

Response to the Editor and Reviewers

Manuscript title: Development and validation of ARMS-gb v2.0: Extending fast radiative transfer modeling capability to all-sky conditions for ground-based microwave radiometer retrievals

Dear Editor and Reviewers,

We sincerely thank the Editor and the two reviewers for their careful assessment of our revised manuscript and for their constructive minor comments. We have addressed every remaining point and prepared a second revised manuscript.

The principal revisions are summarized as follows:

We added the requested methodological reference, clarified the treatment of hydrometeor temperatures between 273 and 275 K, corrected the notation and citations, and explained the choice of pressure layers in the idealized experiments.

We stated explicitly that the optical-property LUT was constructed from physical scattering calculations and is independent of the observational datasets used for evaluation.

We moved the instrument description and Tables 1 and 2 out of Section 2.1 and placed them together with the ERA5 data description in Section 3.1.

We redrew Figure 7 as time series of observed minus simulated brightness temperature and added a scene-classification bar for clear-sky, cloudy, and precipitation periods.

We removed the few data points with very high brightness temperatures from the specified channels in Figure 8, recalculated the regressions and statistics, and updated the corresponding results and conclusions.

Below we provide point-by-point responses to all reviewer comments. Reviewer comments are reproduced in italic font, followed by our responses in blue font.

Response to Reviewer 1

Comment 1:

lines 117 to 118, references should be give to " These single scattering properties are then integrated over a modified gamma size distribution to obtain bulk optical parameters".

Response:

We thank the reviewer for pointing out the missing reference. We added Petty and Huang (2011), which describes the modified gamma size distribution used to derive bulk optical properties. The revised sentence in Section 2.1 (Page 5, Lines 117–118) reads:

“These single scattering properties are then integrated over a modified gamma size distribution to obtain bulk optical parameters (Petty and Huang, 2011).”

The following reference has also been added to the reference list (Page 23, Lines 489–490): Petty, G. W. and Huang, W.: The Modified Gamma Size Distribution Applied to Inhomogeneous and Nonspherical Particles: Key Relationships and Conversions, Journal of the Atmospheric Sciences, 68, 1460–1473, <https://doi.org/10.1175/2011JAS3645.1>, 2011.

Comment 2:

lines 118 to 119, how to do with the case if the hydrometeor temperatures are ranged from 273 to 275 K?

Response:

We have clarified how this temperature interval is handled. Hydrometeor phase is determined by the input category. Liquid hydrometeors between 273 and 275 K use the liquid LUT values at 275 K, whereas solid hydrometeors remain represented by the solid LUT. The current version does not apply a separate treatment to melting particles. The following text has been added to Section 2.1 (Page 5, Lines 120–122):

“Hydrometeor phase is prescribed by the input category. Between 273 and 275 K, liquid hydrometeors use the liquid LUT values at 275 K, whereas solid hydrometeors use the corresponding solid LUT. Melting hydrometeors are not treated separately in the current version.”

Comment 3:

line 161, "refer to the phase function, the SSA. " should be written as "refer to the phase function and SSA, respectively".

Response:

We agree and have revised the wording as suggested. It now reads (Page 7, Line 155):

“refer to the phase function and SSA, respectively.”

Comment 4:

lines 188 and 193, the references should be given completely.

Response:

We thank the reviewer for identifying the incomplete citations. Both have been replaced with the complete author and year citation. The revised sentences in Section 2.2 (Page 8, Lines 182–183 and 186–187) read:

“The definitions of all symbols are consistent with those in Shi and Weng (2025).”

“The detailed derivations for both scattering and non-scattering layers are provided in Shi and Weng (2025).”

Comment 5:

lines 205 to 207, the reasons for setting cloud liquid water and rainwater at those pressures, or there are some references?

Response:

We have added the rationale for the pressure ranges used in the idealized experiments. In the U.S. Standard Atmosphere, the selected liquid and solid hydrometeor layers correspond approximately to 2–3 km and 5–8 km, respectively, and represent lower-tropospheric liquid clouds and precipitation and colder ice and snow layers aloft. The revised text in Section 3.2 (Page 10, Lines 216–218) reads:

“These pressure ranges correspond to approximately 2–3 km and 5–8 km, respectively, in the U.S. Standard Atmosphere. They were selected to represent lower-tropospheric liquid clouds and precipitation and colder ice and snow layers aloft in the idealized sensitivity experiments.”

