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Interactive comment on "Improvement of Vertical Velocity Statistics Measured by a Doppler Lidar through Comparison with Sonic Anemometer Observations" *by* Timothy A. Bonin et al.

Anonymous Referee #1

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The manuscript "Improvement of Vertical Velocity Statistics Measured by Doppler Lidar through Comparison with Sonic Anemometer Observations" presents an estimation of vertical velocity variance derived using the auto-covariance technique following Lenschow et al (2000). In this study, this technique is evaluated using two Doppler lidars measurements and sonic anemometers for a two day period. The auto-covariance technique is a well established method for obtaining the higher-order moments of turbulent variables in the convective boundary layer. However, here in this study, the authors attempt to measure the vertical velocity variance in stable conditions when turbulence is weak. The authors conclude that auto-covariance technique improves the Doppler lidar variance estimates even when the turbulence is weak in stable conditions.

Printer-friendly version

Discussion paper

I do not recommend the manuscript for publication in this journal in the present form. The manuscript could be considered for publication after questions and suggestions for major revisions are addressed.

General comments An interesting study is made by the authors to improve the accuracy of vertical velocity variance measurements made from Doppler lidars. Lenschow et al. (2000) methodology for the estimation of the vertical velocity variance is evaluated. However, the validation needs more focus. Main points are as follows

1) Lenschow et al. (2000) derived the higher-order moments from the noisy lidar data in the convective boundary layer (CBL) i.e. during convective conditions. All the studies mentioned in the manuscript using the auto-covariance technique were made during convective conditions when the CBL top became quasi- stationary and turbulence was dominant. Here in this paper, the authors show results from the total observation period including stable conditions where turbulence was weak. Is the inertial subrange detected in the stable conditions from Doppler lidar measurements? Are the major part of the turbulent fluctuations resolved during these periods. The spectra shown here in Figs. 8 and 9 show that the inertial subrange was not reached in all cases.

The authors show the integral time scale in Fig. 4. Please also show the integral time scale, tint (or length scale) profiles for the respective cases with Doppler lidar measurements. It is important that the major part of the turbulent fluctuations must be resolved with the measurement system, so that the temporal resolution(dt) of the system is sufficient (tint » dt) to sample the turbulent eddies, so that the inertial subrange in the spectrum and dissipation range in the auto-correlation function becomes resolved (Wulfmeyer at al .2010; Lenschow et al. 2012; Turner et al. 2014). If all the above conditions are met, then it is possible to derive the variance profiles. It would be good to split the total data into stable, unstable and neutral conditions. For example, during stable conditions (Fig.7c), the first 4 min data shows different behavior between the lidar observation and the sonic measurement. Hence, this will also show the differences in the variance comparisons with respect to a variety of conditions and improvements.

2) Here the authors choose 30 min period for the analysis of the vertical velocity variance. In general most earlier studies use 2 hour time period for the analysis of higher-order moment data in convective conditions. It would be interesting to compare if any differences would be found if the same analysis is performed using 1 hour and 2 hour data sets for the variance estimates. This will also make the study more robust.

3) The number of lags needed for the extrapolation of the structure function to lag zero is given in detail in Behrendt et al (2015 and references there in). The zero crossing of the auto-covariance function appears at 2.5 times the integral scale, hence the resulting integral scale must be larger than the averaging time of the measured data. Here in this study, in Fig. 9 a shows that the zero crossing is already found at 15 lags and the tmax used is 8 s. The above condition is not met here in this case. For the other cases in the same figure larger variances are found indicating turbulent periods and zero crossing is found at higher time periods. Also, for the lower variance found in Fig. 9a no changes are found in the tmin and tmax values when compared to 9b and 9c. Hence this method of choosing the time lags is questionable? Instead the authors can verify how the differences in the lags chosen for the variance analysis show corresponding differences in the variances obtained at different heights.

4) Figure 10 shows the comparison of vertical velocity variances at 150 m for a) OU DL and d) LLNL WC both at 150 m with sonic anemometers. Even though closely located, large scatter is present between 0 - 0.5 m2s-2 for LLNL WC than the OU DL. Why? The differences in the R2 and the slope between the uncorrected and corrected variances are small in Fig. 10. The difference seems to be notable only at 300 m at low wind speeds. Please explain

Specific comments:

-The authors state that Barlow et al. (2011) and Fuertes et al. (2014) already showed that DLs are incapable of resolving turbulence on small spatial and temporal scales compared to sonic anemometers due to sampling frequency discrepancies. The authors can highlight the new findings they are adding in this manuscript in more detail. Please also provide information on the previous studies of the variance estimates in stable conditions using auto-covariance technique if available

-Please give the methodology used for data quality check from Doppler lidars used for the variance estimates.

-Page 1 line 9 :... over a variety of atmospheric conditions? Please justify the sentence

-Figure 1 shows a schematic of the eddies. This is already well detailed in the text lines 21-28 page no 2. Please replace this figure by showing the measurement site with instrument located.

-Page 12 lines 5 -10 : Please clarify the sentence- in which conditions. Please include how many 30-min periods were available for the study for different conditions.

-Page no 17 line 5- 10: The authors state that differences in sampling volume and frequency have stronger effects during stable conditions. Please show a time series of vertical velocity variance comparison obtained for the 2 day period (30min, so 96 data points should be possible) at 100m and 300 m. This would be give a better visualization for understanding the diurnal variability of the vertical velocity variance comparison between the lidar and sonic measurements at different heights. Similar to Figure 2.

- Please think of adding at least one or two height ranges close to the ground around 60 m in the Figure 10 to show the vertical velocity variance in the surface layer. The authors also state that the SNR was large at 50 m for LLNL WC measurements.

- Please add a new figure comparing the variance profiles between two lidars for different conditions including the noise and sampling errors for both lidars. Also, include the sonic estimates to show the improvement of the technique.

- Please include a new figure similar to figure 11 with respect to noise and sampling errors.

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