Response to Interactive comment on "Characterization of intertidal zone wind turbine wake based on the dual-lidar observations" by C. Feng et al.

Response to Anonymous Referee

The manuscript describes the investigation of wake characteristics during a time period of rising tide. The goal of the paper is to determine if the rising tide contributes to changes in wake length. The topic of research is quite interesting and is worthy of study. However, there are several flaws in this manuscript. The current experiment design although unique, seems quite ill suited for the purpose of this study. In addition, the reviewer finds cases of improper logic and justification. With this in mind, the reviewer recommends a rejection of this paper. Hopefully the comments below will help the authors to refine their future plans for this study. Detailed comments and suggestions to the authors are given below.

A: We have modified the revision and answered every specific comment in what follws.

Specific comments:

1. Why was the angle of the tilted plane chosen to be 4o? This angle seems quite steep to account for lifting of the wake center-line. In addition, the choice of only 1 scanning plane is poor experiment design as there is no guarantee that the wake will be aligned with this tilted plane.

   A:

   a) For ground-based lidar measurement, the altitude difference between lidar and wind turbine rotor diameter resultes in that the elevation of laser beams should be large than 0 degree. We chosed 4^o by refering to some documents, in which the PPI scanning mode with elevation of about 4^o is generally used. For PPI or RHI scanning used by other predecessors, it is necessary to guarantee that the wake should be aligned LOS direction. Besides, we did not know the exacly wind direction before the experiment and the site selection of field experiment was limited. Accordingly, we wanted to adopt dual-lidar method to measure the wind turbine wake. What is more, we want to achieve a kind of coplanar scanning for dual-lidar scanning.

   b) More scanning planes seems better, but we should take the variation of wind direction into account in the multi-scanning. Besides, the multi-scanning is not possible when the elevation increase because the detected wake length might be different as shown in Fig. 3.

   c) For PPI or RHI scanning used by other predecessors, it is necessary to guarantee that the wake should be aligned LOS direction, in which the the intersection of scanning and the wake is still a tilted surface. In the titled scanning mode, if the altitude of the scanning plane is in the spanning range of wind turbine (30m-130m, 80m hub height, 100m rotor diameter), the wake could be detected. Accordingly, it is not necessary to guarantee that the wake will be aligned with this tilted plane. Advantage of this method lies in its feasibility in the situation of various wind directions compared with traditional single instrument measurement.

Aitken, M. L., Banta, R. M., Pichugina, Y. L., & Lundquist, J. K. (2014). Quantifying wind turbine wake characteristics from scanning remote sensor data. *Journal of atmospheric and oceanic technology, 31*(4), 765-787.

2. The authors use a unique scanning geometry to perform the measurements. How- ever, it is not clear, if this actually helps in the present case. One thing is clear, more measurement levels are required.

   A: We have added the description of this scanning geometry in a new section of revision.

   More measurement levels seems a good choice but it is still limited for ground-based lidars shown in Fig.3, in which case diffrent elevation of the beams might result in different wake length measurement.

3. In terms of performing dual-Doppler, the accuracy of the retrieval is a function of the ?AZ within each measurement volume. That is, the retrieval is more accurate as ?AZ approaches 90 deg and less accurate as ?AZ approaches 0 deg (or 180 deg). From the experiment design, it seems like the ?AZ will be quite low towards the left and the right edges as well as close to the lidar locations. Therefore, to put the quality of the measurements in context, please include a figure showing the ?AZ as well as follow uncertainty quantification as described in Simley et al. (2016).

   A: Yes, the accuracy of the retrieval is a function of azimuths of two laser beams (α and β shown in Fig.1). We analyze this method and do the quality control strategy in the revision.

   The item $|\sin(\alpha – \beta)|$ is determined by the position of the measuring point and can be defined as a spatial factor. The spatial factor $|\sin(\alpha – \beta)|$ approaches zero as the measuring point tends to the line through instruments A and B. In this case, retrieval uncertainty increases rapidly, which results in large measurement error. Therefore, the spatial factor can be considered as a reference standard for quality control.

