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Interactive comment on "Mapping flow distortion on oceanographic platforms using computational fluid dynamics" *by* N. O'Sullivan and B. Ward

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Response to Referee

RC: I feel that the authors can be commended for the amount of work which was clearly invested in this study, however I have strong reservations about the analysis of the results as currently presented in the manuscript. Also, based on these results and analysis, I cannot agree with most of the conclusions drawn by the authors.

AC: We would like to thank Dr Popinet for this acknowledgement of the effort invested in these studies. We also acknowledge that the way the results were presented did not clearly express our conclusions, and we have made significant efforts here to clarify the conclusions over the original submission.

RC: The central issue is the confusion regarding the independent parameters controlling the problem. As quoted in section 4 the authors assume: "In accordance with Popinet et al. (2004) two assumptions were made: 1) The wind speeds measured at different locations should scale linearly with some reference velocity, meaning the fluid flow is essentially independent of the Reynolds number, 2) The averaged velocity depends only on the relative wind direction."

If assumption 1) is verified then, by definition, the wind speed is only a scaling factor for the problem, or expressed differently; the solution for any wind speed can simply be obtained by multiplying the solution for a given wind speed by the ratio of the reference (e.g. undisturbed) wind speeds. From a numerical perspective, the practical implications of this assumption are of course important, since in this case, it is only necessary to perform simulations at a single wind speed (rather than the 41 simulations performed by the authors).

AC: Our starting point to this article, as we stated clearly, was based on the assumptions from Popinet et al. (2004). However, we also wanted to expand our knowledge of lesser quantities affecting flow distortion, in which we looked at the effect of wind speed and ship tilt angle with detailed model runs. The Popinet et al. (2004) article conducted simulations for a single wind speed only; we decided to take this further by running multiple simulations over a range of wind speeds from 5-25 ms^{-1}. We believe that this was a worthwhile effort to study the CFD method in more detail, and take advantage of the availability of the OpenFoam open-source software package (which was nonetheless quite an amount of effort to get all these runs simulated).

RC: An important question is of course: is assumption 1) verified in reality? We have shown in Popinet et al. (2004) that wind direction relative to the ship can explain more than 90\% of the variations in averaged (relative) wind speed measurements (and also standard deviations) for a particular vessel for a range of different measurement locations, sea state, ship speeds etc... This means that all other factors (tilt, roll, waves, ship speed etc... including wind speed) are below 10\%.

AC: Our interest was in studying the amount of flow distortion from the lesser important quantities (such as wind speed dependence and ship's tilt). We did not expect that flow distortion arising from these lesser effects to be larger than 10%, and in fact from simulations and experimental results they have been found to be a maximum of 5.6% and 2.5% respectively. This was not clearly stated in the original article, and this may have led the reviewers to the conclusion that we were over-stating the effect of wind speed. This was not our intention.

RC: I would expect the same to hold for R/V Celtic Explorer. The authors can easily check this, but this is not done in the current version of the paper.

AC: Yes, In the case of the R/V Celtic Explorer this also holds true and for clarification figure 1(b) will replace figure 8(a) in the submitted version of the article. In this plot, numerical data have been compared to the overall experimental wind speed using 5 ms^{-1} wind speed bins ranging from 5 to 20 ms^{-1} to show the error dependence on wind direction. Figure 1b is the same plot as Figure 1a, but for numerical data instead of experimental.

Taking a single wind speed bin of 5 ms^{-1}n (indicated by the magenta line in figures 1(a) and (b)), the mean percentage deviation to the total wind speed range is 11%, for wind directions from -60° to +60°. This means that wind direction accounts for 89% of the overall flow distortion, as wind direction is the only variable.

RC: The authors focus on "wind speed difference" between sites which is obviously not a quantity which is independent from the wind speed. If assumption 1) is verified, then wind speed dependence should disappear (to within 10\%) when the authors consider, for example, the _relative_ wind speed difference (or equivalently the wind speeds ratio as in Popinet et al. (2004)).

AC: To further clarify the conclusions of our paper, and in line with one of the recommendations of reviewer 1, we have modified our plots from difference to ratio in order to allow a more direct comparison to Popinet et al. (2004).

RC: Figures 5, 7, 8, 11 should be redone. Fig. 5 in particular, should reveal clearly whether assumptions 1) and 2) are verified. If this is the case experimentally, then one can assume this should also hold numerically (I would trust experimental results more than CFD for turbulent flow modelling). This means that CFD results need to be obtained only for a single wind speed and that "details" such as turbulence models, boundary conditions on the sea surface, inflow profiles etc... should not play a role (as they don't in reality). Note also that in this context, the corrections applied to each measurement site are _factors_, not absolute wind speed differences. The conclusions drawn in the paper need to be reinterpreted in this light too.

AC: Agreed, and we have redone figures 5, 7, 8, 11 to express ratios instead of differences, as mentioned above. As an example, the replacement for figure 5 is shown in figure 1(a), which shows the experimental bin-averaged wind speed ratios between the two reference anemometers.

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Both subplots in figure 1 (experimental and numerical) indicate that wind speed accounts for an overall flow distortion of 1-6%, and that the wind speed dependence increases above 5 ms^{-1}.

