Response to Reviewer 1 (RC1)

Manuscript ID: egusphere-2026-2705

"Evaluation and Correction of Precipitation Types Measured by a PARSIVEL^2 Disdrometer in a Tropical Glacier Environment"

Summary and general assessment

Reviewer comment: *In this work, precipitation measurements from a Parsivel^2 optical disdrometer in a tropical glacier system in the Peruvian Andes are evaluated. For this purpose, precipitation events from a one-year measurement dataset were identified in a first step. Subsequently, a precipitation category was assigned to each event based on particles size-velocity relationships and some additional meteorological parameters, i.e., near-surface temperature and horizontal wind. Eventually, the precipitation intensity was recomputed using revised bulk density values for each category. With this category-based density correction method, the authors managed to increase agreement of precipitation amounts detected by Parsivel^2 and collocated Pluvio^2 observations for most categories. The reclassification revealed large uncertainties in hydrometeor classification by the manufacturers software and thus in precipitation intensity as well.*

In general, I think that the work is methodologically convincing, presents interesting results regarding particle classification and is worth to be published in AMT after some revisions. The manuscript would benefit in several places from more precise or clearer descriptions and argumentation. In addition, some figures in particular, as well as several passages of text, should be revised to better meet academic standards.

Author response: We are sincerely grateful to the reviewer for the time and care devoted to our manuscript and for the positive assessment of its methodology and results. We particularly appreciate the large number of detailed and constructive observations, which cover every part of the manuscript, from its overall structure to individual figures, units and references. We are deeply grateful to have received such a thorough and generous review, which has substantially improved the clarity and quality of our work.

We would like to clarify one point of the summary: the categories are assigned to the particles of each minute (i.e., to each diameter–velocity class) based only on empirical size–velocity relationships, and the corrected event accumulations are then obtained by adding the contributions of all categories. Near-surface temperature and wind were used to characterize the precipitation types reported by the PARSIVEL^2 (Fig. 6) and, in the case of wind, to correct the Pluvio^2 measurements for undercatch, but not for the reclassification.

Revised figures. The reviewer's comments on the figures have already been implemented: Figs. 4–14 have been redrawn following a common standard (vector graphics, a colour-blind-safe palette, consistent units and larger fonts), and the revised versions are shown in this response (Figs. R1–R11). Fig. 2 will be redrawn following the same standard. The revised figures will replace the original ones in the revised manuscript. While redrawing the figures and re-checking the text against the data, we identified and corrected several errors, which we report here for transparency. We emphasize that none of these corrections changes the final results or the conclusions of the study.

Changes to the text. All other changes described below will be implemented in the revised manuscript, which will be submitted after the open discussion; for this reason, they are described in the future tense. In what follows, the reviewer's comments are reproduced in *italics*, our responses in blue, and the changes that will be made in the manuscript in black.

General comments

RC1.1 – Structure of the paper

Reviewer comment: *At the end of the introduction, I would like to see a clear but brief description of the structure of the paper, i.e. the Sections and their content. I think that the sentence in line 51 is therefore misplaced.*

Author response: We thank the reviewer for this suggestion. The last paragraph of the Introduction will be restructured: the objectives and the proposed method will be stated more concisely and followed by a description of the structure of the paper. The sentence in L. 51–52, which states a general motivation, will be moved to the second paragraph of the Introduction (L. 29), where the relevance of accurate precipitation measurements is introduced.

Changes in the manuscript: Introduction, L. 47–52. The last paragraph will read:

> "This study evaluates and adjusts precipitation estimates from a PARSIVEL^2 optical disdrometer using concurrent measurements from a weighing precipitation gauge at a high-altitude tropical glacier environment in the Peruvian Andes. By comparing and combining both instruments, we assess the capabilities and limitations of the PARSIVEL^2 for quantifying liquid and solid precipitation, and we develop a correction method that reclassifies hydrometeors using empirical diameter–velocity relationships and recomputes precipitation with category-specific apparent densities. The remainder of the paper is organized as follows. Section 2 describes the study area, the instruments, and the quality control applied to the data. Section 3 presents the methods, including the PARSIVEL^2 precipitation type identification, the computation of the particle size distribution and precipitation intensity, and the proposed correction method. Section 4 presents the results: Sections 4.1 and 4.2 evaluate the PARSIVEL^2 built-in hydrometeor classification and its precipitation estimates against the Pluvio^2 weighing gauge; Section 4.3 presents the hydrometeor reclassification and the event-based precipitation re-estimation obtained with the correction method; and Section 4.4 examines its effect on the particle size distribution of the extreme events. Section 5 discusses the hydrometeor characterization and its physical implications, as well as the performance and limitations of the transfer function applied to the weighing gauge. Section 6 summarizes the main conclusions."

RC1.2 – Reference list

Reviewer comment: *I expect the authors to carefully revise their "References" section, as multiple references contain comments (e.g. lines 635, 660, 671, 725), mistakes at author naming (e.g. lines 650, 671, 674) or other deficient entries (e.g. line 728)*

Author response: We thank the reviewer and apologize for these errors. We have checked the whole reference list against the original publications, and all entries will be corrected and formatted in the Copernicus reference style. In particular:

- **Entries containing comments** (L. 635–637, 660–664, 671–673 and 725–727) will be corrected: the comments and any other content that does not belong to the reference will be removed, and the bibliographic data will be completed.
- **Author names** will be corrected: "Goodison, B. E., Louie, P. Y. T., and Yang, D." instead of "by BE Goodison, Louie, P., and Yang, D." (L. 650); "Foote, G. B. and du Toit, P. S." instead of "Footec, G. B. and Toit, P. S. D." (L. 671); and "Fuchs, T., Rapp, J., Rubel, F., and Rudolf, B." instead of "Fuchs', T., Rapp', J., Rubep, F., and Rudolf', B." (L. 674). Other author errors found during this check will also be corrected, e.g., "Knight, N. C. and Heymsfield, A. J." (L. 652), "Löffler-Mang, M. and Joss, J." (L. 712) and "Wauben, W." (L. 770).
- **Incomplete or deficient entries** will be completed. The entry in L. 674 will read: "Fuchs, T., Rapp, J., Rubel, F., and Rudolf, B.: Correction of synoptic precipitation observations due to systematic measuring errors with special regard to precipitation phases, Phys. Chem. Earth Pt. B, 26, 689–693, https://doi.org/10.1016/S1464-1909(01)00070-3, 2001." The entry in L. 728, a web page without a publication date, will give the date of last access: "National Snow and Ice Data Center: Science of

snow, https://nsidc.org/learn/parts-cryosphere/snow/science-snow, last access: 28 November 2024, 2024." Entries that were labelled "Tech. rep." but are journal articles, books or manuals will be given their full bibliographic data (e.g., Atlas et al., 1973; Locatelli and Hobbs, 1974; Gunn and Kinzer, 1949; Lawson et al., 1998; Yuter et al., 2006; the manuals of the Pluvio^2 and the PARSIVEL^2, which will be cited as two separate documents; and the WMO Manual on Codes, WMO-No. 306).

All in-text citations will also be checked against the reference list.

Changes in the manuscript: Reference list (L. 632–782) and in-text citations throughout the manuscript.

RC1.3 – Name of the category "Rain Drizzle with Snow"

Reviewer comment: *The Category "Rain Drizzle with Snow" should be renamed to "Rain/Drizzle with Snow" or similar (line 8, 295; Figures 5, 6, 7 (partly including captions))*

Author response: We agree. The category will be renamed "Rain/Drizzle with Snow" throughout the manuscript.

Changes in the manuscript: Abstract (L. 8), Sect. 4.1 (L. 295), Figs. 5, 6 and 7 and their captions.

Specific comments

RC1.4 – Abstract, reference instrument

Reviewer comment: *Line 11: The Parsivel^2 overestimated precipitation compared to what?*

Author response: We agree. The reference instrument will be stated explicitly in the sentence ("Relative to the Pluvio^2, . . . ").

Changes in the manuscript: Abstract, L. 9–12 (see the revised text in our response to comment RC1.5).

RC1.5 – Abstract, meaning of the percentages

Reviewer comment: *Line 11: It's not so easy to understand what the percentage refers to; it's also hard to interpret the 3.92 mm if time periods don't have the same length*

Author response: We thank the reviewer for this comment. The percentages are mean relative biases, i.e. the mean of the event-wise relative differences between the PARSIVEL^2 and Pluvio^2 accumulations, whereas the values in mm are mean biases per event; positive values indicate overestimation and negative values underestimation. Because the events differ widely in duration and accumulation, a mean bias in mm is indeed difficult to interpret and to compare between precipitation phases. This also explains the apparent contradiction for liquid events, which show a mean bias of 0.00 mm but a mean relative bias of +15.7 %: light events are overestimated in relative terms, whereas larger events are slightly underestimated (Sect. 4.2.2). In the revised abstract, we will therefore report the mean relative bias together with the slope of the regression between both instruments, which describes the systematic overestimation independently of the event size. Both metrics will be defined in Sect. 3.3.3, and the mean biases in mm will remain in Sect. 4.2.2 and Fig. 13.

Changes in the manuscript: Abstract, L. 7–18, and Sect. 3.3.3, L. 265–266. The revised abstract will read (changes in L. 7–12 and L. 16–19):

> "Based on one year of observations, the PARSIVEL^2 identified seven precipitation types: rain, drizzle, drizzle with rain, snow, hail, soft hail, and rain/drizzle with snow. Drizzle with rain was the most frequent type (30.6 % of the precipitation minutes), followed by snow (26.2 %). We identified 70 precipitation events (duration ≥10 min; 16 liquid, 17 solid, and 37 mixed-phase) and compared their accumulations with those of a collocated Pluvio^2 weighing gauge (threshold ≥0.25 mm). Relative to the Pluvio^2, the PARSIVEL^2 systematically overestimated mixed-phase and solid precipitation, with mean relative biases of +98.5 % and +84.1 % and regression slopes of 1.936 and 2.103, respectively. For liquid precipitation, the agreement was good (slope 0.918; mean bias 0.00 mm), although light events were overestimated (mean relative bias +15.7 %). [. . .] For solid precipitation, the RMSE decreased from 13.05 to 4.44 mm; for mixed-phase precipitation, the regression slope improved from 1.936 to 1.004. [. . .]"

In addition, "scope value" will be corrected to "slope" (L. 17), and "post processing" and "site specific" to "post-processing" and "site-specific".

The original manuscript reported these metrics without defining them. Their definitions will therefore be added at the end of Sect. 3.3.3 (L. 265–266), where the metrics used to compare both instruments are introduced. They are additional equations and do not replace Eq. 3, which is rewritten separately (see our response to comment RC1.24). The revised paragraph will read:

> "Finally, the event accumulations of the PARSIVEL^2, before and after the correction, were compared with those of the Pluvio^2 using the ordinary least-squares regression line and its coefficient of determination (R^2), the root mean square error (RMSE), the mean absolute error (MAE), the mean bias (MB) and the mean relative bias (MRB):
>
> $$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(P_{\mathrm{PAR},i} - P_{\mathrm{PLU},i}\right)^2}, \qquad \mathrm{MAE} = \frac{1}{N}\sum_{i=1}^{N}\left|P_{\mathrm{PAR},i} - P_{\mathrm{PLU},i}\right|,$$
>
> $$\mathrm{MB} = \frac{1}{N}\sum_{i=1}^{N}\left(P_{\mathrm{PAR},i} - P_{\mathrm{PLU},i}\right), \qquad \mathrm{MRB} = \frac{100\,\%}{N}\sum_{i=1}^{N}\frac{P_{\mathrm{PAR},i} - P_{\mathrm{PLU},i}}{P_{\mathrm{PLU},i}},$$
>
> where $P_{\mathrm{PAR},i}$ is the accumulated precipitation (mm) of event i computed from the PARSIVEL^2 (before or after the correction), $P_{\mathrm{PLU},i}$ is the accumulated precipitation (mm) of the same event measured by the Pluvio^2 and corrected for wind-induced undercatch (Sect. 2.2.4), and N is the number of events of each precipitation phase. RMSE, MAE and MB are expressed in mm and MRB in percent; positive (negative) values of MB and MRB indicate overestimation (underestimation) by the PARSIVEL^2. Because MRB averages the relative differences of individual events, it is dominated by the more numerous light events, whereas MB is dominated by the events with the largest accumulations."

RC1.6 – Regional scope of the references

Reviewer comment: *Lines 23 ff.: All those references refer to the Andes region. This should be mentioned/specified, as those statements do not account for all tropical regions in the world.*

Author response: We agree. The statement will be restricted to the tropical Andes, where the cited studies were conducted.

Changes in the manuscript: Introduction, L. 23: "Concerns about water availability have been linked to declining glacier cover in the tropical Andes region (Buytaert et al., 2017)."

RC1.7 – PARSIVEL^2 performance with respect to particle size

Reviewer comment: *Line 45: There is a lot of research about the Parsivels performance with respect to particle size too. It would be nice if you could add one or two statements here on that.*

Author response: We thank the reviewer for this suggestion. Two sentences on the size-dependent performance of the instrument will be added, one for rain and one for snow, and the paragraph will cite additional intercomparison and quality-control studies. For rain, comparisons with collocated disdrometers showed that the first-generation Parsivel underestimated the concentration of small drops and overestimated that of large drops, particularly at high rain rates, and that these biases were reduced, but not removed, in the PARSIVEL^2 (Tokay et al., 2014; Raupach and Berne, 2015); in strong winds, the errors are largest for drops larger than 4 mm (Lin et al., 2021). For snow, the instrument retrieves a single size parameter, approximately the largest horizontal dimension of the particle, and the fall velocity derived from it becomes increasingly uncertain as the snowflake size increases (Battaglia et al., 2010). In addition, the last sentence of the paragraph will describe more specifically how Ishizaka et al. (2013) used the size–fall speed relationship to identify hydrometeor types, which links the Introduction with the method of this study.

