Response to referee comments: second round

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To begin, I want to thank the referees for their valuable comments on the provided manuscript. We believe that addressing these comments will contribute to the quality of this paper greatly. Moreover, we thank the Copernicus editorial team for their support through this process. In the following, the reviewers' comments are presented followed by our answers in blue. Minimal changes have been applied to the comments to make them compatible with the used text editor.

Following the guidelines for re-submission of a revised manuscript, we have added a list of relevant changes for each comment after the answer is given. The figures and lines numbering is based on the revised manuscript (without track-change).

1 RC1

Minor concerns: (1) I appreciate the author's effort to incorporate a table in response to my previous comment (2). Positioning it in the appendix is appropriate. However, I found the format, which lists individual cases for each figure, to be unconventional for a scientific manuscript. I recommend consolidating the information into a single, comprehensive table that encompasses all the cases, rather than presenting them in separate tables.

Answer: We are glad that you found most of our changes positive and satisfactory. As your suggestion, we change the formatting of the presented tables in Appendix by consolidating them into one table. The column for ϵ is removed as it is the same for all simulations ($\epsilon = 2\Delta x$). A new column is added for U_0 to include cases conducted to respond to comment 4 of the second reviewer. In addition, similar simulations are grouped together to save space.

The list of relevant changes:

- we have changed the format of the tables in the appendix: Simulation Details, by including all cases in one comprehensive table.

2 RC2

1: Please consider additional grammar editing.

Answer: We do another round of proof reading to improve on this.

The list of relevant changes:

– The revised manuscript is checked for grammatical errors and the corrections are made in the revised manuscript. This can be seen in the marked up version of the manuscript.

2: The manuscript needs to be reorganized to improve readability. Figures and tables should be located near where they are first referenced in the text and equations should immediately follow their variable definitions. Searching through the text for variable definitions or the appropriate figure detracts from the quality of the work.

Answer: As your suggestion, we have changed the locations of some figures, tables, and equations to improve readability. We tried to place them as close as possible to where they are mentioned first. However, this was not always possible. In that case, they appear in the relevant section or in the page immediately after. We kindly ask you to inform us if more specific changes are required.

The list of relevant changes:

– Eq. (6) is placed after line 85.

– Fig. 2 orientation is changed to horizontal to save space.

– Figs. 5, 6, 7, 8 now appear in the relevant section.

– Figs. 11, 12, 13, 14 appear in the relevant section.

– The layout of Figs. 16, 17, 18, 19 is changed from vertical to horizontal to save space. Now, they appear in the relevant section.

– The layout of Figs. 22, 23, 24 is changed from vertical to horizontal to save space. Figs. 22 and 23 appear in the relevant section and Fig. 24 appears in the page immediately after.

3: “Number of cells along the rotor diameter” is unwieldy as a figure caption and in the text. If the goal is a qualitative comparison between grid resolutions, a naming convention like “Coarse, Medium, Fine” would be more intuitive for the reader. If a quantitative measure is important I, recommend a quantity with physical significance such as N_{cells}/D, Δx, or $\Delta x/D$.

Answer: We change the "Number of cells along the rotor diameter" to $D/\Delta x_{min}$. The change is applied throughout the text, figure captions, and figure labels. The coarse-moderate-fine convention is used on occasion as we also think it can be more intuitive.

The list of relevant changes:

– The figure labels have changed for Figs. 2, 9, 10, 13, 14, and 15.

– $D/\Delta x_{min}$ is introduced in line 181.

– The header of first column in Table 1 is changed to $D/\Delta x_{min}$.

– The captions of Figs. 6, 11, 12, 21, 22, 23, and 24 are changed accordingly.

– The text is changed accordingly in the first paragraph of 4.1, 4.2, 4.2.3, and 4.3 sections.

