

Response to Reviewer 2, egusphere-2026-507:  
“Estimation of wet radome and rain induced attenuation in cloud  
radar observations”

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Thank you to the editor and the two reviewers for the constructive feedback offered. In the following, reviewers' comments are given in italics with the authors' responses in normal text. Updated or new text is copied here where appropriate in **bold**. The full set of differences in the manuscript are attached in the tracked-changes document.

## Reviewer 2

*General Comments:*

*Please provide a clearer description of the radar radome, including its type, geometry, and material properties, since these characteristics directly affect wet radome attenuation.*

The reviewer raises an important point, as the radome characteristics influence the magnitude of wet-radome attenuation. We have expanded the instrument description to provide additional information on the radome design and construction. The radar is protected with an oval-shaped radome consisting of a foam-like material with a water-repellent outer coating. Unfortunately, more detailed information on the radome composition and physical properties is not available, as these specifications are not provided by the manufacturer. This clarification has been added to the manuscript.

**”The radar is protected with an oval-shaped radome constructed from a foam-like material with a water-repellent outer coating. The radome protects the antenna from environmental conditions while minimizing signal losses under dry conditions. During rainfall, however, water can accumulate on the surface and penetrate the radome material, resulting in additional attenuation of the radar signal. More detailed information on the radome material properties is not available, as these specifications are not provided by the manufacturer.”**

*The disdrometer observations are used to estimate radome attenuation, but the detailed comparison procedure is not sufficiently described. For example:*

- o Which radar height gates are used in the comparison?*
- o How is the radar volume matched with the surface disdrometer observations?*
- o What possible factors could contribute to differences between radar and disdrometer observations besides attenuation?*

We agree that additional details on the radar–disdrometer comparison procedure improve the transparency of the methodology. To address this point, we have expanded the relevant sections of the manuscript to clarify that the comparison is performed using the third radar range gate (153 m above ground level), as the lower gates are more strongly affected by near-field and parallax-related uncertainties. We have also clarified that the disdrometer-derived radar observables are computed from the measured DSD using PyT-Matrix scattering calculations, enabling a direct comparison with the radar observations. In addition, we now provide a more detailed discussion of factors that may contribute to differences between radar and disdrometer observations, including sampling uncertainties, variability of precipitation properties with height, fall-streak effects, and precipitation growth or evaporation processes (lines 456-461). These clarifications have been incorporated throughout the methodology section.

*Many radar-related details are mentioned throughout the manuscript, but the discussion is often brief and fragmented. It would improve readability if the relevant sources of uncertainty and correction factors were consolidated into a dedicated discussion section*

The reviewer raises a valuable suggestion regarding the organization of the manuscript. Rather than introducing a separate discussion section, we chose to expand and reorganize the discussion within the existing sections so that sources of uncertainty, correction factors, assumptions, and limitations are presented alongside the relevant methodology and results. We believe that this approach improves readability while maintaining a clear connection between the methods, results, and their interpretation, and avoids unnecessary duplication of material.

*Wet radome attenuation and rain-path attenuation should be discussed more clearly as two separate physical processes, including their assumptions, limitations, and correction methodologies*

This comment highlighted the need to more clearly distinguish between wet-radome attenuation and rain-path attenuation throughout the manuscript. In the revised version, we have expanded the descriptions of both processes and clarified their respective assumptions, limitations, and correction methodologies. Wet-radome attenuation is treated as attenuation caused by water accumulation on and within the radome and is estimated from the difference between radar-observed and disdrometer-derived reflectivity. Rain-path attenuation is treated as attenuation within the precipitation column and is estimated from disdrometer-derived specific attenuation under suitable atmospheric conditions. Related sections throughout the manuscript have been revised to improve the separation between these two processes and to provide a more consistent description of their retrieval methods and limitations.

*Several factors affecting radar–disdrometer comparison are mentioned in the Introduction (Lines 45–57) and later in Lines 130–146, including near-field effects, parallax errors, evaporation, and pointing errors. Please consolidate these factors and clearly indicate which effects are explicitly addressed in this study and which are not.*

We agree that the discussion of the factors affecting the radar–disdrometer comparison was fragmented between the Introduction and the methodology section. The purpose of the Introduction is to provide a broad overview of the challenges associated with comparing radar and disdrometer observations, including differences in sampling volume, measurement altitude, evaporation, and collision–coalescence processes. The more detailed assessment of near-field effects, parallax errors, and potential pointing errors is presented later in the manuscript.

