Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2016-179-AC1, 2016

Atmospheric Measurement Techniques Discussions

Interactive comment on "Identification of Tower Wake Distortions Using Sonic Anemometer and Lidar Measurements" *by* Katherine McCaffrey et al.

Katherine McCaffrey et al.

katherine.mccaffrey@noaa.gov

Received and published: 30 December 2016

We thank the two reviewers for their specific and constructive comments on our manuscript. Their comments were addressed below, using the recommended format: 1) comments from Referees, (2) author's response, (3) author's changes in manuscript.

Interactive comment on "Identification of Tower Wake Distortions Using Sonic Anemometer and Lidar Measurements" by Katherine McCaffrey et al. T. Price (Referee) tim.a.price@utah.edu Received and published: 21 October 2016 This paper is a good assessment of the tower wake effect of the Boulder Atmospheric Observatory (BAO) tower near Boulder, CO. The results clearly show the flow modification due to the tower using both sonic anemometer and lidar measurements. Although the results are

specific to the BAO facility, the methods used for directly opposed sonic measurements and lidar virtual towers contributes to more robust understanding of tower effects. The effect of the averaging period and role of wake contamination within the averaging period is also helpful. Overall the paper was clear and focused in the purpose and the results are well founded.

(1) Did the authors see any diurnal variation in the wake effect? One area I feel may be interesting is the effect of stability on the wake extent of the TKE. Perhaps there may be further criteria that may widen or narrow the wake boundary and allow for more precise data removal. (2) We had looked into this, but since there was only a minimal difference in magnitude, and none at all in the directional range of impacted velocities, including a figure was not deemed necessary. Since this is of interest, however, the following line was added to discuss this: (3) line 180: "Separating the sonic anemometer observations into daytime (unstable) and nighttime (stable) conditions (not pictured), the peak wind speed ratio when the northwest booms were in the tower wake was 15% larger during the daytime than at night, and when the southeast booms were in the wake, the wind speed ratio was 4% smaller at night. However, the directional extent of the tower wake does not vary with stability."

(1) Also, was there any individual effect seen in the results with the shorter 250 m southeast boom? (2) This is mentioned in the footnote, but to be more specific, I changed it to say that there are statistically insignificant differences: (3) "Though the 300 m booms are at the top of the tower and this level has more equipment inside the tower structure, and although the 250 m boom is shorter, the results at these levels showed statistically insignificant differences from the other heights, and will thus not be compared independently."

(1) Figure 11 is averaged from all heights on the BAO, does the specific 250 m level agree in wake extent? (2) It does agree, as covered in the footnote referenced above.

(1) Finally, line 458 is missing a space. (2) Fixed: (3) line 466: "bin for 5% of observa-

tions”

(1) Overall, a very nice concise paper. (2) Thank you!

Interactive comment on “Identification of Tower Wake Distortions Using Sonic Anemometer and Lidar Measurements” by Katherine McCaffrey et al. Anonymous Referee #4 Received and published: 3 December 2016 This paper presents a nice study of flow distortion characterization around a super- structure, in this case the tall-tower of the Boulder Atmospheric Observatory (BAO) tower near Boulder, CO. The results show the importance of assessing these effects when doing observations with sonic anemometers. By combining both sonic anemometer and lidar technology, the methods used in this study give a clear picture of the distortion impacts and provide suggestions on how to best quality control such data set. Overall the paper and results are interesting but I suggest some modifications for consistency and clarifications. Specific comments: (1) In section 2.1 you refer to a “four-step, six-sigma outlier-rejection scheme” being applied to the data. Can you elaborate a bit on this? Do you mean you plot the distribution, use a six-sigma limit to reject outliers and repeat 4 times? Is that the reason why on Figure 4b, some data are missing for the northwest sonic (blue line) around hour 11? (2) That is correct. I clarified the language. The northwest and southeast sonics are measuring the same wind direction near hour 11, so the blue line is underneath the red line in Figure 4b. (3) line 99: “The sonic anemometer data were sampled at 20 Hz, and a quality-control scheme was repeated four times, in which the data outside six standard deviations (six-sigma) from the mean were removed (less than 0.1% of the data).”