4: The results are well presented and illustrate the impact of various settings on error relative to ALM. However, it is unclear how well they can be generalized to other scenarios without relating optimal parameter settings to underlying physics or ASM theory. For instance, the best sampling location to minimize error appears to be at 0.7 the sector width. If the inflow velocity is increased to 15 m/s, is 0.7 the sector width still the optimal sampling location? If not, is it possible to estimate the correct location from the current results or is a second parameter sweep required?

Answer: To address this comment, we conducted two sets of new simulations with ALM and ASM for different mesh resolutions. The first set uses an inflow velocity of 4 m/s and the second case uses an inflow velocity of 20 m/s. The time step size, rotor speed, and pitch angles are changed accordingly. For the 4 m/s case, the TSR value remains constant (TSR=7.55) as it falls into the below-rated operational region. For the 20 m/s case, the TSR is equal to 4. The power relative errors are then computed compared to their ALM counterpart of the same mesh resolution. We added these two new sets to Fig. 15 of the manuscript.

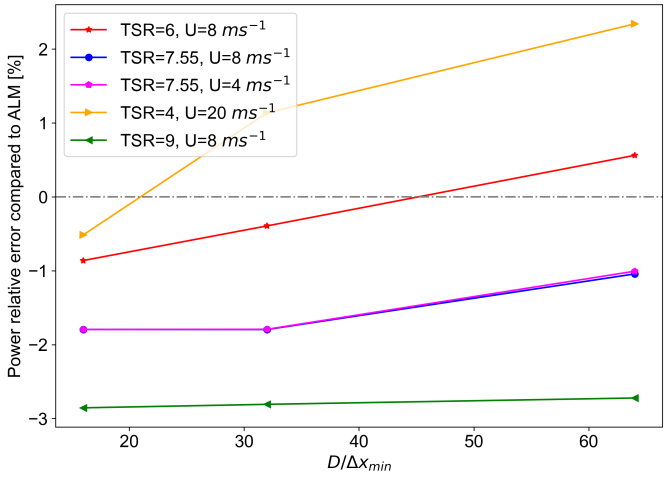

Figure 1. Relative error of power value for different TSR and U_0 values compared to their ALM counterpart of the same mesh resolution

The results are shown in Fig. 1. As can be seen, for the cases where U_0 is constant and only the TSR changes, the error values change. In comparison, for the cases with different U_0 and the same TSR, the error values remain the same. This shows that the suitable sampling location depends on the TSR and is not directly affected by U_0. Relating this to the ASM theory, it can be shown using ASM equations that changing the TSR value can change the number of lines (N_{sector}) within the sector. To do so, we know:

$$\Delta t_{ASM} = \Delta t_{baseline} = 0.5 \cdot (\frac{\Delta x}{U_0}) \tag{1}$$

$$\theta_{sector} = \Delta t \cdot \omega \tag{2}$$

$$N_{sector} = ceil(\frac{\theta_{sector} \cdot R}{\Delta x}) + 1 \tag{3}$$

In addition, from the definition of tip speed ratio (TSR), we have:

$$\omega = \frac{TSR \cdot U_0}{R} \tag{4}$$

Substituting eq. 1, eq. 2, and eq. 4 into eq. 3, we get:

$$N_{sector} = ceil(0.5 \cdot TSR) + 1 \tag{5}$$

which shows that the number of lines within the sector only depends on the TSR value. It is expected that changing the number of lines within the sector changes the distribution of the forces thereby changing the induction within the sector. Therefore, the suitable sampling location changes. Despite this, as can be seen in Fig. 1, the error values remain acceptable for a range of relevant TSR values for the suggested sampling method.

