Review of the manuscript AMT-2022-73, entitled "Behavior and Mechanisms of Doppler Wind Lidar Error in Varying Stability Regimes", by R. Robley and J. Lundquist

This study focuses on the errors associated with the measurements performed with a pulsed profiling Lidar when estimating mean wind direction and speed for the atmospheric boundary layer under different atmospheric stability regimes. The problem is tackled from a numerical standpoint through the virtual lidar technique, namely by sampling the wind field simulated with the WRF-LES model through a Doppler Beam Swing (DBS) scan. Two main sources of error are identified, namely the horizontal heterogeneity and range-weighting function (RWF). These errors are investigated through the random-variable theory and convolution integrals, respectively.
The topic is definitely of interest and thoroughly examined in the manuscript. However, a major point that could be improved is the clarity of the language throughout the manuscript. Some statements may result a bit cumbersome and need to be read several times for a thorough understanding (more details in the following). Furthermore, motivations and discussions are qualitatively reported without including details and references, particularly in Sections 3 and 4.
The quality of the figures (in terms of labels and panel size) could be improved. Finally, from a technical standpoint, I have noticed some confusion in defining the temporal full-width half-maximum (FWHM) of the lidar pulse, range gate, and accumulation time, which are independent parameters (more details reported in the following). Given their importance for this work, I recommend defining them more clearly.

Specific comments

1. **L164**: Earlier you referred to τ_m as "temporal range gate"; please avoid the introduction of new terminology unless strictly necessary. Also, the accumulation time is the time interval when the back-scattered signals are collected from a certain distance and ensemble-averaged in the Fourier space to single out the Doppler shift. Thus, it is independent of what here has been called "temporal range gate" (which is the spatial range gate divided by the speed of light); also, referring to Table 2, $\tau_m = 265\text{ns}$ is too small to be an accumulation time (typically ranging from 0.5 s to few seconds). Please address this point.
2. **L166**: To my understanding, Fig. 2b, c and d refer to time-averaged velocity profiles, which might be marginally affected by the shape of the RWF. The profiles of the Reynolds stresses may be more relevant for this discussion.
3. **LL 292-294**: Using temporal FWHM of 165 ns (as reported in table 2), I obtain a range gate of (Frehlich & Cornman, 2002):

$$\sqrt{\ln 2}\, c \cdot \text{FWHM} = \sqrt{\ln 2} \times 0.29979 \frac{\text{m}}{\text{ns}} \times 165\text{ns} \approx 41\text{m}$$

If you used this relationship, please state it in the text with reference. Also, the effective range gate of the pulsed LiDAR system is defined as the temporal FWHM (multiplied by the speed of light) plus the range gate (Frehlich & Cornman, 2002) (265ns from table 2, corresponding to 79.5m). Please clarify this aspect.

