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Title: Validating Precision Estimates in Horizontal Wind Measurements from a Doppler Lidar

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Summary

In this paper, different methods are used to estimate precision in Doppler wind measurements from a scanning lidar deployed during XPIA. These precision estimates are compared to the actual horizontal wind speed and wind direction differences between the lidar and sonic anemometers on a tower to assess the ability of the various precision estimates to characterize lidar error. These types of precision estimates are extremely useful in the wind energy community, as they enable the calculation of uncertainty (if the lidar is unbiased) without measurements from a reference instrument.

Overall, the paper is clear and well-written. The clarification between uncertainty and precision is very helpful, although this clarification is sprinkled throughout the manuscript. It would be more helpful to state upfront (i.e., in the introduction section) what factors contribute to the random and systematic errors in Doppler lidar velocity data and how these terms relate to the definitions of uncertainty and precision.

The use of the terms uncertainty and precision is still a bit unclear in some parts of the manuscript. For example, in Section 3, σ_{ri} is described as the measurement uncertainty due to random errors (p. 6, Line 2). But isn't uncertainty due to random errors just equivalent to precision? And in Section 4.1, you use the term uncertainty through p. 12, state that you can equate uncertainty with precision in this case because the CDL data are unbiased (p. 12, Lines 11-13), then continue to use the term uncertainty through the rest of Section 4.1. A clarification between these terms, perhaps with some additional symbols or equations, would be extremely useful. These terms are currently not very well-defined in the lidar literature, so laying out clear definitions of precision and uncertainty in the context of lidar measurements would make this paper a valuable reference.

Specific comments on the manuscript are listed below.

Specific Comments

Abstract

p. 1, Line 18: Should uncertainty be changed to precision here?

p.1, Lines 24-25: Briefly describe why ignoring turbulence effects results in uncertainty being equivalent to precision (i.e., how is turbulence defined in the context of random vs. systematic errors?)

1. Introduction

p. 3, Line 7: change “step-stair” to “step-stare”

2. Experimental Setup and Instrumentation

p. 5, Lines 12-18: I assume wind speeds from both sonics at each height were used to make these figures. How did you determine which sonic to use during each 10-minute period?

3. Lidar Wind Retrieval and Precision Estimation

p. 7, Line 5: What is N in these equations?

p. 8, Lines 14-18: It looks like there’s an SNR maximum at approximately 300 m. Does this correspond to the focus height of the lidar?

4. Results

p. 8, Lines 21-23: Make it clear from the beginning of the section what you are calculating the uncertainty of (10-min. wind speeds? Wind speeds from each 40-second VAD scan?)

p. 8, Line 25: Change “the all the” to “all the”

p. 9, Line 2: How far apart in time were the consecutive scans conducted? If they were spaced 10-15 minutes apart in time, how well do these variance measurements actually characterize atmospheric turbulence?

p. 9, Lines 15-16: This line (or a sentence with similar content) should be placed before the trials are described, so the reader is aware from the beginning that “trials” refer to different ways of processing the same data.

p. 9, Line 20: The use of the term “larger precisions” is misleading here. I would suggest changing it to something like “lower precision (higher uncertainty)”.

p. 9, Lines 22-23: Briefly discuss why the uncertainty in Trial 3 shows no distinct diurnal variation.

p. 10, Lines 4-5: Briefly discuss why the averaging time for the sonics was set to twice the time of the PPI scans.

p. 10, Lines 5-6: It is a bit unclear what you mean by “under-sampling” here, and how this relates to the 12 min. PPI intervals and the 40-s scan time.

p. 10, Line 9: Change “rather the wind speeds...” to “rather than the wind speeds...”

p. 10, Lines 10-11: How did you define the wake sectors for the tower?

p. 11, Line 15: Delete extra period after “sonic winds”

p. 12, Lines 8-14: The significance of this statistical test is a bit unclear, so it would help to elaborate on the meaning of the test.

p. 12, Line 22: Please define the relative uncertainty (i.e., how is the uncertainty being normalized?) The term “relative uncertainty threshold” should be changed to “relative precision threshold” to be consistent with the terminology used in Fig. 7.

p. 13, Lines 17-22: Please discuss some possible reasons for the diurnal variability in wind speed and direction differences.

p. 14, Lines 5-7: Were there any noticeable differences in wind speed and direction correlations between the lidar and the tower for different heights or mean wind directions?

p. 14, Lines 9-14: Please elaborate on the significance of these findings and relate the different sub-trials to current lidar scanning techniques. For example, Trial 2a_{2D} is similar to low-elevation scans conducted by scanning lidars to measure, e.g., turbine wakes (although the scanning angle used for this CDL was quite high). Trial 2b is similar to a DBS scan used by a vertically profiling lidar. Practically speaking, at what point is the trade-off between decrease in scanning time and increase in uncertainty worthwhile? It should also be noted that if only 4 beams are used in the PPI scan rather than 8, the scan time would be much faster and it would be more feasible to conduct multiple contiguous PPI scans and/or spend more time collecting data at each azimuth angle.

It’s a bit surprising that there isn’t a significant change in the mean wind speed difference and wind speed difference standard deviation when the w wind component is neglected. I would expect a noticeable change in uncertainty, as the w component contributes significantly to the radial velocity at this PPI elevation angle.

5. Summary

p. 15, Line 12: Add period after “wind retrieval algorithm”

Tables and Figures

Table 1: It would help to add a column or two to this table to summarize the major assumptions made in each trial.

Figure 3a: Gridlines in the background should be made darker.

Figure 4: It would help to also give values of SNR in decibels on the x-axis of these plots, as SNR is often given in decibels in the lidar community.