Changes in the manuscript: Introduction, L. 42–46. The revised text will read: "To address these limitations, previous work has analyzed the recorded drop size distribution (DSD), compared mean values to empirical relationships, classified hydrometeors using density–diameter relations, proposed quality-control procedures for windy conditions, or validated measurements against other instruments such as two-dimensional video disdrometers (2DVD), other optical disdrometers and snow gauges (e.g., Battaglia et al., 2010; Thurai et al., 2011; Friedrich et al., 2013; Angulo-Martínez et al., 2018; Gualco et al., 2021; Lin et al., 2021). These studies showed that the performance of the instrument depends on particle size. For rain, the first-generation Parsivel underestimated the concentration of small drops and overestimated that of large drops, particularly at high rain rates; these biases were reduced, but not removed, in the PARSIVEL^2 (Tokay et al., 2014; Raupach and Berne, 2015). Under strong horizontal winds, the instrument underestimates rain rates, mainly because of errors in the measured diameter and fall velocity of drops larger than 4 mm (Lin et al., 2021). For snow, the instrument retrieves a single size parameter, approximately the largest horizontal dimension of the particle, and the fall velocity derived from it becomes increasingly uncertain as the snowflake size increases (Battaglia et al., 2010). Despite these limitations, the PARSIVEL^2 has been used to characterize snowfall microphysics, including density–size relationships of dry and wet snow (Shen et al., 2022). Other studies have used the measured size–fall speed relationship to characterize precipitation types at specific sites; for example, Ishizaka et al. (2013) identified the hydrometeor type that contributes most to snowfall from the centre of the mass flux distribution in the size–fall speed space." The references Raupach and Berne (2015), Thurai et al. (2011), Friedrich et al. (2013), Angulo-Martínez et al. (2018), Lin et al. (2021) and Shen et al. (2022) will be added to the reference list.

RC1.8 – Date of the photograph in Fig. 1

Reviewer comment: *Figure 1: At which time of the year / date was the picture in the lower right corner taken?*

Author response: The photograph was taken on 2 September 2023 at 07:56 local time (UTC−5) during a routine data-download visit. This information will be added to the caption of Fig. 1.

Changes in the manuscript: Caption of Fig. 1. The last sentence will read: "The photograph of the instruments (c–e) was taken on 2 September 2023 at 07:56 local time (UTC−5) and is courtesy of the TAMYA Project."

RC1.9 – Diameter limits

Reviewer comment: *Line 124: What's the lower and upper size limit that is taken into account here? Consider to shift that part to Section 3.2*

Author response: Thank you. The instrument defines 32 diameter classes, with centres from 0.062 to 24.5 mm. During the study period, however, no particles were recorded in the first two classes (centred at 0.062 and 0.187 mm) or in the last two (21.5 and 24.5 mm). The diameter range of the data used in this study is therefore 0.25–20 mm, i.e. from the lower boundary of the third class to the upper boundary of the thirtieth class. According to the manufacturer's manual, the first two classes are limits that are not evaluated, because they lie outside the measurement range of the instrument (OTT HydroMet, 2019b). For the last two classes, the manual gives no such restriction; no particles of these sizes were recorded at our site. As suggested, the description of the diameter classes and of this range will be moved to Sect. 3.2, where the particle size distribution is defined, and Sect. 2.2.3 will only describe the raw data matrix (see RC1.10).

Changes in the manuscript: Sect. 2.2.3 (L. 121–125) and Sect. 3.2 (L. 150–157). After the definition of the diameter classes in Sect. 3.2 (L. 154), the following sentences will be added: "The first two diameter classes (0.062 and 0.187 mm) lie outside the measurement range of the instrument and are not evaluated (OTT HydroMet, 2019b). In addition, no particles were recorded in the last two classes (21.5 and 24.5 mm) during the study period. The data therefore cover diameters from 0.25 to 20 mm."

RC1.10 – Wording of L. 124–125

Reviewer comment: *Lines 124/125: Please revise the wording / structure of that sentence*

Author response: Thank you. The sentences will be rewritten for clarity.

Changes in the manuscript: Sect. 2.2.3, L. 121–125: "The instrument stores the number of particles detected in each minute in a raw data matrix of 32 diameter classes by 32 velocity classes (1024 classes), whose values are integer counts. The diameter classes and the range covered by the data are described in Sect. 3.2. The formats and units of all variables are given in the user manual of the instrument (OTT HydroMet, 2019b)."

RC1.11 – Table 1

Reviewer comment: *Table 1: Please mention in the caption, that this table is about the Parsivel data. Do the numbers refer to a monthly period each? In that case, don't name the column "Date" but "Period" and write start and end. Filter 1, 2 and 3 show the same numbers. Does it mean that Filter 2 and 3 did actually not filter any data? Please explain / mention that somewhere, preferably under 2.2.4.*

Author response: We thank the reviewer. Table 1 refers only to the PARSIVEL^2 data, and each row corresponds to one month. Because a large fraction of the PARSIVEL^2 records is missing in every month, the first column will be renamed "Month" and will give only the year and month (e.g., 2022-11), instead of start and end dates that could suggest continuous coverage. For transparency, a column with the monthly data coverage (number of files divided by the number of minutes in the month) will be added. The reviewer is right that the three filters showed the same numbers in most months. While re-checking them, we found that the counts of November and December 2022 had been misreported in the original table; the corrected values are given in Table R1 below. Filter 1 removed 12 empty files in total (between 0 and 7 per month). Filter 2 removed 10 files with invalid characters, all in November 2022. Filter 3 did not remove any file, because the sensor status remained 0 (no lens contamination or laser malfunction) in all records. Filter 3 was kept in the table to document this check. The last column gives the number of minutes with recorded precipitation after filtering. The Pluvio^2 record also contains gaps (Fig. 2c), and only events recorded by both instruments were analysed (Sect. 3.3.1). The incomplete monthly coverage is the reason why the analysis is performed on an event basis rather than with a monthly climatological approach. This explanation will be added to Sect. 2.2.4.

Changes in the manuscript: Table 1 (see Table R1) and Sect. 2.2.4 (L. 126–130). The revised caption will read: "Table 1. Monthly number of 1-min PARSIVEL^2 data files before (Original) and after each sequential quality-control filter: Filter 1 removes empty files, Filter 2 removes files with invalid characters (non-standard UTF-8 encoding), and Filter 3 removes the minutes in which the sensor status variable indicates an instrument problem (status different from 0, i.e. lens contamination or laser malfunction). Coverage is the number of valid files divided by the number of minutes in the month. The last column gives the number of minutes with recorded precipitation after filtering."

Table R1. Revised Table 1. Monthly number of 1-min PARSIVEL^2 data files before (Original) and after each sequential quality-control filter: Filter 1 removes empty files, Filter 2 removes files with invalid characters (non-standard UTF-8 encoding), and Filter 3 removes the minutes in which the sensor status variable indicates an instrument problem (status different from 0). Coverage is the number of valid files divided by the number of minutes in the month. The last column gives the number of minutes with recorded precipitation after filtering.

Month	Original	Filter 1	Filter 2	Filter 3	Coverage (%)	Precipitation (min)
2022-11	4 738	4 737	4 727	4 727	10.9	540
2022-12	25 645	25 638	25 638	25 638	57.4	5 225
2023-01	12 703	12 703	12 703	12 703	28.5	1 391
2023-02	19 880	19 880	19 880	19 880	49.3	5 671
2023-03	19 442	19 442	19 442	19 442	43.6	3 486
2023-04	25 244	25 244	25 244	25 244	58.4	1 026
2023-05	19 148	19 146	19 146	19 146	42.9	370
2023-06	4 130	4 129	4 129	4 129	9.6	179
2023-07	1 423	1 422	1 422	1 422	3.2	2
2023-08	7 867	7 867	7 867	7 867	17.6	7
2023-09	9 427	9 427	9 427	9 427	21.8	543
2023-10	1 072	1 072	1 072	1 072	2.4	115
2023-11	6 035	6 035	6 035	6 035	14.0	679

RC1.12 – Title of Sect. 3.1

Reviewer comment: *Line 134: Consider to name Section 3.1 "Precipitation Type Identification"*

Author response: Thank you. The section will be renamed as suggested.

Changes in the manuscript: Sect. 3.1 title: "Precipitation type identification".

RC1.13 – Title of Sect. 3.2

Reviewer comment: *Line 145: Consider to rename this Section. In here, you are describing how precipitation parameters are calculated rather than the (size) spectrum is defined.*

Author response: We agree. The section will be renamed to reflect its content.

Changes in the manuscript: Sect. 3.2 title: "Particle size distribution and precipitation intensity".

RC1.14 – Densities assumed by the OTT software

Reviewer comment: *Section 3.2: Is it known, which densities (or mass-velocity relations) are assumed by the OTT software for which types? If yes, it would be great to note them here. If not, I don't understand correctly how you deal with this as one could interpret Equation 3 in such way, that you are using the precipitation rates from the OTT program for your correction.*

Author response: We thank the reviewer for this important question. The manufacturer does not document the particle densities (or mass–velocity relationships) assumed by the OTT software for the different precipitation types. The density implicitly used by the internal algorithm can therefore only be retrieved by inverting Eq. 2, using the precipitation intensity reported by the PARSIVEL^2 together with the measured $N(D)$ and $V(D)$ for the same minute. In rain-dominated environments, this back-calculated density is close to $1\,\mathrm{g\,cm^{-3}}$ and therefore goes largely unnoticed. At our site, however, it varies widely, from 0.01 to $1.00\,\mathrm{g\,cm^{-3}}$ (Fig. 12; Sect. 4.3.1; see also our response to comment RC1.34), which shows that the internal algorithm does not assign a fixed density to solid and mixed-phase particles. Importantly, the correction

method does not use the precipitation intensity computed by the OTT software; precipitation is recomputed from the raw particle counts (see our response to comment RC1.24 on Eq. 3). Section 3.2 will be revised to state explicitly which densities are documented and which are back-calculated.

Changes in the manuscript: Sect. 3.2 (L. 159–165) and Sect. 4.3.1 (L. 429–432). The first sentences of Sect. 4.3.1 will read: "Before calculating the apparent density, it is worth noting that the density implicitly assumed by the PARSIVEL^2 internal algorithm, which can be back-calculated from Eq. 2 for each classified minute, is not documented by the manufacturer. For liquid precipitation, a density close to that of liquid water would be expected, whereas for snow, a size-dependent density following an empirical relationship such as that proposed by Brandes et al. (2007) would be expected; however, this cannot be confirmed. The back-calculated values (Fig. 12) revealed systematic deviations from these expectations across all precipitation phases." The reference Brandes et al. (2007) will be added to the reference list.

RC1.15 – Subheadings of Sect. 3.3.1

Reviewer comment: *Section 3.3.1: This section is compact enough that no subheadings are needed. I suggest to remove them and instead add one sentence at line 178 which bridges to the selection criteria.*

Author response: We agree. The subheadings will be removed and a bridging sentence will be added.

Changes in the manuscript: Sect. 3.3.1, L. 172 and L. 178–180. The bridging sentence will read: "Subsequently, the analysis was restricted to events detected by both instruments, and the following selection criteria were established to reduce noise from light precipitation, considering the limitations of both instruments:"

RC1.16 – Exclusion of events with zero accumulation

Reviewer comment: *Line 181: Perhaps add here again, that this refers to any of the sensors.*

Author response: Thank you. The sentence will be clarified.

Changes in the manuscript: Sect. 3.3.1, L. 181: "Events with zero accumulated precipitation in either instrument were excluded."

RC1.17 – Selection of the empirical curves

Reviewer comment: *Line 195 f.: This sentence needs rewording and perhaps a few more words for explanation.*

Author response: We agree that this sentence was unclear. The main criterion for selecting the empirical curves from the literature was their agreement with the regions of the diameter–velocity space where the particles recorded by the disdrometer at the site are concentrated.

Changes in the manuscript: Sect. 3.3.2, L. 195–197: "The empirical curves listed in Table 2 were selected because they match the regions of the diameter–velocity space where most of the particles recorded by the disdrometer at the site are concentrated (Fig. 8)."

RC1.18 – Name of the first bullet point

Reviewer comment: *Line 199: I suggest to name that point "Rain" and state that drizzle is also part of it. If those bullet points are named the same way as the categories in the table and the Figures, the message becomes more clear*

Author response: We agree. The bullet points will be named as the categories in Table 2 and in the figures (rain, wet snow, snow, graupel and hail). The revised Table 2, which also merges "Hailstones" and "Hail" into a single category and adds the curve codes used in Figs. 4 and 8, is shown in full in Table R2 below.

Changes in the manuscript: Sect. 3.3.2, L. 199: "Rain (including drizzle): . . . "; Table 2.

Table R2. Revised Table 2. Empirical fall velocity relationships (v in $\mathrm{m\,s^{-1}}$, d in mm) used to define the segmentation masks of each hydrometeor category, with the codes used in Fig. 4. Diameter ranges are those of the original observations in references; outside these ranges the curves are extrapolated. C is the air-density correction factor of Foote and du Toit (1969, Eqs. 7–8), equal to 1.236 for the mean pressure (582.4 hPa) and temperature (1.6 °C) of the selected events. The curves for solid hydrometeors are not corrected for altitude.

