Answer to Referee #1

Review of the manuscript amt-2023-153 entitled "Noise filtering options for conically scanning Doppler LiDAR measurements with low pulse accumulation" by E. Paschke and C. Detring

We would first like to thank the referee for reviewing our manuscript, the overall positive assessment of our work, and for the constructive comments. Below we will respond to the comments and point out changes we made as we revised our manuscript. The reviewer's comments are in black italic; our responses are in blue.

This manuscript proposes revised filtering strategies of Doppler LiDAR data collected through the VAD technique with low pulse accumulation with the aim of retrieving wind turbulence statistics, such as TKE.

The manuscript begins with a roughly comprehensive Introduction, indicating clearly the work by Smalikho and Banakh (2017) as a reference for this work. In Sect. 2, the experimental setup is described followed by a characterization of typical noise encountered in LiDAR measurements. In Sect. 3, a review of some of the filtering techniques for LiDAR data is provided. Subsequently, Sect. 4 describes the filtering techniques proposed, which is followed by some applications of these filters in Sect. 5.

As a Doppler LiDAR researcher, I enjoyed reading this manuscript where the authors share their experience in filtering and processing VAD Doppler LiDAR data. I believe this manuscript will provide good guidelines in that realm, especially for younger researchers and practitioners. I find the filtering techniques proposed very reasonable and hopefully effective for producing noise- reduced LiDAR data. The main comment I have is about the length of the manuscript. I believe the manuscript can be significantly shortened by reducing lengthy, not strictly necessary discussions, and intermediate summaries and recaps provided throughout the manuscript. I think a shorter and more focused manuscript will enhance its impact. Please find below some details comments, which might help to revise the manuscript.

We understand the criticism about the length of the manuscript. We tried to reduce the length of the manuscript by reorganizing its structure, shortening of individual text passages and reducing the number of illustrations. In particular, significant changes have been made to sections 3 and 5. As part of the restructuring, a stronger focus was sought on the filter methods, which now takes up the main part of the manuscript on pages 12 - 26. The advantages of the newly introduced filtering techniques compared

to common filter techniques are then discussed using the example of a special application (TKE retrieval) on pages 27 - 32. Overall, the number of pages in the main part of the manuscript was reduced from 46 pages to 34 pages. At the same time, the number of pages in the appendices increased from 4 to 10.

Detail Comments:

1. L28 – Please add some references for works related to the various turbulence parameters in order to provide sufficient information on the retrieval procedures adopted.

We have slightly revised the text here. In fact, so far only DL-based wind profile measurements are routinely carried out at MOL-RAO. DL-based turbulence measurements based on the retrieval approach introduced by Smalikho and Banakh (2017) are the planned next step. The work submitted here represents a part of the necessary preliminary studies. There is at present no further experience with other retrieval methods for DL-based turbulence measurements at MOL-RAO.

2. L54 – "... increased level of noise..." with respect to what condition? Reducing accumulation time? Please clarify.

Yes, the higher noise level can be attributed to the reduced accumulation time. In text lines 57-68 of the original manuscript, this point is discussed in more detail as a result of a scanning strategy with high temporal and spatial resolution. In the revised manuscript (line 58-59), the text has been adjusted to address this issue more directly.

3. L149 – Please clarify how these noise-free measurements are obtained at this stage.

All three measurement examples in Fig. 1 have been taken with the same DL system with identical configuration (e.g. Na = 2000 pulse accumulations). Despite the low pulse accumulations there are measurement cases with and without noise. This can be explained by the natural variability in the atmospheric aerosol content over the course of a day and with altitude. Aerosols act as backscattering targets and their atmospheric loading influences the quality of the DL signals and therewith the amount of noise in the measurements. A sufficiently large amount of aerosol can contribute to noise-free DL measurements even for low pulse accumulations. Little aerosol combined with low pulse accumulation, however, represent an unfavorable constellation for achieving good data quality. (Note that this explanation has been additionally introduced in the revised text; see lines

157 - 163.)

4. *L271 – "A more simpler", please revise this typo.*

Done.

5. *Sect. 3.2 – For the sake of completeness, it would be good if the authors could summarize the procedures for the retrieval of TKE from the VAD lidar data for both works SM2017 and KR1986.*

The length of the manuscript was criticized and calls for significant reductions were made. We think that an additional summary of both the Kropfli (1986) approach and the Smalikho and Banakh (2017) approach would contradict this request. Moreover, the focus of the present manuscript is clearly set on the noise filtering, and the TKE retrieval just serves as an example for an application of a scanning strategy that requires new ways of noise filtering. We thus feel that providing the references here would be sufficient in this context. Please also note that with the revision of the manuscript Section 3.2 (old manuscript version) was moved to the appendix (new version; Appendix H).

6. *L367-369 – You can briefly summarize the procedure used to retrieve TKE from the sonic anemometer.*

Done. Due to the restructuring of the manuscript, this information can now be found in line 560-563 of the revised manuscript.

7. *L481 – I am not sure you introduced the acronym VV90D. Please verify.*

The abbreviation VV90D has been introduced in analogy to the VAD. Latter is an acronym for **v**elocity-**a**zimuth-**d**isplay which describes a diagram with these axis labels. The notation VV90D was chosen in analogy to the VAD plot. However, VV90D does not represent an acronym formed from the first letters of several words. Although V represents the velocity, V90 represents the same velocity time series shifted by 90 degrees. Unfortunately, the latter cannot be summarized in one word. In order to give the reader a quick solution to what lies behind it, reference is immediately made to the following section with further details (line 280 of the revised manuscript). Note that in the revised manuscript the acronym VV90D is introduced in line 277 instead of line 481.

8. *Fig. 11 – I believe the reader does not have all the information needed to understand Fig. 11, e.g., the two-stage MAD filter. I would suggest re-*

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moving this figure because the description provided in the text is already sufficient.

Done.

9. L492 – at this stage, it is not clear why the authors propose a shift of 90 deg. Please homogenize it with the text.

Next to the VAD representation, the VV90D representation is another way to visualize DL data from a conical scan. As shown in the paper the latter provides a different perspective on the measurement data and reveals characteristic properties of "bad" and "good" estimates, which contributed to the development of the filters presented in the paper. The phase shift of 90 deg has a mathematical background. For DL velocity measurements from conical scans satisfying $V \sim \sin\theta$ a phase shift of 90 deg yields $V90 \sim -\cos\theta$ taking the phase shift identity $\sin(\theta - 90°) = -\cos(\theta)$ into account. Therewith paired data points (x=V90,y=V) plotted in a rectangular coordinate system describe a circle. We describe this in more detail in the revised manuscript in line 284 - 294.

10. Fig. 12 – Letters [c] and [f] are missing in the caption

Done. Note that because of the restructuring of the manuscript Fig. 12 in the old version is now Fig. 6 in the new version.

11. L631 – Please revise "on the one hand".

Done.

12. Eq. 9 – Can you please explain the origin of the coefficient 0.6745?

Here we refer to the work of Iglewicz and Hoaglin (1993).

13. L744-749 – You can remove this summary of the previous section.

Done.

References

Iglewicz, B. and Hoaglin, D.: How to Detect and Handle Outliers, ASQC basic references in quality control, ASQC Quality Press, 1st edn., 87 pp., ISBN 9780873892476, 1993.