0.1 Response to Reviewer 2 Comments

Dear reviewer:

We appreciate the time and effort that you have dedicated to providing your insightful comments on our paper. We have been able to incorporate changes to reflect most of the suggestions provided by you. We have highlighted the changes within the manuscript.

General comments:

1 **My first comment essentially addresses the processing methodology of Sect. 4.1 in light of making an already good manuscript into a better structured and self-contained manuscript to read. Please consider these comments:**

- **The signal processing part is a bit weak. Please include a processing diagram block describing: (i) the standard and (ii) the new signal processing method proposed. This is a core part of the paper. Please connect the contents of Sect. 4.1 with the block diagram.**
- **Structure: I suggest dividing Sect. 4.1 in three parts:**
  - (a) **Standard signal processing of the 3 kHz Doppler spectra: (L152-L159) + L161-L167. I'd say L160 talking about the 50 Hz spectrum is orphan and should be moved somewhere close to L179 when you start talking about the down sampling of the spectrum. Clearly separate between 3-kHz and 50-kHz processing. Clearly enunciate the down-sampling block.**
  - (b) **Comparison between aerosol and rain Doppler spectra (L168-176).**
  - (c) **The "proposed" method of the paper (L177-187).**

The support of literature references included in this section is weak.
Thank you for pointing this out. We agree with this comment. We added a processing diagram block in the draft to show the spectral process steps of our proposed method. Now, Sect. 4.1 is restructured according to the suggestion. The first paragraph is about how Doppler spectra after being averaged to lower frequencies are processed. Then we show the comparison between normal Doppler spectra with only aerosol-induced Doppler signals and the spectra with rain-induced signals. Subsequently, we proposed our rain-suppressing normalization method. Besides, two more references are added in this section.

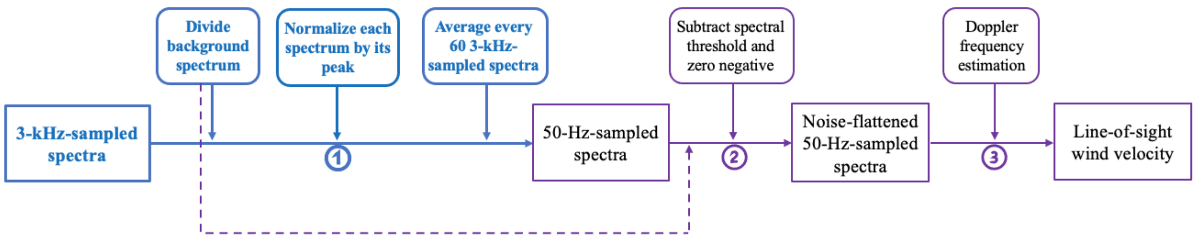

Figure 1: Processing block diagram of the rain-suppressing normalization method (the solid lines from ① to ③) to estimate wind velocity based on 3-kHz-sampled Doppler spectra. Doppler spectra at lower frequencies that do not resolve individual raindrops (like 50 Hz) are processed according to the purple path including the dashed purple line, ②, and ③.

2 **Second, I think the amount of Figure panels in Sect. 5 could substantially be reduced or moved to a Supplementary Materials Section considering that the manuscript already contains as much as fifteen figures, many of them multi-panel. For example, Fig. 12 could be skipped and Fig. 13 retained along with summary comments given in the text or with the help of a supporting Table. Most of the scatter plots can substituted by a Table describing the determination coefficients obtained plus a link to the Appendix /Supplementary Materials for the interested reader. Similarly, Fig. 14 could be streamlined by including only panels b-d-f (WindScanner #3) and a comment or Table with descriptive PDF statistics.**
But I leave the final selection of Figures/panels to the authors, or alternatively, to choose a better art arrangement.
Thank you for pointing this out. It would have been good to have a compacted paper. We agree with you. We have removed Fig. 1 due to its similarity to Fig. 3 and merged Fig. 4 and 5, Fig. 7 and 8, as well as Fig. 12 and 13. However, in our study, we have two lidars with different elevation angles and different focus distances. The rain-suppressing method we proposed has a different performance from the two lidars. Therefore, we would like to keep Fig. 12 (now merged in Fig. 10 in the revised manuscript) and panels a-c-e (lidar #1) in Fig. 14 (now Fig. 11 in the revised manuscript). But we remove panels b-d-f in Fig. 12 and 13 and put the results of R^2 in the plots.

