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Atmospheric Measurement Techniques Discussions

Interactive comment on "Using computational fluid dynamics and field experiments to improve vehicle-based wind measurements for environmental monitoring" *by* Tara Hanlon and David Risk

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We would like to thank Anonymous Reviewer #1 for their time in suggesting changes that will improve our manuscript. Our responses to the review comments are provided below.

Summary: The experiment, as suggested by the abstract, is well motivated and designed. The abstract is exceptionally well written. However, the paper does not meet the expectations from the abstract. I believe that major changes can make this work

an extremely useful contribution. Critical details regarding calculations are missing. The CFD work appears to be well done, except for one very worrisome statement that I suspect the authors can easily explain. However, the CFD work is not useful as presented because it is not put in the context of a moving car, as could be done if the above mentioned equations were added to the paper. The bias adjustments presented in the field study appear to be an artifact of experimental design, rather than physically meaningful. This is again because the above mentioned equations were not used. The promise of meaningful use of the stationary anemometers was not fulfilled. These could have been used to make a correct assessment of biases as a function of the speed of the car (using the above mentioned equations), but this work was not done. While the authors are to be commended on obtaining useful observations and CFD calculations, they should redo the non-CFD work and present the final results in a context that combines the conclusions from the CFD results and field results. Such a reanalysis would make an extremely useful contribution. Furthermore, the field data are not made publicly available, which is preferred and often a requirement for modern journal publications.

We appreciate this summary and have used the comments to make changes as suggested in the detailed comments, where the reviewer expands on these general comments.

Major Comments:

1) Section 2.1, end of first paragraph. Please say why these two sets of experiments of experiments appropriate to address the research objectives. I agree that they are appropriate, but some readers will not understand how they can be combined. This point is not addressed in the conclusions either, making this work needlessly incomplete. The relevant equations are presented in a variety of ways in:

Smith, R. S, M. A. Bourassa, and R. J. Sharp, 1999: Establishing more truth in true winds. J. Atmos. Oceanic Technol., 16, 939-952.

We have added the following text at to P3 L9 in section 2.1:

“By evaluating the vehicle’s external flow field under both varying vehicle speed and wind yaw angle we can quantify the bias the vehicle shape induces on a truck mounted anemometer and calibrate the measurements prior to correcting wind speed and direction measurements for the vehicle’s motion.”

The following text has been added into the Results and Discussion section on P10 L6:

“The empirical calibration must be applied to remove the bias of the vehicle’s shape on anemometer measurements prior to correcting for the vehicle motion.”

The above reference has also been used to address minor comment 3 and add further description to the field methods.

Page 4: lines 10 and 11: The meaning of ‘The drag coefficient was determined when the change in CD was less than 0.001.’ is not clear. Is this condition sufficient? Or is convergence slow enough that this condition leads to large errors. How was it determined that this condition is sufficient, as 0.001 is rather a large faction of the drag coefficient over a smooth surface? The following sentences are insufficient for such a test. Granted, this situation becomes clear later, but it should be clear when presented.

We wanted the CFD results to match the instrument accuracy available in our field tests. As our model was simplified, we knew we could not expect perfect accuracy in the drag coefficient. 0.001 is less than 1% of the manufacturers reported drag coefficient (0.386), and less than the instrument errors used in the collection of field measurements.

3) Separating the experimental design (for two experiments) from the results (for two experiments) is irritating and needlessly confusing. After the experimental design for the CFD I would greatly prefer to see the results from the CFD. a. Why are limitations of the CFD method/results discussed in the section on field observations? b. If this lack of results from flow into the wind is true (as literally read), then why should I read

further? This seems like it could be critical flaw.

We have restructured the manuscript to address this point. We have inserted a discussion section at P14 L7. In this section we discuss the results together, and the limitations from CFD are discussed in this section and no longer in the field results.

4) Are the observational data made publicly available? If so where? If not, should this work be published?

Field data have been made available at: https://figshare.com/articles/Mobile_and_Stationary_SoutheasternSK_May2017_csv/8035235",

doi = "10.6084/m9.figshare.8035235.v1"

5) Page 10, Equation 1 and following line: What are the units of wind direction and wind speed? There will be quite a difference for m/s vs mph, and for radians vs. degrees!