We are conducting a concurrent study using the R/V Knorr (on which we made some measurements in 2011), and we also found that there is a wind speed dependence on flow distortion. However, this dependence is reduced compared to the R/V Celtic Explorer due to the fact that the met mast on the R/V Knorr is immediately at the bow, but increases with increasing wind direction angles.

RC: A second important issue is the results displayed in Figure 13. This graph shows that (according to the CFD results) up to velocities of 15 m/s, the wind speed difference between the sonic site and the undisturbed flow is constant (i.e. independent of both wind speed and tilt angle) and that above 15 m/s, this difference suddenly becomes erratically dependent on both wind speed and tilt angle. This seems very suspicious to me... I can't see any physical explanation on why the (real) flow would suddenly change regime above 15 m/s, however I can imagine many reasons causing simulations to behave erratically (and incorrectly) above some threshold.

AC: To further clarify the Vertical Orientation section, an additional numerical ratio plot has been produced. Figure 2 shows the ratio of bow mast sonic to free-stream at 0° to the bow and pitch angles of 0°, 2°, 4° and 6° to the horizontal. As there was no free-stream measurement available, this analysis can be treated as completely numerical and its validity is based upon the previous numerical and experimental results comparison, which both clearly show wind speed dependence(Figure 1(a) and (b)). Figure 1(a) an experimental bin averaged ratio plot between the bow mast sonic and the ships bridge deck anemometers, was also plotted specifically to address the higher deviations from mean flow at high wind speeds seen in the tilt simulations specifically above 15 ms^{-1}. It can be seen using the error bars that a more turbulent regime is present at higher wind speed bins between -20° to +20° to the bow. This aligns with the flow regime in the Vertical Orientation section as this was conducted solely for 0° to the bow. Figure 2 will also replace figure 13 from the submitted article. The effective change from the submission version of this plot is that the plot has been redone to give a ratio for the chosen tilt angles.

Tilt Angle Range	Numerical % Mean Difference
0-2°	1.95
0-4°	2.49
0-6°	2.54

RC: Furthermore, even the behaviour below 15 m/s is suspicious, since one would expect (according to assumption 1)) that the wind speed difference should scale with the wind speed: i.e. the difference should treble when the wind speed goes from 5 to 15 m/s, not stay constant. Note that the analysis of the experimental results suggested above should allow to confirm or infirm this relation (thus validating or infirming the results of fig 13, at least below 15 m/s). This figure seems to be the basis for the authors' conclusion that both wind speed and ship tilt are independent factors affecting flow distortion. Based on the comments above, I cannot agree with this conclusion.

AC: To clarify the numerical behaviour below 15 ms^{-1}, the results of wind speed dependence shown in (Figure 1), for both numerical and experimental results define a non-linear scaling of error and when taken into account, validate that the tilt simulations hold true for the lower range of wind speeds.

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Specific comments and other minor points

RC: "The Courant number is the speed of sound..." Are you really solving for a compressible flow? (with sound waves)

AC: (poor choice of wording); we have changed the text as follows:

> The Courant number is the input speed multiplied by the ratio of the time step length to the cell length. This ratio is the time required for a quantity or fluid particle to be convected through a small distance.

RC: p. 3493: "Since the ratio between model and domain size is less than 1\%, this creates an infinite domain". How about "The influence of boundaries is minimized by using a ratio of ..."

AC: This has been changed.

RC: p. 3495: "The total number of simulations run for all the variations test was 59". I don't really understand how this can match with 41 wind speeds and 13 wind directions.

AC: Vessel Simulations =13
Vertical orientation of the vessel simulations = 4
The meteorological mast setup simulations = 42
Total number of simulations =59

The number of simulations are based upon orientations of the model. i.e the vessel simulations have 13 different orientations, run for -60° to +60°, in increments of 10°.

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In each individual simulation a varying velocity inlet boundary condition is used, using this 41 different input velocities can be solved during the course of a simulation run. The code uses a set convergence criteria for the residuals of the calculations (i.e when a steady state solution has been reached). When a steady state solution has been reached the code moves onto the next input velocity for the range 5 ms^{-1} to 25 $^{\circ}$ in increments of 0.5 $^{\circ}$. This improves computational costs as a greater range of input velocities can be run without the need to run a completely separate simulation for each individual input velocity.

RC: p. 3496: "the generated shock-wave". There an't any "shock waves" in this flow, unless your vessel is travelling close to the speed of sound...

AC: This has been changed to “velocity gradient”

RC: section 4.1, 2nd paragraph: this paragraph should be rewritten with the updated Figure 7.

AC: Using the previously discussed Figure 1, the previous submitted article has been updated with ratio surface plots and the text has been rewritten accordingly.

RC: section 4.2: "shockwave" again.

AC: Changed to “velocity gradient”

RC: section 4.3: what is the wind direction? I assume it is 0 degrees (i.e. "bow on").

AC: We have added a paragraph at the start of the results section which will clarify our results.

RC: Conclusions need to be rewritten.

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AC: We have re-written the conclusions, and specifically changed the paragraph describing the importance of wind speed.

