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Atmospheric Measurement Techniques Discussions

Interactive comment on "Using global reanalysis data to quantify and correct airflow distortion bias in shipborne wind speed measurements" *by* Sebastian Landwehr et al.

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Response to Referee #1

Many thanks to Referee #1 for her/his constructive and supportive comments, which we have kept in *italic* and labelled as referee comment (RC). We have adjusted the figure numbers in the original comments of Referee #1 to match the submitted manuscript. We provide our author replies (AR) below:

General comments: *Overall, this manuscript presents an intriguing evaluation of the air-flow distortion of wind measurements during the Antarctic Circumnavigation Exper-*

iment (ACE). As the authors note, identifying impacts to wind measurements from a ship's superstructure can be challenging, with CFD modeling being the most accurate, but also costly approach. Their use of reanalysis data to estimate the ship-relative winds to determine the flow bias adjustments was an interesting approach. Overall, I found the manuscript insightful and the results were convincing. They provided a solid justification for why correcting for wind flow distortion is necessary prior to using ship wind observations to develop parameterizations of air-sea exchange processes (in their use case sea spray). The authors did a fairly good job acknowledging the limitations of their methods. I have no major concerns but point out a number of minor additions and changes that will clarify the text and figures. I believe the manuscript is suitable for publication once these minor issues are addressed.

Authors response: We thank Referee #1 for pointing out the value of this contribution and her/his careful review.

Specific comments/suggestions:

RC 1: *Introduction, line 30: The authors note that remotely sensed winds are validated using buoy wind, but should also note that ship winds have also been used to validate these systems (e.g., Bourassa, M. A., D. M. Legler, J. J. O'Brien, and S. R. Smith, 2003: SeaWinds Validation with Research Vessels. J. Geophys. Res., 108, DOI 10.1029/2001JC001028.)*

AR 1: We have extended the sentence to "...and from voluntarily observing ships (e.g., Bourassa et al. 2003)"

RC 2: *Introduction, 5th paragraph: The authors introduce reanalyses and note the assimilation of buoys and satellite data, but neglect the fact that ship data are also assimilated to most of these models. Were any data from the ACE cruise assimilated to ERA-5? I would expect if they were, they would have been from the standard hourly bridge reports that would be contributed to the Voluntary Observing Ship scheme.*

AR 2: Indeed wind speed observations from ships are still used in the data assimilation for ECMWF weather forecast model. In order to acknowledge this fact, we have added ships in the list of the in situ observations in page 3 line 3. The *Akademik Tryoshnikov* reported daily telegrams to the Arctic and Antarctic Research Institute (AARI). Following the request of the Scientific Committee on Antarctic Research (SCAR) and the World Meteorological Organisation (WMO), the observations were also reported to Global Telecommuncation System (GTS) under the call sign UBXH3. ECMWF provided us with a list of the times and locations for which ground wind observations from UBXH3 where assimilated into the Integrated Forecast System (IFS) between November 2016 and April 2017 (see supplement information). The list contains 35 entries exclusively from leg 2, when the ship was south of 60°S. The data from intervals close to these time stamps cluster around ratio of $S_\mathrm{m}\,S_\mathrm{M}^{-1} \approx 1$, however, with considerable scatter (see Figure 1 that is attachde to this reply). To avoid any feedback in the bias correction, we now excluded all observations that where within 3 hours before or after time stamps of the 35 assimilated observations. This leads to an additional removal of 1197 and 1216 five-minute samples for the port and starboard sensors, but has

RC 3: *Introduction, 6th paragraph: Please briefly spell out the "observed effects" of pitch and roll noted in O'Sullivan et al. 2013. This will make it easier for the reader to compare your results with those from the O'Sullivan paper.*

AR 3: We changed the sentence to: "In the results of their CFD simulation, O'Sullivan et al. (2013) observed changes in the relative wind speed bias in dependence of the pitch and roll of the ship as well as the magnitude of the relative wind speed."

RC 4: *Introduction, 8th paragraph: Again, the authors note that reanalyses assimilate buoy and remotely sensed winds, but what about ships? On any given day there are hundreds of ships making standard weather observations over the ocean and these are archived as part of the International Comprehensive Ocean-Atmosphere Data Set (Freeman, E., S. D. Woodruff, S. J. Worley, S. J. Lubker, E. C. Kent, W. E. Angel, D. I . Berry, P. Brohan, R. Eastman, L. Gates, W. Gloeden, Z. Ji, J. Lawrimore, N. A. Rayner, G. Rosenhagen, and S. R. Smith, 2017: ICOADS Release 3.0:*

a major update to the historical marine climate record. Int. J. Climatol., 37, 2211–2232. doi:10.1002/joc.4775). These data are assimilated in many reanalysis products. Please verify whether or not ship data are assimilated into ERA-5.

AR 4: Also here we added ships to the list of data in situ observing platforms.