(1) In section 2.2, what is the width of the WCv2 range gates? You mention a 50m pulse with for the 200S lidars but we don’t know for the WCv2. Also there is something confusing on the 200S scanning strategy. In this section, you mention that from 21-24 March the stares were performed at 50, 100 and 150m. But then in Figure 13 you mention it went from 50 to 300m. Might want to verify for consistency. (2) The length of the WCv2 range gates is 10 or 20 m, with widths dependent on the height, based on

the 28 degree azimuth. The Figure 13 caption was corrected, since both lidars were only compared up to 150m. (3) line 112: “160, and 180 m AGL, with 10-20 m pulse lengths.” Fig 13: “for all heights (50 m intervals from 50-150 m)”

(1) In section 3.2. Line208-209. When the sonic anemometer is in the wake, its TKE should increase and this is what Figure 8 is about. The red dots are depicting the case where the NW sonic is in the wake of the tower, i.e. winds are from the SE, so that NW TKE>SW TKE. And vice-versa. Therefore, one should read “. . ., either above (northwest sonic anemometer is in the wake) or below (southeast sonic anemometer is in the wake).” (2) Yes, you are correct. I’ve fixed it. Thanks. (3) line 216: “either above (northwest sonic anemometer is in the wake) or below (southeast sonic anemometer is in the wake)”

Technical corrections:

(1) line 32: “solidity of the tower” are you insinuating that a less solid tower would not disrupt the free-stream flow? Perhaps use shape, structure, frame . . .

(2) Changed. (3) line 35: “the structure of the tower”

(1) line 49: Replace “5.7 x” by “5.7 times”

(2) Changed. (3) line 52: “a distance of 5.7 times”

(1) line 207: “The biases in observed TKE are displayed in the scatterplot in Fig. 8” (2) Fixed. (3) line 215: “displayed in the scatterplot”

(1) lines 259-261. Numbers not consistent with figure and table 1. Also part of the sentence is redundant with lines 257-258. I suggest “The northwesterly winds see wake effects 54 degrees clockwise from the northwest boom, and 46 degrees counter-clockwise from the northwest boom. (2) Fixed. (3) line 264: “Based on TKE, the tower impacts extend 51 degrees to the east (clockwise) from the northwest boom and 54 degrees east (counter-clockwise) from the southeast boom, while, to the west, the wakes only reach 34 and 21 degrees from the northwest and southeast booms,

respectively."

(1) Table 1. Add a line describing the columns. For instance " columns indicate swath counterclockwise (CCW) and clockwise (CW) from boom of interest" (2) Changed. (3) Table 1: "Columns indicate swath counterclockwise (CCW) and clockwise (CW) from boom of interest."

(1) Line 332: Northwest and southeast are flipped. One should read "the northwest (top panel) and southeast (bottom panel) booms of the BAO tower." (2) Fixed. (3) line 338: "the northwest (top panel) and southeast (bottom panel) booms"

(1) Line 344. "This effect is not, however, seen in the WCv2, and is not visible in the comparisons. . .". This is not consistent with what is said in section 4.1 and figure 13b where we see that the ratio from the WCv2 dips below 1 in the 90-210 range. . .please correct. Perhaps: "This effect is not visible in the comparisons. . ." (2) The "effect" is that there is a difference between the northwest and the southeast booms when they are in the upstream wind directions. Clarified: (3) line 350: "This difference between northwest and southeast upstream behavior is not, however, seen in the WCv2"

(1) Line 352: "The WCv2 does not see this dip in wind speed. . ." I thought we were talking here about the situation where the ratio is above 1. Perhaps replace dip by increase or move this phrase where it belongs. (2) It's a dip/decrease in wind speed, but an increase in wind speed ratio. Clarified: (3) line 359: "The WCv2 does not see this decrease in wind speeds (increase in wind speed ratio),"

(1) Line 416-418: "the question arises as to what fraction of data points are in a wake in a temporal averaging interval and how it will substantially alter the mean observation away from the free-stream value. " (2) Fixed. (3) line 424: "the question arises as to what fraction of data points are in a wake in a temporal averaging interval and how it will substantially alter the mean observation away from the free-stream value."

