Answer to the Referee #2 – Manuscript tc-2024-1708

General comment:
This manuscript is a reappraisal of melting calorimetry for the measurement of liquid water in wet snow. Both melting and freezing calorimetry are compared. The work achieved is certainly valuable and worth of publication.

We thank the reviewer for his thoughtful comments and valuable suggestions, which will undoubtedly enhance the quality of our manuscript. Our responses are reported in blue in the following.

However, the paper should be more concise. For instance, the part of Section 3 before Subsection 3.1 is not necessary because it is repeated later. And the figure captions should simply be descriptions of the figures needed for understanding.

We agree that the paper should be more concise. Interestingly, our original intent was a short communication that addressed two key points clarifying the Colbeck's claims about the calorimeter inaccuracy and providing a clear field protocol for consistent measurements. However, as we delved deeper using the calorimeter, we uncovered broader issues related to its use in existing literature. This led us to create a more in-depth review and potential correction of the current state of the art for LWC estimation using calorimetry. With this round of revision we aimed at eliminating redundancies, avoiding repetition, simplifying figure captions, and reorganizing some sections (see responses to review 1) of the paper for improved readability. This allowed us to reduce the length of the manuscript and make it more concise.

Main comments:
My main concern is related to the key quantity, the volumetric liquid-water content, first mentioned in the abstract, and later at several places of the manuscript, e.g. Line 664. Its definition is the volume fraction of liquid water for a given test sample of snow, $\theta_v = V_v/V_s$ *, where* V_v *is the volume of liquid water and* V_s *is the volume of the snow. In Table 1, the respective quantity* θ_w *first appears as a percentage of liquid water "for snow volume", whatever this means. A few lines later in this table,* θ_w *appears as the mass fraction of liquid-water mass to total snow mass, independent of the snow volume. And this is the quantity required in the heat-budget equation (1). To get the volumetric liquid-water content,* θ_w *must be multiplied with the ratio of snow density to density of liquid water. This ratio only reaches 1 when all snow is melted. Otherwise, it is smaller than 1. The dielectric sensors used today for the measurement of the liquid-water content are based on* θ_v*, , not* θ_w*, see e.g. the intercomparison paper of Denoth et al. (1984.). It appears that the authors do not distinguish between the two quantities. And this is a mistake.*

We thank the reviewer for identifying this error that could have caused significant confusion. This oversight escaped our initial proofreading. The correct form in table I and L185 is

$M_{W\theta\omega} = \theta_\omega M_s \rho_s / \rho_w$. In general, we are following the for all the our notation the one proposed by the international classification of snow, where θ_w is used for both volume and mass (see Appendix D pag. 53). Indeed, we recognize there are two main definitions adopted: one using the mass (e.g., CROCUS, calorimetry) and one using the volume (e.g., SNOWPACK, dielectric probes). Interestingly enough some years ago we started a discussion on how SMRT should specify the liquid water content within the community, since it was specified with the fractional volume of water with respect to ice, a convenient quantity in electromagnetism, but not for a snow scientist. These are all "liquid water content" but expressed in different units. While converting between the different definitions is straightforward, distinct symbols should be used for clarity. Additionally, it is crucial to consider how errors propagate under each definition. Since our research primarily focuses on the volume fraction of liquid water within snow, particularly due to our interest in radar and dielectric sensors, we consequently expressed θ_w in volume fraction (%) in this paper. We have adopted the notation recommended by the international classification of snow for consistency i.e., θ_w but it has to be distinguished from the percentage of mass liquid water content. Thank you for highlighting this crucial point, as it could have led to misunderstandings.

Please also note that "Mass of liquid-water fraction" (in Table 1, and near Equation (1)) is incorrect. A mass cannot be a fraction, because mass has units of kg, whereas a fraction is a number.

Thanks for pointing out this. We indeed meant the "percentage of mass liquid water content" but somehow we contract this long form in an incorrect way. This will be changed.

Another remark to Table 1 is to the description of the snow temperature, Ts. The given temperature is the melting temperature of pure ice, and indeed, this temperature is found throughout in wet snow (if salt or other ionic impurities are not involved). This value is not "by definition", but because water and ice are in good contact in wet snow, and heat conduction forces ice and water to be at the same temperature in wet snow.

We appreciate the reviewer for highlighting this critical point. By stating "by definition," we intended to emphasize that our calorimetric formula is strictly applicable to wet snow at 0°C. Our aim with the "by definition" statement was to caution users about the calorimetric applicability to prevent invalid measurements (e.g., Mavrovic et al. (2020)). We will clarify this point further in the revised manuscript and delete "by definition".

Small details:
Line 107: clarifiy ... "technique accuracy"....

Thank you for pointing out this issue, we will change the sentence as: "This provides a more rigorous understanding of the technique reliability, quantifying the measurement uncertainty, so that the application of melting calorimetry in the future is correct and sound from the critics".

Line 118: correct ... "do not account not"...

Thanks for pointing out this error. Corrected.

Line 119: "Something that was never attempted in the past." Please be careful with such statements. You cannot be sure.

Thanks for pointing out this issue. This is to our knowledge. We removed this statement as suggested.

Line 143; ..."create an adiabatic environment, ensuring ideal heat exchange"... This sounds contradictive, because there is no heat exchange in adiabatic processes. Perhaps you mean that there is no heat exchange between the environment and the calorimeter.

Thanks for pointing out this aspect that may generate confusion. We change this sentence as follows: “The calorimeter is designed as an insulated container to maintain a given temperature and create an insulated environment from the outside, ensuring ideal heat exchange between the snow sample and the melting or freezing agent”.

Line 257: Change "The uncertainty... as the squared root" to "The uncertainty... as the square root"...

Thanks. Modified.

Line 430: Change "temperature spectrum" to "temperature range".

Changed.