explanation to the revised manuscript:

$\boldsymbol{A}$ and $\boldsymbol{B}$ denote the retrieval error covariance matrix and the background error covariance matrix, respectively.

Q7: In Fig.4 the temperature Jacobian spectrum is calculated from just one sample under different weather conditions or the average of many samples?

Reply: Thank you for raising this question. The temperature Jacobians shown in Fig. 4 were not calculated from a single sample, but represent the average results from a large number of samples. Specifically, 1,000,000 samples were randomly selected for each of the clear-sky, cloudy, and precipitating conditions. For each sample, the Jacobians of each channel with respect to the atmospheric temperature profile were calculated, and the results were then averaged within the same weather condition. We have added the following clarification to the revised manuscript:

Figure 4 first shows the atmospheric temperature Jacobians across all non-hyperspectral channels under various weather conditions. For each weather condition, the Jacobians were calculated separately for each of the 1,000,000 samples described above and then averaged.

Q8: Fig.8 is not clear, especially label of 90、95，AC.

Reply: We apologize for the unclear labels in Fig. 8. We have redrawn Fig. 8 by enlarging the font sizes of the labels and legends. We also checked the other figures and ensured that all information is clearly legible.

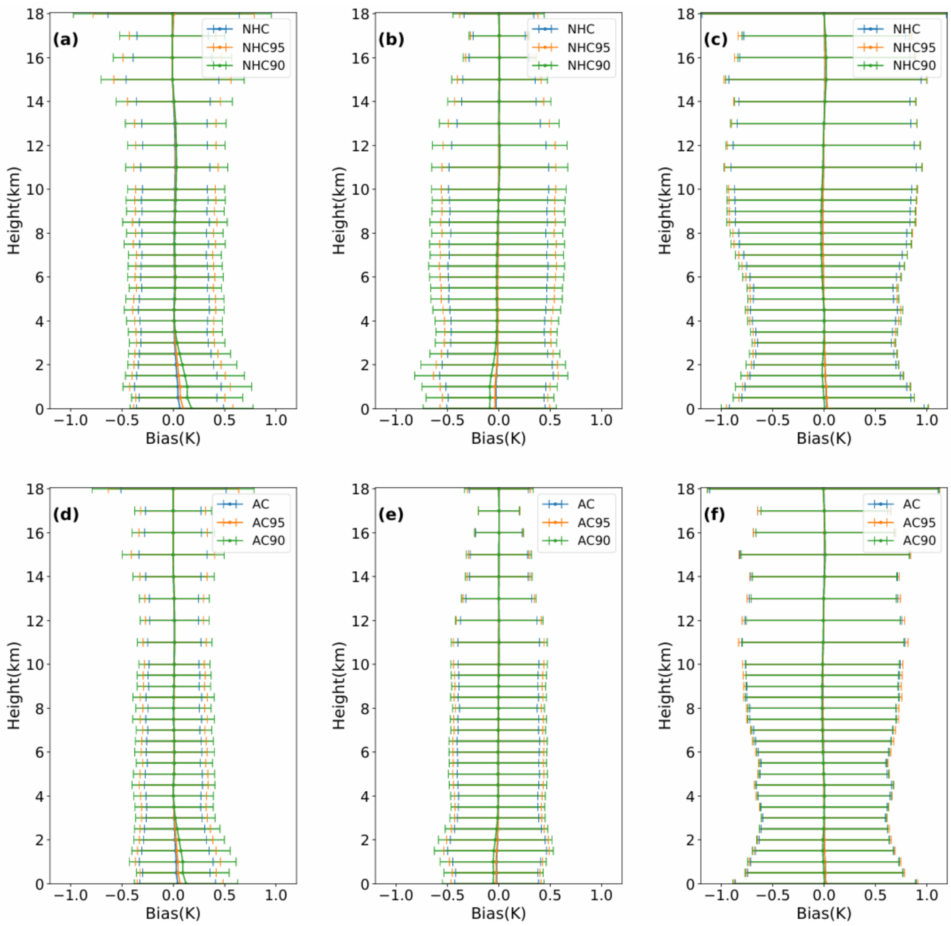

Figure 8. The statistical results of temperature profile retrieval errors for different channel configurations with only non-hyperspectral channels (upper row), and those

including hyperspectral channels (bottom row). Columns from left to right correspond to clear, cloudy, and precipitating conditions. Error bars indicate RMSE.