RC 5: *Same paragraph: Add the ACE acronym to the text where the Antarctic Circumnavigation Experiment is first mentioned.*

AR 5: Thanks! The acronym has been added.

RC 6: *Section 2, line 11 : When you mention Leg 4 in the text, it would be good to refer to the cruise tracks on a map (e.g., refer to figure 8).*

AR 6: We added a reference to Fig. 4 (a) in Young and Donelan (2018)

RC 7: *Section 3, first paragraph: Also, a good place to refer to figure 8 cruise map.*

AR 7: Following the request of a map in the methods section, we added an additional Figure to show the track of ACE during legs 0–4 and keep Figure 8 in the results section.

RC 8: *Section 3.1, second paragraph. There are several items regarding the instrument set up that should be clarified a. Add more details on the different sonic anemometers used. Are the anemometer models from the same company? The acronyms/model numbers are not very useful. Do they have the same accuracy, precision, sampling rates, etc. b. How tall were the vertical poles for each anemometer? Were they the same height above the nearest deck? If you have them, photos of the installation would be great to add. c. Was the zero-reference mark on each anemometer checked before each cruise? Our experience has shown that any anemometer can come loose over time and the orientation can change. Especially if the sensor were swapped between cruise legs. Was the orientation offset between the zero-reference mark on the anemometer and the zero in the ship's coordinate reference accounted for in your calculations (see Smith et al. 1999)?*

AR 8: a) We added the information that both anemometer are distributed by Vaisala. The model numbers allow to quickly find manuals and further references. The sampling rate was 1/3 seconds, the accuracies (1% and 2% for WMT702 and WS425 and 2° for both) are mentioned in Section 3.3.
b) The poles were about 2 m tall and where at the same height (8 meter) above the nearest deck. Please note that the height of the anemometer was indeed 31.5 and not 30.5 m a.s.l. We have also corrected the annotation of the drawings in Figure 1. However, this small change does not affect our results. We have now added all this information in Section 3.1. and provide an additional figure with photographs of the set-up.
c) To our knowledge all sensors where checked to prior the cruise. We have no information that there would have been an offset between the zero-reference and the ship's main axis. Sensors where not swapped or relocated in between the cruise legs. Considering symmetry of the wind speed ratios and direction differences around the ship's main axis, we can exclude any major offsets.

RC 9: *Section 3.2, 4th paragraph: Change "Due to the complex..." to "Due to the complexity..."*

AR 9: We have corrected this mistake.

RC 10: *Same line you mention the "structures nearby the anemometer". Are these symmetric for the port and starboard anemometers? Are their differences in the upstream obstacles? Again, photos would be enlightening.*

AR 10: The two radar antenna mounted on the top platform of the main mast (see photographs) are the two main features that introduce asymmetry to the set-up. We do now elaborate on this in Section 3.1.

RC 11: *Section 3.4. It would be helpful to have a figure or table that quantifies the number of available observations in each relative wind sector. Also, a figure or table showing the results the sensitivity to your choice of averaging period (e.g., how much do the results change for 5 min vs 60 min averages?).*

AR 11: We currently provide the number of "unique" samples per wind direction bin in the bottom panel in Figure 4. To make the graphics more readable we split Figure 4 into two figures. Besides the number of "unique" samples we do now also provide the total number of samples per wind sector in the figure. We have added an appendix figure to show $S_{\mathsf{m,port}}\, S_{\mathsf{M}}^{-1}$ as well as $D_{\mathsf{m,port}} - D_{\mathsf{M}}$ for 5 min and 60 min averages. The results do not change significantly for 5-minute vs 60-minute averages however due to the lower number of samples for 60-minute averages, we cannot find a reliable average ratio for some of the wind sectors.

RC 12: *Section 3.5, paragraph 3: How many unique observations were available for bias estimation after all the quality checks. The authors note 44%, but how many observations does that translate to? A table showing the number of original observations for each anemometer and the # of values removed by each test/criteria would be nice.*

AR 12: We avail of 34013 and 33923 five-minute average observations from the port and starboard sensor. For the port and starboard sensor 15049 and 14867 five-minute average observations remain after the quality controls these are 44% of the available data. After the IQR-based outlier removal, 13010 and 12863 observations remain, which amounts to 38% of the originally available data. With the additional removal of the data within 3 hours of the instances where ground wind speeds from UBXH3 where assimilated the values change to 12055 and 11948 samples (35% of the initial data set) that pass all quality control measures and are used to derive the flow distortion correction factors. For the port sensor, the number of unique samples is provided in Figure 4 there is not much differnce for the starboad sensor. We have now added the number of available and finally used samples in the text.

RC 13: *Section 4.3, first paragraph: The second sentence starts "The correction tends..." Maybe I missed it, but I was not clear at this point as to how the correction was calculated. Please cross reference back to this equation earlier in the text at this point just to make this clear to the reader.*

AR 13: We changed the sentence to: "The correction of the measured wind vector via Eq. (9) tends to reduce the true wind speed but the magnitude of the correction varies by more than

$5\,\mathrm{m\,s^{-1}}$."

