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Comment on amt-2021-246

Anonymous Referee #2

Referee comment on "Radiation correction and uncertainty evaluation of RS41 temperature sensors by using an upper-air simulator" by Sang-Wook Lee et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2021-246-RC2, 2021

Review of "Radiation correction and uncertainty evaluation of RS41 temperature sensors by using an upper-air simulator" by Lee, et al.

Summary:

The manuscript by Lee et al. studies the solar radiation influence on temperature measurements by the Vaisala RS41 radiosonde using the Korean KRISS Upper Air Simulator environmental chamber.

The authors characterize the radiation error of this radiosonde as function of pressure, temperature, ventilation speed, and sensor orientation and tilt. They discuss the uncertainties of their measurements and show a rough comparison with the operational correction of this effect built into the Vaisala sounding system software.

The setup of their chamber and the measurements done as part of this study are excellent. However, the interpretation requires significant refinement, especially since they are providing a quantitative analysis of their measurements, which should eventually become applicable to sounding operations.

I would recommend publication of this manuscript only after major revisions, for which I provide detailed comments and suggestions below.

Major comments:

I will start from the end, since this is where this study potentially may have the most important significance.

A) Application to real atmospheric observations and comparison to the Vaisala radiation correction table

The largest weakness of this manuscript is that the measurements as such cannot be easily applied to sounding operations, since a substantial amount of interpretation of the measurements is missing. This is best demonstrated by the comparison with the Vaisala operational radiation correction table, which is presented, but discussed in only one sentence.

The Vaisala radiation correction table is applied in a significant fraction of soundings globally. The study here has the potential to support or improve this table. Unfortunately, this is not done and the reader is unable to decide, whether any of the measurements that were presented are in contradiction or support of the Vaisala table, or what factors need to be considered to make such a comparison. To be able to do so, some elements of the comparison have to be clarified. First, the solar angle used by Vaisala is not the same as the incident angle used by the authors. This needs to be clarified. Using their measurements, it should be possible to create a table similar to that by Vaisala. This requires describing the tilt of the sensor boom on the radiosonde in operational use and making some assumptions about the pendulum and rotation movement of the sonde and applying their measurements to those. Second, the solar flux requires much more discussion. The radiation correction depends on the total flux, not just the direct solar flux. Some discussion about albedo and cloud cover is essential before a comparison can be done. It may not be possible to provide a direct validation of the Vaisala table, but at least the factors that contribute must be described in much more detail. The authors very briefly mention an effective solar flux and should expand this discussion greatly.

B) Uncertainties and their interpretation

The uncertainty discussion is very important, but can be much improved. Table 4 is just an overview of the measurement ranges and a little confusing here. It could be deleted without loss. The discussion of the uncertainty in pressure and temperature measurement can be deleted as well. As Table 9 shows, this uncertainty does not contribute to the final result, which is immediately obvious given the weak dependence of the radiation error as function of pressure and temperature.

The uncertainty in the ventilation speed requires more discussion. The table lists a stability, but does not define to what it refers. It also lists a spatial gradient without specifying over which distance it applies. Most importantly, some discussion about the flow regime would be very useful. For laminar flows such as are more likely at low pressures, there should be significant velocity gradients from the walls inward. This is not discussed. If present, such gradients could explain the tilt results shown in Figure 6.

The uncertainty in irradiance lists the spatial gradient as the largest source. Again, gradient over what distance is meant here? It could be mentioned that the uncertainty of the radiation source is a negligible contribution compared to the lack of knowledge of the radiation field in true atmospheric soundings. This could be contrasted. In their conclusion, the authors indicate that they are working on a two-thermistor measurement with different emissivities. This discussion should be expanded and reference to the multi-thermistor work done by Schmidlin and others could be provided for reference.

The uncertainty due to sensor rotation seems to be larger than the measured signal, which questions the uncertainty derivation; in particular since there clearly is a signal present.