Comment 6:

about the tests, if the evaluations to AMRS-gb v2.0 using the two measured dataset are in-dependent for the developing the LUT completely? If no, you should use some other independent dataset to evaluate them.

Response:

Yes. The two measured datasets are completely independent of LUT development. The LUT was generated from Mie and DDA scattering calculations, and neither observational dataset was used to construct or tune it. The two datasets therefore provide an independent evaluation of ARMS-gb v2.0. We have added the following sentence to Section 2.1 (Page 5, Lines 126–127):

“The LUT was constructed entirely from physics-based scattering calculations and is therefore independent of the observational datasets used for model evaluation.”

Response to Reviewer 2

General comment:

The manuscript has improved significantly with the revisions. However, there are still a few minor points that need to be considered before I recommend publishing the manuscript:

Response:

We thank the reviewer for the positive assessment of the revised manuscript and for the remaining constructive suggestions. We have addressed all three points as described below.

Comment 1:

The part which describes the instruments (Lines 124-130, as well as tables 1 and 2) should be taken out of section 2.1. It does not fit into this section, and needs to be placed elsewhere. It could be together with an introduction into the ERA-5 data that you are using.

Response:

We agree and have moved the instrument description and Tables 1 and 2 out of Section 2.1. They are now presented together with the ERA5 data description in Section 3.1, entitled “Ground-based microwave radiometers and ERA5 data” (Page 9, Lines 192–204; Tables 1 and 2). This section first introduces YKW-1 and YKW-2 and their channel settings and then describes the collocated hourly ERA5 atmospheric and hydrometeor profiles used in the simulations. Section 2.1 now focuses on the cloud particle absorption and scattering module.

Comment 2:

Regarding Fig. 7 (Time series of brightness temperatures), I would suggest to provide the differences between OBS and SIM (and not the absolute values). This would make the information much better visible for the reader.

Response:

We have revised Figure 7 as suggested. It now shows the time series of the difference between observed and simulated brightness temperatures (O–B) instead of the two absolute brightness-temperature series. This directly displays the magnitude and temporal variation of the simulation departures. A scene-classification bar above the panels identifies clear-sky, cloudy, and precipitation periods. The corresponding discussion (Page 15, Lines 321–332) and Figure 7 caption (Page 16, Lines 334–336) have been revised accordingly, and the revised figure is reproduced below.