Specific comments:

1 **L5 "the noise-flattened Doppler spectra." Consider: "the noise-flattened 3-kHz-sampled Doppler spectra".**
Thank you for pointing this out. We agree with this comment and incorporated your suggestion in **L8**. The new sentence is "We demonstrate that the rain bias can effectively be removed by normalizing the noise-flattened 3-kHz-sampled Doppler spectra with their peak values before they are averaged down to 50 Hz prior to the determination of the speed.".

2 L9 Consider: "at 50-Hz (20 ms) temporal resolution"

Thank you for this suggestion. We agree with this comment and incorporated your suggestion in **L9**. The new sentence is "In comparison to the sonic anemometer measurements acquired at the same location, the wind velocity bias at 50 Hz (20 ms) temporal resolution is reduced from up to -1.58 ms^{-1} of the original raw lidar data to -0.18 ms^{-1} of the normalized lidar data.".

3 L10 Please clarify "conventional"

Thank you for pointing this out. We have changed "conventional" to "original raw" to avoid ambiguity in **L10**. The new sentence is "In comparison to the sonic anemometer measurements acquired at the same location, the wind velocity bias at 50 Hz (20 ms) temporal resolution is reduced from up to -1.58 ms^{-1} of the original raw lidar data to -0.18 ms^{-1} of the normalized lidar data after suppressing rain signals.".

4 L25-30 In Sect. Introduction Please comment a bit on the probe-length turbulence averaging effects in comparison to e.g., cup anemometers since this is an important drawback of focusing lidars (e.g., averaging of spatial turbulence scales).

Thank you for pointing this out. We agree with this comment and incorporated this suggestion in **L25**. The revised sentence is "In-situ cup and sonic anemometers installed on meteorological masts (met masts) can provide only point measurements of wind velocity [Izumi and Barad, 1970]. On the contrary, Doppler lidars can accurately and remotely sense wind velocity by measuring Doppler spectra albeit with their limited ability in measuring turbulence due to probe-length averaging effects [Sathe and Mann, 2013].".

5 L26 Change "that" into "which"

Thank you for this suggestion. We agree with this comment. Because the original sentence is quite long, we reformulated the sentence in **L25**. The new sentence is "In-situ cup and sonic anemometers installed on meteorological masts (met masts) can provide only point measurements of wind velocity [Izumi and Barad, 1970]. On the contrary, Doppler lidars can accurately and remotely sense wind velocity by measuring Doppler spectra albeit with their limited ability in measuring turbulence due to probe-length averaging effects [Sathe and Mann, 2013].".

6 Not sure the acronym "CW" (continuous wave) has previously been defined. Preferably, use "CW" in caps.

We agree with this. We have defined this abbreviation in **L54** and have incorporated your suggestion in **L72** and figure captions throughout the manuscript. The definition of CW is in the sentence "A field measurement campaign was carried out at Risø where three coherent continuous-wave (CW) Doppler lidars [Mikkelsen et al., 2017] were deployed to point towards a common focus point very close to a mast-mounted sonic anemometer at 31 m height.".

7 L84 "can be approximated as [REF needed],"
Thank you for this suggestion. We agree with this comment. The reference is added in **L84** as "The full-width-at-half-maximum (FWHM) of the Lorentzian weighting function or the probe length can be approximated as [Sathe and Mann, 2013],"

$$\text{FWHM} = 2 \cdot z_R = 2 \cdot \frac{\lambda \cdot R^2}{\pi r^2} \tag{1}$$

8 Tab. 4. Please check if "angle to the North" is computed correctly. In a Cartesian coordinate system, angles are defined positive CCW. And angles between vectors (or between e.g., vector "1" and vector North) are computed by using equipollent vectors so that their origin coincides with the Cartesian origin (i.e., point 5 = projection of point 4 in the XY plane). From the geometrical angles given in Fig.3b and assuming North is 0 deg then I'd say "Angle to North" should be: (WindScanner 1) -42.6 deg; (WindScanner 2) 180 + 7.1.deg = 187.1 deg; (WindScanner 3), 60.7 deg. Please clarify if other Math/Physics conventions are used.
Thank you for this suggestion. We agree with this comment. However, in the case of our study, we would like to show the lidar's geographic beam direction in Table 1 with the assumption that the North is 0 degrees and clockwise is positive. Therefore, the three lidars' geographic beam directions are 42.6°, 172.9°, and 299.3°. Hope this would be accepted by you.

