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WIND ENERGY SCIENCE DISCUSSIONS

Interactive comment on "Turbulence characterization from a forward-looking nacelle lidar" *by* Alfredo Peña et al.

Anonymous Referee #2

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The characterization of 3-D turbulence from lidar for more accurate quantification of the rotor-disk wind resource and for predicting wind power generation and loads is in critical need, especially as lidar become more prevalent across wind farms. The paper by Pena et al. presents two methodologies for improving our understanding of and measurement techniques for obtaining accurate estimates of atmospheric turbulence across a turbine rotor-disk using forward-looking nacelle-mounted lidar systems. Lidar measurements of the radial-velocity, as well as the velocity spectra, and derived variances, are compared against tower-mounted cup anemometer and sonic anemometer measurements. Results are presented for both pulsed and continuous wave lidar systems and as a function of beam orientation, atmospheric stability, wind speed class, and cone angle. The authors conclude from the results that the use of a central beam and a larger cone angle would improve the accuracy of lidar turbulence measurements.

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This topic is of high interest to the wind energy community as research investigating the sizes of turbulence and effects of 3-D turbulence on power generation and fatigue loads is currently being presented by numerous research groups, often offering alternative methodologies for obtaining accurate estimates of turbulence from lidar. I recommend acceptance of the manuscript after revisions, largely to help with the clarity of the results findings.

Major points: The manuscript is currently very long; results are not presented until page 20. I recommend that the authors consider whether the material presented in Section 2: General Background can be shortened. Does this information exist in earlier publications and can be largely cited here instead of explained in detail? The same comment is relevant for Section 3. These sections would be easier for the reader to digest if they were made more concise.

The use of sonic anemometry and cup anemometry is confusing throughout the results section. Please state that the sonic anemometer is 3-D. Only someone familiar with the CSAT3 would be aware of this since it is not mentioned in the text (as far as I can see). I recommend that a discussion is added either to Section 4 or to the Discussion Section which states the measurement differences between all of the instruments. This is briefly mentioned at the end of the manuscript but the point is important. A cup anemometer does not measure the three velocity components; instead mean horizontal velocity and variance is measured. Because of this, the reader is left wondering why the authors rely so heavily on the cup anemometer measurements for comparison to the lidar estimates of variance. At the very least a discussion needs to be included which outlines the limitation of deriving turbulence measurements from a cup anemometer.

The discussion would be strengthened by comparing these results to prior studies that have derived or utilized methodologies for estimating turbulence from lidar. Many of these studies use vertical-profiling or scanning lidar, however they are still relevant. Examples include recent work by J. Newman et al. (2016) whose group examined the accuracy of lidar variance against 3-D sonic anemometry. Lastly, please add additional discussion concerning the motivation for needing better lidar turbulence measurements. This is briefly addressed in the abstract "....useful to predict the loads on a turbine", however the connection between the two is left up to the reader without additional information. Also, please discuss the connection between turbulence and power generation as many recent studies have been published in this area.

Minor points: 1. Figure 1. Please connect the ends of the beam lines. It took this reviewer a long time to realize that beam #2 and beam #4 were not in the same plane. Also, why are 13 beams drawn for the CW system? Is this an arbitrary number?

2. P 5 Line 20. Please be more specific. Which frequencies does the lidar average out? This includes "most eddies" of what size?

3. P 6 Line 3. Elaborate on why the sonic u-spectrum is considered "ideal".

4. P 6 Line 6-7. "...and upward pointing beam spectra is smaller than the differences between ordinary velocity-component spectra..." What are ordinary velocity-component spectra?

5. Page 6 and throughout, Please comment on what Zr/L represents. If I understand correctly Zr is constant for a particular lidar, so this ratio is a function of atmospheric stability?

6. Page 6 L 31. Aren't the two stress fluxes small because of the applied coordinate rotation?

7. Page 12 L 12-13. The last part of this sentence "...., five days were used to measure with the ZephIR..." is confusing and does not warrant inclusion. Better to leave this info out.

8. Page 13 L 30. The 5-s and 18-s time period were chosen to mimic the lidar sampling frequencies, right?

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9 Figure 7, top right. What are the dots with a value of 1 along the y-axis? Are they blade interference? Better to remove these points from the figure and use the same y-axis for the left and right panels.

10. Page 15 Line 5. Please comment on the appropriateness of the logarithmic profile for the site here.

11. Figure 8. Left panel. Is this not showing evidence of overspeeding by the cup anemometer?

12. Page 15 L5-11. This section needs to be discussed in terms of instrument measurement technique differences and common errors associated with each measurement device. Is it not surprising that the cup anemometer is measuring higher variance than the sonic since it may be contaminated by the w component. It needs to be clear that horizontal variance from a sonic and cup anemometer are not expected to be equal, there will be a bias. Is this total horizontal or u?

13. Page 16 L 5. The reader may not know which scales are included in the inertial subrange. Please state.

14. Page 15 L 13. Doesn't local isotropy assume neutral conditions? If the conditions are stable, wouldn't this explain why the w spectrum is also lower than the u spectrum?

15. Figure 10 and text below. The sonic and cup anemometers appear to not suffer from noise at the high frequency end of the spectra. So why was the same noise filter applied to these data, especially since it "distorted the shape" of the sonic u-spectrum?

16. Figure 12. Please list the date periods that these lines correspond to. Also the stability conditions for each.

17. Page 20 L 25-30. Instead of using (1/L)-1, why not discuss z/L here since these values are in the table. Plus, isn't (1/L)-1 just L?

18. Figure 13 Left panel. Why is it assumed that sigma_u/U is constant as a function

of wind speed?

19 Table 1. I don't think mean values of z/L are meaningful, especially since the mean values you list are well above all of your stability classes. Try using median values instead.

20. Page 28 Line 22. Please talk about the fundamental differences in way the instruments measure velocity and turbulence. It is more than "due to the way they probe the atmosphere".

21. Page 30 Line 10. How do you get uw and w variance from a cup anemometer?

22. Page 32 Line 14. The authors conclude that a larger cone angle would improve estimates of turbulence, but doesn't this make the assumptions about flow homogeneity across the scanning cone less valid?

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