Category	Code	Type	Diameter range (mm)	Fall velocity ($\mathrm{m\,s^{-1}}$)	Reference
Rain	R	Raindrops	$d < 5$	$(9.65 - 10.3\,e^{-0.6d})\,C$	Atlas et al. (1973), based on Gunn and Kinzer (1949); C: Foote and du Toit (1969)
Wet snow	W	Wet (melting) snow	0.6–9	$4.65 - 5\,e^{-0.95d}$	Fehlmann et al. (2020)
Snow	S1	Unrimed side planes	0.4–1.2	$0.81\,d^{0.99}$	Locatelli and Hobbs (1974)
	S2	Densely rimed dendrites	1.8–4.0	$0.62\,d^{0.33}$	Locatelli and Hobbs (1974)
	S3	Aggregates of unrimed radiating assemblages of plates, side planes, bullets and columns	0.2–3.0	$0.69\,d^{0.41}$	Locatelli and Hobbs (1974)
	S4	Aggregates of unrimed side planes	0.5–4.0	$0.82\,d^{0.12}$	Locatelli and Hobbs (1974)
	S5	Aggregates of densely rimed radiating assemblages of dendrites or dendrites	2.0–12.0	$0.79\,d^{0.27}$	Locatelli and Hobbs (1974)
	S6	Aggregates of unrimed radiating assemblages of dendrites or dendrites	2.0–10.0	$0.8\,d^{0.16}$	Locatelli and Hobbs (1974)
	S7	Densely rimed aggregates	–	$1.1\,d^{0.15}$	Ishizaka (1995), in Ishizaka et al. (2013)
	S8	Rimed aggregates	–	$0.96\,d^{0.12}$	Ishizaka (1995), in Ishizaka et al. (2013)
	S9	Dendrites	–	0.3	Nakaya (1954), in Ishizaka et al. (2013)
Graupel	G1	Lump graupel ($\rho = 0.05$–$0.1\,\mathrm{g\,cm^{-3}}$)	0.5–2.0	$1.16\,d^{0.46}$	Locatelli and Hobbs (1974)
	G2	Lump graupel ($\rho = 0.2$–$0.45\,\mathrm{g\,cm^{-3}}$)	0.5–1.0	$1.5\,d^{0.37}$	Locatelli and Hobbs (1974)
	G3	Lump graupel ($\rho = 0.1$–$0.2\,\mathrm{g\,cm^{-3}}$)	0.5–3.0	$1.3\,d^{0.66}$	Locatelli and Hobbs (1974)
	G4	Hexagonal graupel	0.8–3.2	$1.1\,d^{0.57}$	Locatelli and Hobbs (1974)
	G5	Conical graupel	0.8–3.0	$1.2\,d^{0.65}$	Locatelli and Hobbs (1974)
	G6	Graupel-like snow of lump type	0.5–2.2	$1.1\,d^{0.28}$	Locatelli and Hobbs (1974)
	G7	Graupel-like snow of hexagonal type	0.8–2.8	$0.86\,d^{0.25}$	Locatelli and Hobbs (1974)

Category	Code	Type	Diameter range (mm)	Fall velocity ($m\,s^{-1}$)	Reference
Hail	H1	Fresh hailstones	6.3–15.4	$8.445\,(0.1d)^{0.553}$	Knight and Heymsfield (1983)
	H2	Soaked hailstones	–	$10.58\,(0.1d)^{0.267}$	Knight and Heymsfield (1983)
	H3	Hail (maximum diameter)	–	$12.43\,(0.1d)^{0.4792}$	Heymsfield et al. (2014), in Allen et al. (2020)
	H4	Graupel and hail, $\rho = 0.2\,g\,cm^{-3}$	–	$5.23\,(0.1d)^{0.65}$	Heymsfield and Wright (2014)
	H5	Graupel and hail, $\rho = 0.9\,g\,cm^{-3}$	–	$12.07\,(0.1d)^{0.64}$	Heymsfield and Wright (2014)
	H6	Graupel and hail, size-dependent density	–	$4.88\,(0.1d)^{0.84}$	Heymsfield and Wright (2014)

RC1.19 – "Some other types"

Reviewer comment: *Line 202: "some other types" is very unspecific. If you mean other crystal types / crystals with other shapes etc., write it like this.*

Author response: Thank you. The sentence will specify the snow crystal types listed in Table 2.

Changes in the manuscript: Sect. 3.3.2, L. 202: "We applied all empirical curves for aggregated snow crystals and for the other snow crystal types listed in Table 2 (side planes, rimed dendrites, rimed aggregates and dendrites)."

RC1.20 – Exclusion of spurious detections

Reviewer comment: *Line 209 f.: I think that this information is misplaced as you are mainly listing the five different classes here. Consider to give that information as normal text after the bullet points.*

Author response: We agree. The exclusion of spurious detections will be described as normal text after the list of the five categories, together with the remark on the hail region (L. 207–208), which also belongs after the list. The description of the spurious detections will also answer comment RC1.37.

Changes in the manuscript: Sect. 3.3.2, L. 206–210. The text after the list of categories will read: "Because the observed fall velocities remained below $14\,m\,s^{-1}$, only a few particles fell within the hail region (Fig. 4f), close to its lower diameter and velocity bounds. Finally, particles larger than 10 mm with fall velocities below $1\,m\,s^{-1}$ lie outside the segmentation masks of all categories and were treated as spurious detections. Such diameter–velocity pairs are not consistent with the fall behaviour of any hydrometeor. They can arise from particles crossing the laser beam obliquely under strong wind (Friedrich et al., 2013), from two or more particles crossing the beam simultaneously and being measured as a single larger particle, or from non-meteorological objects such as insects or debris. Because the instrument does not provide particle images, these causes cannot be distinguished. Following Gualco et al. (2021), these particles were excluded from the analysis."

RC1.21 – Figure 4

Reviewer comment: *Figure 4:*

- *Increase legends!!*
- *Increase the fontsize of "(a)" etc.*
- *Remove y axis label from panel e*
- *Increase tick labels on both axes*

- *Stay consistent with conventions --> m/s to m s-1, if equations should remain, write exponents as superscripts instead of **, etc.*
- *I suggest to remove the equations as they are contained in Table 2.*
- *I also suggest to somewhere include the respective category name somewhere in or above each subplot.*
- *Caption: you are naming six categories here!*

Author response: We thank the reviewer for these suggestions. Figure 4 will be redrawn as follows:

- **Colour scheme:** in panel (a), each segmentation region will be shown in a distinct colour; in panels (b)–(f), the category of the panel will be highlighted in its colour and the remaining regions will be shown in much lighter tints of their own colours, so that the panels remain distinguishable also when printed in black and white.
- **Category names:** the name of the category will be written in each panel.
- **Panel labels, axis labels and tick labels:** their font size will be increased.
- **Panel (e):** the y-axis label will be removed.
- **Units:** $\mathrm{m\,s^{-1}}$ will be used.
- **Equations:** all equations will be removed from the panels, since they are listed in Table 2; the segmentation boundaries in panels (b) and (c) will be labelled only by their relative deviation from the reference curve (e.g., $\pm 50\,\%$).
- **Reference curves:** the legends will be removed. Each empirical curve will be drawn as a simple black line and labelled directly with a short code (e.g., S1–S9 for snow, G1–G7 for graupel, H1–H6 for hail), which will be added as a new column in Table 2. This keeps the figure readable for readers with colour vision deficiencies and in black-and-white print.
- **Caption:** it will list the five categories (rain, wet snow, snow, graupel and hail), and the altitude correction factor C (Foote and du Toit, 1969) will be defined.

Changes in the manuscript: Figure 4 and its caption (Fig. R1). The caption will read: "Figure 4. Velocity–diameter segmentation masks and empirical fall velocity curves (Table 2). (a) The five categories used for reclassification. (b)–(f) Each category highlighted in its colour, with the remaining categories in lighter tints: (b) rain (R), corrected for air density following Foote and du Toit (1969) ($C = 1.236$ at the site), with the $\pm 50\,\%$ boundaries; (c) wet snow (W) and its lower boundary ($-20\,\%$); (d) snow (S1–S9); (e) graupel (G1–G7); (f) hail (H1–H6). Solid lines indicate the diameter range observed in the original studies and dotted lines the extrapolation. The curves for solid hydrometeors are not corrected for altitude. Note the different axis ranges in (d) and (e)."

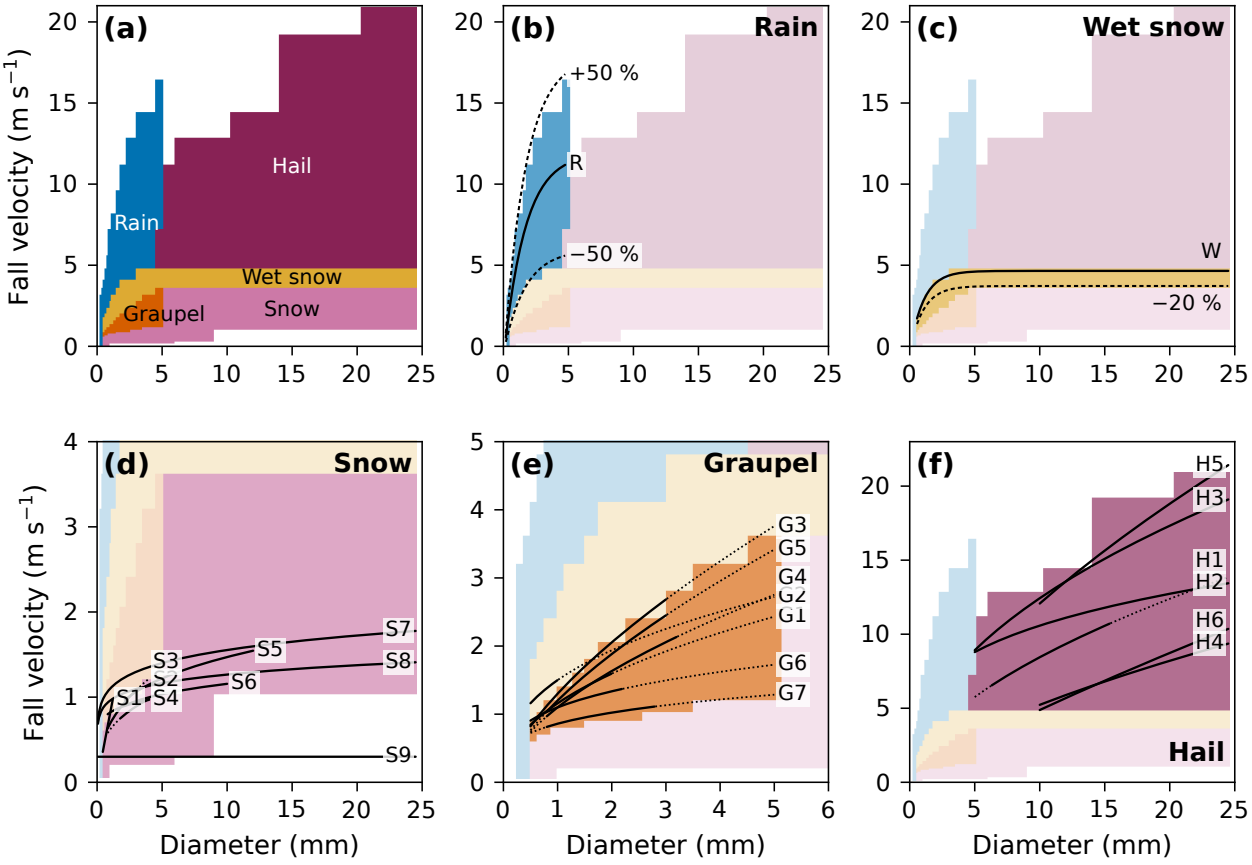

Figure R1. Revised Fig. 4.

RC1.22 – Wording of L. 224

Reviewer comment: *Line 224: Rewording suggested: "Further literature suggests. . . "*

Author response: Thank you. The sentence will be reworded as suggested.

Changes in the manuscript: Sect. 3.3.3, L. 224: "Further literature suggests ranges from 0.07 to 0.45 g cm^{-3} (diameter 0.5–1.0 mm) . . . "

RC1.23 – Additional reference

Reviewer comment: *Line 228 ff.: Heymsfield and Hobbs (2010) would be another important reference here but I leave it up to the authors whether to include it or not*

Author response: We thank the reviewer for this suggestion. We could not find a publication by Heymsfield and Hobbs from 2010. We assume that the reviewer refers to Heymsfield and Westbrook (2010, J. Atmos. Sci., 67, 2469–2482), who showed that the fall speed of ice particles depends on their mass, maximum dimension and projected area, and proposed a method to compute it from these properties. This is directly relevant to the statement in L. 228–229 that snow density, size and fall velocity are related, and we will cite it there. If the reviewer had a different publication in mind, we would be grateful for the full reference, and we will include it as well.

Changes in the manuscript: Sect. 3.3.3, L. 228–229: "Snow density is influenced by multiple factors including crystal structure, size, fall velocity, temperature, and riming processes (Ishizaka et al., 2013). In turn, the fall velocity of ice particles depends on their mass, size and projected area, and therefore on their effective density (Heymsfield and Westbrook, 2010)." The reference will be added to the reference list.

RC1.24 – Equation 3

Reviewer comment: *Equation 3: Is P the precipitation rate? This was previously introduced as R (Eq. 2). Please carefully introduce the variables and abbreviations here. Furthermore: Do I understand it correctly, that you are using P from the OTT software and multiply it with the newly assigned density for that particle type? I struggle a bit with the fact that the OTT software likely already performed a "density correction" for solid particles (as you indicated in Eq. 2). So if you are using P from the software, aren't you correcting a second time for the density? Please clarify.*

Author response: We thank the reviewer for pointing out this inconsistency in notation, and we realise that the original description of Eq. 3 was ambiguous. In the revised manuscript, R will denote the precipitation intensity ($\mathrm{mm\,h^{-1}}$), as in Eq. 2, and P the event-accumulated precipitation (mm), which is the quantity compared with the Pluvio^2 accumulation.

P is not taken from the OTT software. For each hydrometeor category k, the intensity R_k is computed with Eq. 2 from the raw particle counts (32×32 matrix) that fall within the segmentation mask of that category, using the density of liquid water ($\rho_w = 1\,\mathrm{g\,cm^{-3}}$), and it is then accumulated over the event to obtain P_k. Because the bulk density of each category is assumed constant, it can be taken out of the integral in Eq. 2; computing R_k with ρ_w and then multiplying by ρ_k/ρ_w is therefore equivalent to computing it directly with ρ_k. Consequently, the density correction is applied only once, and the densities assumed by the OTT software play no role in the corrected estimates.

The apparent densities ρ_k were obtained by testing all combinations of density values within the literature ranges of each category (Table 3) and selecting the combination with the highest R^2 and the lowest RMSE against the Pluvio^2 event accumulations (L. 260–262).