The final uncertainty (Section 4.10) is most likely pressure dependent, but no such pressure dependence is given. Whether or not there should be a pressure dependence would certainly require some more explanation.

C) Rotation and tilt discussion

The discussion of rotation and tilt is rather sparse and could provide much more detail. The authors do not mentioned that the sensor boom of the Vaisala radiosonde is tilted from the vertical in operational use, which justifies their tilt measurements. I assume the 27 deg tilt used refers to the tilt of the sensor boom in operational use, but this has not been said. The tilt in real world soundings also depends on the pendulum motion of the radiosonde such as described by Dirksen et al. (2014). Thus, the sensor tilt is a little more complicated.

It is also important to point out, that the sensing element of the Vaisala radiosonde is a lengthy device, where tilt and rotation are likely to play an important role. Other radiosondes using spherical bead thermistors would be much less affected by tilt and rotation.

Measuring the temperature variation during rotation at 5 s is questionable, when the resolution of the data system is at best 1 s. Could it be that the minimal change at this speed is due to the inability to resolve the variations in time?

The authors speculate that mostly conduction from the sensor boom is responsible for the temperature variations during rotation. This is a reasonable assumption, but may require some more explanation and possibly an additional figure showing the geometry during rotation. Since the actual temperature sensor is in parallel with the axis of rotation, no change in surface area is expected here. However, the exposed surface area of the sensor boom changes significantly, which justifies the assumption. This should be shown explicitly. The temperature increase due to conduction appears to be small compared to the temperature increase due to direct irradiation of the sensor. This could be expanded as well.

D) Underlying physical model

All fit equations have the form shown in Figure 1. Is there a physical model that justifies this equation? If not, then this fit equation may be not be the most suitable, since it forces a split of the measurements into two pressure regimes. Using a single 5^{th} order (or even 3^{rd} order) polynomial of delta T over LOG P could provide a single fit over the entire pressure range from 5 to 500 hPa with similar results.

In addition, the fit equation provides a constant radiation error between 500 and 1000 hPa, which is somewhat surprising and in contrast to the model underlying the Vaisala table. A polynomial fit could improve here.

The polynomial fit would retain the temperature dependence at low pressures, which is an interesting result of their study.

Minor comments:

The authors could also make a statement how they expect the radiation correction to behave at speeds lower than 4 m/s. Some research groups fly radiosondes at lower ascent speeds to gain higher vertical resolution and would be interested in seeing the effect of the slower ascent.

In the introduction, the authors should also mention that the first approach to reducing the solar heating effect is applying highly reflective coatings. This is particularly relevant, since they later refer to thermistors with different emissivities.

The authors could provide a discussion about the homogeneity of the temperature in their system, in particular the wall temperatures versus the air temperature, given that they have a very strong heat source.

In Section 3.5, it is not perfectly clear, whether the authors varied the radiative flux or not. I assume that they did not, but rather do make the argument that the results should scale with the flux. This is reasonable, but could be made a little clearer.

The use of the factor SQRT(3) is mentioned repeatedly, but never justified. A reference to GUM would be useful with a brief explanation of what this factor does. This should be done only once at the beginning of the uncertainty section and other repetitions could be deleted.

The arrows in Figures 1a and 1b should be a lighter color to make them better visible. The photo in Figure 1a could be brightened. The direction of the airflow should be indicated.

In the legend of Figures 2 through 4, for simplification, the symbols and dashed lines should be combined (e.g.: --o--). The caption could then explain that the dashed lines show the fit and the symbols the actual measurements.

Figure 2: If a 5^{th} order polynomial was used, then panels a) and b) could be combined to show the results over the entire pressure range using a logarithmic pressure axis.

Figure 4: The indications of the different slopes should be removed from the actual Figure and the values could be added in a brief discussion either in the caption or in the main text.

Figure 6: The fat arrows should be removed. What they are supposed to indicate could be explained in the caption.

The language could be checked by a native speaker for more unusual expressions used by the authors.