Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2019-466-AC1, 2020

Atmospheric Measurement Techniques Discussions
Open Access

Interactive comment on “Automated precipitation monitoring with the Thies disdrometer: Biases and ways for improvement” *by* Michael Fehlmann et al.

Michael Fehlmann et al.

michael.fehlmann@unige.ch

Received and published: 17 June 2020

Specific comments

1.1 Page 2. Lines 20-25: Several studies have been done to evaluate the performance of Thies Clima and some references related to this topic need to be added in the Introduction section. At that regard, following there are some suggestions - Lanza et al. 2012 and Lanzinger et al. (2006) described the result of a a WMO experiment that showed a bias that range between 5% and 20% comparing rain gauge and Thies Clima disdrometer rainfall amount - In Upton et al. (2008), Angulo-Martínez et al.(2017), and Adirosi et al. (2018), the Thies Clima perfromance has been evaluated with respect to Parsivel disdrometer.

Printer-friendly version

Discussion paper

Response: Thank you very much for this comment and for suggesting additional literature. Also in accordance with a short comment (SC), we have added the suggested literature and reformulated this part of the introduction (please also see corresponding SC).

Changes in the manuscript (section 1): However, there are only few studies which assess the uncertainties of the Thies disdrometer, mostly comparing the instrument to OTT Parsivel disdrometers (e.g., Adirosi et al., 2018; Angulo-Martínez et al., 2018; Guyot et al., 2019; Upton and Brawn, 2008) and in a few cases to rain gauges (e.g., Lanza and Vuerich, 2012; Lanzinger et al., 2006).

1.2 Section 2: Did the Authors applied any filtering method to eliminate the so called "spurious drops" due to win, splashing, or mismatch? Several studies that used disdrometer measured DSD applied a filter criterion based on fall velocity such as the one adopted in Tokay et al. 2001 and valid only for rain.

Response: Thank you very much for this comment. Indeed, this effect exists and several studies apply filter algorithms to remove spurious measurements of mostly larger particles from 2DVD or other video disdrometer measurements by applying a filter based on the combined velocity-diameter information (e.g., von Lerber et al., 2017; Raupach and Berne, 2015). However, as shown by Friedrich et al. (2013) such effects mostly occur at high wind speeds (exceeding 20 m/s) and as our study is extremely wind sheltered we did not see the need of applying such a filter in this study. This is described now in the revised manuscript.

Changes in the manuscript (section 2.1): Note that in some studies using 2DVD or other video disdrometer measurements, additional filters are applied to remove spurious measurements of mostly larger particles, usually being based on a validity check of the combined diameter and velocity information (e.g., Raupach and Berne, 2015; von Lerber et al., 2017). However, as investigated in detail by Friedrich et al. (2013) such spurious measurements mostly occur at wind speeds exceeding 20 m/s. As our study site is extremely wind sheltered (see also section 4) we thus did not apply such a filter in this study.

1.3 Section 2: Different classification methods are applied to Thies disdrometer and 2DVD data to distinguish between rain, snow and mixed phase. Is it possible to applied the proposed classification method to Thies data (of course applying the method to binned data instead of drop-by-drop data)? In this way the obtained results can be compared with the classification provided by the Thies software. If not, why do not apply a classification method that can be easily applied to 2DVD and Thies data? It can help to exclude the possible effect of the application of different classification methodologies on the obtained results

Response: Thank you very much for this comment and proposal of this additional analysis. It is indeed possible to apply the proposed classification method to the Thies data, given the limitation that only binned data instead of drop-by-drop data is available as you mention correctly.

As you proposed, we have applied the classification method to the binned Thies data, using the “centroid” (i.e. the mean velocity V and mean diameter D) of each V-D class to assign a precipitation type to all particles within the corresponding V-D class. The result is shown in Fig. 1 and 2 in analogy to Table 5 and Fig. 11 in the manuscript.