Changes in the manuscript: Sect. 3.3.3, L. 260–264. Equation 3 will be replaced by:

$$R_k(t) = \frac{6\pi}{10^4}\,\rho_w \int_{D_{\min}}^{D_{\max}} N_k(D,t)\,V(D)\,D^3\,\mathrm{d}D, \tag{1}$$

$$P_k = \sum_{t\,\in\,\text{event}} R_k(t)\,\Delta t, \qquad \Delta t = 1\ \text{min}, \tag{2}$$

$$P_{\text{corr}} = \sum_k \frac{\rho_k}{\rho_w}\,P_k, \qquad k \in \{\text{rain},\ \text{snow},\ \text{wet snow},\ \text{graupel},\ \text{hail}\}, \tag{3}$$

where $N_k(D,t)$ is the particle size distribution computed (Eq. 1) only from the particles assigned to category k in minute t.

RC1.25 – Figures 5 and 11

Reviewer comment: *Figure 5 and Figure 11: I like the idea of presenting two pie charts for the category distribution before and after your correction. The labels and numbers, however, need to be displayed clearer, i.e. without overlapping and with an appropriate font size! Consider to display the text and numbers outside the chart and connect with lines to the respective fields. Perhaps, display the phase inside and the more specific categories outside. Also consider to use yellow-like colors instead of green to make the figures more color-blindness-friendly.*

Author response: We thank the reviewer for this positive comment and the suggestions, which will be implemented in the revised manuscript as shown in the revised figures (Figs. R2 and R3):

- **Labels:** they will be placed outside the charts and connected by leader lines, without overlapping and with a larger font size.
- **Layout:** the phases will be shown in the inner circle and the specific types or categories in the outer ring.
- **Colours:** a colour-blind-safe palette (based on Okabe and Ito, 2008) will be used consistently in all figures, with yellow tones for the mixed phase instead of green.
- **Quantity represented:** the captions will state that Fig. 5 shows the percentage of 1-min records of each type reported by the PARSIVEL^2 (one type per minute), whereas Fig. 11 shows the percentage of

particles in each corrected category, since after the reclassification a single minute can contain several categories. Hail, which represents 0.011 % of the particles, will be indicated below the chart.

Changes in the manuscript: Figures 5 and 11 and their captions: "Figure 5. Distribution of the precipitation types reported by the PARSIVEL^2 (percentage of 1-min records with precipitation). Inner circle: phase; outer ring: type." and "Figure 11. Distribution of the corrected precipitation categories after the reclassification (percentage of particles in each category). Inner circle: phase; outer ring: category. Hail represents 0.011 % of the particles."

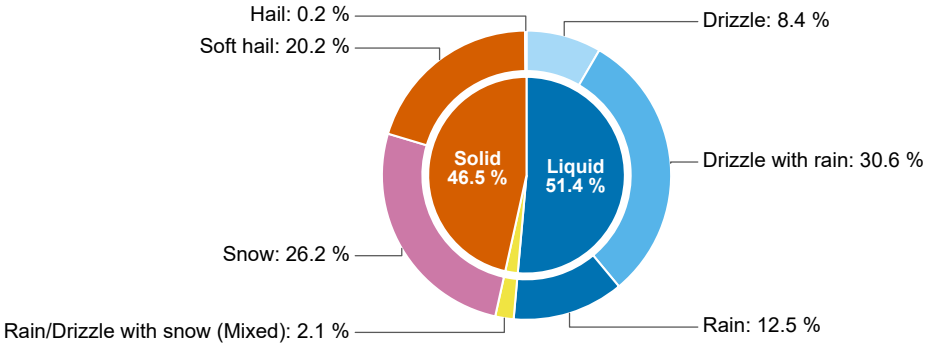

Figure R2. Revised Fig. 5.

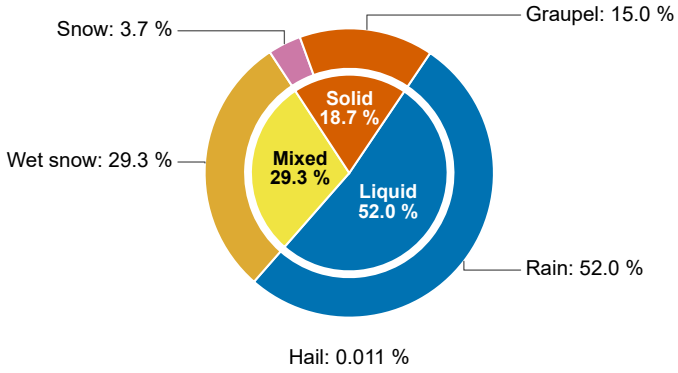

Figure R3. Revised Fig. 11.

RC1.26 – Name of the mixed category

Reviewer comment: *Line 295: I think the category should be named "rain/drizzle with snow" or "rain or drizzle with snow" instead of "rain drizzle with snow". Also update in the respective Figures, please!*

Author response: We agree; see our response to comment RC1.3.

Changes in the manuscript: Sect. 4.1, L. 295, and Figs. 5, 6 and 7.

RC1.27 – Figure 6

Reviewer comment: *Figure 6: The figure would benefit from being a vector graphic. Also consider to use yellow-like colors instead of green to make the figures more color-blindness-friendly.*

Author response: Thank you. Figure 6 will be replaced by a vector graphic with the colour-blind-safe palette described in our response to comment RC1.25 (revised version in Fig. R4). The precipitation types

will be ordered from liquid to mixed to solid, as in all other figures, and the values labelled inside the boxes will be the means (see also our response to comment RC1.65).

Changes in the manuscript: Figure 6 (Fig. R4).

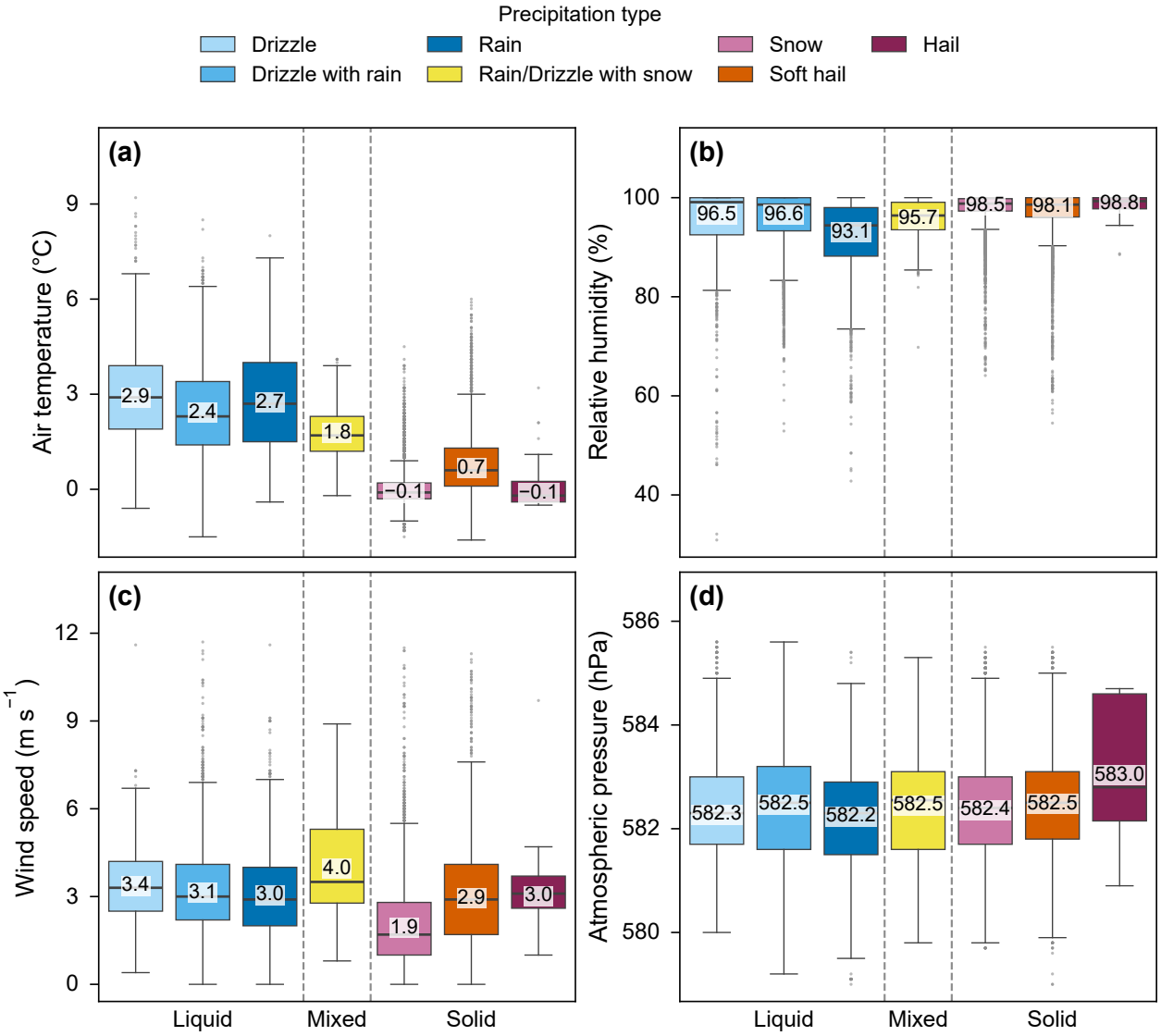

Figure R4. Revised Fig. 6.

RC1.28 – Figure 7

Reviewer comment: *Figure 7:*

- *I assume that the data in plot (a) do not represent the actual logarithm of N(D) but are only plotted with a logarithmic axis. Therefore, the y axis label should be "N(D) (m^{-3} mm^{-1})" without the log10 beforehand*
- *Increase legend a bit*
- *Increase tick labels (and reduce the amount a bit)*
- *Caption: "both decreasing with increasing particle diameter" is not true, e.g. for V(D) of solid particles up to 6.5 mm*

Author response: We thank the reviewer for these observations, which led us to re-examine the computation behind panel (a). The PARSIVEL^2 reports $N(D)$ as $\log_{10}$ values of the concentration ($m^{-3}\,mm^{-1}$). In the original figure, these logarithmic values had been summed over all 1-min records of each type, which does not yield a physically meaningful quantity and depends on the number of records. Figure 7 will be recomputed and redrawn as follows (revised version in Fig. R5):

- **Mean $N(D)$:** each 1-min record will be converted to linear concentrations, and the mean $N(D)$ of each type will be computed over all its records (classes without particles counted as zero). With this correction, hail shows the highest mean concentrations over most of the diameter range, whereas snow and soft hail take intermediate positions (Fig. R5); the text discussing Fig. 7a will be revised accordingly. Panel (b), the maximum fall velocity per diameter class, will not change.
- **y-axis label of panel (a):** $N(D)$ ($m^{-3}\,mm^{-1}$), plotted on a logarithmic axis, will be used. The text after Eq. 1 (L. 153) will clarify that $N(D)$ is reported in logarithmic form by the instrument but is used in linear form in Eq. 2.
- **Legend and tick labels:** the legend and tick labels will be larger, and the number of ticks will be reduced.
- **Caption:** we agree that $V(D)$ does not decrease with diameter for all types; the statement will be removed.

Changes in the manuscript: Figure 7 and its caption; Sect. 3.2 (L. 153); Sect. 4.2.1 (L. 302–318). Only the description of the size distributions changes; the computations of the correction method are not affected, because they use the raw particle counts (Sect. 3.3) and not the averaged $N(D)$ shown in Fig. 7. The revised text of L. 302–318 will read:

> "For all precipitation types, the mean PSD peaked at small diameters (0.44–0.56 mm) and decreased with increasing diameter (Fig. 7a). Hail showed the highest mean concentrations over most of the diameter range, whereas snow and soft hail took intermediate positions and extended to the largest diameters (19 mm). Because the 31 minutes classified as hail were dominated by high concentrations of particles smaller than 5 mm, this result points to misclassification rather than to the presence of hailstones (see below). Since the instrument measures equivalent spherical diameter and fall velocity without imaging capabilities, the recorded particles may represent individual snow crystals, aggregated snowflakes, or rimed particles. Individual snow crystals typically measure 0.5–5 mm (Straka, 2009), while aggregated snowflakes under favourable conditions (temperatures near 0 °C, high humidity) can exceed 25 mm in diameter (Lawson et al., 1998; Locatelli and Hobbs, 1974). The maximum observed diameter of 19 mm is therefore consistent with aggregated snowflakes.
>
> Particles classified as rain were recorded up to 17 mm, although their concentrations above about 7.5 mm were very low and discontinuous (Fig. 7a). This range extends beyond the natural raindrop maximum of approximately 8.8 mm documented under extreme conditions (Hobbs and Rangno, 2004), indicating misclassification. Drizzle particles were mostly smaller than about 2 mm, which is inconsistent with the meteorological definition of drizzle (drops smaller than 0.5 mm). Moreover, isolated drizzle particles reached 6.5 mm, overlapping with the rain size distribution. This overlap suggests limitations in the automated discrimination of the instrument, particularly during mixed precipitation conditions. Hail was recorded up to 15 mm and soft hail up to 19 mm, but both types were dominated by particles smaller than 5 mm. This conflicts with field observations, in which hailstones typically range from 5 to 19 mm (Allen et al., 2020), and suggests that small frozen particles were classified as hail."

The caption will read: "Figure 7. (a) Mean particle size distribution, $N(D)$, and (b) maximum fall velocity, $V(D)$, per diameter class for each precipitation type identified by the PARSIVEL^2. $N(D)$ was converted from the logarithmic values reported by the instrument ($\log_{10}$ $m^{-3}\,mm^{-1}$) to linear concentrations for each 1-min record and then averaged over all records of each type; records without particles in a diameter class were counted as zero. Number of 1-min records: Drizzle 1610, Drizzle with rain 5863, Rain 2389, Rain/Drizzle with snow 394, Snow 5016, Soft hail 3875, and Hail 31."

