Response to referee 1

Dear Wim Bierbooms,

Thank you for your general comments on our work, which we consider very important in helping us to improve the manuscript. Here is our response to each of your comments. Comments from the reviewer are reported in bold black and followed by our answers in blue.

Besides your general comments, we found out that the y, z coordinates of the SpinnerLidar were defined using a too small focus distance in the numerical simulation. We corrected those and updated results shown in Fig. 14(a). We simulated using 100 turbulence boxes to ensure the results are statistically significant. Compared to the figure in the submitted version, the major difference is that the uncertainties of the Reynolds stresses terms that involve with v' and w' are larger, as expected. All results regarding $R_{u'u'}$ (σ_u^2) are not affected, since the x coordinate and the modeling of probe volume were correct in the simulation.

Best regards,

The authors

Main comments:

- Eq. (22), mention that, refer to Eq. (5), n1=-cos phi, n2=cos theta * sin phi and n3=sin theta *sin phi

We added them and referred to the equation as suggested.

- line 181: explain in a few sentences why "we need at least six radial velocity variances from different beam directions"

We explained the reason as follows: "To compute the six Reynolds stresses, we need at least six radial velocity variances from different beam directions to ensure that the large matrix in Eq. (23) is not degenerate (i.e., its determinant is not zero) (Sathe et al., 2015). If fewer than six variances of the radial velocity are available, we have fewer knowns than unknowns. If the nacelle lidar beams have only one opening angle ϕ, the equations will be linearly dependent, and so the determinant will be zero and Eq. (23) will have infinite solutions. In those cases, only σ_u^2 can be well determined, and the stresses involving the lateral component will be more noisy (Peña et al., 2019)." (L183-188 in the revised version) More detailed explanation can be found in Sathe et al., 2015.

- line 268: "below 0.2 m/s"; shouldn't it be "above"?

Yes, we corrected that.

- line 269: why 100? (perhaps a reference can be added)

This is a criterion that worked well in Peña et al., 2019. We added this reference in the revised version.

- caption Fig. 5: introduce "beam index"

We introduced "beam index" as "the index of the 400 beams in each full scan" in the caption.

- line 292: explain "bore point"

The bore point is the perpendicular beam to the exit of the lidar's telescope. We explained this in L297 of the revised version.

- section 4.3.2: perhaps a 3rd option can be applied, according to the IEC: sigma_v=0.7 sigma_u, sigma_w=0.5 sigma_u

We think this is a very good idea. We added this new method in Sect. 4.3.2. The results are shown in Fig. 16 and described in Sect. 5.3 in the revised version. Table 2 was updated with new results. We also modified the conclusion according to this.

- Fig. 15: add titles on top of the 3 rows: "maximum", "median", "centroid"

We added the titles as suggested.

- Fig. 16: add titles on top of the 3 rows: "LSP sigma_u^2", "LSP isotropy", "U variance"

We added the titles as suggested.

References:

Sathe, A., Mann, J., Vasiljevic, N., and Lea, G.: A six-beam method to measure turbulence statistics using ground-based wind lidars, Atmo-spheric Measurement Techniques, 8, 729–740, 2015.

Peña, A., Mann, J., and Thorsen, G.: SpinnerLidar measurements for the CCAV52, Tech. Rep. DTU Wind Energy E Vol. 0177, DTU WindEnergy, 2019.

Response to referee 2

Dear referee,

Thank you for your general comments on our work, which we consider very important in helping us to improve the manuscript. Here is our response to each of your comments. Comments from the reviewer are reported in bold black and followed by our answers in blue.

Besides your general comments, we found out that the y, z coordinates of the SpinnerLidar were defined using a too small focus distance in the numerical simulation. We corrected those and updated results shown in Fig. 14(a). We simulated using 100 turbulence boxes to ensure the results are statistically significant. Compared to the figure in the submitted version, the major difference is that the uncertainties of the Reynolds stresses terms that involve with v' and w' are larger, as expected. All results regarding $R_{u'u'}$ (σ_u^2) are not affected, since the x coordinate and the modeling of probe volume were correct in the simulation.

Best regards,

The authors

General comments:

The writing of the article can be improved.

We improved expressions in some parts of the article, where we think they were not clear enough.

Specific comments:

L11-13: Should the authors clearly explain in conclusion why "the variances of the radial velocities estimated from the maximum of the Doppler spectrum are less affected by the lidar probe volume compared to those estimated from the median or the centroid of the Doppler spectrum."?

When introducing Fig. 15 we state that "Results from both the simulations using 30 turbulence boxes and the measurements indicate that turbulence attenuation is most severe using the centroid method from the Doppler radial velocity spectrum, while the maximum method gives the closest value, as expected (Held and Mann, 2018)."(L391-394 in the submitted version). Your question was investigated in detail in Held and Mann, 2018.

L99: What is λ in Equation 8.

We added that λ is the laser wavelength below Eq. (8) in the revised version.

L157-158: Is this a good approach?

This approach assumes that the horizontal wind $w = 0$. This approach should also work if the horizontal wind is not zero and the same at four beams. When the horizontal wind is not zero, as shown in Eq. (9),

the contribution from w to the radial velocity is very small, unless $|w|$ is very high. Besides, this approach has the limitation that four radial velocities at four beams need to be available to reconstruct the mean wind.

L177-182: I am not sure I understood it correctly. Which six beams have been used to retrieve the six Reynolds stress terms? It looks like the authors have considered all the combinations of six beams. Is it correct? Is this retrieval at a particular distance? Have you considered the curvature of the scan?

In this study, we use all radial velocity variances of the SpinnerLidar to calculate the six Reynolds stresses. We added this sentence to L188 in the revised version. Also, as described in Section 4.2.3 (L308-309 in the submitted version), "All grid cells with at least 900 Doppler radial velocity spectra within each 10-min period are considered for the reconstruction of the mean wind and the Reynolds stresses."

The retrieval of the turbulence statistics in this study is at a particular focus distance for all three lidars, as shown in Table 1. The SpinnerLidar scanning points are not in a plane due to its curvature. We considered the curvature both in simulation and in measurements.

References:

Held, D. P. and Mann, J.: Comparison of methods to derive radial wind speed from a continuous-wave coherent lidar Doppler spectrum, Atmospheric Measurement Techniques, 11, 6339–6350, 2018.