> Previous research (Popinet et al. 2004; Yelland et al. 2002) concluded that wind direction is the dominant factor in flow distortion errors for micro-meteorological measurements on research vessels. It has also been shown from our results that the magnitude of the wind speed is a quantity of importance, in which the magnitude of flow distortion deviates from a linear trend by up to 5.6% in wind speeds between 5-10 ms^{-1}. "

`RC: Figure 13: it looks like there are many more than 41 data points (for the wind speed dependence). Where do these points come from?`

AC: As a result of the varying velocity inlet boundary conditions that is available with OPenFOAM, the code solves velocities between 0-25 ms^{-1}, in steps on 0/5 ms^{-1}. However, the code cannot accurately solve these in large step changes, so there are 48 intermediate steps between each 0.5 m/s velocity (this gives us 2400 data points). This method is more computationally efficient than running individual wind speeds, and give the same results.

References Cited

Popinet, S., Smith, M., and Stevens, C.: Experimental and numerical study of the turbulence characteristics of airflow around a research vessel, J. Atmospheric and Oceanic Technology., 21, 1575–1589, 2004.

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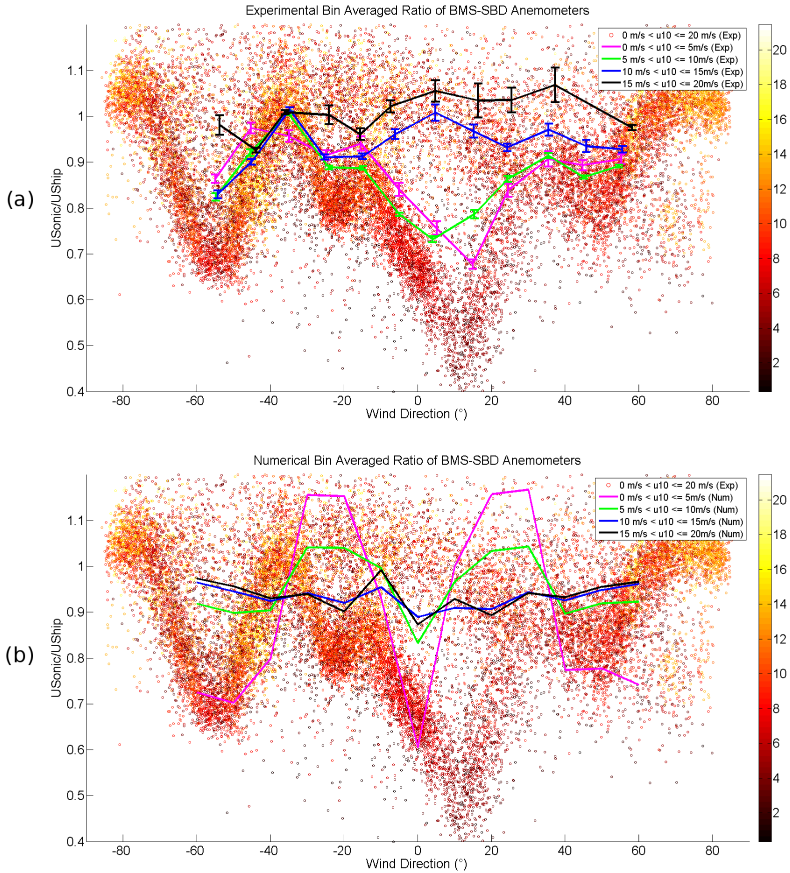

Fig. 1.

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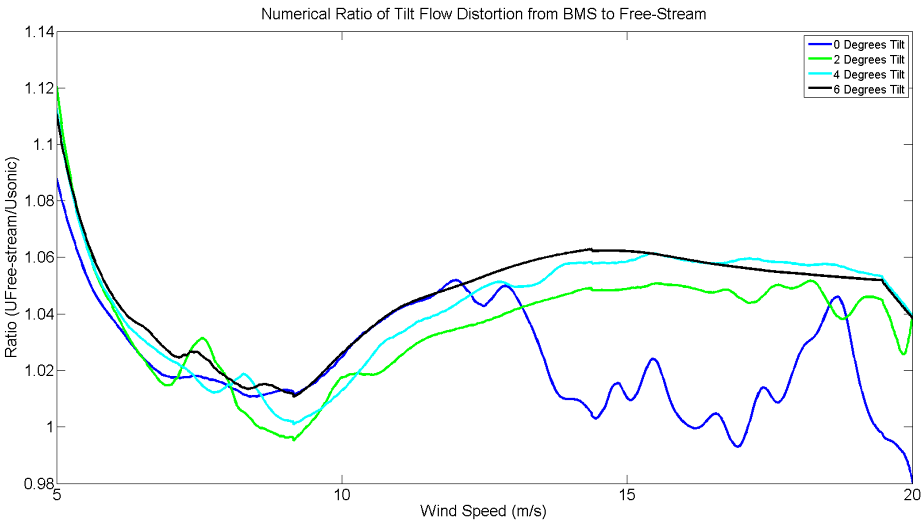

Fig. 2.

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