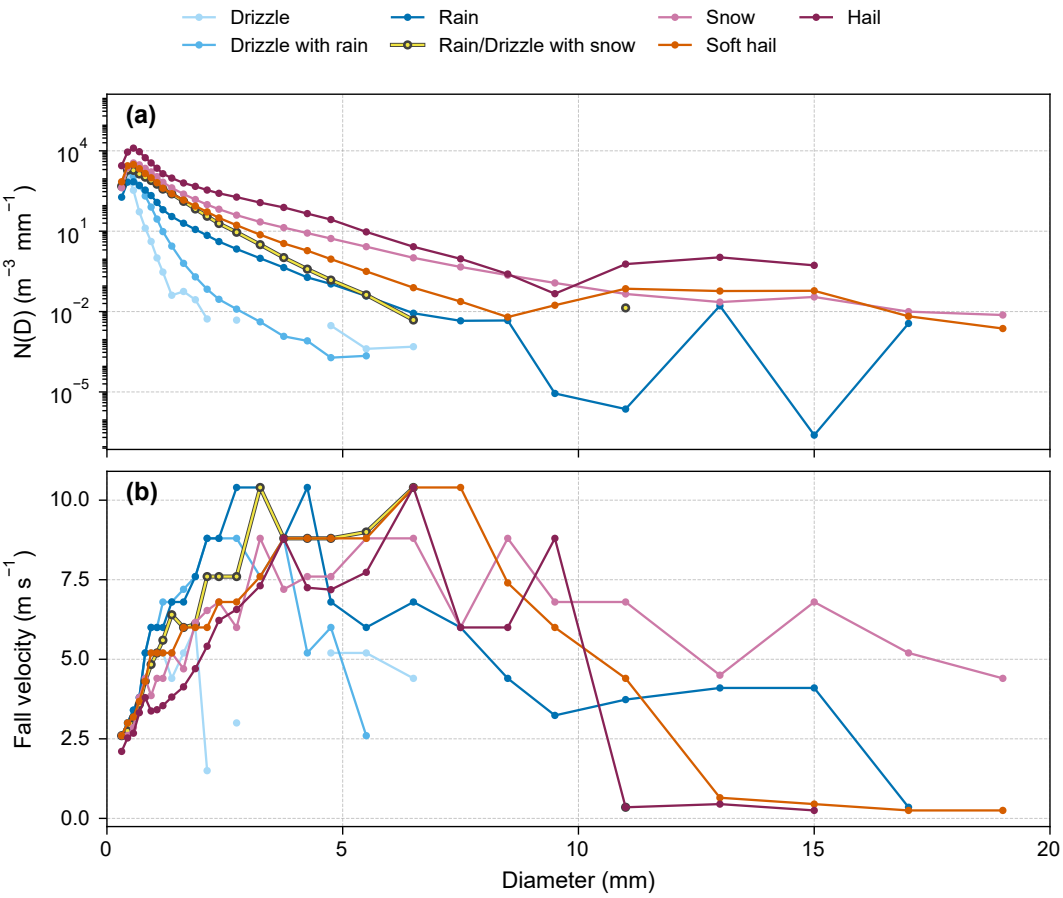

Figure R5. Revised Fig. 7.

RC1.29 – Explanation of the discrepancy (L. 332–334)

Reviewer comment: *Lines 332 - 334: Please reword and explain your findings a bit more clear and detailled. Explain clearly, what exactly is here the discrepancy. Take care that the sentences do not sound like a Figure caption. If you write about graphs, also mention in this sentence again, that you speak about Figure 8.*

Author response: We agree that these sentences were unclear and read like a figure caption. The discrepancy is that the particles assigned to each precipitation type by the PARSIVEL^2 do not follow the fall velocity relationship expected for that type: they lie in regions of the diameter–velocity space that correspond to other hydrometeors, and several types occupy the same regions. The paragraph will be rewritten to state this explicitly and to describe what Fig. 8 shows for each group of types. It will also lead to the explanation given in the next paragraph (L. 335–338), namely that the instrument assigns a single type to each minute, during which several hydrometeor types often coexist.

Changes in the manuscript: Sect. 4.2.1, L. 329–334. The revised text will read: "According to the manufacturer (Nemeth and Beck, 2011), the classification relies on the empirical velocity–diameter relationship of Gunn and Kinzer (1949) for rain. To assess whether the types assigned by the instrument are consistent with the fall behaviour expected for each hydrometeor, Fig. 8 compares the diameter–velocity distribution of the particles of each type with reference fall velocity relationships (Table 2). In general, the particles assigned to each type do not follow the relationship expected for that type. For the liquid types (Fig. 8a–c), most particles smaller than about 4 mm lie close to or below the rain curve, but the rain type also includes particles larger than 10 mm with fall velocities below 6 m s^{-1}, far below the terminal velocity of raindrops. Conversely, most particles classified as snow and soft hail (Fig. 8e, f) fall between the curves of densely rimed aggregates

(S5) and wet snow (W), i.e. faster than dry snow, and some reach velocities of about $9\,\mathrm{m\,s^{-1}}$, typical of graupel and small hail. Most particles classified as hail (Fig. 8g) are smaller than 5 mm and fall more slowly than $4\,\mathrm{m\,s^{-1}}$, well below the hail curves (H1–H3). Finally, the same regions of the diameter–velocity space are occupied by several types (Fig. 8a–g), and the dominant type changes abruptly between neighbouring classes (Fig. 8h)."

RC1.30 – Figure 8

Reviewer comment: *Fig. 8: would profit from larger Legend font sizes. Consider to plot the number of occurences in the lower right corner of each plot instead of behind the Category name. The colors of the composite plot are a bit hard to interpret as they have different scales than the legend. Would it make sense to squeeze each of those seven single color bars into the respective secment of the composite color bar? Maybe with a different color scheme?*

Author response: We thank the reviewer for these suggestions. Figure 8 will be redrawn as follows (revised version in Fig. R6):

- **Legends and labels:** their font size will be increased, and the number of 1-min records of each type will be given in each panel.
- **Composite panel:** following the reviewer's comment, panel (h) will no longer overlay the seven colour maps with different scales. It will show, for each diameter–velocity class, the dominant precipitation type (the type with most particles), using the discrete colours of the common palette and a categorical legend.
- **Reference curves:** they will be taken from the revised Table 2 and labelled directly with their codes.

Changes in the manuscript: Figure 8 and its caption: "Figure 8. Number of particles in each diameter–velocity class recorded by the PARSIVEL^2 for each precipitation type (a–g), and dominant type in each class (h; note the different velocity scale). The number of 1-min records of each type is given below its name. Black lines show reference fall velocity relationships labelled with their code in Table 2: R, rain at the site (Atlas et al., 1973, corrected for air density); Gunn–Kinzer (dashed), the same relationship at sea level, used by the manufacturer as reference; S5, aggregates of densely rimed dendrites; W, wet snow; H1–H3, hail."

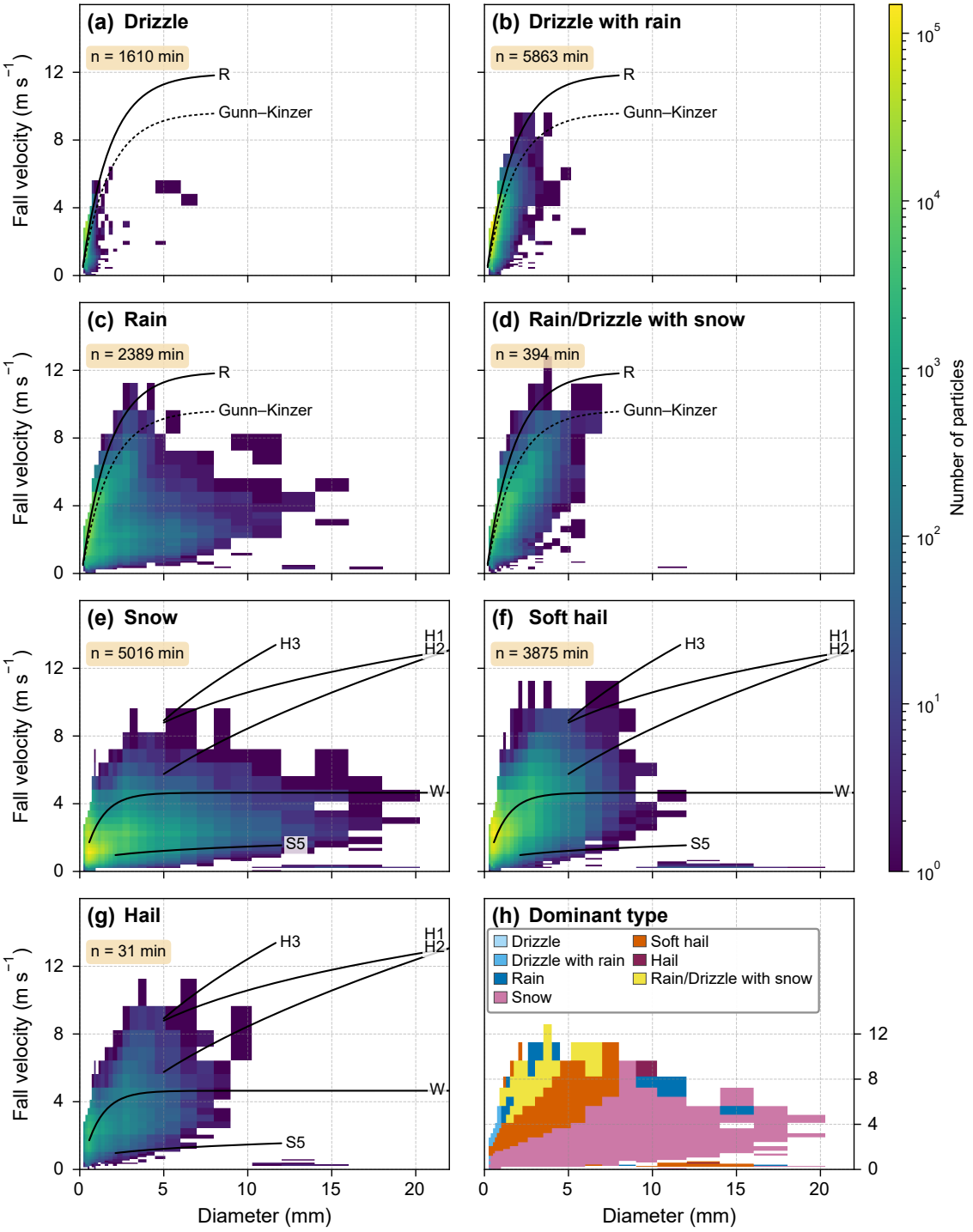

Figure R6. Revised Fig. 8.

RC1.31 – Interpretation of the intercept (L. 359)

Reviewer comment: *Line 359: Actually it just indicates that the parsivel is more sensitive to light precipitation than the Pluvio.*

Author response: We agree. The intercept shows that, for light events, the PARSIVEL^2 records more

precipitation than the Pluvio^2, which is consistent with its higher sensitivity to light precipitation. This higher sensitivity is also documented in Sect. 4.2.2 by the 34 events detected by the PARSIVEL^2 but not by the Pluvio^2 (Fig. 9, L. 374–377). The sentence will be corrected accordingly, and we will add what the intercept and the slope imply together: since the slope is below unity (0.918), the regression line crosses the 1:1 line at about 2.1 mm ($0.176/(1-0.918)$). The PARSIVEL^2 therefore overestimates the events below this value and underestimates the larger ones, which explains why a mean bias of +0.00 mm coincides with a mean relative bias of +15.7 %.

Changes in the manuscript: Sect. 4.2.2, L. 358–361: "The positive intercept (0.176 mm) indicates that the PARSIVEL^2 records more precipitation than the Pluvio^2 in light events, consistent with its higher sensitivity to light precipitation (see also Fig. 9). Together with a slope below unity (0.918), it implies that the PARSIVEL^2 overestimates events smaller than about 2.1 mm and underestimates larger events. Therefore, despite the negligible mean bias, the mean relative bias is +15.7 %, because it is dominated by the more numerous light events."

RC1.32 – Figure 9

Reviewer comment: *Fig. 9:*

- *consider to adjust font sizes of axes labels and tick labels so that they are more equal*
- *Why are the axes labels bold in this figure but not in most others?*
- *consider to use an axis break for the x axis at 500 min with a more condensed second part (I leave that up to the authors)*
- *Legend:*
  - *I suggest removing "Type"*
  - *"Pluvio_registered" could be rewritten to "registered by Pluvio" but it is confusing, does it mean only detected by Pluvio? otherwise, it should be an asterisk, or am I wrong?*
  - *ideally, place the legend in some corner, like the lower right one*
- *Caption:*
  - *Please revise with regard to typos and grammar (e.g., Comparison of, no semicolon, missing or redundant whitespaces). I also suggest to change "colors dots" to "color code", "black asterisk" to "asterisks", "black dot" to "dots", and "extracted from total events 129" to "extracted from 129 total events". "the number of intense occurrences (...) is labeled on the yellow-marked locations." could also use some rewording.*

Author response: We thank the reviewer for the detailed suggestions. The reviewer is right: in the legend, the asterisk denotes events detected by both instruments and the dot denotes events detected only by the PARSIVEL^2; "Pluvio_registered" was the name of the legend group and will be removed. Figure 9 will be redrawn as follows (revised version in Fig. R7):

- **Fonts:** axis labels and tick labels will have similar font sizes, and bold labels will be removed.
- **Legend:** "Type" will be removed, the symbols will be described explicitly, and the legend will be placed in the lower right corner.
- **Axis break:** following the reviewer's suggestion, the x axis will be broken at 500 min, which resolves the short events much better.
- **Caption:** it will be revised as suggested.

Changes in the manuscript: Figure 9 and its caption: "Figure 9. Comparison of the event precipitation measured by the PARSIVEL^2 and the event duration for the 129 events. The color code indicates the dominant precipitation type of each event; asterisks mark events also detected by the Pluvio^2, and dots mark events detected only by the PARSIVEL^2. Dashed lines show the thresholds of 0.25 mm and 60 min. Yellow labels identify the extreme events (> 10.6 mm). The x axis is broken at 500 min, and the y axis is linear between 0 and 0.1 mm and logarithmic above."