To improve clarity, we have revised the Introduction to distinguish between the factors considered in the general discussion and those explicitly assessed in this study. Near-field effects, parallax errors, and residual pointing errors are examined in detail and are used to motivate the use of the third radar range gate and above in the subsequent analysis. The potential impact of evaporation and collision–coalescence growth is also evaluated. Other factors are acknowledged as possible sources of uncertainty but are not explicitly corrected for. The revised text now better links the introductory discussion to the detailed analysis presented later in the manuscript.

**Added to the lines 45-57: "In addition, near-field effects, parallax errors, and residual pointing errors may influence the lowest radar range gates. The impact of these processes on the radar–disdrometer comparison is also evaluated in this study."**

*The manuscript would benefit from a clearer explanation of the assumptions underlying the rain-path attenuation retrieval. In particular, please clarify under what atmospheric conditions the method is expected to work reliably.*

The reviewer highlights an important aspect of the methodology. In the revised manuscript, we now state more explicitly that the rain-path attenuation retrieval is intended for stratiform precipitation below the melting layer, where the surface-derived DSD is representative of the precipitation column and attenuation is the dominant cause of reflectivity changes with height. We also identify situations in which the method may become unreliable, such as the presence of embedded cloud layers associated with seeder–feeder processes or substantial vertical variability in precipitation microphysics. To improve clarity, related sections throughout the manuscript have been revised to provide a more consistent description of the assumptions, applicability, and limitations of the retrieval method.

*Specific Comments:*

### **Introduction and Background**

*Line 23: The manuscript mentions attenuation in the melting layer in the Introduction, but this topic is not discussed further. Does the melting layer affect the radar–disdrometer comparison or attenuation retrieval in this study?*

We thank the reviewer for this comment. The melting layer is not directly relevant to the analyses presented in this study and therefore is not discussed further. It was mentioned in the Introduction because, in general, attenuation from rain, the melting layer, and the radome must be considered when retrieving ice cloud properties from radar observations. However, as stated in line 46, "The objective of this study is to estimate radome and rain-path attenuation at temporal scales of one minute". Consequently, melting-layer attenuation falls outside the scope of the present work and has already been investigated in detail by Li and Moisseev (2019). Furthermore, the melting layer does not affect either the radar–disdrometer comparison or the attenuation retrieval presented here. The observations used in this study are obtained at and approximately 153 m above ground level, and the attenuation correction is applied only below the melting layer.

*Lines 49, 54, 57: Please clarify what is meant by "computed radar retrievals."*

We agree that the phrase "computed radar retrievals" was ambiguous. We have revised the text to clarify that this refers to radar-equivalent quantities (e.g., reflectivity factor, rainfall rate, and specific attenuation) that are calculated from the disdrometer-derived drop size distributions. We added the following sentence:

**"Specifically, the observed DSDs from the disdrometer are used to estimate radar-observable quantities, including the reflectivity factor ( $Z$ ), rainfall rate ( $R$ ), and specific attenuation ( $A_i$ )."**

*Lines 65 and 72: These statements appear somewhat repetitive and could be consolidated.*

We thank the reviewer for pointing this out. We agree that these statements were unnecessarily repetitive. The text has been revised and consolidated to remove the duplication and improve the flow of the paragraph. Small parts are updated in the first paragraph of section 2.

**Lines 65-69: "The method is illustrated on data collected at the ACTRIS cloud remote sensing station in Hyytiälä, during rain events recorded in the years 2022 and 2023. The method is illustrated on two case studies. One case is selected to have minimal radome attenuation and one case shows strong radome attenuation."**

**Lines 71-74: "This study is based on measurements collected at the University of Helsinki Station for Measuring Ecosystem-Atmosphere Relations (SMEARII) located in Hyytiälä, southern Finland (61.844°N, 24.287°E) Hari and Kulmala 2005. As an ACTRIS cloud profiling station, SMEARII is equipped with a set of collocated standard instruments consisting of a disdrometer, ceilometer, 94 GHz cloud radar, two precipitation gauges, weather station, and microwave radiometer."**

*Line 65: Two chirp modes are mentioned. Besides of range difference, what are other setup difference between the two mdoes Which chirp configuration is used in this study?*

We appreciate the reviewer’s comment. We assume the reviewer is referring to line 85 (rather than line 65). In addition to their range coverage, the first and second chirps differ in their Nyquist velocities and Doppler velocity resolutions. To make this clearer, we have expanded the instrument description to include these parameters. We have also clarified that both chirps are utilized in this study, as the proposed method focuses on rainfall below the melting layer and therefore uses radar observations from the altitude ranges covered by the first and second chirps.