(1) Line 433. "(123−179 and 310−10 degrees)" – numbers not consistent with table.

Perhaps you mean 100-175 and 300-25? (2) All fixed to match the table and the figures. The wake removed in Figure 18 is the largest wake, from 100-189 and 288-28 degrees. (3) line 441: "(100-189 and 288-28 degrees)"

(1) Line 474. Numbers not consistent with figures and table. One should read "between 115 and 17, and 315 and 10 degrees" (1) Line 480. Again number not consistent with figures and table. One should read "from 100−175 and 300−25 degrees from north " (2) All fixed to match the table and the figures. The wake removed in Figure 18 is the largest wake, from 100-189 and 288-28 degrees. (3) line 481: "Wind speed deficits up to 50% are observed by the sonic anemometer in the wake of the BAO tower between 115 and 170, and 315 and 10 degrees from north, with significant decreases in correlation from 134-181 and 300-13 degrees. Furthermore, just outside the boundaries of the wake regions that experience slowed wind speeds, the downwind sonic anemometers experience a 5% increase in wind speed over the upstream sonic anemometers, which tapers off as the wind direction rotates away from approximately downwind to a more perpendicular direction. Comparisons of turbulent kinetic energy measured by opposing sonic anemometers showed a wider range of angles impacted by the BAO tower structure - including portions of the region of speed-up - from 100-175 and 300-25 degrees from north, with significant decreases in correlation from 104-189 and 288-28 degrees."

(1) Figure 3 bottom needs more legend and clarification to be consistent with the discussion in the text. Mention that the crosses are the center or the measurement volume (cyan square) and VTS footprint (black circle) or get rid of them. Also describe the line by saying here they represent the extent of the range gates from the 200S lidars and that the circles are the centers. Similarly add a note on the fact that we see the WCv2 lidar on the top picture. (2) Good suggestions! Fixed. (3) Fig. 3: "AGL. The WCv2 is also shown near the BAO tower. Bottom: bird's-eye view of the measurement volume (cyan box, with x at the center) resulting from the range gates of the three scanning lidars, drawn with circles at the centers of the beams, to scale. The footprint of the

beams of the VTS is shown in the black circle, with an x at the center."

(1) Figure 12b. Shall we assume that N=2188 as in 12a? (2) Yes. This was added to the caption. (3) Fig 12: "20 m increments (number of points, N = 2188). The black dashed line is the one-to-one line, and the red line is the line of best fit, with slope, m, and intercept, b, as noted. The mean difference between measurements, and correlation coefficient, R, are also shown.

(1) Figure 15: Are we looking at 2-min data? Perhaps add it in the caption. Also correct your x-axis label to show that it is "theta lidar" or "theta WCv2" to be consistent with labeling of figure 13. (2) Yes, 2-min data. I added this. The label is not specified as "theta lidar" because the black line uses no lidar data, but uses theta from the sonic. (3) Fig. 15: "Difference in 2-minute mean wind direction between the sonic anemometers on the two booms (southeast minus northwest: solid black; mean of southeast and northwest: green) in 10-degree bins as determined by the southeast sonic anemometers' wind directions, and the WINDCUBE V2 profiling lidar at 50, 100, and 150 m (southeast sonic anemometers minus WCv2: blue; northwest sonic anemometers minus WCv2: red), in 10-degree bins as determined by the WCv2 wind directions."

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-179, 2016.