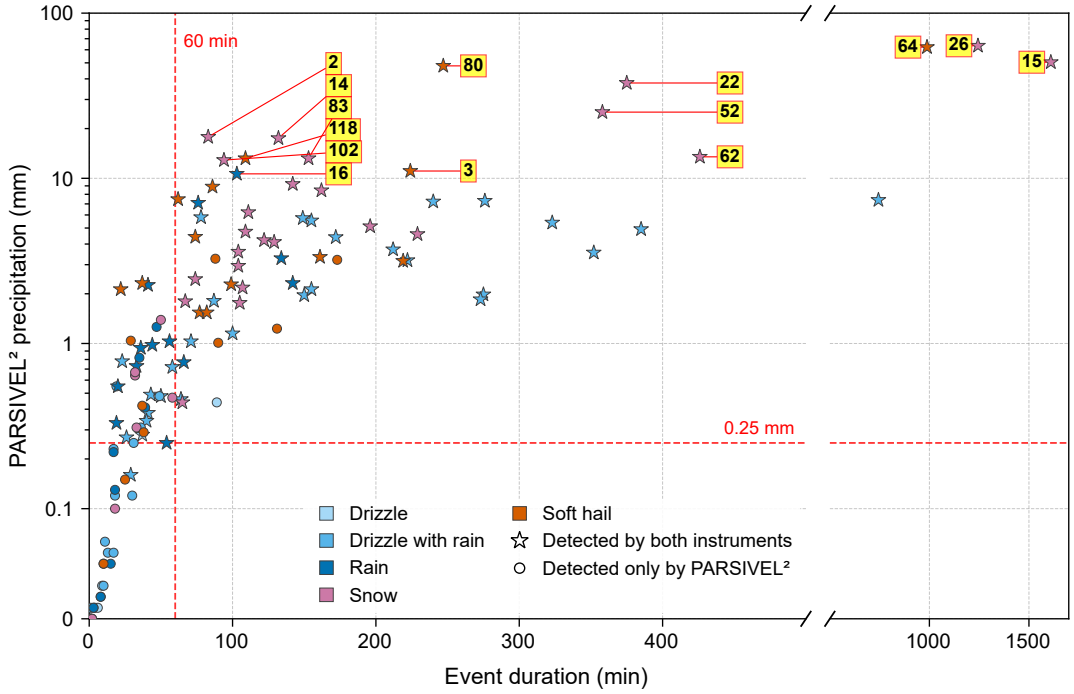

Figure R7. Revised Fig. 9.

RC1.33 – Figure 10

Reviewer comment: *Figure 10:*

- *Add (a) - (c)*
- *in general, I would suggest to not show titles here but describe a to c in the caption.*
- *(a): plot the curves last, so that they are in the foreground*
- *In the legend, I suggest to only label the two instruments as lines but label the categories as boxes/patches, otherwise, the legend is not directly clear*
- *47.9 mm / 8.2 mm is not directly clear, write that part in the caption and explain which number belongs to which instrument*
- *(b) and (c): please adjust the width of the color bar and revise color bar labels (units!)*
- *I suggest to plot the diameter only to 17.5 or so to beter resolve the range with the actual data*
- *this figure would benefit from being plotted as vector graphic*
- *Caption: I suggest "overestimation event 80 on March 17, 2023 showing time series of (a) Precipitation intensity colred by classified type, (b) mean fall velocity by particle size, and (c) . . . "*

Author response: We thank the reviewer for these suggestions, which will be implemented as shown in the revised figure (Fig. R8): panels (a)–(c) will be labelled and the titles removed; in panel (a), the instrument curves will be plotted in the foreground over the background coloured by the classified type, and the legend will show the instruments as lines and the types as patches; the accumulations of both instruments will be given in the caption; the colour bars of (b) and (c) will be narrower and include units; the diameter axis will be limited to the range with data; and the figure will be provided as a vector graphic. Panel (c) will show $N(D)$ as linear concentrations on a logarithmic colour scale (see our response to comment RC1.28).

Changes in the manuscript: Figure 10 and its caption: "Figure 10. Overestimation event 80 on 17 March 2023, 09:29–15:24 local time (PARSIVEL^2 47.9 mm; Pluvio^2 8.2 mm, or 11.5 mm after the correction for wind-induced undercatch). (a) Precipitation intensity measured by the PARSIVEL^2 and the Pluvio^2, with the background coloured by the precipitation type classified by the PARSIVEL^2 in each minute; (b) mean fall velocity and (c) particle size distribution, $N(D)$, per diameter class and minute, with $N(D)$ shown on a logarithmic colour scale. Times are local time (UTC−5). Minutes without records are left blank. Large

particles ($> 10\,\mathrm{mm}$) with fall velocities $\leq 1\,\mathrm{m\,s^{-1}}$ in (b) fall outside the segmentation masks and are removed by the correction."

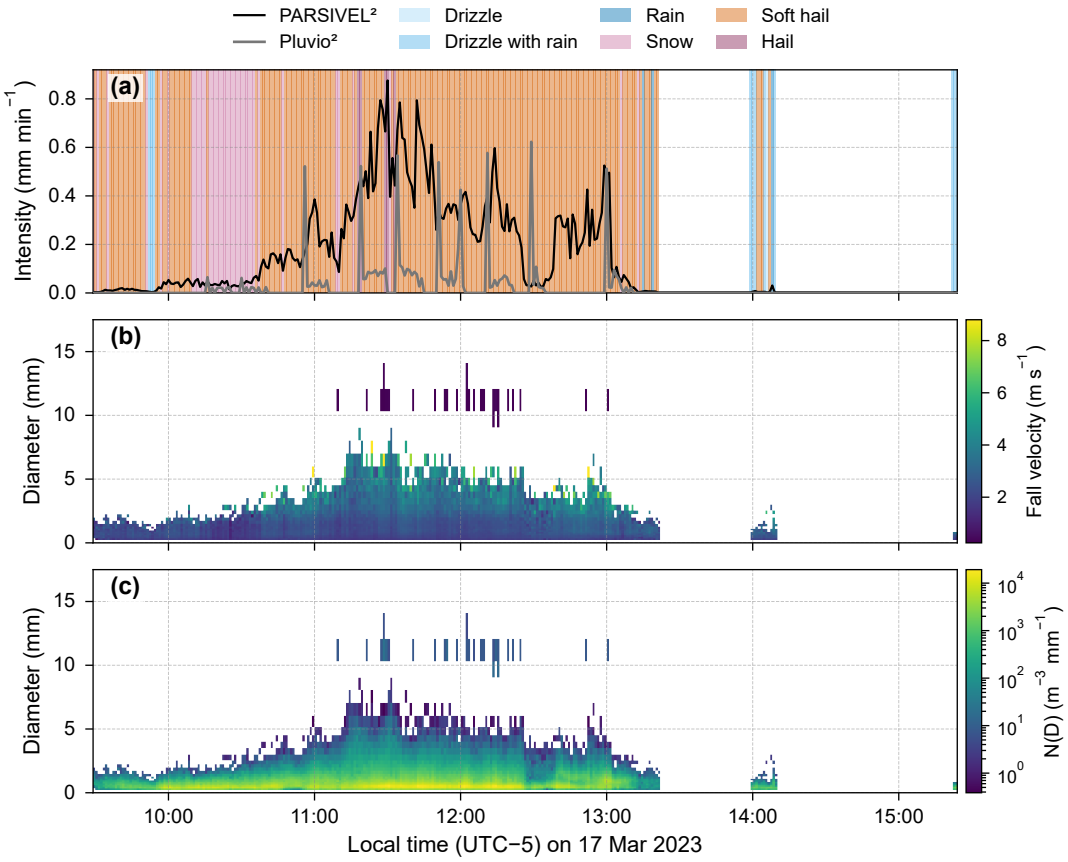

Figure R8. Revised Fig. 10.

RC1.34 – Figure 12

Reviewer comment: *Figure 12:*

- *Consider to plot this as one-column figure and as one figure without having three subfigures. Consider to only have y ticks at 0.2 steps.*
- *Please revise y axis label.*
- *Caption:*
  - *stay with unit convention (g cm-3)*
  - *I suggest "Distribution of density values grouped by..." and "The density values range from ...".*

Author response: Thank you. Figure 12 will be redrawn as a single one-column panel, with y ticks every $0.2\,\mathrm{g\,cm^{-3}}$ and the y-axis label "Density ($\mathrm{g\,cm^{-3}}$)" (revised version in Fig. R9). While redrawing it, we found an error in the computation of these densities: the width of the diameter classes between 2.75 and 4.75 mm had been set to 0.25 mm instead of 0.5 mm, and the centres of the classes between 1.375 and 2.375 mm were slightly shifted. This halved the recalculated intensity of those classes and inflated the density, producing values of up to $1.9\,\mathrm{g\,cm^{-3}}$, which are physically implausible. With the class centres and widths of the manufacturer's manual, the densities range from 0.01 to $1.00\,\mathrm{g\,cm^{-3}}$, with medians of 0.92 (liquid), 0.80 (mixed) and $0.42\,\mathrm{g\,cm^{-3}}$ (solid). This error affected only Fig. 12; the correction method used the correct class widths. The interpretation of Sect. 4.3.1 is unchanged (the internal algorithm does not assign a fixed density to solid and mixed-phase particles), but its values will be updated. The caption will be revised as suggested and will state that the values are derived from the PARSIVEL² internal algorithm.

Changes in the manuscript: Figure 12 and its caption; Sect. 4.3.1 (L. 429–440). The paragraph will read (the first sentences are those proposed in our response to comment RC1.14, and "reliably" is deleted as suggested in L. 439):

> "Before calculating the apparent density, it is worth noting that the density implicitly assumed by the PARSIVEL^2 internal algorithm, which can be back-calculated from Eq. 2 for each classified minute, is not documented by the manufacturer. For liquid precipitation, a density close to that of liquid water would be expected, whereas for snow, a size-dependent density following an empirical relationship such as that proposed by Brandes et al. (2007) would be expected; however, this cannot be confirmed. The back-calculated values (Fig. 12) revealed systematic deviations from these expectations across all precipitation phases. Liquid minutes clustered around a median of 0.92 g cm^{-3} (interquartile range 0.88–0.96 g cm^{-3}), although some values fell to 0.01 g cm^{-3}. Mixed-phase minutes (rain/drizzle with snow) showed a narrow distribution (median 0.80 g cm^{-3}; interquartile range 0.77–0.83 g cm^{-3}), much closer to the density of liquid water than to that of wet snow (0.1–0.2 g cm^{-3}; Sect. 3.3.3). Solid minutes showed the largest variability, with a median of 0.42 g cm^{-3} and an interquartile range of 0.19–0.67 g cm^{-3}, and values spanning almost the whole range from 0.01 to 0.99 g cm^{-3}. These results indicate that the internal algorithm does not assign a fixed density to each precipitation type and that, for most mixed and solid minutes, the implied densities exceed those reported for snow and wet snow (Sect. 3.3.3). These deviations confirm that the internal algorithm of the disdrometer does not reproduce standard theoretical density values, underscoring the need for site-specific calibration."

The caption will read: "Figure 12. Distribution of the apparent density values derived from the PARSIVEL^2 internal algorithm, grouped by precipitation phase. The density is the ratio between the precipitation intensity reported by the instrument and the intensity recalculated with Eq. 2 from $N(D)$ and $V(D)$ assuming liquid water ($\rho = 1\,\mathrm{g\,cm^{-3}}$), for all 1-min records with precipitation during the study period. The density values range from 0.01 to 1.00 g cm^{-3}, with mean values of 0.89 (liquid), 0.79 (mixed), and 0.44 g cm^{-3} (solid). Boxes span the 25th to 75th percentiles, the inner line is the median (0.92, 0.80, and 0.42 g cm^{-3}), whiskers extend to the most extreme values within 1.5 times the interquartile range, and dots are values beyond it."

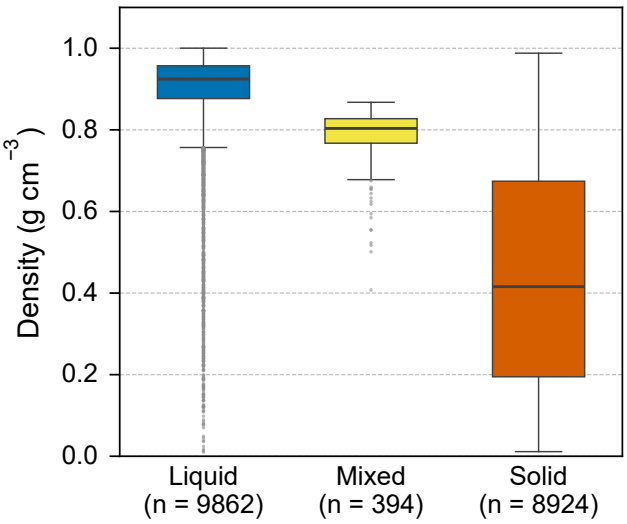

Figure R9. Revised Fig. 12.

RC1.35 – Time-varying density (L. 467)

Reviewer comment: *Line 467: Can you comment a bit more on why "poorly constrained uncertainty" would be introduced? Did you try that for liquid precipitation?*

Author response: We thank the reviewer for this question, which shows that the sentence needs a better explanation. By "poorly constrained uncertainty" we referred to what we observed for the PARSIVEL^2 itself. Its internal algorithm implies a density that changes from minute to minute (Fig. 12; see RC1.34). These values are not documented by the manufacturer, they are not constrained by any independent measurement, and they produced large errors in the event accumulations (mean relative biases of +98.5 % for mixed-phase and +84.1 % for solid events). A time-varying density in our correction would face the same problem, because it could only be adjusted against the Pluvio^2. The Pluvio^2 provides a reliable reference only for event totals: it responds with a delay of about one hour and shows an oscillating signal during intermittent precipitation (Fig. 10a; L. 391–396), so it cannot constrain a density at the minute scale. We did not test a time-varying density, neither for liquid nor for the other categories. For liquid precipitation, there is also no physical reason for it, because the density of water is constant. The value of $0.9\,\mathrm{g\,cm^{-3}}$ is an apparent density that absorbs residual errors, such as the sizing of drops by the instrument and particles of other phases classified as rain.

