We are grateful to the referee for the comments, which helped to improve the manuscript. Our replies to the comments below are shown in blue below. The line numbers given in the reply refer to the revised manuscript. A manuscript with tracked-changes is also provided.

Major issue

The data is analysed without any wind sector information. The surrounding of the turbine has different roughness lengths and obstacles that can cause different internal boundary layers effecting the short distance behind the turbine, measured free wind and wind speed at hub height. Things around the turbine (Financial Park, Johns Hall etc.) look like around 9-10m tall. It is too optimistic to assume that they do not have impact. Therefore, selection criteria are not clear to me. Compared (or summed up) results might be from different conditions and current filtering methods might not be enough. Some inconsistent data (see minor issues) might be product of this situation and that should be addressed at least at discussions or conclusion. If it is assumed that the wind direction does not matter for the analysis, a proof comparison from different sectors with similar conditions can be used.

In the following, we show that the heterogeneity and topography of the surface around the wind turbine should not interfere with the measurements at hub height by (i) clustering our results for different wind direction, and (ii) based on the blending height concept.

First, we investigated the effect of individual buildings in the vicinity of the wind turbine by clustering the measurement data according to the wind direction (see Fig. 1 below). If individual buildings or topography features have a pronounced influence on the results, then the data from a particular wind direction cluster should exhibit marked differences to the other two clusters. The below Fig. 2 shows that the wind direction clusters are mixed throughout the main results of the manuscript, indicating that individual roughness elements do not have a strong impact on the results.

The roughness sublayer is the layer directly above the surface where individual surface roughness elements induce horizontal variability of the flow statistics. We assume that if we are measuring above the roughness sublayer, then the footprints of individual buildings have been blended (or spatially averaged) by the turbulence and should not interfere with the measurements. This is also often referred to as the blending height concept in literature. While the depth of the roughness sublayer depends on many factors and is not fully understood yet (Mahrt, 2000), we provide two practical approaches below:

- Turbulent flux measurements with the eddy-covariance method need to be conducted above the roughness layer to measure a spatially averaged signal representative of the local area (e.g. Aubinet et al., 2012). The range given in literature for the roughness sublayer height in urban environments ranges from $1.5h_c$ over densely built-up areas to $5h_c$ over low-density areas (Grimmond and Oke, 1999). Assuming a building height of $h_c = 10$ m for the area around the wind turbine (two and three-story buildings), the hub height of the wind turbine is above the roughness sublayer for both build-up densities. An example with eddy covariance measurements that were conducted at three times the building height above a city and are assumed to be in the constant flux layer is shown in Velasco (2009).
- Raupach (1994) estimates the depth of the roughness sublayer above plant canopies starting at the displacement height (d) with $z^* = 2 * (h_c - d)$, with d between $\frac{2}{3}h_c$ and $\frac{1}{30}h_c$. Therefore, the small patches of wood are also not expected to have any effect on the wake measurements.

In summary, we believe our measurements at the hub height (77 m) are above the roughness sublayer and hence we would not expect that the footprints of individual buildings affect the measurements based on the blending height concept.

We added a short paragraph at beginning of Sect. 3 (lines 149 to 153) that states that the results are not differentiated according to the wind direction following scale arguments and a cluster analysis without going into the details shown here.

References

- *Mahrt, L. Surface Heterogeneity and Vertical Structure of the Boundary Layer. Boundary-Layer Meteorology 96, 33–62 (2000). https://doi.org/10.1023/A:1002482332477.*
- *Aubinet, M., Vesala, T., Papale, D., 2012. Eddy Covariance: A Practical Guide to Mea-surement and Data Analysis. Springer, 460 pp.*
- *Grimmond C.S.B., Oke T.R. (1999) Aerodynamic properties of urban areas derived from analysis of urban form. J Appl Meteorol 38:1262–1292*
- *Velasco, E., Pressley, S., Grivicke, R., Allwine, E., Coons, T., Foster, W., Jobson, B. T., Westberg, H., Ramos, R., Hernández, F., Molina, L. T., and Lamb, B.: Eddy covariance flux measurements of pollutant gases in urban Mexico City, Atmos. Chem. Phys., 9, 7325–7342, https://doi.org/10.5194/acp-9-7325-2009, 2009.*
- *Raupach, M. R.: 1994, Simplified Expressions for Vegetation Roughness Length and Zero-Plane Displacement as Functions of Canopy Height and Area Index, Boundary-Layer Meteorol.71, 211–216.*