9 L95a Please state and clarify to the reader the "key" numbers of the processing. Don't let the reader guess them. Specifically:

(a) Fast Fourier Transform (FFT) frequency_resolution: 120 MHz / 512 samples = 234.4 kHz/samples → speed resolution = (λ/2)*freq_resolution = 0.183 m/s

(b) Spectrum_estimation period = sampling rate (1/120 MHz) x 512 (samples/spectrum) x 78 spectrum/average = 332.8e-6 [s] → spectrum_ estimation rate = 1/spectrum_estimation_period = 3 kHz

Thank you for this suggestion. We agree with this comment and revised **L92 to L101** to emphasize this point. The new sentences are

(a) The backscattered light mixed and amplified by the local oscillator is sampled at a rate of 120 MHz and Doppler spectra containing 512 frequency bins are calculated by Fast Fourier Transform (FFT) with a frequency resolution of (120 MHz)/512 = 234.4 kHz. The wind speed resolution is calculated from this frequency resolution and the laser wavelength λ, yielding $(1.565\mu\text{m}/2)\cdot(234.4\ \text{kHz}) = 0.183\ \text{ms}^{-1}$.

(b) Subsequently, a block averaging of 78 spectra results in a final sampling period of $512 \cdot 78\ /(120\ \text{MHz}) = 0.33$ ms, corresponding to a spectrum rate of 3 kHz.

10 L95b Please briefly summarise which power spectral density (PSD) and which peak spectral estimation method is used to retrieve the Doppler shift. I think this should also be remembered by the reader and shortly discussed later on, in L153-155.

Thank you for pointing this out. We agree with this comment and have added two sentences, which are "Additionally, Bartlett's method is used to obtain the power spectral density (PSD) of each spectrum [Press et al., 1988, Chap. 13], which is the square of the absolute value of the FFT of the detector's time series. The median method [Held and Mann, 2018] is employed to determine wind velocity." in **L99**. This is mentioned again in **L190** as "the median method is used to determine line-of-sight velocity from the final 50 Hz spectra (Fig. 8c), as it has the least biases for weak signals [Angelou et al., 2012] in comparison to the maximum and centroid methods [Held and Mann, 2018]"

11 L93 I recommend to repeat "all times are UTC+1" in all figure captions involving time series to help the reader.

Thank you for pointing this out. We agree with this comment and have added the term "UTC+1" in all figure captions and the text involving time.

12 L100 "less than the beam transit time of a typical rain drop". Please add literature REFERENCE.

Thank you for pointing this out. We restructured the sentence to remove "typical". "Typical" here means a large raindrop has the highest falling speed, which is 9 ms^{-1} from the disdrometer measurement in Fig. 6b, not from references. The new sentence in **L102** is "The shortest beam transit time can be determined based on large raindrops' maximum downfall speed of 9 ms^{-1} from the disdrometer measurement in Fig. 6b, the beam width (twice of the beam waist w_0), and the elevation angle of a lidar. For lidar #1 with a beam width of 1.12 mm and an elevation angle of 57.9°, the shortest beam transit time is 0.234 ms $= 1.12/(9 \cdot \cos(57.9°))$, while it is 0.362 ms $= 3.14/(9 \cdot \cos(15.3°))$ for lidar #3 with a beam width of 3.14 mm and an elevation angle of 15.3°. Most often, however, raindrops' transit time is longer than the aforementioned shortest time if their paths are away from the lidar focus and if they fall slower. In this study, it is reasonable to set the spectral sampling frequency to 3 kHz so that the sampling period for a spectrum (0.333 ms) is shorter than the beam transit of raindrops [see Jin et al., 2022, Fig. 5b], as shown below. Therefore, the rare instances where a raindrop resides in the beam could be identified and suppressed based on the lidar measurements.".