A size-dependent relationship would be a natural alternative for the solid categories, but the literature shows its limitations. Brandes et al. (2008) derived power-law relationships between the fall velocity and the diameter of snow aggregates from 2DVD observations. They found that the coefficient depends on the composition of the aggregates (plates, columns or dendrites) and on their degree of riming, which they could not determine and therefore replaced by temperature. Moreover, fall velocities varied widely at a given size, and the fits were influenced by the large number of poorly sampled small particles. Because fall velocity and density are related, similar limitations are likely to apply to a density–diameter relationship. Such relationships would therefore have to be derived for the conditions of each site, which is not possible without independent observations of particle mass or type. For these reasons, we adopted a constant apparent density for each category, restricted to the ranges reported in the literature (Table 3). The sentence will be rewritten to explain these points.

Changes in the manuscript: Sect. 4.3.2, L. 462–468. The revised text will read: "The modest increase in RMSE (0.71 → 0.86 mm) and MAE (0.40 → 0.50 mm) reflects the use of a single apparent density for a particle population whose effective density may vary within and between events. At this high-altitude site, the liquid category may include small non-spherical drops and partially frozen particles, whose effective density deviates from that of liquid water. A density varying in time could, in principle, represent this variability, but it would be poorly constrained. The internal algorithm of the PARSIVEL^2 illustrates this problem: it implies densities that vary from minute to minute (Fig. 12), and yet it overestimated the event accumulations. In our correction, a time-varying density could only be adjusted against the Pluvio^2, which does not resolve minute-scale accumulations reliably (Fig. 10a). Size-dependent relationships also have limitations: for snow aggregates, their coefficients depend on the composition and degree of riming of the particles, and fall velocities vary widely at a given size (Brandes et al., 2008). We therefore adopted a constant apparent density for each category ($0.9\,\mathrm{g\,cm^{-3}}$ for rain), which keeps the number of fitted parameters small and the method reproducible."

RC1.36 – Figure 13

Reviewer comment: *Figure 13:*

- *it's not common to have a title above the figure. Better use the first Sentence of the caption for that*
- *the "Note" box is redundant as the info is given in the caption*
- *an increased font size for tick labels, equations, and the legends would be beneficial*
- *Why are labels bold but in most other figures not?*

Author response: Thank you. The title and the "Note" box will be removed, the font size of the tick labels, equations and legends will be increased, and bold labels will be removed (revised version in Fig. R10). In addition, the columns will be ordered liquid, mixed and solid, as in all other figures; the panel references in the text will be updated accordingly.

Changes in the manuscript: Figure 13 (Fig. 10 in the revised numbering; see RC1.75) and its caption: "Figure 13. Event precipitation measured by the PARSIVEL^2 against the Pluvio^2 weighing gauge, before (a–c) and after (d–f) the reclassification and density correction, for liquid (a, d; $n = 16$), mixed (b, e; $n = 37$), and solid (c, f; $n = 17$) events. Event phases are based on the uncorrected PARSIVEL^2 output, using a threshold of > 80 % fractional contribution of rain for liquid events and of snow, soft hail, and hail for

solid events. Each panel shows the ordinary least-squares regression line (red) and its equation, the 1:1 line (dashed), and the root mean square error (RMSE), mean absolute error (MAE), coefficient of determination (R^2), and mean bias in mm and as a percentage over- or underestimation. Yellow labels identify the extreme events (PARSIVEL^2 precipitation > 10.6 mm), which strongly influence the regression statistics."

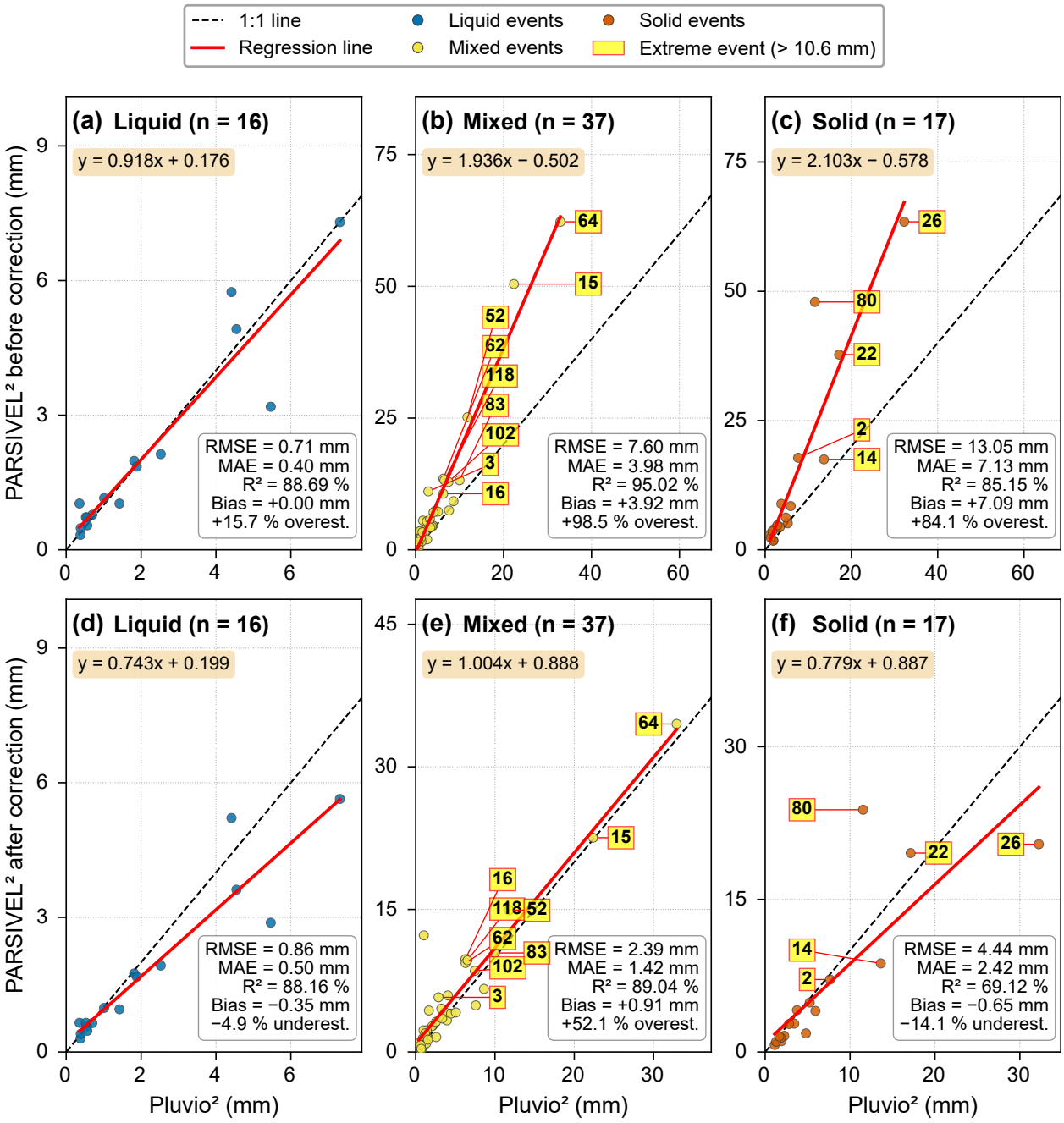

Figure R10. Revised Fig. 13.

RC1.37 – Contaminating particles (L. 503)

Reviewer comment: *Line 503: What do you understand as contaminating particles? Like insects etc.? Could it be also wrongly detected hydrometeors, like two at the same time etc.?*

Author response: We thank the reviewer for this question. By "contaminating particles" we meant detections whose diameter–velocity pair is not consistent with the fall behaviour of any hydrometeor, in particular particles larger than 10 mm falling at less than 1 m s^{-1}. The reviewer is right that these are not necessarily foreign objects. Possible causes include insects or debris, but also wrongly measured hydrometeors: two or more particles crossing the beam at the same time and being measured as a single larger particle, as the reviewer suggests, or particles crossing the beam obliquely under strong wind, which Friedrich et al. (2013) identified as a source of large particles with unrealistically low fall velocities. Because the PARSIVEL^2 provides no particle images, these causes cannot be distinguished. The term "contaminating particles" will therefore be replaced by "spurious detections", and their possible causes will be described where the exclusion criterion is introduced (Sect. 3.3.2; see our response to comment RC1.20).

Changes in the manuscript: Sect. 3.3.2, L. 209–210 (see RC1.20), and Sect. 4.4, L. 503 (see RC1.38).

RC1.38 – Figure 14

Reviewer comment: *Fig. 14*

- *needs to be replotted. See comments on Fig. 7!*
- *Caption:*
  - *the comma after (a) should be removed*
  - *the second sentence should be revised with respect to grammar and content.*
  - *"cleaned" is not ideal here, I suggest "removed after the correction"*

Author response: Thank you. Figure 14 will be recomputed and redrawn (revised version in Fig. R11). As for Fig. 7, the mean $N(D)$ of each event will be computed from linear concentrations (see our response to comment RC1.28). Because the reclassification only removes the diameter classes whose particles fall outside the segmentation masks (large diameters with low fall velocities), the $N(D)$ before and after the correction are almost identical except at the largest diameters. The revised figure will therefore show the corrected $N(D)$ separately for (a) the solid and (b) the mixed extreme events, with the removed classes left blank and the precipitation before and after the correction given in the legend. The caption will follow the reviewer's suggestions.
This new representation also changes part of the interpretation of Sect. 4.4. Because the size distributions are almost unchanged by the correction, the reduction of the event totals (8–68 %) cannot be explained by the removal of spurious large particles. In event 14, for example, no diameter class was removed, and its total still decreased by 50 %. The reduction results mainly from the reclassification of the particles of each minute into several categories and from the category-specific apparent densities. This shows that the overestimation by the PARSIVEL^2 is driven mainly by the coexistence of different hydrometeor types within the same minute. In addition, the mean size distributions of all 14 events peak at 0.44–0.69 mm (class centres), not at 0.5–2.5 mm as stated in L. 510 and L. 542, which will be corrected. The text of Sect. 4.4 will be rewritten accordingly.

Changes in the manuscript: Figure 14 and its caption; Sect. 4.4 (L. 494–522). The revised text of L. 495–518 will read:

> "Figure 14 shows the mean PSDs of the 14 extreme events (PARSIVEL^2 precipitation > 10.6 mm), separately for the five solid (a) and the nine mixed (b) events. All PSDs are unimodal, with the mode in the diameter classes centred at 0.44–0.69 mm, and concentrations decrease by several orders of magnitude towards the largest diameters. The correction removed only the largest diameter classes, whose particles fell outside the segmentation masks because they combined large diameters (9.5–19 mm) with low fall velocities (Sect. 3.3.2). Such classes were removed in four of the five solid events and in five of the nine mixed events, and their mean concentrations were low (< 1 m^{-3} mm^{-1}); the rest of the PSDs was not modified. After the correction, particles larger than 11 mm remained mainly in mixed events, in which the largest diameters reached 15–17 mm (events 52, 62 and 83). In solid events, the largest diameters were 8.5–11 mm, except for an isolated class at 17 mm in event 22. This is consistent with large, partially melted aggregates coexisting with smaller particles during mixed-phase precipitation.
>
> Corrected event totals decreased by 8 %–68 % relative to the uncorrected values, e.g., event 26 (63.4 → 20.4 mm; −68 %), event 2 (17.8 → 7.1 mm; −60 %), event 15 (50.4 → 22.5 mm; −55 %) and

event 64 (62.3 → 34.5 mm; −45 %). Because the PSDs were almost unchanged, these reductions cannot be attributed to the removal of spurious detections. In event 14, for example, no diameter class was removed, and its total still decreased by 50 %. The reductions result mainly from the reclassification of the particles of each minute into several categories and from the category-specific apparent densities (Sect. 4.3). This confirms that the overestimation by the PARSIVEL^2 was driven mainly by the coexistence of different hydrometeor types within the same minute, to which the instrument assigns a single precipitation type (Sect. 4.2.1), together with the internally calculated densities, which deviate systematically from theoretical expectations (Sect. 4.3.1)."

The caption will read: "Figure 14. Mean particle size distribution, $N(D)$, of the extreme events (PARSIVEL^2 precipitation above the upper whisker of 10.6 mm) for (a) solid and (b) mixed events. $N(D)$ was converted from the logarithmic values reported by the instrument to linear concentrations for each 1-min record and averaged over the event duration. Diameter classes whose particles fell outside the segmentation masks (large diameters with low fall velocities) were removed after the correction and are left blank. The legend gives the event number and the PARSIVEL^2 precipitation before → after the correction."

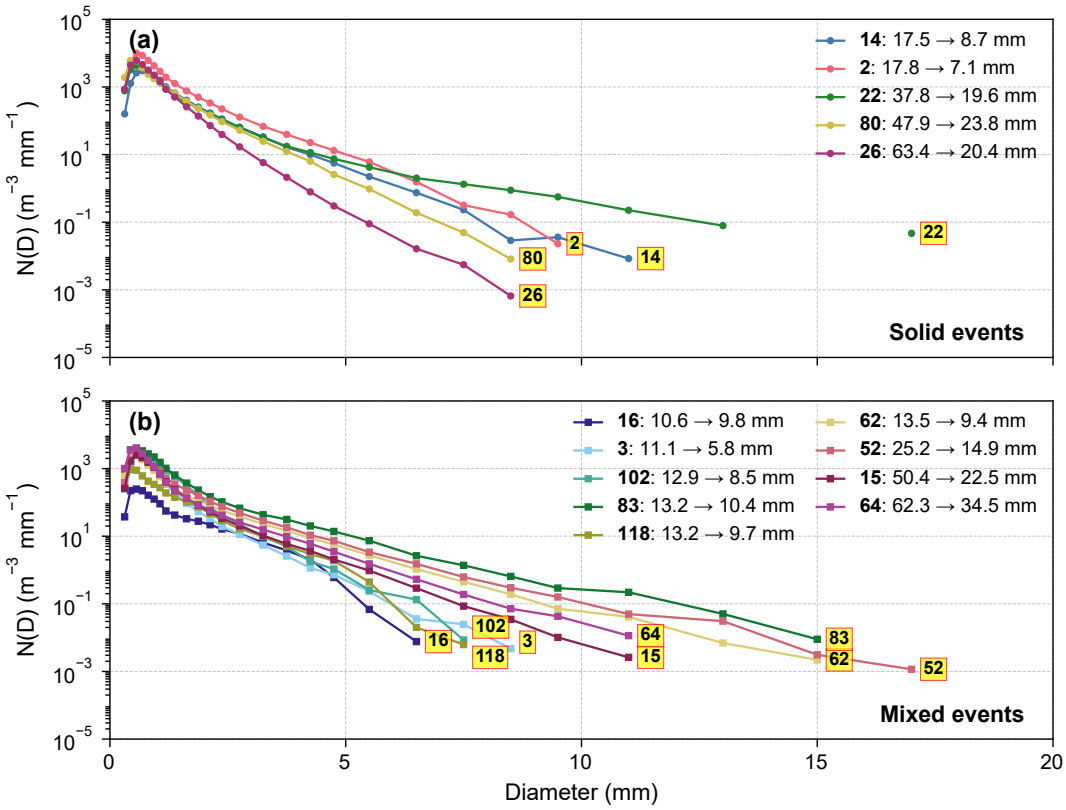

Figure R11. Revised Fig. 14.