”The first chirp is used for measurements below 996 m with a range resolution of 25.5 m, a **Nyquist velocity of  $10.7 \text{ ms}^{-1}$** , and a **Doppler velocity resolution of  $0.021 \text{ ms}^{-1}$** . The second chirp covers ranges from 996 m to 3577 m **with the same range resolution, a Nyquist velocity of  $5.1 \text{ ms}^{-1}$** , and a **Doppler velocity resolution of  $0.020 \text{ ms}^{-1}$** . The temporal resolution of the radar observations is 3.35 s.”

### Disdrometer Measurements

*The following description is confusing:*

*“The lowest and highest measurable range of drop sizes measured for liquid precipitation ranges from 0.2 mm to 8.0 mm... The minimum detectable drop size is 0.312 mm...”*

*Please clarify the difference between:*

*o measurable drop size range, and*

*o minimum detectable drop size.*

*Why are these values different?*

The reviewer raises a valid point. The original wording did not clearly distinguish between the nominal size-class range defined by the instrument and the effective detection limit. While the Parsivel data are categorized into predefined size classes extending down to 0.2 mm, the first two size classes are below the instrument’s minimum detectable drop size. Consequently, the smallest reliably detectable drop size is 0.312 mm (class 3). We have revised the text to clarify this distinction and avoid potential confusion.

”These measurements are subsequently categorized into one of the 32 predefined size and velocity classes. The classification of drop sizes depends on whether the type of precipitation is in a liquid or solid state. The lowest and highest measurable range of drop sizes measured for liquid precipitation ranges from 0.2 mm to 8.0 mm, while for solid precipitation the range is from 0.2 mm to 25.0 mm. **However**, the instrument’s minimum detectable drop size is 0.312 mm (class 3). **Consequently, although size classes are defined down to 0.2 mm, the two smallest classes lie below the detection threshold and are therefore not effectively observed. Thus, the smallest reliably detected particles correspond to class 3.**”

*Line 100: “...the raw data...” Please clarify what is meant by “raw data” in this context.*

We appreciate the reviewer’s observation. The term “raw data” was indeed too generic and could be interpreted in different ways. In this context, it refers to the original disdrometer measurements before the derivation of higher-level parameters, specifically the original size–velocity matrix containing the particle counts for each size and fall-velocity class. We have revised the text to clarify this point.

”Furthermore, this study uses the categorization of precipitation type by precipitation codes, the number of detected particles, the number density, the drop velocity distribution and the raw data (**i.e., the original, unprocessed size–velocity matrix.**”

*Line 118: "...computed after 5 minute integration." Please clarify:  
o the native temporal resolution of the precipitation gauge data, and  
o what is specifically meant by "5 minute integration."*

We agree that the original description did not clearly distinguish between the sampling interval and the integration period. The OTT Pluvio<sup>2</sup> provides both real-time and non-real-time outputs at a temporal resolution of one minute. The difference is that the non-real-time product is calculated using a five-minute integration period, which reduces measurement noise and yields a more accurate estimate of precipitation. In this study, the non-real-time one-minute data product is used. The text has been revised to clarify the distinction between the output interval and the integration period.

**"The gauge records measurements of the bucket weight at one-minute intervals in both real-time and non-real-time. The non-real-time product is derived using a five-minute integration period, resulting in higher measurement accuracy (OTT HydroMet GmbH, 2014). This study uses the non-real-time one-minute data product. From these records, precipitation intensity and accumulation are computed."**

### **Radar–Disdrometer Comparison**

*Line 133: The manuscript discusses near-field effects, parallax errors, and evaporation as possible explanations for decreasing reflectivity toward the surface. However, only the near-field effect is discussed in detail later. What about the impacts of:  
o parallax errors, and  
o evaporation?*

We acknowledge the reviewer's concern. To our understanding, both parallax errors and evaporation are already discussed in the manuscript. The potential impact of parallax errors is addressed in lines 151–163, while the role of evaporation is discussed in lines 169–198. To improve readability and make these discussions easier to locate, we have revised the text to separate each possible explanation to its own paragraph.