4. **L310**: In my opinion, an important point missing in this analysis, with respect to a real-scale experiment, is the decreasing of the backscatter coefficient moving away from the lidar, and, thus, the carrier-to-noise ratio (CNR). In other words, the presence of noise in the backscattered signal can severely impair the outcome from the lidar, and, thus, the velocity statistics. I understand that this effect is out of the scope of this analysis, but it could be mentioned when the error analysis is carried out.
5. **LL323-331**: This part would be clearer with a figure reporting vertical profiles of statistical estimators of the error. Please remove Appendix A and put the relative figure here.
6. **LL336-340**: From figure 5 (leftmost panel), I expected the mean error for the volume-averaged case to be lower than that for the 'tower' case considering the lower standard deviation. Can you please add some comments on this feature?
7. **LL427-428**: Is this velocity still a function of time? If so, please add this detail.
8. **LL444-445**: In general, the homogeneity is not violated due to the presence of turbulence. A flow can be homogeneous in a certain direction (i.e. having the same p.d.f. for all the sampled points) even in presence of turbulence. The lack of homogeneity is given by local spatio-temporal variations of the mean flow and turbulence statistics. Please rephrase this sentence accordingly, if you agree.
9. **L506-507**: I am not sure why the RWF should impact the time-, streamwise- and spanwise-averaged velocity components for a homogeneous flow since the time and length scale of the flow are much greater than the probe volume. Please clarify.
10. **Figure 12**: If the aim is to highlight the flow heterogeneity, then instantaneous flow visualizations cannot provide this information. Flow visualizations would work better. On the other hand, if you just want to show the positioning of the Windcube V2 within the domain, this figure works fine.
11. **L653**: Please provide more details about the trend line.
12. **LL 668-671**: This improvement is not so evident in Figure 15. If you want to highlight it, for instance, you can plot the median Normalized Wind Speed Error (plus-minus 25th percentile) as a function of the misalignment.
13. **L681**: The term "noise" here is misleading. It can be replaced, for example, with "scattering" or "variability".
14. **LL 702-704**: This sentence is unclear. It might not be correct to mention "mean error" referred to individual measurements. Further, it is unclear what the authors mean by saying "the time average approaches the potentially less biased 'ensemble' error from the selective sub-sample". Please clarify or rephrase it.
15. **L705**: To my understanding, here you refer to the variance (i.e. the uncertainty) associated with the mean of the random process, which is a function both of the variability of the process and the number of samples. Please clarify this aspect.
16. **L708-709**: This observation is qualitative and potentially not true. Please either remove this sentence or provide references.
17. **L717**: This assumption is correct, but it relies entirely upon the estimate of the decorrelation time τ_c. Please provide details about its calculation. Or, as an alternative, if you are interested in a more precise estimate of the standard deviation error, a good reference is Benedict & Gould (1996).
18. **L739**: What do you mean with "background signal"? Do you refer to the time or space average?
19. **L900**: This equality is unclear. Please clarify and/or rephrase it.

Technical comments:

20. **L15**: Which velocity components are named u, v?
21. **L21**: Please add the meaning of the acronym lidar.
22. **L31**: Please state clearly that the measured velocity is the along-beam, i.e. radial or line-of-sight, component.
23. **L105**: Also mention the conclusion reported in Sec. 5.
24. **L114**: For the sake of clarity, please put table 2 at this point of the discussion.
25. **L150**: Please mention that Δp is the lidar range gate.
26. **LL194-195**: This sentence is unclear, please rephrase it.
27. **Table 2**: Please add one row reporting the azimuth angles used by the DBS scan.
28. **L297**: Please revise this sentence as it sounds unclear.
29. **Figure 5**: In the caption, instead of "dotted", you should refer to solid lines to indicate the volume-averaged reference.
30. **L358**: Please add a reference to figure 6 here.
31. **LL391-392**: To my understanding, the error metric is the same both for the pointwise and the volume-averaged reference. It would be more correct to say "[...] merging of the two error distribution profiles".
32. **L451**: Please provide a reference.
33. **L559**: I guess here you refer to figure 12.
34. **L644**: Please revise this sentence as it sounds unclear.
35. **LL659-661**: This sentence is unclear, please rephrase it.
36. **L706**: Please replace "variables" with "samples".
37. **L716**: Please provide any reference or derivation for this equation. Also, provide a brief description of the terms reported here, which have not been introduced before.
38. **L821**: This study offers a relevant comparison for the present work, so it should be discussed at the beginning of the previous Section.
39. **L884**: You can replace this Appendix with simple literature references you deem pertinent.
40. **L897**: Do you refer to Equation 22 here? If so, please state it clearly.

References:

Benedict, L. H., and R. D. Gould. (1996). Towards better uncertainty estimates for turbulence statistics. *Experiments in Fluids,* 22(2), 129-136.

Frehlich, R., & Cornman, L. (2002). Estimating spatial velocity statistics with coherent Doppler lidar. *Journal of Atmospheric and Oceanic Technology*, *19*(3), 355–366.