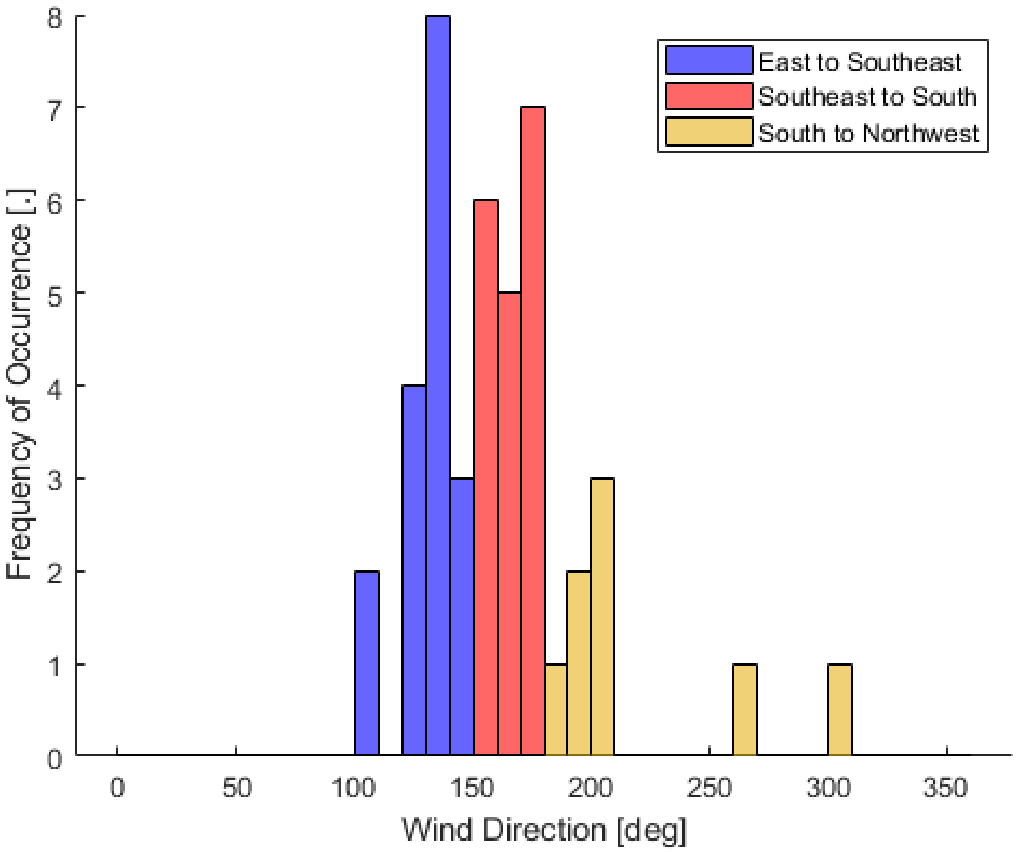

Figure 1: Histogram of the wind direction from the SCADA data for the data sets analyzed in the manuscript. The colors show the three wind direction clusters defined to investigate the effect of surface heterogeneity on the results.