RC 14: *Section 5, 2nd paragraph: I agree completely with the authors that testing agreement between anemometers is not an indicator of their reliability. The approach presented in this paper shows promise for wider application.*

AR 14: Thank you for the acknowledgement. We will make the code available to facilitate the application of this method.

RC 15: *Section 5, 3rd paragraph: the text is not clear regarding the averaging of the wind speeds. Were averages made separately for the port and starboard anemometers? Or was all data from both anemometers combined and averaged? Just a change in wording is needed to clarify. (the same wording problem exists in the conclusions, 4th paragraph).*

AR 15: We change this to "When the wind speed measurements from the port and starboard sensor are averaged, ..."

RC 16: *Figures: All are rather small to see the details, but that may just be how they were presented to reviewers. Several plots show the relative wind direction as negative to positive – it would be helpful to label this axis with "port" and "starboard" as well to make this easy to see.*

AR 16: We add the following sentence to Section 3.1. "Where D is used as x-axis in the figures, we have values reaching from $-180°$ to $+180°$ in order to create a panorama. Negative values of D denote wind from the port side and positive values from the starboard side, respectively." We find this display very intuitive and don't see the necessity to add further annotation to the figures.

RC 17: *Figure 2: Colors are hard to differentiate (maybe a more distinct color scale would help like the one in figure 3).*

AR 17: We changed Figure 2 to a different color scale and increased the marker size. The main point of this figure is to show the variability in $S_\mathsf{m}\,S_\mathsf{M}^{-1}$ and $D_\mathsf{m} - D_\mathsf{M}$, and to highlight that this

variability is mostly related to direction changes of the ship within the averaging interval.

RC 18: *Figure 4: Use of negative N in the latitude labels is confusing. In the text you call this south (S) latitude. Please do the same in the figures to be consistent with the text.*

AR 18: We changed the labels in Figures 4 and 9 to "60°S to 40°S", "North of 40°S", and "South of 60°S".

RC 19: *Figure 8: Sort the data by the magnitude of the difference and plot with the largest ratios (both + and -) on top. At present, some of the smaller ratios are plotted over the larger ratios, thus the plot underestimates the differences.*

AR 19: The main point of this figure is to highlight regions and prolonged time periods, when the wind speeds differ systematically. The data are plotted consecutively in time so no bias towards larger or smaller differences is introduced. We choose to indicate the magnitude of the true wind speed with the marker size to highlight discrepancies for high wind speeds that are more relevant to air-sea gas-exchange and sea spray emission. The issue of entirely overlapping data points occurs only for periods where the ships was moored, this could only be fixed by presenting the data as time series. We have reduced the overall marker size in order to reduce the overlap between neighbouring observations.

RC 20: *Figure 10: Please clarify the meaning of the lines versus the shading in this figure. I assume the line is the median, and the shading the IQR, but state this in the caption.*

AR 20: Indeed the lines are the median values while the shading indicates the IQR. We have modified the caption to clarify this.

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2019-366/amt-2019-366-AC1-supplement.zip

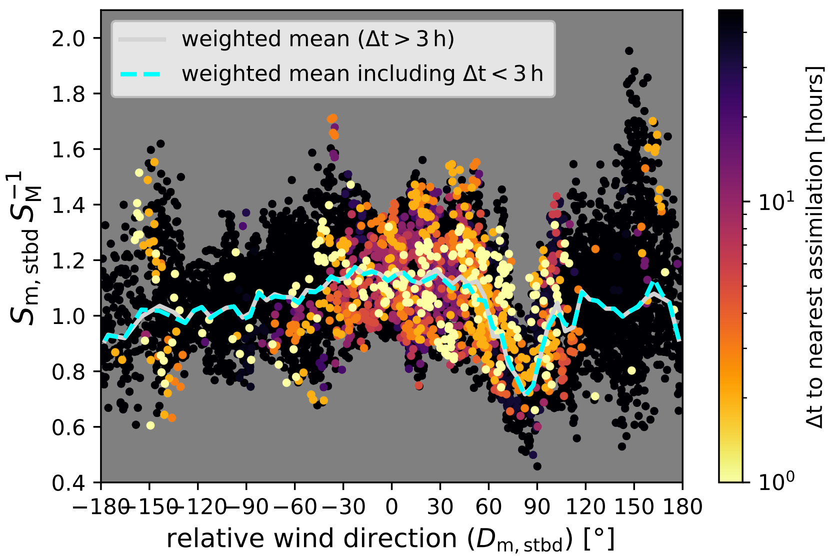

Fig. 1. Wind speed ratio as function of the relative wind direction. The marker colour denotes the absolute time difference to the 35 events, when data from UBXH3 was assimilated.