We have modified presentation of the equation to be more descriptive with assigned variables and include units. The equation was modified to include both the anemometer windspeed (AWS,) and the corrected windspeed (WS) for clarity.

The following text has been added to P10 L1 :

“The polynomial pictured in Fig 5 is multiplied by the Anemometer windspeed (AWS), to give the corrected wind speed (WS). Equation 2 gives the side-mounted anemometer’s correction function for wind direction (WD) measurements ranging from $-40^\circ < WD < 40^\circ$. Wind speed units are in km h-1 and wind direction units are in degrees.

6) Figure 6: It appears that there are fluctuations in the ratio of anemometer wind speed to vehicle wind speed that is associated with the speed of the car. This is not surprising because the measured speed is equal to the magnitude of ‘the wind velocity minus the car velocity.’ Such a dependency is expected as an artifact of the situation, and not as a systematic correction in the manner that the authors suggest. Showing the math requested in comment (1) would help the authors organize their thoughts and

experiment in a manner that conveys useful information. I had expected the authors to use differences from the stationary anemometers to illustrate these biases, but that work is not contained in this paper.

The objective of this figure is to show that the short anemometer placement consistently measures higher wind speeds than the tall anemometer placement. The manuscript has been edited to better describe the figure and its importance of anemometer height a top the vehicle.

The statement , “Figure 6 shows the tall and short anemometer measurements scaled with vehicle speed” has been modified to say “Figure 6 shows magnitude of the tall and short anemometer measurements when normalized by the vehicle speed.”

The reference to Smith et al., 2009 from comment 1 has been used to add an equation and text to P7 L4. Please refer to our response to minor comment 3 and detailed comment 9 in our Response to RC2 for the detailed changes.

7) Page 12, figure 8: What is actually shown in Fig. 8b? The caption and text claim that the figure shows the corrections, which suggests that the corrections are nearly identical to the measured winds. It appears that what is shown is the corrected winds.

Please refer to our Response to RC2 for revisions proposed for Fig. 8.

Minor Comments: 1) Line 3: ‘Used to study Meteorology’ is too broad. Be more specific about the scale and the type of vehicle (for example, ships are vehicles, but not included in this study).

The text has been replaced to say, “Currently, land vehicle-based wind measurements are used to study severe weather-related mesoscale meteorology (Belusic et al., 2014, Straka et al., 1996), lake meteorology (Taylor et al. 2011; Curry et al. 2017) and are integrated into methane measurement studies to detect, quantify, and map emission plumes from oil and gas developments (Atherton et al., 2017; et al., 2015; Zazzeri et al., 2015).

2) Table 1: Improve the caption to explain the labels of the table rows and columns.

The caption has been changed to “Drag comparison of three turbulence models with inlet velocity of 22.2 m/s. The drag coefficient (CD) for each turbulence model is reported with the number of iterations required to achieve a solution and the percent difference (∆CD) from the manufacturers reported CD of the vehicle model.”

The turbulence models in the rows of the table are described on P4 L7 before introducing the table.

3) Page 6, line7 and line 10-12: How were these corrections made? Was the car motion subtracted from the wind, or was the adjustment done correctly following Smith et al. 1999)? The statement that the calculations were done is R does not tell us how they were done. Smith, R. S, M. A. Bourassa, and R. J. Sharp, 1999: Establishing more truth in true winds. J. Atmos. Oceanic Technol., 16, 939-952. How was the temporal averaging done? See the above paper for the importance of the correct averaging while wind directions are changing relative to the vehicle.

We have added the following text to P6 L7:

“To correctly compute true winds, vehicle based wind must be corrected for the vehicle’s motion over the fixed earth. The vehicle vector has a direction equivalent to the vehicle’s course over the ground, and a magnitude equivalent to the vehicle’s speed over the ground (Smith et al., 1999).”

Please also refer to detailed comment #9 our Response to RC2, where we describe the subtraction equation.