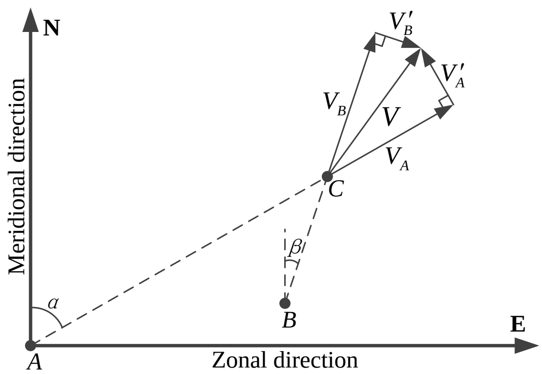

Figure. 1. Geometrical relationship of measuring vector wind (denoted by V) at a certain probing volume (denoted by point C) with two instruments (denoted by points A and B) using dual-Doppler method. VA and VB are LOS components of vector wind V measured by instruments A and B, respectively. α and β are angles between north and radial direction of instruments A and B, respectively.

4. There is no description of the data quality control. This should be properly defined.

   A: Thanks for your suggestion. We did data quality control and added the description in the revision.

   "Quality control procedures were applied to LOS velocity by setting threshold of Signal-to-Noise Ratio (SNR) and effective detection range of 1.5 km for lidar A and 2 km for lidar B, and applied to vector wind by setting the spatial factor $|\sin(\alpha–\beta)| \geq 0.35$."

5. Wake merging: From figures 2 and 3, panels (b), (c) and (d): It seems like the magnitude of the wake deficit is on the same order of the spatial variability within the individual transects. This is quite interesting and needs investigation. However, it is not the best example to study wake merging as several other background effects dominate.

   A: Thanks for your suggestion. This is a very interering example but there is no better example to study wake merging. It would be great to specialize in this phenomenon in future expereiment by any chance. We decided to delete this section in the revision.

6. As the authors point out themselves on page 8, line 20, the reduction in deficit is most probably due to the measurement plane leaving the wake region. Therefore, the "measured" wake length is not an accurate estimation of the actual wake length (the sudden drop in deficit should point to this). This (again!) points to the requirement of having several levels of measurements in order to accurately estimate the actual wake length

   A:

   The wind turbine rotor disk spans a height of 30m-130m. Altitude of the measured wake was closed to 80m, and the measurement plane approached to the wake region.

   The fig. 4 in the revision was measured before tide rising and the Fig 9 was measured during the rising tide. Both were measured in the low part of the wake. Both wake width were obviously different. The first one was rather small and it resulted in the diffcult to more accurately define the wake region in lateral direction, which was partly caused by the weaker ground effect resulted in stronger diffusion in vertical direction.

   Several levels of measurements seem a better method. But it is still necessary to take the sanning period, wind direction and the position of the lidars into account, because wind might veer obviously in a short time and the position of the lidar should be at upstream of the wind turbine for single ground-based lidar observation. Besides, the elevation angle of PPI scanning is quite small (about 4°), and the observation range is limited (might samller than wake length) when the elevation is increased resulting in different observed wake length. Morover, the multi-scanning still could not guarantee that every level could detect entire wake when the wake direction is approximately perpendicular to lidar-lidar line as shown in Fig. 3. That is the reason why single level scanning is mostly used in wake length detection.

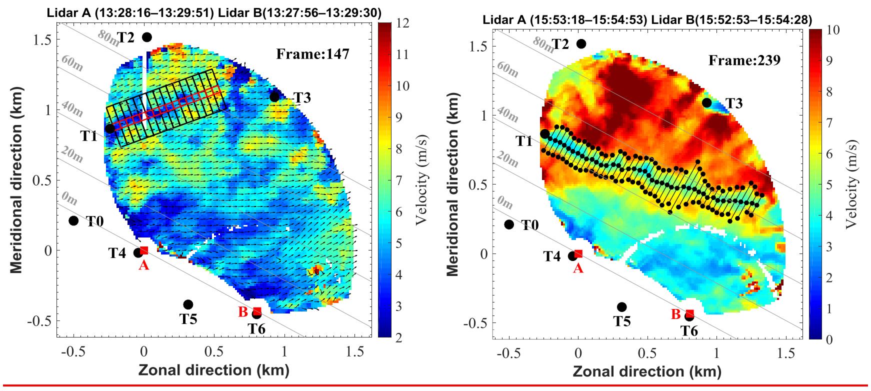

Figure. 2. the different measurments during the experiment (corresponding to fig. 4 and fig. 9 in the revision)