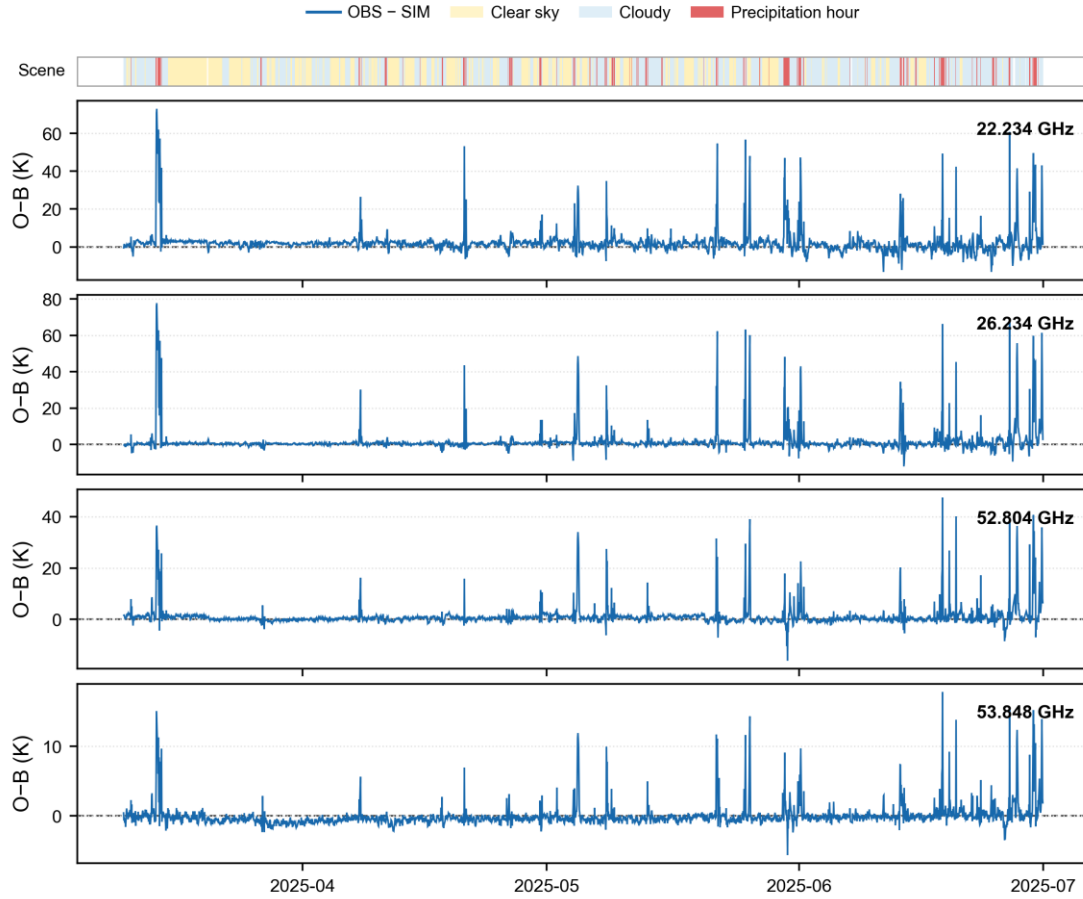


Figure 7: Time series of differences between observed and simulated brightness temperatures (O-B) for ARMS-gb v2.0 at four representative YKW-1 channels at Yan'an from 10 March to 30 June 2025. The scene classification bar indicates clear sky, cloudy, and precipitation periods.

Comment 3:

From looking at the scatter plots in Fig. 8, I would be very careful to draw strong conclusions (like ARMS-gb v2.0 is much better than the other models). There are only 1 or 2 data points for high brightness temperatures (esp. for the 6 channels in the upper and middle lines of the figure) that have a strong influence on the regression line.

Would you get a similar improvement in correlation if you exclude these upper data points? Please show the correlation without these very high outlier values.

Response:

We thank the reviewer for this observation. Following the reviewer's suggestion, we removed the few data points with very high brightness temperatures from the analysis for the channels between 22.234 and 30.000 GHz and for the 51.248 GHz channel. The regression lines and all statistics in Figure 8 were then recalculated from the retained samples.

The improvement remains after these high brightness-temperature values are excluded. At 30.000 GHz, R^2 increases from 0.55 for ARMS-gb v1.0 to 0.77 for ARMS-gb v2.0. At 51.248 GHz, ARMS-gb v2.0 reduces RMSE from 5.23 to 3.22 K and increases R^2 from 0.52 to 0.81 relative to ARMS-gb v1.0. At 22.234 GHz, the three models give similar R^2 values of 0.95, 0.96, and 0.95 for ARMS-gb v1.0, ARMS-gb v2.0, and RTTOV-gb, respectively. Thus, the recomputed results support the improvement at the hydrometeor-sensitive 30.000 and 51.248 GHz channels without relying on the few very high values.

We revised the paragraph preceding Figure 8 (Pages 16–17, Lines 337–352), Figure 8 and its caption (Page 18, Lines 354–357), the Abstract (Page 1, Lines 22–25), and the Conclusions (Page 21, Lines 406–412) to report the recalculated statistics. The revised Figure 8 is reproduced below.

