Author’s Response

On the community comment on "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://doi.org/10.5194/amt-2021-233-CC1, 2021

26.11.2021

Marijn Floris van Dooren et al.

Dear Etienne Cheynet,

Thank you for taking the time to post a community comment on the pre-print manuscript amt-2021-233 on 17.09.2021. We are very pleased that you regard this as a valuable study for engineers and scientists working on turbulence flow measurement techniques. In this author’s response, we will rephrase your remarks and questions in blue and answer them in black.

1. The studies present some coherence measurements, which I found really interesting, given that similar studies were conducted with the short-range WindScanner system in an outdoor environment in 2014 [1]. The coherence can be defined for longitudinal, lateral and vertical separations. Therefore, it was unclear to me if the studies discussed lateral or longitudinal coherence. Maybe this can be explained in a few lines?
   In this study the coherence that is presented is not representing any specific spatial coherence as a property of the flow but is used as a tool to compare two different sensors with one another. Indeed, there was a 7 cm separation between the WindScanner measurement point and the reference hot wire anemometer, however, the different measurement principles are assumed to have a much higher impact on the coherence graph than this spatial separation in the lateral direction. We included a better explanation in the paper about how this coherence function should be interpreted (**L384-389** in the revised manuscript).

2. The manuscript suggests that the frequency at which the lidar power spectrum deviates from the hot wire reference spectrum is the frequency at which the coherence drops under 0.5. Maybe a more accurate unit than the frequency is the wavenumber. Otherwise, the frequency at which the coherence becomes lower than 0.5 may depend on the mean wind speed. To go even further, the wavenumber multiplied by the separation distance D could be used as the coherence is a function of D. Therefore, at large distances, the frequency at which the coherence is under 0.5 will be much lower than at small distances.
   You are right about the relevance of the wave domain when we are speaking about lidar probe volume averaging. In this study we opted for working in the frequency domain, and we assumed Taylor’s Hypothesis to hold true, such that there is indeed a direct dependency on the mean wind speed, see Eq. (1):

$$k = \frac{2\pi}{\lambda} = \frac{2\pi f}{u_\infty}$$

   To be consistent with the spectral analysis in the paper, also performed in the frequency domain, we would like to stick to the current variable.

We acknowledge that the so-defined 'coherence cut-off frequency' will indeed decrease for increasing separation distances. However, as explained in the answer to question 1, we are dealing with only one spatially separated measurement comparing a single WindScanner to the reference hot wire anemometer, and thus the separation distance is not varied in this study.

3. How does the spectral correction improve the coherence estimates? In [1], it was suggested that since the coherence is a normalized spectral characteristic, the spatial averaging effect has a limited influence on the coherence estimates. However, in [5], it was also suggested that the spatial averaging may not be negligible if the probe volume is significantly larger than a typical length scale of turbulence.

   Unfortunately, we cannot make a statement on whether a spectral correction on the lidar measurement will improve the spatial coherence estimates, based on this data set, since the definition of coherence we present is the coherence between the WindScanner and the hot wire anemometer.

4. For engineering applications, one fundamental turbulence characteristic in wind tunnel tests is the integral length scale, which can be calculated with the autocorrelation function. Have you attempted to estimate it with the lidar system? If yes, how does it compare with the hot wire anemometer measurements? In [1], an overestimation by the lidar system was observed. I am curious to know if it is also the case in your study.

   We have not calculated the autocorrelation function based on either the lidar or the reference hot wire anemometer measurement before, however we did investigate it now. We used the approach from [1] to define the integral time scale based on the autocorrelation as such:

$$T = \int_{t=0}^{t(R(t)=0)} R(t)dt$$

   Where $R(t)$ is the normalized autocorrelation function of a time series (lidar or hot wire) and T is the integral time scale. Using Taylor's Hypothesis, the integral length scale L follows from the multiplication with the mean wind speed $\bar{u}$:

$$L = \bar{u}T$$

   In Figure 1, plots of the autocorrelation function are shown for both lidar and hot wire time series, for cases 1a, 1b and 2c, for the region between $t = 0$ and $t(R(t) = 0)$. Table 1 provides an overview of the calculated integral time and length scales for the three cases.

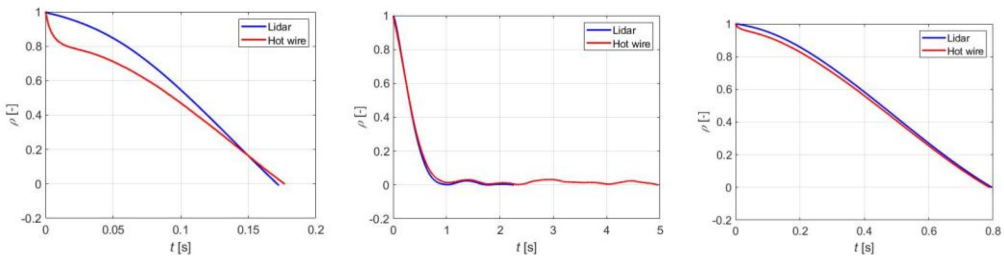

Figure 1: *Plots of the autocorrelation function of lidar and hot wire time series for three cases (1a, 1b and 2c).*

Table 1. *Overview of calculated integral time scale and integral length scale for both lidar and hot wire anemometer for three cases (1a, 1b and 2c).*

Case	T_{lidar} [s]	T_{hw} [s]	L_{lidar} [m]	L_{hw} [m]
1a	0.10	0.09	0.99	0.87
1b	0.40	0.34	3.35	4.08
2c	0.45	0.43	3.22	3.12

The values for the integral length scale are in the order of meters, much smaller than the values found in [1], which can be attributed to the differences between the flow in the free field and inside the wind tunnel. On average there is no consistent over- or underprediction by the lidar, as it depends on the case.
These results have not been included in the revised paper.

5. Although the purpose of the paper is on the high-frequency correction of the lidar velocity spectrum, the measurement technique presented in the manuscript has a wide range of potential applications in a wind tunnel facility. One of them is the study of wake behind bluff bodies. The short-range WindScanner has been successfully used in the past to study the turbulent flow around bridge decks [2], a tree [3] or a fence [4] in "full-scale". What about scaled models in a controlled environment? Do you think including such a discussion in the manuscript may be relevant to highlight the possible applications of the short-range WindScanner system in wind tunnels in the field of wind engineering, wind energy or fluid mechanic?
We acknowledge the potential applications of short-range WindScanner technology that you mention. Indeed, there already have been measurements of model wind turbine wakes inside a wind tunnel [6, 7] that successfully demonstrated this application. These references and more are mentioned in the introduction (**L39-43** in the revised manuscript). However, the main objective of the paper is the modelling of the lidar's measured spectrum in case of undisturbed flow, without any objects of study placed inside the wind tunnel. Therefore, we would like to keep the discussion focussed on the further verification of the model for different wind conditions in both the wind tunnel and in the open field.

References

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