*Lines 143–147: The statement regarding a 0.05° pointing error producing 4 dB corrections near the surface requires more justification. Please explain:  
o why such sensitivity occurs,  
o how the correction factors are estimated, and  
o whether there are references supporting these claims.  
Since the lowest gates appear highly sensitive to pointing errors, why not exclude or increase the minimum usable range gate? Additionally, is it possible to estimate the actual beam pointing offset of the radar?  
The discussion here also appears somewhat contradictory to the conclusions in Line 150.*

The reviewer correctly notes that additional explanation is needed. The strong sensitivity of the lowest range gates to small pointing errors arises from the incomplete overlap of the transmit and receive antenna beams in the radar near field. As a result, small changes in beam alignment can produce relatively large changes in the overlap factor and, consequently, in the parallax correction at short ranges. The correction factors presented here were estimated using the formulation of Sekelsky and Clothiaux (2002), which relates the overlap efficiency to the antenna geometry, beam widths, and pointing direction. We have expanded the discussion to better explain the origin of these estimates and provide additional context for their sensitivity. Concerning the exclusion of the lowest gates, this is indeed the conclusion drawn from this analysis (at the end of section 3.1). The purpose of this section is to assess whether residual parallax errors could

explain the observed near-surface reflectivity decrease. Our results indicate that small pointing errors can substantially affect the lowest gate and, to a lesser extent, the second and third gates, while their influence rapidly decreases with range. Consequently, the analysis presented in the remainder of the manuscript starts from the third range gate and above. This is stated explicitly at the end of the section. We have revised the text to make this conclusion clearer and to avoid any apparent contradiction.

Regarding the actual beam pointing offset, no independent measurements were available to quantify the residual pointing error during the observation period. The value of  $0.05^\circ$  was therefore selected as a plausible illustrative example to demonstrate the sensitivity of the correction rather than as an estimate of the true pointing offset. While the radar software automatically computes and applies the parallax correction, the correction can still be sensitive to small residual inaccuracies in the pointing direction. As demonstrated by the example above, even a small pointing error can lead to noticeable changes in the correction factor at the lowest range gates. Consequently, relatively small residual errors in the beam pointing could already result in appreciable uncertainties in the corrected reflectivity close to the radar. This clarification has been added to the manuscript. The discussion in line 150 is about the near field effect.

”The radar software computes compensation for the parallax error, i.e. error caused by not a complete overlap of receiver and transmitter antenna beams, by taking into account the distance between the antennas and their beam widths. **Sekelsky and Clothiaux (2002) derived a formula to calculate the parallax error for a dual-antenna radar. Under nominal alignment, this correction is about 3 dB for the lowest gate and about 1.3 dB for the third gate. However, the correction is particularly sensitive to antenna pointing accuracy at short ranges, where the beam overlap changes rapidly with distance. For example, a residual pointing offset of  $0.05^\circ$ , chosen here as a plausible example, increases the correction factor to approximately 4 dB for the lowest gate and 2 dB for the third gate. Although the radar software automatically computes the parallax correction, small residual pointing errors may still affect the result. As demonstrated by the example above, even minor pointing inaccuracies can lead to changes in the correction factor at the lowest range gates and consequently introduce noticeable uncertainties in the corrected reflectivity. For range gates at and above the third gate, the correction is comparatively small and less sensitive to pointing errors. Therefore, while residual parallax errors may contribute to the anomalous reflectivity behaviour observed in the lowest gates, their impact is expected to be limited at greater ranges. Based on this analysis, the subsequent analysis is restricted to the third range gate and above.**”

*Line 183: “...this effect is range dependent and will decrease with height...”  
Please clarify the wording. Do you mean the effect decreases with increasing height?*

We agree that the original wording was not sufficiently clear. The intended meaning is that the effect decreases with increasing height (or equivalently with increasing range from the radar) as the overlap between the transmit and receive beams improves. The text has been revised to state this more explicitly.

