Review of manuscript “Laboratory characterisations and intercomparison sounding test of dual thermistor radiosondes for radiation correction” by Sang-Wook Lee, et al., AMT-2021-343

General

The manuscript presents a method to estimate and correct the solar radiation error of radiosonde temperature measurements, using a dual thermistor radiosonde. Accurate in situ measurements of temperature profiles by radiosondes constitute a highly relevant topic, for example for climate monitoring, and reference-quality temperature measurements by radiosondes are of high demand.

The method presented in this paper relies on the temperature difference between a black-coated and an aluminum-coated thermistor to derive the effective radiation field which is used in the temperature correction of the Al-coated temperature sensor. The advantage of this method is that it does not rely on modeled assumptions on the radiation field or sensor properties, but aims to measure it directly. With this approach, the authors continue earlier pioneering work by e.g. Schmidlin 1986.

The novel aspect is that the approach relies on purely experimental sensor characterisation in terms of sensitivity to radiation. This is different from previous studies using dual or multiple sensor techniques which are based on solving multiple heat balance equations and therefore require a number of assumptions or estimates with regard to sensor dimensions, material properties and other parameters. Although there are not many easily accessible publications on multi-sensor radiosondes (Schmidlin, Luers, and references herein), the authors should refer to these in their study.

The manuscript is clearly structured. However, it reads as a straightforward and rather technical description with a strong emphasis on the metrological aspects, in particular uncertainties. Although this should of course make up a significant part, more motivation, explanation or interpretation would be appropriate or even required in several places with regard to the methods and results (see detailed comments) in the light of the physical processes taking place. This would not only ‘loosen up’ the text but may help understanding the effects and improve the potential impact in the radiosonde data user community.

Detailed comments

Abstract:

L9: The white sensor is in fact coated with Aluminum, and should be referred to as such here. The classification "white" can be used later in the manuscript.

The abstract should mention the ratio of the heating rates of the white and the black sensors (which is 1:3), see e.g. Schmidlin (1986)

L12-15: Think of a different phrasing: more motivating instead of just list a number of facts.

Introduction:

L32: It may be referred to the co-location issue and flight trajectories of balloon soundings.

L57: Remove “…as previously reported (Lee et al.)”

L72: “freezing” -> “climate”

Section 2.2:

The authors should reference to the work of Francis Schmidlin (NASA Tech. Paper 2637, 1986) on the multiple thermistor radiosonde.

Section 3.1:

L114-115: The exact procedure for the calibration and characterisation measurements is unclear at this point. Add a sentence that these will be discussed in detail in the following sections.

L115: “via” -> “due to”

L116: “…to include the differences in the sensitivities of the individual thermistors in the radiation correction.”

Fig. 2 (c): Which parts of the sensor boom beyond the thermistors are irradiated?

Section 3.2:

Obviously, spatial temperature inhomogeneities within the calibration “box” dominate the calibration uncertainty (Fig. 3 (b)), which to a wide extent dominates the overall uncertainty of the corrected temperature (Fig. 9 (c) and (d)). Could this be reduced, e.g. through suitable ventilation?

L127: “…by the five…”

L129: “gradient” -> “differences” or “deviations”

L131: Between “polynomial equation” and “yields” you may insert “, i.e. the inclusion of a quadratic term, which is not present in the Steinhart-Hart equation, “

L132: “…, the Steinhart-Hart equation is modified…”

Section 3.3:

L144-146: Make more clear that the effect of the temperature of the radiosonde electronics board on the thermistor resistance (or temperature) measurement is investigated here.

Fig. 4(b): Use symbol for unit; don’t use “k” and “M” for x-axis labels of resistance; Caption: “… (c) Residual after conversion of resistance to temperature as function of temperature.

L155: What is meant by “roughly distributed”?