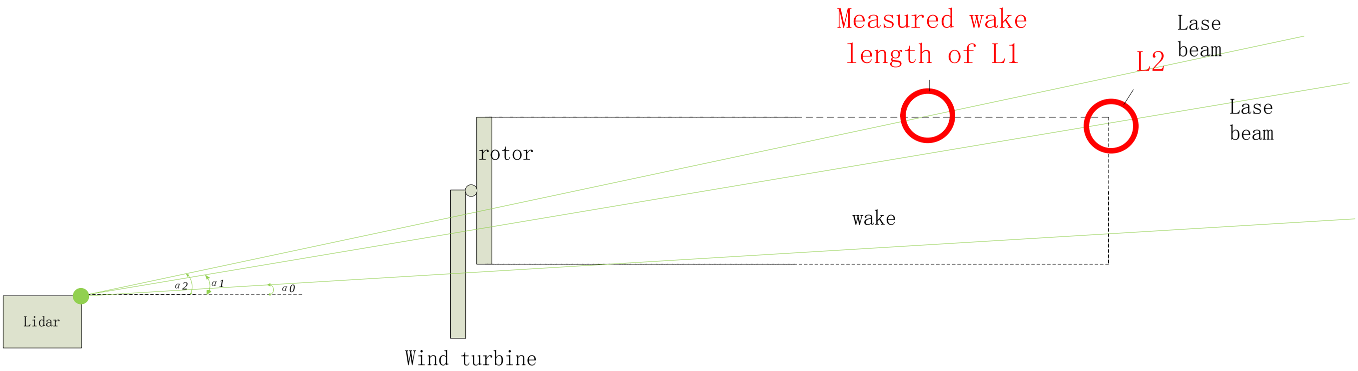

Figure. 3. Schematic diagram of ground-based lidar scanning for wind turbine wake measurement. The three green lines mean different elevations during wake observation. In which case α1 andα3 could not detect the entire wake length in the near and far region, respectively, and result in different wake length for α1 andα2.

7. The authors report that as the tide rises, so does the wake length. However, they fail to note the importance of wind direction. During the time period of the tide rise, the wind direction shifts from south-westerly to westerly. As the wind direction shifts to westerly, now, the wake from turbine T1 is measured. In this case, the measurement plane is almost parallel to the turbine hub axis along the wake direction. Hence, the wake region remains in the measurement plane for much longer, resulting in reporting of longer wake lengths. Therefore, the increase in wake length is NOT due to tide levels, but rather the angle of the measurement plane relative to the turbine hub axis! It just turns out that the wind direction shift is correlated with the rising tide and the authors mistake this correlation for causation.

   A: Thanks for your careful consideration. We do take this into account and we have checked the retrieved wind field again and again before we submit the manuscript.

   Firstly, we guarantee that all the wakes of wind turbine T1 were in the wind turbine disk spanning range (30m-130m), which could be seen according to the contour lines (gray line in retrived wind field)

Secondly, what you concern is that the detection range of wind turbine wake is different when the wind directionveers. However, when wind blew from south-westerly, all retrieved wind field shows that there is no case that the wake length of wind trubine T1 reach the boundary of retrieved wind field. Fig.3 and Fig.9 in the revision are the typical examples before and dureing rising tide. All the wakes before tide rising are in the detection range and no case before the tide rising reach the boundary of the retrieved result.

8. Apart from the above point, any conclusions about the impact of change in sur- face roughness characteristics on wake length need to be back by reproducible results spanning several time periods. One case study is not enough as presented here. It is suggested to have several periods of wake measurements for each set of turbines with similar characteristics (hub-height, rotor diameter, wake fetch etc).

   A: It is a pity that we just have only one-day measurements. Accordingly, we modified the conclusion in the revison and the conclusion was limited on that day. It is a good idea and necessary that several periods of wake measurements fore each set of turines with similar characteristics. By any chance, we would try your suggestions in fugure.