”This effect is **strongest at short ranges, where beam overlap is incomplete, and decreases with increasing height as the overlap improve**”

*Lines 175–180: Does the analysis of surface reflectivity and particle size under different relative humidity conditions support the interpretation that evaporation contributes to decreasing reflectivity toward the surface?*

This is an important question. To clarify this point, we note that the evaporation analysis was performed for droplets falling from the third radar range gate (153 m above ground level) to the surface under different

relative humidity conditions. The results support the conclusion that evaporation contributes to a decrease in reflectivity toward the surface. As droplets fall through unsaturated air, evaporation preferentially reduces the size of smaller droplets, leading to a reduction in the radar reflectivity. However, our calculations indicate that the magnitude of this effect is limited. Even under relatively dry conditions (75% relative humidity), the estimated reflectivity reduction is only on the order of 0.2–0.7 dB, while under the more typical humid conditions encountered during rainfall (>95% relative humidity), the effect decreases to approximately 0.1 dB. Therefore, the results support the interpretation that evaporation contributes to the observed decrease in reflectivity toward the surface, but its impact is too small to account for the full magnitude of the observed variations in the lowest radar range gates. We have revised the text to emphasize this conclusion more clearly.

**”Under relatively dry conditions (75% relative humidity at 10°C), droplets falling from the third radar range gate (153 m above ground level) to the surface decrease in diameter by roughly 0.05 mm for the smallest measurable droplets and in the order of  $10^{-3}$  mm for droplets with diameters of 10 mm. These changes correspond to reflectivity reductions of about 0.2–0.7 dB at respectively 10 dBZ and 15 dBZ, depending on the shape of the DSD. However, such dry conditions are typically limited to the onset of precipitation. As rainfall develops, relative humidity increases rapidly (e.g., to > 95%), which suppresses evaporation and reduces its impact on reflectivity to approximately 0.1 dB. These results indicate that evaporation generally causes a slight decrease in reflectivity toward the surface. However, its magnitude is small and primarily limited to the early stages of rain events. Therefore, evaporation explains only a minor fraction of the observed reflectivity variations in the lowest radar range gates.”**

#### Rain Attenuation and DSD Assumptions

*Line 224: Another velocity–diameter power-law relation is introduced. How does this relation differ from Equation 2, and why is an additional formulation needed?*

We agree that the introduction of a second velocity–diameter relationship could be confusing without further explanation. Equation (2) is used to describe the measured or assumed drop fall velocity in the context of the radar/disdrometer analysis, whereas the Atlas and Ulbrich (1977) power-law relation is introduced specifically to derive an analytical expression for the disdrometer sampling volume as a function of drop diameter. Because the sampling volume depends on the distance traveled by a droplet during the integration period, expressing the fall velocity as a power-law function of drop diameter provides a convenient way to combine the sampling volume formulation with Eq. (3). We have revised the text to clarify the purpose of this relationship and its distinction from Eq. (2).

**”Because the raindrop velocity depends on droplet size, the sampling volume is size dependent. To obtain an analytical expression for this dependence, we use the velocity–diameter power-law relation of Atlas and Ulbrich (1977),  $v(D) = 3.78D^{0.67}$ . This formulation is convenient for use in combination with Eq. (3). The expected number of observed droplets during an integration time,  $\Delta t_{int}$ , for a disdrometer with a sampling area,  $A$ , can be estimated as”**

*Line 274: During normalization using min–max scaling, should the skewness of the PSD parameter distributions (shown in Figure 1) be considered?*

The reviewer raises an interesting point regarding the normalization procedure. In the present study, min–max scaling is applied solely to rescale the DSD parameters to the interval [0,1] prior to further analysis. Since this operation is a simple linear transformation, it does not rely on assumptions about the underlying parameter distributions and is therefore unaffected by skewness.

*Line 308: The manuscript states that radome attenuation is identified when the difference between computed and measured reflectivity exceeds the expected uncertainty. Please clarify:*  
*o which radar height is used for this comparison,*  
*o what additional factors besides uncertainty and radome attenuation could contribute to the differences*  
*o why the estimated radome correction in Figure 7c occasionally becomes negative.*

The reviewer raises several important points regarding the attenuation retrieval methodology. The comparison between computed and radar reflectivity is performed at the third radar range gate (153 m above ground level), as the analysis excludes the lowest gates due to uncertainties associated with near-field effects and parallax correction.

In addition to radome attenuation, differences between computed and measured reflectivity can arise from several sources, including uncertainties in the disdrometer-derived reflectivity estimates, sampling effects related to the limited disdrometer sampling volume, residual calibration uncertainties, and potential radar measurement errors. These factors are accounted for through the expected uncertainty threshold used in the attenuation detection procedure.