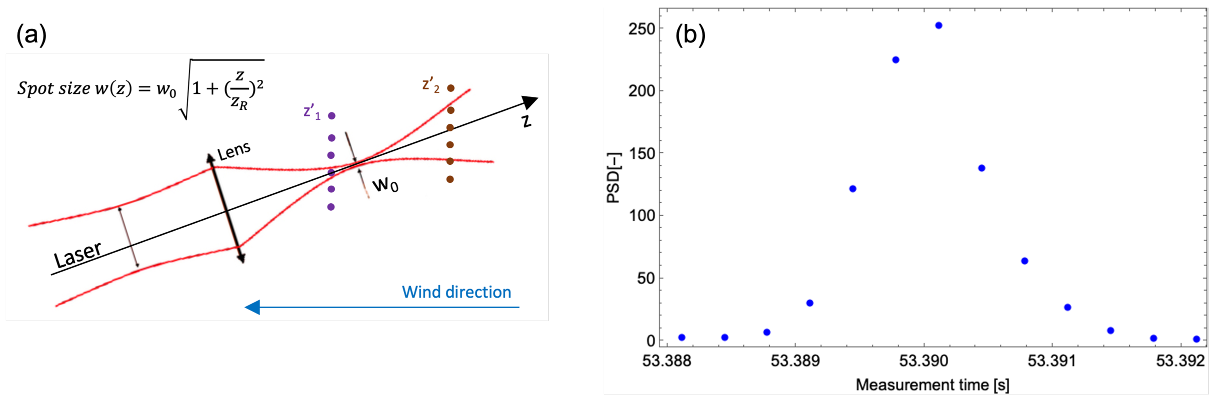

Figure 2: The geometry of raindrops falling through a focused laser beam. (a) shows raindrops cross the laser beam at random positions, where $w(z)$ is the spot size along the beam, w_0 is the beam waist which is 2.35 mm in our case, $z_1^{'}$ and $z_2^{'}$ are two axial distances from the beam's focus, and z_R is the Rayleigh length which is 11.1 m. (b) presents the measurements of the power of the back-scattered signal at the Doppler frequency during a raindrop's passage through the beam, following a Gaussian distribution.

13 **L101 Please briefly clarify how the 0.35 ms transit time was estimated. E.g., at 9 m/s fall velocity we get, 9m/s x 3.14 mm = 28 ms (in the near field "waist" of the laser beam).**

You have raised an important point here. However, it should be 3.14mm/(9m/s) to get the transit time. In **L102**, we wrote: "The shortest beam transit time can be determined based on large raindrops' maximum downfall speed of 9 ms^{-1} from the disdrometer measurement in Fig. 6b, the beam width (twice of the beam waist w_0), and the elevation angle of a lidar. For lidar #1 with a beam width of 1.12 mm and an elevation angle of 57.9°, the shortest beam transit time is 0.234 ms $= 1.12/(9 \cdot \cos(57.9°))$, while it is 0.362 ms $= 3.14/(9 \cdot \cos(15.3°))$ for lidar #3 with a beam width of 3.14 mm and an elevation angle of 15.3°. Most often, however, raindrops' transit time is longer than the aforementioned shortest time if their paths are away from the lidar focus and if they fall slower. In this study, it is reasonable to set the spectral sampling frequency to 3 kHz so that the sampling period for a spectrum (0.333 ms) is shorter than the beam transit of raindrops [see Jin et al., 2022, Fig. 5b]. Therefore, the rare instances where a raindrop resides in the beam could be identified and suppressed based on the lidar measurements.".

14 **L109 Consider to give the manufacturer/model for the wind vane and temp sensors.**

Thank you for this suggestion. We agree and have incorporated your suggestion in **L116**. The updated sentence is "Furthermore, the mast is instrumented with a vector wind vane (W200P from Kintech Engineering) at 41 m, and two air temperature sensors (Pt 100, developed by DTU) mounted at 18 m and 70 m, respectively.".

15 **I recommend drawing X, Y, and Z labels on Fig. 3a to help the reader identify the given unit vectors ([−0.36, −0.39, −0.85], [−0.10, +0.82, −0.57] and [+0.84, −0.47, −0.26]).**
Thank you for pointing this out. We agree with this comment and have added X, Y, and Z labels to Fig. 2 now.