As can be seen in Fig. 1 compared to Fig. 11 in the manuscript, the proposed classification method results in a very similar classification of snow when applied to binned Thies disdrometer data and 2DVD data, respectivly. The hit rate of the Thies disdrometer with respect to the 2DVD is even slightly higher than for the classification of the Thies software (98.0% compared to 95.3% in Table 5 of the manuscript). For liquid and mixed precipitation, higher differences exist: when applying the proposed classification method to the binned Thies data, more “mixed”precipitation is detected at temperatures $> \sim 1^{\circ}$C than when applying the same classification to 2DVD data. The hit rate of the Thies disdrometer with respect to the 2DVD for liquid precipitation therefore also drops to 86% and at the same time the hit rate for mixed precipitation increases to 60.2% (as compared to 99.7% and 16.6% in Table 5 of the manuscript, i.e. when using the Thies classification software).

The most interesting result in our opinion is here that we find that the classification of liquid vs. "mixed" precipitation is very sensitive to the choice of the thresholds used for the assignment of "mixed" precipitation. In our opinion, the problem of consistently defining "mixed" precipitation already exists for human observations, but will be more pronounced when replacing human with automated observation. We also have included the following statement in the original manuscript: "In this context, we would like to point out that the agreement during mixed precipitation with any reference observation will depend on the mixing ratios, which are explicitly or implicitly considered as mixed."

The additional analysis presented here indicates that any reasonable definition of mixing ratios considered as "mixed" precipitation will furthermore depend on the instrument used, which we state now also in the revised manuscript.

Changes in the manuscript (sections 2.2 and 4): 2.2: To investigate the effect of applying different classification methodologies on obtained results, the classification algorithm described above was also applied to Thies data. Given the binned data, the mean velocity and diameter of each V-D class were used for the classification rather than information about individual particles. 4: Our analysis indicates that the distinction between liquid and mixed precipitation is particularly sensitive to the choice of such a threshold. Furthermore, the application of the proposed classification algorithm to both disdrometers indicates that a reasonable choice of these thresholds might differ between different instruments.

1.4 Section 2: Is there a minimum values of precipitation amount that can be detected by OTT pluviometer? Such as the 0.2 mm for the tipping bucket gauge? Response: Thank you for this comment. We added the sensitivity according to the manual of the

Printer-friendly version

Discussion paper

OTT pluviometer as well as a description of insights from a study applying a minimum threshold for weak precipitation to this instrument in the description of the measurement devices (2.1). Regarding a careful interpretation of results, we have already covered this aspect in the manuscript in our opinion and refer to the corresponding response of reviewer #2 for further comments. Changes in the manuscript (section 2.1): According to the operating instructions of the OTT pluviometer, the instrument provides the raw precipitation values every 6 seconds using a resolution of 0.001 mm. After the application of special filter algorithms (e.g. a correction for wind effects), non-real time 1-min outputs are available at a resolution of 0.01 mm. Of course, it can be questioned whether very weak precipitation can actually be measured so accurately. For example, Tiira et al. (2016) found in their mass retrieval (performed approximately every 5 minutes) that the output seems to fluctuate and used a threshold 0.2 mm/h for their analysis. 1.5 Page 6 last sentence: it is not clear to me. Please clarify. Response: Thank you for this comment. The sentence was indeed not very clear. Also, it is rather an interpretation than a description of the result, so we moved this statement to the discussion (section 4) and try to explain the meaning/ interpretation of the false alarm rate in more detail there. This is also in accordance with a comment of reviewer # 2 (please check the corresponding comment for more details).

To understand our interpretation please consider the following: - Given is a number of corresponding Thies and OTT pluviometer observations in terms of precipitation yes/ no. - Using the OTT pluviometer as a reference, the false alarm rate of the Thies disdrometer is defined as: FAR = # false alarms / (# false alarms + # correct negatives),

or in other words: FAR = # of cases where Thies = precip and OTT pluviometer = no precip / # of cases where OTT pluviometer = no precip.