Regarding the negative values occasionally observed in Figure 7c, these occur when the radar reflectivity slightly exceeds the computed reflectivity. Such cases are physically inconsistent with radome attenuation and reflect the combined effect of measurement uncertainties in the radar and disdrometer observations. As a result, small negative estimates can occur even in the absence of actual attenuation. We have expanded the discussion to clarify the origin and interpretation of these values.

”Estimation of the radome attenuation is based on a comparison of computed and measured reflectivity factors, **at the third radar range gate (153 m)**. If the difference is larger than the expected uncertainty, radome attenuation is identified and computed. **Small negative estimates of radome attenuation may occasionally occur when the measured reflectivity slightly exceeds the computed reflectivity.**”

*Line 309: Please explain more clearly how rain-path attenuation is estimated from disdrometer derived specific attenuation. Specifically:*  
*o What assumptions are made?*  
*o What is meant by “ideal conditions”?*  
*o How is the path-integrated attenuation retrieved from the reflectivity profile slope?*

We agree that this part of the methodology would benefit from additional clarification. The rain-path attenuation is estimated from the specific attenuation computed from the intrinsic DSDs using PyTMatrix calculations. In this context, ideal conditions refer to stratiform rainfall conditions, where precipitation properties vary only gradually with height and attenuation is the dominant cause of changes in reflectivity. Instead, under the assumption of stratiform conditions below the melting layer, the specific attenuation is considered approximately constant with height. In such cases, the expected slope of the reflectivity profile is equal to the specific attenuation derived from the intrinsic DSD, allowing a direct comparison between the observed reflectivity gradient and the attenuation estimated from the disdrometer observations. We have expanded the text to clarify the assumptions underlying the retrieval and the relationship between specific attenuation and the reflectivity profile.

”For the rain path attenuation, the specific attenuation is computed **from the intrinsic DSDs using PyTMatrix calculations**. Under ideal conditions, **i.e. stratiform rainfall below the melting layer, precipitation properties vary only gradually with height and the specific attenuation can be assumed to be approximately constant**. The proposed retrieval is therefore expected to perform best under stratiform precipitation conditions, where the surface-derived DSD remains representative of the precipitation column. The method may become less reliable in the presence

of embedded cloud layers associated with seeder–feeder processes or other situations where significant microphysical changes occur with height. In such cases, attenuation is expected to be the dominant contributor to the decrease in reflectivity with range, and the slope of the reflectivity profile should therefore be equal to the specific attenuation derived from the disdrometer observations. The path-integrated attenuation is then obtained by integrating the specific attenuation along the radar propagation path below the melting layer.”

#### Event Interpretation

*Line 345: “...heavy rainfall saturated the radome...”*

*Please clarify what is meant by “saturated the radome.” Do you mean complete water coverage of the radome surface?*

We acknowledge that the term “saturated the radome” was not sufficiently precise. In this context, saturation refers to the formation of a continuous water layer on the radome surface, together with the penetration and retention of water within the radome material. These effects lead to enhanced attenuation of the radar signal. To avoid ambiguity, we have revised the text to explicitly describe the physical mechanism responsible for the observed attenuation.

”At the beginning of the event, heavy rainfall (reaching  $53 \text{ mmhr}^{-1}$ ) is observed, **resulting in rapid accumulation of water on and within the radome. The resulting continuous water coverage and water retention within the radome material** causing strong radome attenuation (Fig. 6c).”

*Line 359: The manuscript states that the difference between gauge accumulation and disdrometer-derived accumulation exceeds the expected uncertainty. This discussion is unclear for two reasons:*

- 1. In the figure, the light blue, black, and ensemble disdrometer estimates appear nearly identical. Please clarify what uncertainty estimate is being referenced.*
- 2. The comparison mixes accumulated precipitation differences with instantaneous measurement uncertainty. Please explain how these quantities are being compared.*

This is a helpful observation. The uncertainty referred to in the original text is the uncertainty in the accumulated precipitation estimate, represented by the red shaded area in the figure 6c, rather than the uncertainty associated with individual rainfall measurements. We agree that this was not sufficiently clear, particularly because the individual disdrometer estimates shown in the figure are nearly indistinguishable. We have revised the text to explicitly state which uncertainty estimate is being referenced.

We also agree that the comparison between accumulated precipitation differences and instantaneous measurement uncertainty was not appropriately formulated. The intention was not to directly compare the event-total accumulation difference with the uncertainty of individual measurements. Rather, the observed discrepancy in total accumulation is interpreted in the context of a systematic bias that becomes increasingly apparent during periods of higher rainfall intensity. To clarify this distinction, we have revised the discussion and separated the concepts of instantaneous uncertainty and event-integrated accumulation differences.