16 **Tab. 2 What does symbol "/ ≥" means in "0.1875/ ≥ 8? Is that a typo?**
Thank you for pointing this out. Yes, it's a typo. We have deleted it in Table 2.

17 **Fig.7-8. Font size. The "10-min" text in the X and Y labels of panels (b) can barely be seen. Please enlarge the font and include in the captions "Comparison of 10-min wind speed".**
Thank you for this suggestion. We agree and have incorporated your suggestion in the manuscript. Wind speed and direction plots are now merged into one figure (Fig. 5) and we have enlarged the font size. The new figure caption is "Comparison of 10-minute wind measurements with the wind vane, sonic and cup anemometers at several vertical heights. **(a)** 10-minute wind speed by sonic (SW_{sp}) and cup (W_{sp}) anemometers. **(b)** 10-minute wind direction by sonic anemometers (S_{dir}) and the wind vane (W_{dir}). **(c)** and **(d)** Linear regression of 10-minute wind speed and direction. The two red lines mark the comparison period of lidar and sonic data from 15:12 to 18:11 (UTC+1).".

18 **Fig. 9 CAPTIONS (comment to be extended to all manuscript figure captions) I recommend setting label letters at the beginning of each sentence and not at the end or in the middle of the sentence, for better clarity. I recommend to begin each figure caption with a sentence giving an overview of what the figure is about. Then use follow-up labels (a), (b) addressing each panels. E.g., "Rain event September 27th, 2022, 15:00-19:30 measured by the Thies (. . .). (a) Rain Intensity. (b) Distribution of the number of measurements . . . (color coded)."**
I also recommend including in the caption the temporal resolution of the data (although this may seem repetitive), e.g., 1 minute, in this case.
Thank you for pointing this out. We agree with this comment and have changed all the figures' captions in the recommended way and added the temporal resolution.

19 **L155 Please introduce the acronym "power spectral density (PSD)" See also comment L95b for discussion.**
Thank you for pointing this out. We agree with this comment. We have introduced this in **L101** as "Additionally, Bartlett's method is used to obtain the power spectral density (PSD) of each spectrum [Press et al., 1988, Chap. 13], which is the square of the absolute value of the FFT of the detector's time series.".

20 **L157-160 Different issues. Unclear. I would suggest expanding the spectral estimation part. In detail:**

(a) **"However, if the wind velocity is around zero, this procedure does not work." Why, taking into account that the noise PSD is not zero? Please clarify.**

(b) **L158-160 "where the line-of-sight velocity fluctuates around zero". At this point in the text, mention to the reader that the vertical line at approx. bin 255 (please clarify bin no.) corresponds to the zero-Doppler shift.**

(c) **Why does such a negative red peak at bin 255 occur for the background noise (red trace) in Fig. 10a?**

Thank you for this suggestion. We agree and have incorporated your suggestion in the manuscript.

(a) We have clarified this sentence: "However, this procedure will not work if the wind velocity is around zero, since the wind Doppler signal would be present on both sides of the zero frequency bin. Then a real, atmospheric Doppler signal would be included in the background spectrum rather than the real background noise." in **L195**.

(b) We have added "(the vertical line at frequency bin 257 corresponding to the zero-Doppler shift in Fig.8)" in **L198**. Now the new sentence is "Therefore, in the case of lidar #1 where the line-of-sight velocity fluctuates around zero (the vertical line at frequency bin 257 corresponding to the zero-Doppler shift in Fig. 8), a background spectrum is calculated for a period where the line-of-sight speed is away from zero.".

(c) It is always 0 value at frequency bin 257 corresponding to zero frequency because the lidar has a high-pass filter that suppresses the near-zero frequency fluctuations. Therefore, there is a negative red peak in Fig. 10a (now Fig. 8 in the revised manuscript). It is an unavoidable feature of continuous-wave lidars.

21 L178 "down sample". Please clarify how the "down-sampling" procedure is carried out. Is it that given the normalized spectra, which make evident the rain returns as very high and narrow peaks, these spectra are screened out for "very large" peaks, therefore, removed from the spectra average? This is known as histogrammed filtering but no quantitative criterion is given. Please give a quantitative criterion for screening out the "rain returns" in Fig. 10d. For example, is that percentile 90 of the cumulative distribution? Please consider to include this histogrammed filtering block in the proposed processing diagram above.