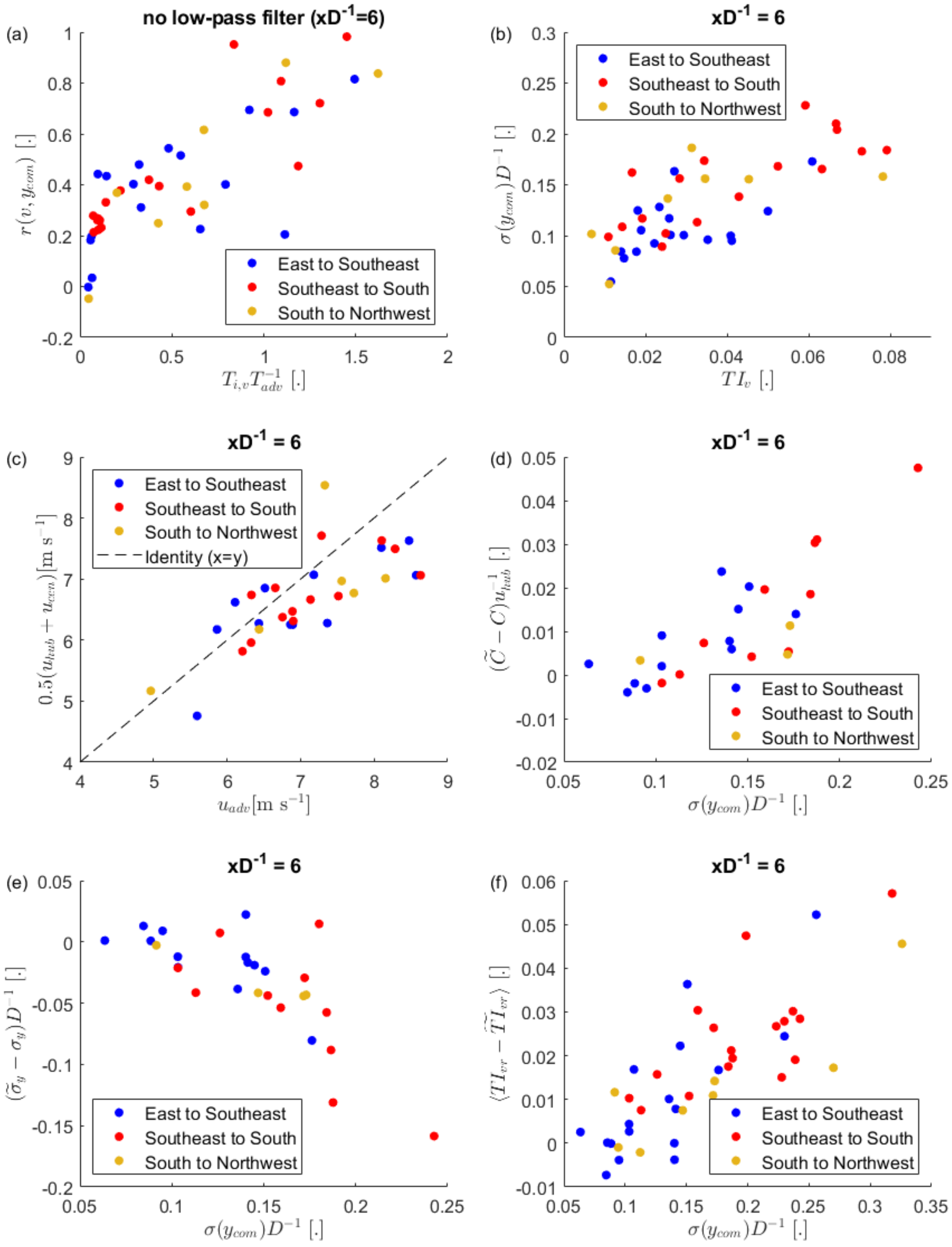

Figure 2: The main results from the manuscript are shown for different wind direction clusters. The panels (a) to (c) correspond to the results of Section 3.1 (namely Fig. 4a, Fig. 7a, and Fig. 9). The panel (d) to (f) corresponds to the results of Section 3.2 (namely Fig. 11a, Fig. 11b, and Fig. 12a).

Minor issues

Page 2/line 50: Although I have found the location quite easily over Google Earth, I think you should add the exact coordinates (41.916578°, -91.650871°) to the paper.

We added "The wind turbines coordinates are 41.9165° latitude and -91.6508° longitude." to the caption of Figure 1.

Page 3/Lines 65: Says "The rejection criteria for wake scans not suited for further analysis based on data quality, turbine yaw activity, and inflow characteristics will be presented at the beginning of Sect. 3." But Section 3 does not give any information about directional rejection (if any). If all wind directions are accepted, wouldn't there be a discussion about the wind flow coming from urban areas? Wouldn't that effect the lateral or vertical advection?

The rejection criteria did indeed not include any directional rejection, because we assume that the effects of individual roughness elements have been spatially averaged according to the blending height concept at hub height. A verification of this assumption has been presented in our reply to the major issue above with the directional clustering. A paragraph stating this has been added to the manuscript (lines 149-153).

As a side note here, we noticed a mistake in our previous selection of the suitable cases: the time stamps of the SCADA data were sometimes one second to early (e.g. hh:59:59 instead of hh+1:00:00). This led to some wake scans being discarded wrongly, because we believed the SCADA data was missing and after adjusting the post-processing for this issue, we have now 43 suitable wake scans. Further, the outlier mentioned in Fig. 8 of the previous version of the manuscript is no longer an issue with this change (here both time stamps at the beginning and the end were one second to early).

Page 4/Figure 2 I did not understand the parenthesis saying, not to scale. (Sorry)

The rectangle representing the nacelle and thickness of the line indicating the rotor are too big given the x-axis and y-axis of the plot. If we plotted them according to the true dimension of the wind turbine, they would be too small to be useful.

Page 4/ Line 74 I think radial velocities are converted to vertical components in x-axes is rather more correct then are corrected.

The sentence has been removed from the manuscript and we now use the radial velocities directly for the analysis following a comment from referee #1 (page 5, lines 82-84).

Page 4/ Line 76 I don't understand the simplification of the trigonometric equation! Why do you need to do that?

