In this document, the reviewer comments are in black, the authors responses are in red.

The manuscript entitled "Three-dimensional structure of wind turbine wakes as measured by scanning lidar" deals with the analysis of field measurements performed during stable atmospheric conditions on the velocity field downstream of a group of four wind turbines, captured by a scanning LiDAR.

The study is of great interest for the wind energy community since it can contribute to better quantify the wind turbine wake properties and so, to validate some wake models and numerical simulations.

The authors thank the reviewer for their time in reviewing this contribution and we are pleased that this work is considered of great interest.

The experimental set-up is well detailed, the method to detect the wake locations of multiple wakes on each snapshot is well described and the content is well structured. On the other hand, the discussion is rather poor: several results, which are not intuitively expected, are mentioned but not justified. For instance:

Thank you for pointing out that the discussion of the results should be improved. We will justify our results as explained in the next paragraphs.

- The reason why the velocity deficit is smaller for outer wakes than for inner wakes. Is it possible to give an explanation without having information about the wind turbine operating conditions? The velocity deficit is also primarily related to the power coefficient of the wind turbine.

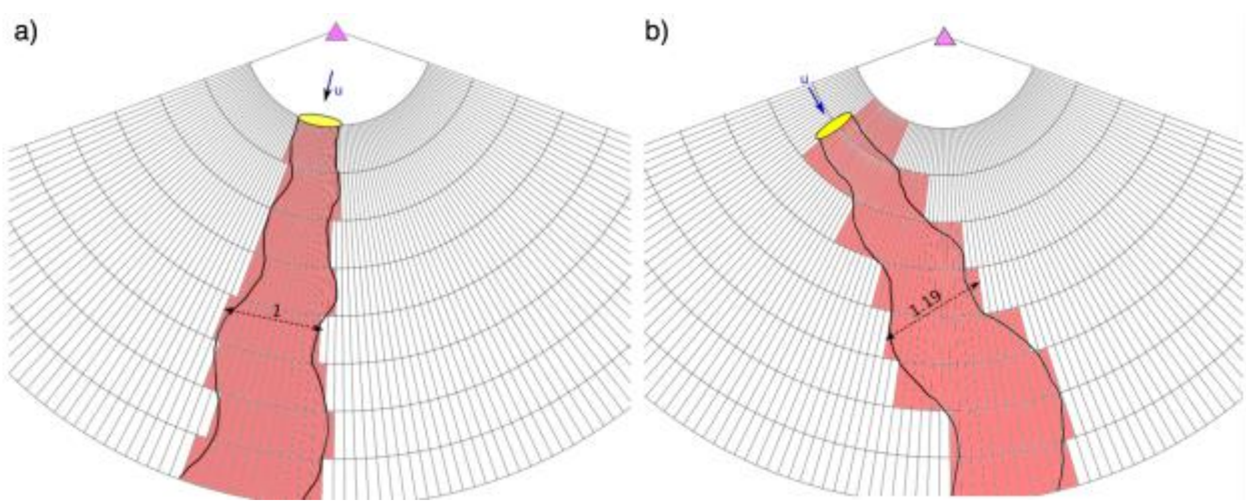
To provide a possible explanation of this result, we will include the following sentence at the end of Section 4.2: "The presence of outer turbines seems to reduce the effectiveness of lateral entrainment of faster air to recover wind conditions in the inner wake regions of the wind farm." Moreover, to provide additional insight, the plot with the results for the 23 August will be included in the revised manuscript.

The turbines are all the same model of turbine and therefore would have the same power coefficient at each wind speed regime, and we have verified (not shown as the data are not publicly available) that the turbines are all producing, on a daily average basis, within 15kW and 31kW of each other during 23 and 26 August 2013, respectively.

- The reason why the wake width is dependent on the relative position between the wake and the scanning lidar. Please elaborate an explanation.

Thank you for pointing out that we did not provide a sufficient discussion for this. We will add the following paragraph and Figure to our manuscript:

"This result is due to the relationship between the viewing angle and the aspect ratio of the lidar retrieval "pixels", which are related to the relatively long range gate (50 m) and relatively narrow azimuthal resolution (0.5 degree). As qualitatively shown in the schematic of Figure 10, the scanning lidar measures the line-of-sight velocity in narrow pencil-shaped "pixels". With this geometry, if the wind direction - and thus the wake - is aligned with the line-of-sight from the lidar, the wake width can be assessed with high precision due to the high azimuthal resolution in each pencil-shaped area (panel a). However, if the wind direction - and thus the wake - is not aligned with the line-of-sight from the lidar (panel b), then the same wake will be measured as generally wider, since the retrieval of the wake width is now affected by the relatively coarse radial resolution of the lidar coordinate grid. In the schematic diagram shown in Figure 10, at an arbitrary fixed downwind distance from the turbine, the (same) wake would be detected as 19% larger when it is not aligned with the line-of-sight from the scanning lidar. This result becomes more evident the when the laser beam is more perpendicular to the wake. This result is due to the aspect ratio of the lidar "pixels," and thus would affect other wake characterization approaches relying on instruments not co-located with the turbine such as in Banta et al. (2015); Aitken et al. (2014a), but would not affect nacelle-mounted wake measurements, such as in Bingöl et al. (2010); Aitken and Lundquist (2014) as nacelle-mounted wake measurements are usually aligned with the wake, unless the wake is intentionally yawed (Fleming et al., 2016; Trujillo et al., 2016)."