Thank you for pointing this out. We have investigated this method before in our previous work [Jin et al., 2022], by defining an optimal threshold to filter away rain-induced Doppler signals based on the histogram. However, this method is not suitable for all cases since we have to try different thresholds and determine the optimum value when the wind velocity difference is the smallest compared to sonic data. However, in this paper, we proposed this rain-suppressing normalization method to suppress rain-induced Doppler signals rather than completely sieve them out. Therefore, we changed the term "filter away or filter out" to "suppress" in the manuscript.

22 Fig. 10. Please vertically align panels (a) and (c). Please use the same X-axis range to ease comparison.
Thank you for this suggestion. We agree and have incorporated your suggestion in the manuscript. Now panels (a) and (c) are aligned in Fig. 10 (now Fig. 8 in the revised manuscript) and the same frequency range for panels (a), (b), and (c) is used.

23 Fig. 10 caption. Please add: "The solid black line stands for the zero frequency bin" (as in Fig. 11).
Thank you for this suggestion. We agree and have incorporated your suggestion in the manuscript. The new caption is "Examples of representative Doppler spectra measured at the moderate-rain minute (15:48, UTC+1) with the highest rain intensity. **(a)** A 3-kHz-sampled spectrum containing only wind signal (blue) and the mean background spectrum (red). **(b)** A 3-kHz-sampled spectrum containing rain signal (blue) and the mean background spectrum (red). **(c)** A noise-flattened 50-Hz-sampled spectrum and its spectral threshold. **(d)** Histogram of the maximum spectral energy S_{max} of 180000 raw spectra over the duration of the same minute with a red circle marking the strongest rain signals. The solid black line stands for the zero-Doppler shift at frequency bin 257." (same as Fig. 9 in the revised manuscript).

24 Fig. 10. Which method is used to compute the PSD? E.g. Periodogram or others. Please include literature reference.
Thank you for pointing this out. It is Bartlett's method to compute the PSD. We added the information in **L99** as "Additionally, Bartlett's method is used to obtain the power spectral density (PSD) of each spectrum [Press et al., 1988, Chap. 13], which is the square of the absolute value of the FFT of the detector's time series.".

25 Fig. 11 Caption, L4. "represent the median frequency bin" or "stand for the median frequency bin"
Thank you for this suggestion. We agree. The new caption is "The red and blue dashed lines represent the median frequency bin of the raw and the normalized Doppler spectra, which are used to derive line-of-sight wind velocity.".

26 Fig. 11 (b)(d) Please use the same frequency-range (X-axis) in both panels.
Thank you for this suggestion. We agree. We have used the same frequency range for panels (b) and (d) in Fig. 11 (now Fig. 9 in the revised manuscript).

27 L209 Change "that occurred" into "which occurred"
Thank you for this suggestion. We agree. However, we have deleted this sentence because another reviewer suggested that such information should be added in the section

that introduces sonic anemometers. Therefore, we removed this part to **L127** in Section 2.2 as "It is evident from the sonic status information that wind velocity measurements by sonic anemometers can be affected by raindrops. In those cases, the sonic anemometer would repeat the previous velocity value and the status would be "4". Thus, the linear interpolation method was used in this study to eliminate repeated velocities, which represented about 60% of the 50 Hz sonic data recorded at moderate-rain minutes.".

28 L222 "more" missing → it rains more heavily than lightly

Thank you for pointing this out. We agree. However, L241 was written as "it rains more heavily than lightly", but we changed "more" to "it rains more heavily than lightly" in **L280**. The new sentence is "These lead to the same conclusions discussed previously that rain-suppressing normalization performs well for the large probe length when it rains as well as for the small probe length when it rains more heavily than lightly.".

29 Tabs. 4-5 Please repeat in the caption key information on "rain intensity" and "probe length".

Thank you for this suggestion. We agree and have added the probe length and rain intensity in Tables 4 and 5. The new caption of Table 4 is "1-minute averaged wind velocity based on 50 Hz data and the corresponding bias between the sonic anemometer and WindScanner lidar #3 (probe length of 9.8 m) at three minutes, with (norm) and without (raw) normalization. Rain intensity at the light-rain and moderate-rain minutes are 1 mmh^{-1} and 4 mmh^{-1}.", same as Table 5.