Section 3.4:

The first paragraph should be worded more clearly and more precisely. E.g., L158: “… the unit difference in terms of the correction value.”: Does that mean something like "sensitivity to irradiation and therefore the amount of radiation correction may vary for individual radiosondes, presumably related to the production process of the thermistors..."?;

L161: “Irregularities in the construction of the leads connecting sensor and boom…” It is interesting that these variations in the properties of the sensors, such as e.g. its diameter, have such a big influence. The authors should discuss this in more detail. A helpful reference may be de Podesta et al. (2018) (DOI: 10.1088/1681-7575/aaaa52).

Second paragraph:

What irradiance is applied? What are the conditions with regard to air pressure and ventilation in the RRT? Is the pump used to vary the pressure, or to create an airflow, or both? If there is no significant ventilation I would expect a certain variation of the results from that, because the cooling efficiency should strongly vary with air flow at low or vanishing flow rates. That might at least partially explain the distributions in Figs. 5 (c) and (d). If the ventilation is controlled, is it adjusted similar to what is used in the UAS (~5 $m \cdot s^{-1}$)?

Fig. 5 (b): Rad. warming of Al-coated is more than one third of that for the black thermistor in Fig. 5 (b), and the absolute value of ~1.2 K in the example seems unexpectedly large at a first glance (is that a typical example?). Does that mean that the reflectivity of the Al-coating is not that close to one, but say ~0.7 or so?

Quantitative information on irradiance (is it the 960 $W \cdot m^{-2}$?), pressure and ventilation for the RRT tests would be helpful to better assess or classify the results.

Is there a test to see if the two thermistors influence each other (e.g. via heat conduction)? This could be assessed by selective irradiation.

How are the T-differences extracted/evaluated from the data in Fig. 5 (b)?

Section 4.1:

First paragraph: (How) Is the angle of the sensor boom, i.e. the irradiation angle and boom orientation, and the angle relative to the air flow taken into account in the UAS measurements?

L190: Better: "… with the fitting coefficients being functions of T_W_on…"

L193/194: Isn't the point here that the effective long-wave cooling is *different* for the two thermistors, according to the different emissivities, whereas the SW-absorption does not depend on T?

Eq. (2): What motivated the exponential functions as fitting model?

L216: The radiation flux of 960 $W \cdot m^{-2}$ is known. Is the (re)fitting done for the purpose of estimating uncertainties in terms of the residuals?

Eq. (10): Is the equation valid only for 7-100 hPa and 4-6.5 $m \cdot s^{-1}$?

Fig. 6 (also Fig. 7): The trend of the data points is difficult to see at low p; consider using a logarithmic scale.

Section 4.2:

Eq. (19): Validity range with regard to p and v?

L234f: Please discuss the influence of the temperature dependence of the efficiency of convective cooling, i.e. at low temperatures the thermal conductivity of air decreases leading to an increase of the radiative heating of the temperature sensor.

Section 5:

At what time was the daytime sounding performed? What was the cloud situation?

Add more discussion on what is observed in the plots in Fig. 8. The reconstructed solar (ir)radiance decreases with altitude in the stratosphere. This is opposite to what is expected. Please compare the reconstructed radiation profile to RTM calculations, and discuss the differences. See for example Philipona et al 2020 (doi: 10.1127/metz/2020/1044) for in situ measurements of the radiation profile.

In particular, it could be discussed more how the different long-wave backgrounds in the experiments and in the situations during the real soundings may influence the results, or what potential systematic errors of the radiation correction may be in connection to this.

Can it be assumed without reservation that the sensitivity of the thermistors is the same with regard to long-wave and short-wave radiation (wavelength-independent emissivity/absorptivity)?

Mention in the caption of Fig. 8 that the effective irradiance is calculated using Eq. (9) (or 10).

Section 6.2

L340/341: "enhance" -> "improve" or "reduce"; It should be discussed here (or in 3.2) whether and how the calibration uncertainty, which is obviously due to air temperature inhomogeneities within the calibration volume, can be reduced.

Section 6.3

Fig. 9 (f): The >0.2 K offset at ~16 km is striking, please comment on this.