"Figure 10. Qualitative sketch of the dependence of detected wake width on the orientation of the coordinate grid used by a scanning lidar (purple triangle) as a function of the wind direction. Panel (a) shows the case of a wake aligned with the line-of-sight from the scanning lidar (wind direction shown by the blue arrow), while panel (b) shows the case of a wake not aligned with the line-of-sight from the lidar. The dashed arrow highlights the difference in the detected wake width for the two cases, at fixed downwind distance from the turbine (yellow ellipse)."

- The correlation between the veer and the wake stretching angle is rather poor (figure 11), the data present a very high scatter, with no linear trend. It is hazardous to make some interpretation with this plot. Parallel to the previous remark on the dependence of wake widths to lidar beam orientation, could the measurement set-up and the scanning lidar limitations be responsible of this wake stretching, instead of the veer? Again, the conclusion that the inner and outer wakes behave differently with the veer effect must be justified.

We agree that the quality of the linear fits is rather poor, however we think they are useful to show the different behavior between wakes from inner and outer turbines. To make this clear and to include the suggestion of another reviewer about oscillations in this relationship, we will rephrase the description of these results as follows: "as suggested by the linear regression fits, wakes from outer turbines often present a larger angular difference in wake centerlines compared to wakes from inner turbines, though with variability for different veer values that motivates further study".

We do not think that the measurement set-up may have affected this result, since the same results are obtained for both 23 and 26 August (i.e. for different wind directions), while for the wake width different wind directions caused different results.

To provide a possible explanation for this result, we will add the following paragraph at the end of Section 4.4.1: "A possible physical explanation for this phenomenon can be detected in the interaction between wake rotation due to rotating blades and wind veer. The blades of the wind turbines in CWEX-13 wind farm rotate clockwise and so the downwind wakes rotates counter-clockwise [Burton 2001]. The wake can thus be considered as a sort of plume with its own momentum and rotation, which interacts with the ambient veer, that in turns tends to rotate the wake in the opposite direction (in the Northern hemisphere), thus causing a reduction in the global wake vertical stretching than would be present if only the ambient veer affected the wake. Inner wakes seem to be less subject to the effect of ambient wind veer, as if the presence of outer turbines reduces the ability of ambient wind characteristics to reach and impact inner regions of the wind farms."

Minor comments:

- Page 4, line 12: 30-min cycle: do you mean that, during 30 minutes, several PPI and RHI are collected? If yes, please indicate the duration to collect one PPI and one RHI. It will give an idea of the temporal resolution of the obtained velocity field.

Yes, several PPI and RHI scans are collected in each 30-min cycle. To make this clear, the revised text will include the following sentence: "each PPI scan lasted approximately 100 seconds, spanning an azimuth range of 50deg with a speed of 0.5deg/s, while a RHI had a duration of about

30 seconds". A table will also be included (see comment below) with more details about the 30-min cycle.

- Give the range of azimuth angles that have been scanned during PPI and RHI. A table with all these information would be appropriate.

The following table with a detailed description of the scans performed during the experiment will be included in the manuscript:

Table 2. *Description of the 30-min cycle of scanning lidar scans in CWEX-13 field campaign. The characteristic fixed angle refers to the elevation angle for PPI and VAD scans, the azimuth angle for RHI scans.*

number of scans	type of scan	characteristic fixed angle	duration of each scan	cumulative time
2	VAD	75°, 60°	132 s	0:00 - 4:24
6	PPI	2.8°, 2.5°, 2.2°, 2.1°, 1.8°, 1.5°	104 s	4:24 - 14:48
3	RHI	160°, 170°, 180°	32 s	14:48 - 16:24
6	PPI	2.8°, 2.5°, 2.2°, 2.1°, 1.8°, 1.5°	104 s	16:24 - 26:48
6	RHI	160°, 170°, 180°, 180°, 170°, 160°	32 s	26:48 - 30:00

- Page 5, figure 5: the y-axis legend indicates "detected wakes [% scans]" but the maximum value is 1, and not 100.

Thanks for noticing this incongruity. We will revise the plot accordingly.