To make this even more intuitive, we can interpret the FAR as follows: Given a period without precipitation according to the reference instrument (OTT pluviometer), the FAR can be interpreted as the probability of the evaluated instrument (Thies disdrometer) nevertheless indicating precipitation during this period. - Observed behaviour in Figure

4 (left): The FAR of the Thies disdrometer increases with increasing length of the observations considered, i.e.: given a very long ‘dry period’ (= no percip) in the reference instrument, the probability of the Thies disdrometer to indicate precipitation is higher than for a very short ‘dry period’. - Interpretation: This behaviour can be expected when assuming that the Thies disdrometer is wrongly indicating precipitation at more or less regular time intervals. In this case, “the chance of misinterpreting a signal as precipitation is increasing with increasing integration time” as stated in the text. This could either be due to a regularly occurring misinterpretation of a signal/ disturbance as precipitation or indeed be related to very weak precipitation events which are not detected by the OTT pluviometer. This critical view on the reference instrument (OTT pluviometer) is also emphasized by reviewer # 2 and has led to some changes in the revised manuscript (please check the corresponding comment for more details).

Changes in the manuscript (sections 3.1 and 4): The statement was removed from the results (section 3.1). Instead, we added the following to the discussion (section 4): The false alarm rate, which indicates the probability of the Thies disdrometer detecting precipitation during a dry period, is increasing with increasing integration time. This can be somewhat expected, as the chance of misinterpreting a signal or disturbance as precipitation is increasing with increasing duration of this period. Furthermore, false alarm rates might be affected by the sensitivity of the reference instrument, but are comparable to findings of Bloemink. and Lanzinger (2005) who use human observations as a reference.

1.6 Page 7, first paragraph: which is the range of variability of the thresholds used to obtain the ROC diagram? The threshold are applied to both disdrometer and gauge data?

Response: Thank you for this comment. We used fixed thresholds THROC in mm/h for all integration times with THROC = {0, 0.001, 0.002, . . ., 0.05, 0.1, 0.15, . . ., 1, 1.2, 1.4, . . ., 3}. The thresholds are only applied to the measurements of the Thies disdrometer, as the OTT pluviometer is used as a reference instrument representing the “ground truth”. This was indeed not clarified in the text and was added in the revised manuscript together with a more detailed description of the concept of ROC curves (see comment 2.6 of reviewer #2).

Changes in the manuscript (section 2.3): In the case of precipitation detection (yes/ no), we further investigate the effect of minimum precipitation thresholds applied to measurements of the Thies disdrometer on hit and false alarm rates by investigating the so-called Receiver Operating Characteristic (ROC) curves (e.g., Jolliffe and Stephenson, 2012). A ROC curve thereby depicts the variation of hit and false alarm rates with the variation of such a threshold. For example, using a threshold of 0 mm/h for precipitation detection (i.e. always reporting precipitation regardless of the measurement) will result in both a hit and a false alarm rate of 1. On the other hand, choosing an indefinitely high minimum precipitation threshold will result in both a hit and a false alarm rate of 0. Between these extremes, the resulting hit and false alarm rates depend on the capabilities of the Thies disdrometer to detect precipitation as compared to the reference instrument, while the theoretical optimum (hit rate of 1 and false alarm rate of 0) can usually not be achieved. To establish ROC curves for different integration times we use the fixed thresholds THROC = {0, 0.001, 0.002, . . ., 0.05, 0.1, 0.15, . . ., 1, 1.2, 1.4, . . ., 3} in mm/h.

1.7 Figure 8 right and Table 3: How do the Authors compute the correction factor in these cases?

Response: Thank you for this comment. We follow the method proposed by Raupach and Berne (2015) simply using the ratio of drop concentrations per diameter class as correction factors. While Raupach and Berne (2015) use the median ratio over multiple time periods, we use the ratio of the summed drop concentration over the whole calibration period. The description can be found in section 2.3 (p. 6 line 10ff in the original manuscript) and was slightly extended in the revised manuscript.