30 Tab. 4. Please stick to two decimal digits everywhere. Please check for errors/typos in column "light-rain minute"

Thank you for pointing this out. We agree and have changed all the numbers with two decimal digits and corrected the calculation errors from 0.11 and 0.14 to 0.01 in the third row in Table 4.

Table 4. 1-minute averaged wind velocity based on 50 Hz data and the corresponding bias between the sonic anemometer and lidar #1 (probe length of 1.2 m) at three minutes, with (norm) and without (raw) normalization. Rain intensity at the light-rain and moderate-rain minutes are 1 mmh^{-1} and 4 mmh^{-1}.

	V_{sonic} (ms^{-1})	V_{raw} (ms^{-1})	$V_{sonic} - V_{raw}$ (ms^{-1})	V_{norm} (ms^{-1})	$V_{sonic} - V_{norm}$ (ms^{-1})
No-rain minute 15:13:20+1min	-1.01	-1.07	0.06	-1.08	0.07
Light-rain minute 16:36:20+1min	-0.38	-0.39	0.01	-0.39	0.01
Moderate-rain minute 15:48:20+1min	-0.64	-0.49	-0.15	-0.60	-0.04

31 Figs. 12-13. Legends: The logical order should be "sonic-raw-norm" instead of "raw-sonic-norm".

Thank you for this suggestion. We agree with this point and have incorporated your suggestion in the manuscript. We have changed the legend order to "sonic-raw-norm" in Fig. 12 (now Fig.10) and 13 (now Fig.11).

32 Fig. 16 caption. Please repeat in the caption "probe length" values to help the reader.

Thank you for this suggestion. We agree and have added the probe length in the caption, which is now "Difference of 1-minute averaged wind velocity between lidar and sonic measurements together with the rain intensity (the solid black curve) from 15:12 to 18:11 (UTC+1). **(a)** Lidar #1 with the probe length of 1.2 m. **(b)** Lidar #3 with the probe length of 9.8 m. The raw and normalized lidar data are marked in red and blue.".

33 CONCLUSIONS Please give conclusions on your findings about the performance of the methods for different probe lengths (short/large probe length, which is an important point –although more risky- or your research) as well as future lines. Part of the conclusions given in L183-185, L221-224, L244 should be rewritten / summarised in Sect. Conclusions.

You have raised an important point here. We agree and have added the findings regarding the different probe lengths, the conclusions from L183-185, L221-224, and L244 as well as some outlooks. Therefore, the new CONCLUSIONS is "In this paper, we have shown an experimental proof-of-concept demonstration of a method to reduce the bias caused by precipitation on continuous-wave Doppler lidar measurements of wind speed. This is accomplished by sampling Doppler spectra faster than most raindrops' beam transit time, which in the current case was at 3 kHz. Subsequently, the 3 kHz spectra are normalized with their peak values to suppress strong backscatter signals from raindrops before being averaged down to 50 Hz from which the radial wind velocity is determined.

Results from lidar beams with different elevation angles and focus distances were studied under different rain intensities measured by a disdrometer. The derived wind velocities were compared with a sonic anemometer reference. From the comparison, we find that the rain-suppressing normalization has the most significant impact on reducing bias when the probe volume (growing with the fourth power of the focus distance) is the largest. However, when the probe volume is small (shorter focus distances), the impact of rain is limited. Rain-induced bias also varies according to elevation angle but to a lesser extent. However, the exact nature of these relations remains to be further verified and understood. The tendency is that the more it rains, the stronger the bias and the more the rain-suppressing normalization is reducing the bias. For moderate rain intensity (we do not have a heavy rain period in our data), the range of the bias is reduced from the interval 0.1 to 0.4 ms^{-1} to 0.0 to 0.1 ms^{-1}. The suggested method in this study could also be investigated for rain events (containing heavy rain) on several days and also for pulsed Doppler lidars even though their measurement volume is quite larger than that of the continuous-wave lidars. Further investigations could also attempt to retrieve the falling velocity and the size distribution of raindrops using the fast Doppler spectra.".

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