Author’s Response

On the second referee comment during the second review round of the manuscript "Modelling the Spectral Shape of Continuous-Wave Lidar Measurements in a Turbulent Wind Tunnel" by Marijn Floris van Dooren et al., Atmos. Meas. Tech. Discuss., https://amt.copernicus.org/preprints/amt-2021-233/#discussion, 2021.

03.02.2022

Marijn Floris van Dooren et al.

Dear Sir/Madam,

Thank you very much for reviewing our revised manuscript again and for your valuable feedback. We isolated and rephrased your comments in blue and included our response in black.

Comments

1: The authors have significantly improved the manuscript and thoroughly addressed the review comments. The only point of question is the development of Eq. (11), which has been presented thoroughly and explicitly in the author’s response but has not been discussed in the manuscript. The reviewer suggests that Fig. 3 (of amt-2021-233-author_response-version1.pdf) could be included in the paper.

We acknowledge that the justification of Eq. (11) might still not be sufficiently covered in the paper. Therefore, we now added an Appendix B to the manuscript, which describes the development of said equation in more detail, including a plot with the correlation between noise standard deviation and the term including energy dissipation rate and mean wind speed.

2: Further, a statement that there was no correlation between σ_η and the ambient temperature, which could hypothetically be a function of how hard the wind tunnel blower has to work to produce given global flow conditions, would remove the remote possibility that internal lidar noise is somehow a factor.

We have indeed recorded the ambient temperature in the wind tunnel before every 10-minute measurement, which was in the range between 17.8°C and 19.1°C for the measurements presented in the manuscript. No significant correlation between the ambient temperature and the value of σ_η could be identified, of which Fig. 1 is proof.

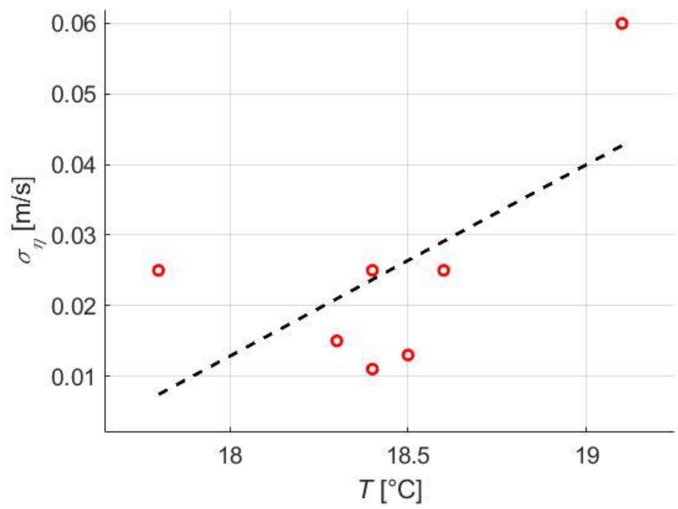

Figure 1: *Plot of the relationship of the lidar spectral noise standard deviation σ_η with the ambient temperature T inside the wind tunnel.*

Following the reviewer's suggestion there is a statement about this added to the manuscript (L229-L230), however, the plot in Fig. 1 is not deemed important enough to include in the paper.

3: The reviewer also wonders if the results of the empirical analysis, which indicate that the white noise is due to shot noise and global flow parameters, do already have some basis in literature. The global flow parameters will influence the de-correlation time of the lidar return. Specifically, turbulence level and scanning speed are known to influence de-correlation time (Lindelöw, 2008, Appendix B; others), and these two parameters could have relation to the energy dissipation rate and mean flow velocity, respectively, that were identified by the present authors as influencers of the noise magnitude (the mean flow velocity might be considered a surrogate for scan speed in the case of the static, off-axis scan configuration considered by the authors). In cw-lidar, the de-correlation time affects the width of the Doppler spectra, which may affect the precision of the parameter estimation process used to determine the line-of-sight velocity.

Lindelöw (2008) discusses the effects of changing aerosol backscatter correlation time on measured spectra obtained with a cw-lidar. In Appendix B, it is mentioned that the width of a single measured Doppler spectrum is inversely proportional to the correlation duration τ unless the spectral width is dominated by spread due to different speeds in the ensemble of many spectra sampled in the sampling volume, that is, by turbulence. It is stated that the global flow parameters such as mean flow velocity and dissipation rate will in general influence the de-correlation time of the lidar return. Specifically, turbulence level and scanning speed are known factors to influence de-correlation time.

For our study in the wind tunnel, the WindScanner cw-lidars, based on ZephIR technology, are configured to sample 200,000 spectra per second, based on a sampling time per spectrum of 5 µs. The lidar's signal-to-noise ratio after sampling $\sim$443 spectra per measurement (at sampling rate of 451.7 Hz) is found to be sufficiently high that the observed spectral spread can be assumed to be dominated by turbulence in the flow, and not due to changing de-correlation times due to flow parameters over individual single 5 µs sampling time. Presumably, the biggest effect of a short de-correlation in the backscatter signal would result in lower signal-to-noise ratios, but to a lesser degree in measured spectral width observations. Please also note that we have been intermittently applying generous seeding in the wind tunnel (See L98-L103 of the manuscript), to guarantee a sufficient amount of homogeneously distributed particles in our measurement region.

Even if a specific flow condition would influence the de-correlation time, it would probably not affect the measured Doppler shift estimation to a large extent, since it is determined from the mean Doppler shift from 443 spectra in case of 451.7 Hz sampling. The width of the ensemble-averaged spectral as used per measurement will be dominated by turbulence in the probe volume, as opposed to the width of the individual spectra. Where the individually sampled spectra and their width may be affected by changes in de-correlation time due to specific flow conditions, the ensemble-averaged spectra, from which we determine the effective Doppler shift by fitting a centroid mean value, will probably not.

References

Lindelöw, P. Fiber Based Coherent Lidars for Remote Wind Sensing. Ph.D. Dissertation Thesis. Danish Technical University, 2008.

Changes in the revised manuscript

Here the changes that have been implemented in the manuscript are listed point-by-point.

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Methodology, Part II: The Physical Models

- A statement has been added addressing the investigation of the dependency of the standard deviation of the noise on the standard deviation of the mean wind speed and the ambient temperature (L228-L230).
- A reference to the newly added Appendix B has been added (L236-L237).

Appendix A

- An introductory sentence has been added to Appendix A.

Appendix B

- The newly added Appendix B contains a more elaborate explanation of the development of the expression in Eq. (11), including a plot.

References

- The references to the recently published papers by Berger et al. (2021) and Neuhaus et al. (2021) have been updated accordingly.

Berger, F., Onnen, D., Schepers, J. G., and Kühn, M.: Experimental Analysis of Radially Resolved Dynamic Inflow Effects due to Pitch Steps, Wind Energ. Sci., 6, 1341–1361, https://doi.org/10.5194/wes-6-1341-2021, 2021.

Neuhaus, L., Berger, F., Peinke, J., and Hölling, M.: Exploring the Capabilities of Active Grids, Experiments in Fluids, 62, https://doi.org/10.1007/s00348-021-03224-5, 2021.