Changes in the manuscript (section 2.3): The correction factors used for this scaling correspond to the ratio of summed 2DVD drop concentrations to summed Thies drop concentrations in the calibration period (2017-07-01–2018-06-30), and are separately calculated for rain and snowfall.

1.8 Page 9, third line: “This suggest. . .. . ..intensities”. Looking at the results obtain for rainy minutes in terms of bias it seems that the adjustment to the OTT pluviometer is the one that reduces the bias while the other adjustment provides same or higher bias values. In all the other columns of Table 4 the differences between the uncorrected data, the data corrected with OTT pluviometer and the data corrected with 2DVD are negligible! Please provide a more detailed comment on this

Response: Thank you very much for this valuable comment. This was also brought up by reviwer # 2 and we have indeed not interpreted Table 4 detailed enough. As you state correctly, the adjustment to the OTT pluviometer is able to reduce the bias for liquid precipitation also in the validation period whereas the adjustment to the 2DVD introduced a positive bias. With regard to snowfall, both correction methods have only a small impact and even slightly increase the bias. With regard to correlation, the linear adjustment has no effect by nature, while the adjustment to the 2DVD can slightly improve correlation with respect to snowfall.

Based on these observations, we would clearly recommend to use the proposed adjustment to the OTT pluviometer for correcting the estimation of liquid precipitation intensities and state this in the revised manuscript. If interested in the drop spectra the adjustment to the 2DVD could nevertheless be of interest. Also, the analysis of the PSD is seen as valuable in this study to investigate possible reasons of the biases in precipitation intensity estimates, which we state in the conclusions (section 4).

Changes in the manuscript: (please see answer to corresponding comment of reviewer # 2 for more information on changes in sections 3.2 and 4 in the revised manuscript.)

Minor comments

1.10 Figure 3: please move the legend. In this position it covers the data

Response: Thank you for this comment. We have moved the legend accordingly in the revised manuscript.

Changes in the manuscript (Figure 3): The legend is plotted outside the plot window.

1.11 Figure 6: Check x-label

Response: Thank you very much for this comment and observation. We changed the x-label so that the full date (2019-07-01) is displayed in the revised manuscript.

Changes in the manuscript (Figure 6): Change in x-label so that the full date (2019-07-01) is displayed

References Adirosi, E., Roberto, N., Montopoli, M., Gorgucci, E., & Baldini, L. (2018). Influence of disdrometer type on weather radar algorithms from measured DSD: Application to Italian climatology. Atmosphere, 9(9), 360.

Angulo-Martínez, M.; Beguería, S.; Latorre, B.; Fernández-Raga, M. Comparison of precipitation measurements by Ott Parsivel2 and Thies LPM optical disdrometers. Hydrol. Earth Syst. Sci. Discuss. 2017. Lanza, L.G.; Vuerich, E. Non-parametric analysis of one-minute rain intensity measurements from the WMO Field Intercomparison. Atmos. Res. 2012, 103, 52–59.

Lanzinger, E.; Theel, M.; Windolph, H. Rainfall amount and intensity measured by the Thies laser precipitation monitor. In Proceedings of the WMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observation (TECO), Geneva, Switzerland, 4–6 December 2006

Tokay, A., Kruger, A., & Krajewski, W. F. (2001). Comparison of drop size distribution measurements by impact and optical disdrometers. Journal of Applied Meteorology, 40(11), 2083-2097.

Upton, G.; Brawn, D. An investigation of factors affecting the accuracy of thies disdrometers. In Proceedings of the Technical Conference on Instruments and Methods of Observation (TECO-2008), St. Petersburg, Russia, 27–28 November 2008.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2019-466, 2020.