”It should be noted that during the second event, there is also a notable difference in observations of precipitation accumulation. The weighing gauge measures about 47 mm of total precipitation accumulation during the event and disdrometer derived accumulation is only 42 mm. **A closer inspection of the event (Fig. 6c) indicates that the discrepancy increase during periods with rainfall rates exceeding approximately  $3 \text{ mm, hr}^{-1}$ . In contrast, during the May 2022 event (Fig. 5c), where rainfall intensities remain below this threshold, the differences are generally within the expected uncertainty range. This behaviour is likely associated with sampling limitations**

of the disdrometer, particularly the underrepresentation of larger droplets at higher rainfall rates. While the applied correction method accounts for truncation effects in the small-drop regime, it is less sensitive to biases related to larger drop sizes, which may contribute to the observed difference in accumulated precipitation.”

*Line 374: “...we assume that the whole column is characterized by these observations.”  
Please clarify what “these observations” refers to.*

The reviewer correctly identifies an ambiguity in the text. Here, “these observations” refers to the disdrometer-derived DSD properties measured at the surface. In the attenuation retrieval, it is assumed that these surface measurements are representative of the precipitation properties throughout the rain column below the melting layer. We have revised the text to explicitly state this assumption.

### Figures and Interpretation

*Figures 7 and 8: Please explain:  
o how the corrected radar reflectivity in panel (b) is obtained, and  
o what quantity is shown in panel (d).*

We agree that additional explanation is beneficial. The procedure used to obtain the corrected radar reflectivity shown in Figs. 7b and 8b was not described explicitly in the original manuscript. We have therefore added a brief explanation stating that the corrected reflectivity is obtained by first applying the retrieved radome attenuation correction and subsequently correcting for rain-path attenuation using the specific attenuation derived from the disdrometer observations.

Regarding panel (d), the quantity shown is already described in the text (lines 471-487). Nevertheless, to facilitate interpretation of the figure, we have added text to point to the correct axis.

**”The corrected radar reflectivity shown in Figs. 7b and 8b is obtained in two steps. First, the retrieved radome attenuation is added to the observed radar reflectivity. Subsequently, the rain-path attenuation correction is applied by integrating the specific attenuation derived from the disdrometer observations from the third range gate to each range gate below the melting layer. The resulting reflectivity field represents the radar observations corrected for both radome and rain-path attenuation.”**

*Figure 9 and Line 392: The manuscript states that only two profiles satisfy the criterion shown in Figure 9. Please indicate:  
o which two profiles satisfy the criterion, and  
o why the other profiles do not.*

We acknowledge that the original text did not explicitly identify which profiles satisfy the criterion. The profiles observed at 0850 UTC and 1400 UTC have more than 75% overlap between the observed and modeled reflectivity profiles and therefore satisfy the criterion. In contrast, the profiles observed at 0605 UTC and 1030 UTC do not satisfy the criterion because substantial portions of the observed reflectivity profiles fall outside the uncertainty bounds of the modeled profiles. To make this clearer, we have revised the text accordingly.

**”As can be seen in Fig. 9, the profiles observed at 0850 UTC and 1400 UTC exceed the 75% overlap threshold and therefore satisfy this criterion, whereas the profiles observed at 0605 UTC and 1030 UTC do not. For the latter two profiles, large portions of the observed reflectivity profile lie outside the modeled uncertainty bounds.”**

*Line 368: Please include the lidar depolarization ratio observations since they are important for identifying melting layer boundaries.*

The reviewer raises a relevant point regarding the identification of the melting layer. The melting layer boundaries in this study are determined using linear depolarization ratio (LDR) observations following the methodology of Li and Moisseev (2020). However, we have chosen not to include the LDR observations in the figures, as the melting layer can already be identified from the radar reflectivity observations by the pronounced reflectivity decrease upwards at around 2 km altitude. To make this clearer for the reader, we have revised the text to explicitly indicate how the melting layer can be recognized in the reflectivity field.