This approximation has been introduced for an easier to understand presentation of the results. The cross-sections of the Doppler LiDAR scans are a segment of a circle (see Figure 2 in the manuscript) and the correct presentation in the various figures of the manuscript would be a radial distance with an azimuth angle as the ordinate. However, by assuming $x = r\cos^{-1}\phi \approx r$ we can label a particular cross-section with a single downstream distance, while using an ordinate in the units of meter. We believe an ordinate in meter will be more familiar to most readers and it can be directly compared with the rotor diameter.

Page 5/line 83 An example figure would be nice to see the steps 5 and 6 to see and understand the quality of the process since no single instantaneous wake measurement is shared.

Examples of instantaneous wake and the resulting wake center positions are shown in the results section. Fig. 6a and 6b, Fig. 7, and Fig. 11a show instantaneous wake measurements and the instantaneous wake center position from Eq. (2) is also shown in those figures.

Page 5 / Line 91 See my comments about Page 3/line 65 for inconsistent data

The first four range gates of this Doppler LiDAR type have generally bad measurements (independent from the setup of the LiDAR). For the fifth and sixth range gate, which have reliable observations typically, we observed velocities biased towards positive values and higher standard deviations compared to range gates at greater distances (see Fig. 3 below for an example). We believe the issues of the fifth and sixth range gate are caused by the influence of the wind turbine on the flow field that might extend beyond the rotor diameter (e.g. a flow displacement due to a blockage effect and the resulting turbulence). However, beyond the 7th range gate until the signal-to-noise ratio of starts to decrease at 1600 m, the turbulence is fairly homogenous. We added a more precise description of this issue and our reasons to choose the 7th range gate for the lateral velocity to the manuscript (page 5, lines 96-99).

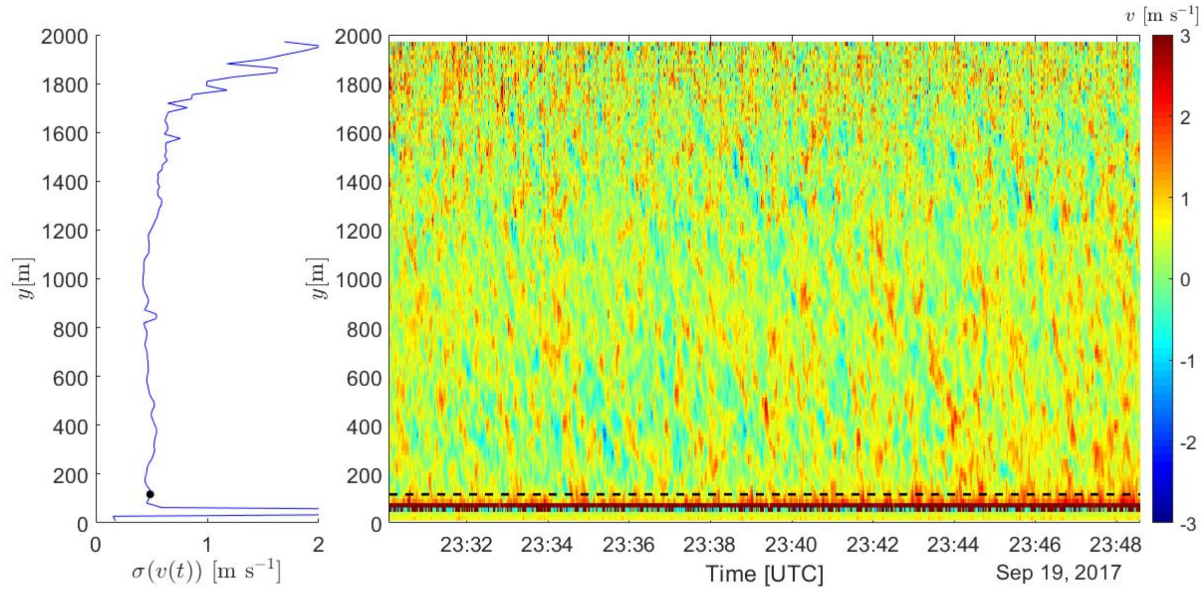

Figure 3 : Standard deviation of the lateral velocity component (left panel) and time series the radial velocity from the Doppler LiDAR in the lateral staring mode. The black dot (or black dashed line) indicate the 7th range gate at y=117 m. This figure uses raw data from the Doppler LiDAR without any quality control to illustrate error. The bad measurements of the first four range gates are visually apparent. A bias towards positive velocities (more red) can be seen for the 5th range gate (for other cases as well for the 6th range gate). The increase of the standard deviation at y>1600 m is caused by noise due to a decreasing SNR with distance.