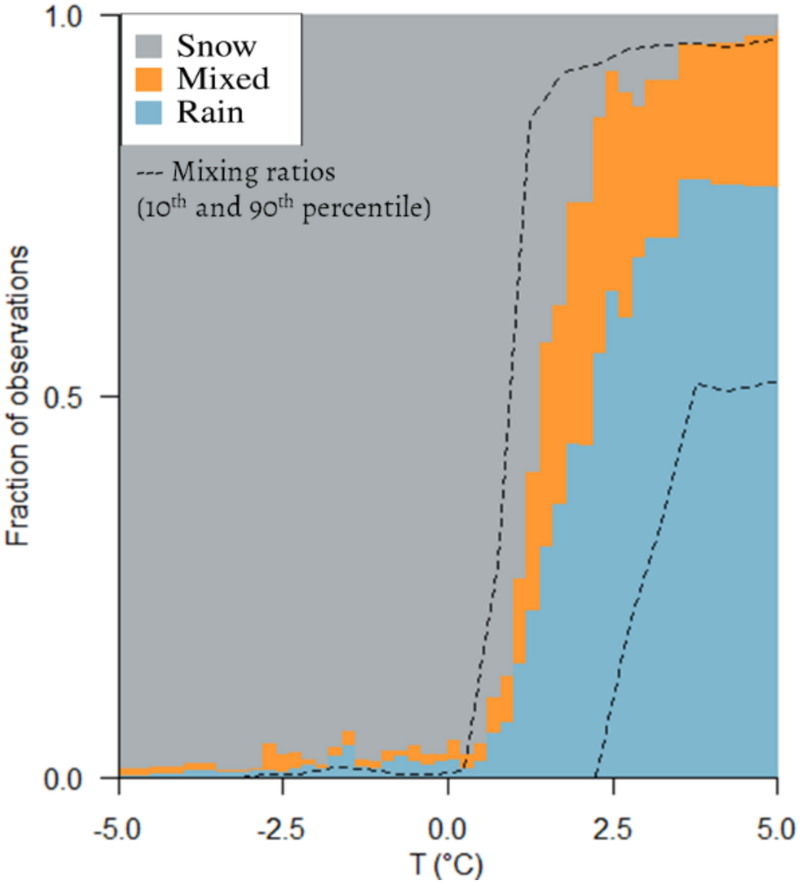
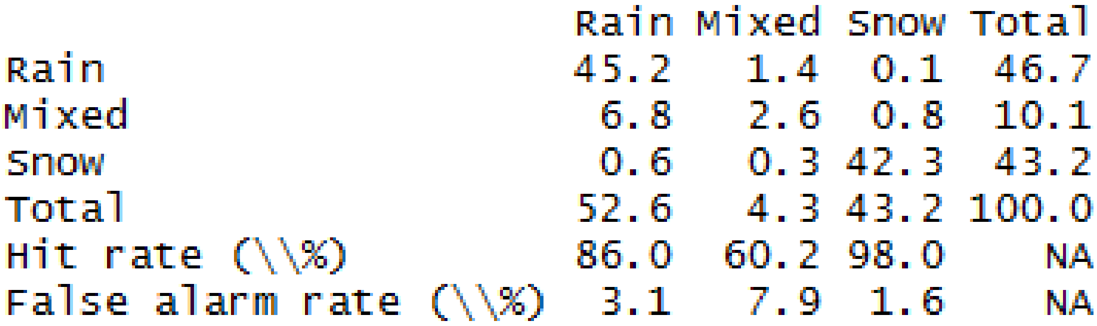


Fig. 1. Relative frequency of the observed dominant precipitation phase by the classification algorithm applied to binned Thies disdrometer data as a function of air temperature during two years of measuremen



```
                          Rain Mixed Snow Total
Rain                      45.2   1.4  0.1  46.7
Mixed                      6.8   2.6  0.8  10.1
Snow                       0.6   0.3 42.3  43.2
Total                     52.6   4.3 43.2 100.0
Hit rate (\\%)            86.0  60.2 98.0    NA
False alarm rate (\\%)     3.1   7.9  1.6    NA
```

Fig. 2. Comparison of the precipitation phase detected by the Thies disdrometer (rows) and the two-dimensional video disdrometer (columns), applying the classification algorithm proposed in section 2.2 to bot

Printer-friendly version

Discussion paper