RC1.39 – Imaging systems (L. 547)

Reviewer comment: *Line 547: This reference is also about the MASC. I suggest to name three types of imaging systems instead (like MASC, PIP, VISSS; including references)*

Author response: We thank the reviewer for this suggestion. The sentence will name three types of imaging systems and their main advantages for validating the classification obtained in this study: the Multi-Angle Snowflake Camera (MASC), the Precipitation Imaging Package (PIP) and the Video In Situ Snowfall Sensor (VISSS). The MASC provides high-resolution stereoscopic images of individual particles, from which the hydrometeor type, the degree of riming and melting snow can be identified (Praz et al., 2017). The PIP has

an open design with a large measurement volume and derives an equivalent density and the precipitation phase from 1-min size and fall velocity distributions (Pettersen et al., 2020, 2021). The VISSS combines a large measurement volume with a higher resolution than the PIP and views each particle from two perspectives (Maahn et al., 2024).

Changes in the manuscript: Sect. 5.1, L. 545–548. The revised text will read: "Future studies should incorporate particle imaging instruments to validate the hydrometeor classification inferred from the velocity–diameter method. Each type of system offers a different advantage. The Multi-Angle Snowflake Camera (MASC; Garrett et al., 2012) photographs each hydrometeor from three angles at high resolution (about 30 µm per pixel), which allows the hydrometeor type, the degree of riming and the presence of melting snow to be identified automatically (Praz et al., 2017). The Precipitation Imaging Package (PIP) has an open design with a large measurement volume, which limits wind disturbance and reduces the sampling uncertainty of the size distribution, and it derives an equivalent density and the precipitation phase from 1-min particle size and fall velocity distributions (Pettersen et al., 2020, 2021). Its ability to separate precipitation phases during mixed-phase and transition events (Pettersen et al., 2021) is particularly relevant for sites such as ours. The Video In Situ Snowfall Sensor (VISSS) combines a large observation volume with a higher pixel resolution (43–59 µm) by viewing each particle from two perspectives with telecentric lenses, which provides accurate particle sizes, shapes and fall velocities (Maahn et al., 2024)." The references Pettersen et al. (2020, 2021) and Maahn et al. (2024) will be added to the reference list.

Technical comments

We thank the reviewer for the careful reading and for the detailed list of corrections. All of them will be implemented, as summarized below. Comments that require a longer explanation are referred to the responses above.

No. / Line	Reviewer comment	Author response and change
RC1.40 / whole text	*Please stay consistent with the spelling of the Parsivel² instrument. You are changing between PARSIVEL2, PARSIVEL², and Parsivel2 – please decide for one. This concerns as well the title, abstract, and axes labels of figures.*	PARSIVEL² will be used throughout, including the title, the abstract and all figures.
RC1.41 / whole text	*Same with the PLUVIO²S / Pluvio2 / Pluvio² / PLUVIO² (stay with "Pluvio2" if you make the statement in line 92)*	Pluvio² will be used throughout, as defined in L. 92, including the axis labels of Fig. 13.
RC1.42 / whole text	*Please revise the semi blank spaces between number and unit in the whole manuscript!*	A thin space will be used between all numbers and units.
RC1.43 / Figs. and tables	*All Figures and Tables should be displayed at the top of the page! This is currently not the case for Figures 2, 3, 4, 7, 11, 12, 14 and Table 3.*	All figures and tables will be placed at the top of the page.
RC1.44 / Figs.	*If possible, plot your figures as vector graphics*	All figures except the map and photographs of Fig. 1 will be provided as vector graphics (PDF); their revised versions are shown in this response.
RC1.45 / L. 30	*"measurements" instead of "measurement"*	This will be corrected.
RC1.46 / L. 60	*Whitespace missing before "The"*	This will be corrected.

No. / Line	Reviewer comment	Author response and change
RC1.47 / L. 66	*stay consistent, either use "-" or "to" when describing ranges*	Ranges will be written with an en dash throughout (e.g., 13–15 °C).
RC1.48 / L. 70–71	*unit convention! (mm day-1)*	The unit will be corrected to mm d^{-1}, in the text and in Fig. 2.
RC1.49 / L. 75–76	*are parentheses missing around "Fig. 2d"?*	Yes; this will be corrected to "(Fig. 2d)".
RC1.50 / Fig. 2	*enlarge the tick labels, legends, second y axis label at c), and the letters a) to d)! Also stay consistent with the units on the y axes (mm d-1 and m s-1 instead of mm/d and m/s)*	Figure 2 will be redrawn as suggested: larger tick labels, legends, second y-axis label of (c) and panel labels, and units mm d^{-1} and m s^{-1}. Its caption will also state that the error bars indicate ±1 standard deviation of the 1-min records.
RC1.51 / L. 130	*redundant whitespace*	This will be corrected.
RC1.52 / L. 132	*redundant parentheses*	This will be corrected to "proposed by Kochendorfer et al. (2017)".
RC1.53 / Eq. 1	*should the second "n" be an "m"? Otherwise n=m=32 in line 154 would be redundant*	Yes, thank you; the upper limit of the second sum will be m (number of velocity classes).
RC1.54 / L. 159	*introduce abbreviation "R" here*	This will be corrected to "... precipitation intensity (R, mm h^{-1})". R will denote intensity and P accumulation throughout (see RC1.24).
RC1.55 / L. 201	*there is no Figure 11a*	The reference will be corrected to Fig. 4b.
RC1.56 / L. 203	*I suggest "from 0.5 m to the ..."*	This will be corrected to "from 0.5 mm to the last diameter class (24.5 mm)".
RC1.57 / L. 205	*there is no Figure 11c*	The reference will be corrected to Fig. 4e.
RC1.58 / Table 2	*If hailstones and hail belong to the same category, I suggest to remove the horizontal line which separates them. Does it make sense to include the bulk densities in this table? I leave it up to the authors.*	"Hailstones" and "Hail" will be merged into a single category (Hail), without a separating line (Table R2, see RC1.18). We prefer to keep the densities in Table 3, which gives both the literature range and the fitted apparent density of each category; Table 2 will refer to Table 3.
RC1.59 / L. 206	*I suggest ">10 mm in diameter"*	This will be corrected.
RC1.60 / L. 207	*redundant whitespace and missing parenthesis behind "(2014)"*	This will be corrected to "(0.9 g cm^{-3}; Heymsfield and Wright, 2014)".
RC1.61 / L. 258	*"mm diameter" needs rewording*	This will be corrected to "... for the smallest drops (diameter < 0.47 mm, classified as drizzle)".

No. / Line	Reviewer comment	Author response and change
RC1.62 / L. 260	*"adjusted measurements adjusted" needs rewording*	This will be corrected to "The density values were determined by comparing the event accumulations of the weighing gauge, corrected for wind-induced undercatch, with those computed for all combinations of density values within the range of each category."
RC1.63 / L. 262	*define RMSE here instead of in line 265*	RMSE will be defined at its first use (L. 262), and the formulas of all metrics will be given at the end of Sect. 3.3.3 (see RC1.5).
RC1.64 / L. 277	*I suggest "weak-updraft low-layer clouds"*	This will be corrected.
RC1.65 / L. 286	*"3 m s-1": 2.9m/s written in line 282, I suggest to not mention it here again. Otherwise, the number should match with the one at line 282.*	The two values refer to different types shown in Fig. 6: soft hail (2.9 $\mathrm{m\,s^{-1}}$, L. 282) and hail (3.0 $\mathrm{m\,s^{-1}}$, L. 286). To avoid confusion, the hail value will be given with one decimal and explicitly attributed to hail. As the values labelled in Fig. 6 are means, "median" will be replaced by "mean" in L. 275–286 (see RC1.27).
RC1.66 / L. 291	*update reference!*	The reference will give the date of last access (see RC1.2).
RC1.67 / L. 294	*"observe" might be the wrong term here*	This will be corrected to "As shown in Fig. 6, . . .".
RC1.68 / L. 313	*I suggest starting a new sentence with "Moreover"*	This will be corrected (see the revised text in RC1.28).
RC1.69 / L. 335	*minute-by-minute*	This will be corrected.
RC1.70 / L. 338	*should "D<1 mm" be in math mode?*	Yes; this will be corrected to $D < 1\,\mathrm{mm}$.
RC1.71 / L. 347	*missing whitespace*	This will be corrected to "70 (54.3 %)".
RC1.72 / L. 348	*I suggest removing "3.3.1". I also suggest "For fifteen events, the recorded duration was below 10 minutes. . . "*	This will be corrected as suggested.
RC1.73 / L. 349	*weighing instead of weighting*	This will be corrected.
RC1.74 / L. 351	*Q3 and IQR should be defined when used the first time*	This will be corrected to "the third quartile (Q3) plus 1.5 times the interquartile range (IQR)". While checking this sentence, we found that the threshold of 10.6 mm is the upper whisker (Q3 + 1.5 IQR) of the precipitation of the 129 events, and not the 95th percentile as stated; the reference to the 95th percentile will be removed.

No. / Line	Reviewer comment	Author response and change
RC1.75 / L. 353	*I think that it's common to order the Figures according to their first appearance in the text. Therefore, Fig 13 should be Fig. 10. Perhaps, give a statement that in Section . . . , you are explaining / discussing the results of d to f from this figure.*	We agree. The figures will be renumbered according to their first citation: Fig. 13 will become Fig. 10, and Figs. 10–12 will become Figs. 11–13. Section 4.2.2 will state that the panels after the correction are discussed in Sect. 4.3.2.
RC1.76 / L. 355 f.	*missing whitespace, wrong placement of comma; comma instead of point; linear instead of lineal*	This will be corrected to "As a result, we obtained 16 liquid, 17 solid and 37 mixed events, which were analysed by linear regression." The number of mixed events is 37, as in Fig. 13 and L. 367, not 38.
RC1.77 / L. 365, 371	*add whitespaces between numbers*	This will be corrected to "(e.g., 2, 14, 22, 26 and 80)".
RC1.78 / L. 366	*Why the x and the "?*	The "×" indicated a ratio and the quotation mark was a typo. The sentence will read: ". . . overestimated the Pluvio^2 accumulations by factors of 1.3 to 4.2."
RC1.79 / L. 376	*mm min-1*	The unit will be corrected to mm min^{-1}.
RC1.80 / L. 405	*missing whitespace*	This will be corrected.
RC1.81 / L. 424	*methodology: "method" fits slightly better, one could also skip the work completely*	This will be corrected to "after applying the correction".
RC1.82 / L. 439	*I suggest to delete "reliably" here.*	The word will be deleted (see the revised text in RC1.34).
RC1.83 / L. 471	*pre-existing*	This will be corrected.
RC1.84 / L. 473	*2 missing commas after "point" and "it"*	This will be corrected.
RC1.85 / L. 498	*missing whitespace*	This will be corrected in the rewritten paragraph (see RC1.38).
RC1.86 / L. 501	*non-monotonic*	This will be corrected in the rewritten paragraph (see RC1.38).
RC1.87 / L. 502	*size-velocity*	This will be corrected in the rewritten paragraph (see RC1.38).
RC1.88 / L. 515	*pre-correction*	This will be corrected.
RC1.89 / L. 535	*I suggest "hydrometeor type"*	This will be corrected.
RC1.90 / L. 541	*missing whitespace; event-integrated*	This will be corrected. In the same sentence, the modal diameters will be corrected to 0.44–0.69 mm (see RC1.38).

No. / Line	Reviewer comment	Author response and change
RC1.91 / L. 543	*whitespace; "This is a"*	This will be corrected to "...regardless of event intensity. This is a finding that may inform ...".
RC1.92 / L. 574	*check names in reference*	This will be corrected to "(Goodison et al., 1998)".
RC1.93 / L. 576	*whitespace before "OTT"*	This will be corrected to "the OTT PARSIVEL^2 optical disdrometer".
RC1.94 / L. 584	*I suggest "developed in here"*	This will be corrected to "The correction method developed in this study integrates ...".
RC1.95 / L. 613	*"acquired downloaded" needs rewording*	This will be corrected to "The data used in this work can be downloaded from ...".
RC1.96 / L. 614	*missing "." Behind "(2026b)"?*	This will be corrected to "(Perez, 2026b).".
RC1.97 / L. 635, 650, 660, 674, 725, 728	*check references*	This will be corrected (see RC1.2).
RC1.98 / L. 671	*doi: 10.1175/1520-0450(1969)008<0249:TVORA>2.0.CO;2 Authors name is Foote, not Footec!*	This will be corrected to "Foote, G. B. and du Toit, P. S.: Terminal velocity of raindrops aloft, J. Appl. Meteorol., 8, 249–253, https://doi.org/10.1175/1520-0450(1969)008<0249:TVORA>2.0.CO;2, 1969."

We thank the reviewer once again for the time and effort dedicated to improving our manuscript.