

Reviewer Comment on *Improving thermodynamic profile retrievals from microwave radiometers by including Radio Acoustic Sounding System (RASS) observations* by Djalalova et al.

The submitted manuscript takes up on the ground-based remote sensing synergy approach of combining microwave radiometers (MWR) and RASS by applying a state-of-the-art physical retrieval approach. This is important, since MWR are known to show very accurate performance in temperature profiling in the lowest 500 m, whereas RASS are able to adequately capture the typical temperature inversion at the top of the atmospheric boundary layer (ABL) and thus, in theory, the synergy of both could lead to an improved temperature profile throughout the whole ABL.

Major points

- 1.) The way to showing the latter point above, however, is obviously severely hampered by the quality of the MWR data, most probably in terms of a TB bias. While the authors do show a bias correction applied to the MWR TBs, it is unclear whether this was done only for zenith observations or also at 15° elevation (Fig. 1). Here a detailed analysis is missing. If this manuscript is to be accepted for publication using real TB data, the reason for the biases shown in Figs. 6 c and f (black a grey lines) must be identified, discussed and corrected for.
- 2.) The paper shows hardly any quantitative discussion, which is necessary for a sound scientific analysis. Except for just a few passages, discussions of the figures are carried out only in a qualitative, rather unspecific manner. With respect to this, specifically the sections 3 and 4 should be thoroughly rewritten. E.g., avoid using “This might..”, “We believe...”, “seemingly”, “Differences”, “better” or “improve” etc. without referring to adequate statistical measures. A lot of the data is there in the XPIA data set and you can use to confirm, deny or to quantify your assumptions, respectively results.
- 3.) Because the authors write they could not apply any bias correction to the NN approaches, I strongly suggest omitting them from the paper. The comparisons are thus “unfair” and I do not see what benefit the reader has from including the NN retrievals when the actual goal is evaluating the MWR/RSS synergy potential that can be achieved with the PR. Instead, in all the corresponding figures, I would like to see the results of RSS-only PR, i.e. without including the MWR so the reader has an impression what these systems are capable of in a stand-alone manner.
- 4.) How did you deal with clouds, what about precipitation? Did you retrieve LWP simultaneously to temperature and water vapor? What influence do clouds have on the retrieval? I find no information about this throughout the manuscript.
- 5.) The sections describing microwave radiometry need more background and scientific accuracy.

Further specific points and questions to be addressed

- 1.) Abstract, last paragraph: It is not clear if the improvements described refer to the PR compared to the NN or the MWR+RASS combination compared to the MWR-only retrieval.
- 2.) Introduction: A description of the physical principle that allows temperature (& humidity) profiling (and LWP retrieval) from passive MWR observations is missing.

When doing so, please consider reformulating the advantages and disadvantages of the MWR retrieval methodology, because they are currently not scientifically sound. Be sure to differentiate how the frequency dependence and elevation angle dependence of TB can both lead to resolving the temperature profile in the vertical.

- 3.) Line 109: MWR don't "apply radiative transfer equations and neural network retrievals..." – please reformulate.
- 4.) Line 115: Please make clear what you mean with "deep layer of the atmosphere".
- 5.) Section 2.1, lines 203-204: The purpose of using observations at 15° elevation is not to "average out small scale horizontal inhomogeneities of the atmosphere" but to obtain TB observations at different optical depths.
- 6.) Section 3.1, lines 280-286: Why does the Y vector and the error covariance matrix contain both "zenith" and "zenith+oblique" components. If I understand correctly, you can choose to use only zenith observations and add the off-zenith (=oblique) TBs to improve the retrieval? So then should it not be "zenith" and "oblique"? Please clarify.
- 7.) Line 310: Do you mean the covariance between the uncertainties of the measurements?
- 8.) Section 3.2: There seems to be a non-consistent use of terminology. Please use "uncertainty" only in the sense of random uncertainty and distinguish it clearly from systematic offset (=bias).
- 9.) Lines 323-324: erroneous, please reformulate in a consistent manner
- 10.) Line 327: The 30 GHz channel is not predominantly water vapor, but liquid water sensitive.
- 11.) Lines 328-330: "The random uncertainty in brightness temperature was calculated as its standard deviation during clear sky times and for this channel is approximately 0.3 K": Why is this calculated standard deviation related to the TB uncertainty? Over what time window did you average? What about water variability in the atmosphere during the calculation time? Why actually did you calculate this standard deviation and where do you use it in the course of your study?
- 12.) Lines 332-333: How were the clear-sky days selected?
- 13.) Lines 333-334: How did you calculate the bias?
- 14.) Before line 358: a description and a quantitative discussion of the S_a and S_e matrices applied needs to be given before going on describing retrieval results.
- 15.) Lines 425 and following, referring to Fig. 3: quantitative argumentation missing and VRES "jumps" in Fig. 3 are not discussed
- 16.) Section 4.1, lines 469-471: unspecific sentence, please reformulate
- 17.) Fig. 5: How many cases are used for the statistics, how many are clear-sky, how many are cloudy sky? How did you deal with cloudy cases in general?
- 18.) Fig. 8: Can you derive meaningful statistical measures such as RMSE from only 15 cases?

- 19.) Fig. 9: The MWRz2sigma449 performs best compared to the other retrievals. This retrieval relies on an increase in the MWR uncertainty, which was chosen in an arbitrary manner. This choice should be thoroughly justified and set into context with the performance of the 449-only retrievals which I would like to see (see “Major points” above).
- 20.) Section 4.4, lines 683-686: This sentence is formulated in a general, rather unspecific way and could be given without any of the studies conducted here.

Technical comments

- 1.) Figures are given in rather low resolution, a higher one would have been nice to be able to better interpret the results.
- 2.) Equation fonts appear in a non-standard, unorganized way.
- 3.) In general: please write K or °C, but not °K.
- 4.) Section 3.1, lines 280-286: Numerate all equations, be consistent with equation fonts and text fonts, be consistent with variables (i.e. L, LWP), explain all variables (and indices) in the text. Please be neater.
- 5.) Line 348 and following: use a new sub-section, the paragraphs are not related to “Bias-correction” anymore
- 6.) Section 3.3, lines 415-421: move text to Fig. 3 caption