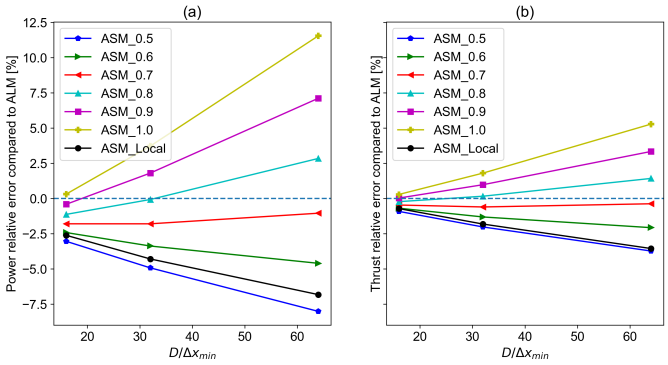

Figure 2. Relative errors of power and thrust values of different sampling methods compared to their ALM counterpart of the same mesh resolution with old position updating scheme: (a)Power relative error, (b)Thrust relative error

Looking at the error values seen in Fig. 1 (Fig. 15 of the manuscript) and Fig. 2 (Fig. 9 of the manuscript), one could conclude to use the sampling location of 0.6 for $2 < TSR \leq 4$ corresponding to $N_{sector} = 3$. In addition, for $8 < TSR \leq 10$ values yielding $N_{sector} = 6$, the 0.8 sampling location can be adopted to further improve the error values. For most if not all wind turbines, TSR=10 is an upper limit due to various considerations such as noise and safety.

It is perhaps possible to relate the suitable sampling location to the TSR and N_{sector} by fitting a curve to the suitable sampling locations for different N_{sector} or by means of an analytical model. However, this is beyond the scope of this study. We add this as a suggestion for the future work.

In light of this, we rewrite 4.2.3 section and add this discussion. Also, we change the manuscript accordingly where it is needed.

The list of relevant changes:

- The ceiling operator was missing in Eq. (4) of the manuscript and now is added.
- Section 4.2.3 of the manuscript is rewritten.
- Minor changes are applied to section 4.4 (time step size) in light of the new insight.
- Minimal corrections are made to the conclusion section.
- New simulations are added to the Table in Appendix.

5: Line 84, please move Equation 6 to the end of this paragraph.

Answer: we move this equation to the proposed location.

The list of relevant changes:

- It appears now in the suggested location.

6: Line 100-113 and Figure 2, if these are results please move them to the results portion of the paper.

Answer: These are results in the sense that they come from the conducted simulations. However, since they are used to clarify why new and old position updating schemes are considered, we prefer to present them in this section. We think that presenting them in another section could cause confusion. Nevertheless, we kindly ask you to inform us if you think it is required to move them to another section.

7: Table 1, why are there 5 sectors for each resolution? Shouldn't the number of sectors increase with θ following Equation 4? This may also explain why error increases with mesh resolution.

Answer: As already shown in the response to comment 4 and eq. 5, the number of lines within the sector depends only on the TSR value. Therefore, it does not change with the mesh resolution. In other words, although the θ changes, since the Δx also changes, the number of the lines remains constant.

8: Line 166, how many points per line were used for each case? Did the number of points vary with mesh resolution?

Answer: The same number of points is used for all mesh resolutions. This is equal to 40 points. We add this to the revised manuscript.

The list of relevant changes:

- The number of points is added to line 79.

9: Lines 271-285 and Equations 7-9, please move this to Section 2. Although it is relevant to the results at hand it interrupts the flow of the manuscript.

Answer: We move this part along with the equations to section 2 to avoid interrupting the flow of the manuscript.

The list of relevant changes:

- Lines 271-285 and Equations 7-9 are moved to section 2. Now they appear between line 149-164.

3 Additional changes

- The title of appendix is changed to "Simulation Details".
- The variable $U_{incoming}$ is changed to U_0. An explanation is added to line 65 to introduce U_0 as the inflow velocity.
- The equations use $\cdot$ to show multiplication whereas previously $\times$ was used on occasion.

4 Final words

We would like to thank the referees and the editorial team again. We did our best to address the received comments. We kindly ask you to inform us about any further required changes and clarifications if necessary.

Kind Regards,

The authors