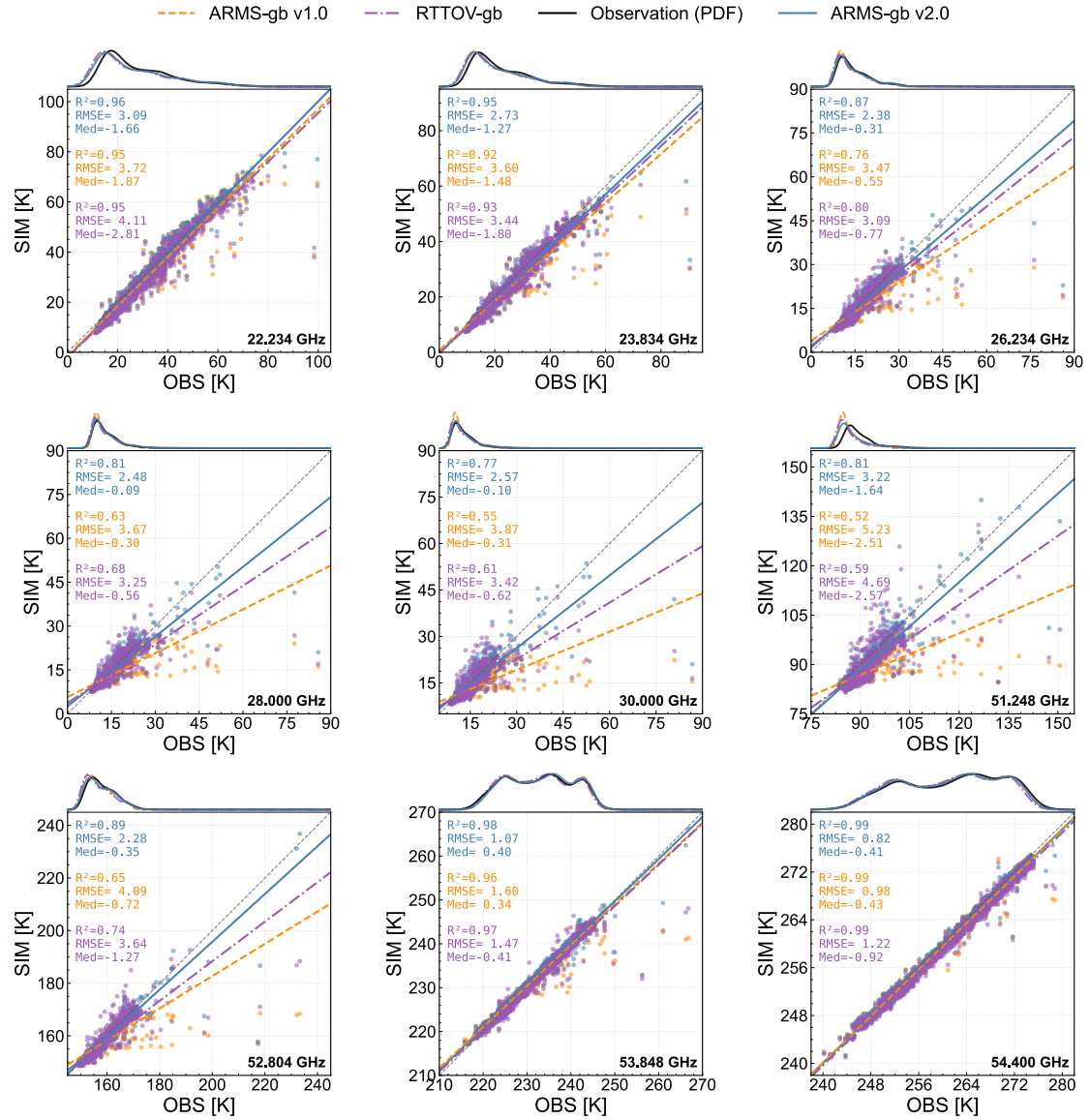


Figure 8: Scatter plots of observed versus simulated brightness temperatures at selected YKW-1 channels, comparing ARMS-gb v1.0, v2.0, and RTTOV-gb with regression lines and summary statistics. The few data points with very high brightness temperatures were excluded from the analysis for the channels between 22.234 and 30.000 GHz and for the 51.248 GHz channel. Marginal PDFs of observations (black) and simulations are shown above each panel.