”The melting layer boundaries are estimated using linear depolarization ratio (LDR) observations (Li and Moisseev, 2020). **Although the LDR observations are not shown, the melting layer can be readily identified in Figs. 5a and 6a by the jump in reflectivity, located at approximately 2 km altitude, from higher values below the melting layer to subsequent lower values above it.**”

*Lines 392–394: The manuscript attributes differences to a seeder–feeder process and embedded cloud layers identified from attenuated backscatter observations. Please explain more clearly:  
o how the embedded cloud layers are identified, and  
o what observational evidence supports this interpretation.*

This comment highlighted the need for a more explicit explanation of the observational evidence. The embedded cloud layers are identified as regions of enhanced attenuated backscatter below the melting layer and separate from the precipitation signal near the surface. These layers indicate the presence of liquid cloud droplets that can be collected by falling raindrops. The combination of enhanced backscatter and deviations between the observed and modeled reflectivity profiles supports the interpretation of a seeder–feeder process. The revised manuscript now explains this reasoning more clearly.

”The difference can be attributed to the seeder–feeder process, where raindrops are growing by collision–coalescence in the embedded cloud layers. **These cloud layers are identified in the ceilometer attenuated backscatter observations as regions of enhanced backscatter, for example between 03:00 and 05:00 UTC in Fig. 9b, where the signal becomes fully attenuated below the 500 m altitude. Their presence indicates liquid cloud droplets that can be collected by falling raindrops, resulting in additional precipitation growth. The simultaneous occurrence of these cloud layers and deviations between the observed and modeled reflectivity profiles supports the interpretation that the surface DSD observations are not fully representative of the precipitation column. An example of this behaviour can be seen in the 06:05 UTC reflectivity profile shown in Fig. 9c, where the observed profile (black) decreases more rapidly with height than the modeled profile (green).**”

*Lines 413–416: The description of embedded liquid cloud layers and their impact on attenuation requires further clarification. Please explain:  
o how these layers are detected,  
o how the melting-layer base is determined, and  
o why lower cloud layers are assumed to have a stronger influence on attenuation.*

We acknowledge that the original description did not sufficiently explain how the embedded cloud layers and melting-layer boundaries are identified. The embedded cloud layers are detected from the ceilometer attenuated backscatter observations as regions of enhanced backscatter below the melting layer. The melting-layer base is obtained from the standard Cloudnet categorize product, which is derived using the

attenuated backscatter observations. The rationale for considering low-level cloud layers particularly important is already discussed in the text, namely that the surface-derived DSD becomes representative of only a limited fraction of the vertical precipitation profile when additional growth processes occur aloft. To make the methodology clearer, we have revised the manuscript to explicitly describe how the cloud layers and melting-layer boundaries are identified.

**”To aid the interpretation of the results**, the presence of embedded liquid cloud layers is explicitly indicated. **These layers are identified from regions of enhanced ceilometer attenuated backscatter below the melting layer. The melting-layer base is obtained from the standard Cloudnet categorize product, which is derived from the attenuated backscatter observations.** These layers are flagged starting from the detected cloud base up to the melting layer base, under the assumption that lower cloud layers exert a stronger influence on the attenuation because in such case the observed DSD is only representative of a limited fraction of a vertical profile.”

*Paragraphs 409–417 and Figures 10–11: These sections are difficult to follow and require substantially more explanation regarding the methodology, assumptions, and interpretation of the results*

We acknowledge that the original description was too concise and did not sufficiently explain the methodology and interpretation of the results. To improve readability, we have expanded this section to more clearly describe (i) the retrieval status before and after applying the attenuation correction, (ii) the role of the second criterion in determining when the correction can be applied, (iii) how embedded liquid cloud layers are identified, and (iv) why the presence of such layers can affect the representativeness of the surface-derived DSD observations. We have also revised the text to provide a clearer interpretation of the results shown in Figures 10 and 11.

Only the first part is shown as the latter part was already revised in the previous comment. ”Prior to Cloudnetpy version 1.66 (Tukiainen et al., 2024), no attenuation correction was applied, and consequently, ice water content (IWC) retrievals were not performed in conditions affected by uncompensated rain attenuation. Figures 10a and 11a show the IWC retrieval status reported for the two case studies before the introduction of the attenuation correction in version 1.66. **Following the application of the attenuation correction described in this study, the retrieval status was re-evaluated using the second attenuation-correction criterion, which compares the projected reflectivity below the melting layer with the observed reflectivity. When the difference is less than 1 dB, the attenuation correction is considered applicable and IWC retrievals can be performed. The updated retrieval status is shown in Figures 10b and 11b.**”