The averaged vehicle-based anemometer measurements presented in Figure 8 were calculated by expressing all of the wind speed and direction measurements in complex exponential form to keep wind speed and direction as one vector, as opposed to separating them into components. Figure S1 in the supplement details how the components of each vector were calculated, and how the averaging was done.

4) Page 7, line 3: 'similar qualitative trends' is so vague as to be nearly meaningless.

P7 L3 has been modified to say, "The CFD and field experiments showed that the measured wind at the anemometer location varied under wind yaw angle. The bias found in the CFD varied with the rotation of the truck, and the field results concluded that the measured wind differed in head, cross and tail wind conditions."

5) Page 7, line 10: This statement makes sense only for a fixed wind speed and direction. If it is being applied in general as suggested by the writing, then this result cannot be correct – or important caveats are missing.

P7 L10 has been modified to:

"In each computational domain, we found that the wind bias scaled with vehicle speed and the amount of bias (slope) differed with the location above the vehicle."

6) Page 7, lines 21-22 & page 8, line 3 The logic '(where measured windspeed = true windspeed)' must be missing key caveats.

The following text on P7 L21: " This observation is similar to a conclusion by Moat et al. (2005), stating that shipboard anemometers should not be placed close to the line of equality (where measured wind speed = true wind speed) as high pressure gradients are present in this region. The line of equality would be expected to move vertically to some degree, according to the ground and/or wind speed."

References the work Moat et al., conducted on airflow distortion at anemometer sites on ships. As part of the study, the authors used Vectis CFD code to model the flow over generic voluntary observing ship models. The study presents the flow pattern above a bulk carrier model, and shows that above the bridge there exists a decelerated region of flow and at a greater height above the bridge, an accelerated region of flow. Between the decelerated region and accelerated region of flow there exists a line where the flow is equivalent to the wind speed. In this region the velocity gradients are very steep, and sensitive to bias. Moat et al., concluded that an anemometer should not be placed in

this region.

In our CFD model, we also found that a decelerated region of flow existed below the accelerated region of flow. We recommend placing the anemometer above this region to avoid the steep velocity gradients, and referenced this text to support our results.

7) Page 7, line 34: 'How big is 'significant' in terms of heights? The existing text is too vague.

P 7 L 34 has been replaced with "When exposed to large yaw angles, the wind bias over the truck at low heights can be twenty percent, and even at a height of 1.7 m above the vehicle, a bias of greater than 5 percent is present."

8) What is meant by wind speed > 3 standard deviations? Standard deviations of what (relatively to what)?

Good point. This information was lacking in the manuscript. The yellow circles represent wind speed measurements that are greater than 3 standard deviations away from the mean wind speed measurement. The mean wind speed measurement is calculated specific to a) the wind speed measurements from the vehicle-based anemometer after the frontal-correction was applied, b) the wind speed measurements from the vehicle-based anemometer after the empirical correction, and then frontal correction was applied, c) the wind speed measurements from the stationary anemometer located at the 4 different vehicle bearings.

The caption of Figure 7 has been modified to include: " The yellow circles represent wind speed measurements that are greater than three standard deviations away from the mean wind speed of the wind speed measurements calculated with the a) frontal correction applied, b) empirical correction and frontal correction applied, and c) specific to the stationary anemometer at each bearing."

9) Page 9, line 2: What is meant by 'normalized wind speed'?

The normalized wind speed is the measured wind speed divided by the inlet velocity.

The text has been changed to:

“The normalized wind speed (measured wind speed: inlet speed) at the location of an anemometer mounted in the same location as the field test was computed for each yaw angle simulation.”

10) Page 10: At or near the end of the CFD results, please remind the reader that these are CFD results rather than field results. Changing the order of the paper to put method and results together would reduce this problem. a. The last line of this section belongs in the section on field results b. How was this yaw determimed? c. How was temporal averaging applied? Was it after individual calculations were corrected, or was the averaged corrected? The first approach is correct when the vehicle relative wind direction is changing.

a) This has been addressed with by the addition of a discussion section in response to major comment 3. b) The yaw is determined by the raw anemometer wind direction measurements. c) There is no temporal averaging on the mobile measurements.

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2018-354/amt-2018-354-AC2-supplement.pdf

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