Response to Reviewers' Comments on WES-2023-177

Tsvetelina Ivanova, Sara Porchetta, Sophia Buckingham, Gertjan Glabeke, Jeroen van Beeck, Wim Munters

October 22, 2024

We thank the reviewer for their feedback and for acknowledging improvements in the manuscript. We appreciate the additional minor comments, and we address them here to enhance clarity before publication.

Response to Reviewer 1

Overview

The authors have successfully addressed most of my comments and the manuscript has improved immensely. The manuscript is much more coherent, and the analysis provides a more thorough investigation on the use of observational nudging with the wind farm parameterization for improving hour-ahead forecasts and simulations of past events relevant for wind turbine operations. I have a series of minor comments to clarify different aspects of the manuscript prior to publication.

Response:

We would like to express our gratitude to the reviewer for their constructive feedback and valuable insights. We are glad to hear that the revised manuscript is considered significantly more coherent and in-depth. In this document, we respond to the reviewer's minor comments, which helps us to further enhance our manuscript.

Minor comment 1

Methods: Consider reframing the use of five domains to three simulations where the only difference is in the use of the WFP and FDDA in domain d03.

Response:

We take this remark in consideration, and in Methodology (Line 98) we now further highlight how the three innermost domains differ:

"The model configurations in the three innermost domains (with $2\ \mathrm{km}$ grid spacing) differ in the following way: D03 is for simulations without WFP, D04 is for active WFP, and D05 – for active WFP while performing FDDA."

Minor comment 2

It appears you are nudging the simulations using lidar observations from a single height (104.5 m) and the vertical radius of influence will affect the wind profile across all vertical levels in the model. Please clarify why you did not nudge the simulations using the wind measurements from all the lidar-measured heights.

Response:

In the beginning of this study, while we were setting up the simulations, we did try numerical experiments in which we would assimilate the whole profile. However, assimilating just a single point provided convincing improvements (due to the lack of constraints in the vertical weighing function of the nudging algorithm, as explained in Line 334 of the revised manuscript). Therefore, to further emphasize the value of upwind point measurements, we proceeded with assimilating only the near-hub height level. We clarify why in Section 2.5, Line 274:

"Finally, to highlight the benefit of offshore measurement campaigns, nudging is applied specifically at near-hub height (104.5 m) rather than across the entire LiDAR profile. This approach underscores the value of such offshore campaigns: even

if data collection is spatially limited by weather conditions or technical issues, the data can still provide meaningful input for improving model accuracy."

Minor comment 3

Page 8, Line 189: "contained" instead of "located"?

Response:

Resolved (now this is in Line 193).

Minor comment 4

Please specify the distance between the last turbine row and the LEG and EPL lidars for the predominant wind direction.

Response:

We specify these distances in the text in Sect. 2.3, Lines 201 and 209. They are as follows:

- Waked WTs to LEG: approx. 63 km
- Waked WTs to EPL: approx. 56 km

Minor comment 5

Section 2.4: The objective for F1, F3, and F4 seems to be the same. However, the conditions under which the nudging happens may differ (negative wind speed bias in F3, and positive wind speed bias in F4). Please clarify.

Response:

Indeed, the objectives for F1, F3 and F4 are very similar. Therefore, we clarify this in Table 2, and we add that their conditions may differ also in Table 2 (in terms of wind speed biases, for example). In Sect. 2.4, we add a short clarification in Line 237.

Minor comment 6

"Cyclic" routine: Calling it a cyclic routine implies that the ON/OFF nudging procedure has a broader goal. However, as stated in line 383, the cyclic routine showcases the potential for improved hour-ahead forecasts only, there is minimal benefit afterwards. Also, Figure 8 shows that after nudging is deactivated the simulation will inevitably converge to the solution without nudging. Thus, I am not sure this should be framed as a "cyclic" procedure, but rather as exemplifying the improvement in hour-ahead forecasts.

Response:

We thank the reviewer for this observation. The term 'cyclic' was chosen to emphasize that we repeat the routine, in which FDDA can be applied in successive hourly intervals using WRF restart files. Indeed, nudging provides the most significant improvement during the hour-ahead forecast window. The intention behind the 'cyclic' is to highlight the potential for recurring assimilation after each forecasting window. However, we now substitute 'cyclic' with 'consecutive' nudging routine throughout the text, to avoid the presumption that 'cyclic' implies 'going back to the same starting point'. We hope that this choice of terminology is more intuitive.

Minor comment 7

Figure 4: Please show the radius of influence in the figure for reference.

Response:

In Figure 4, a reference distance of 20 km is now shown in the maps on the right.

Minor comment 8

Page 14, Line 317: Please clarify what you mean by "compensating". Are you implying that the accelerations/decelerations near the radius of influence are due to mass conservation? I would think mass conservations will drive in vertical motions instead. These accelerations/decelerations are likely due to numerical diffusion and advection near the nudged region. Also, flow along a coastline typically displays horizontal gradients in wind speed along the cross-stream direction. So, the accelerations/decelerations within the radius of influence may be explained by the fact that you are nudging spatially using a point measurement.

Response:

We thank the reviewer for these suggestions. We substitute the mentioned sentence with the following, in Line 325 of the revised manuscript:

"Figure 4 further illustrates both positive and negative variations in wind speed values within the difference fields on the left, likely attributed to numerical diffusion and advection in the proximity of the nudged region."

Minor comment 9

It is worth pointing out that observational nudging may improve the results near the radius of influence, but the large-scale background flow will remain largely unaffected and will still dominate flow evolution far from the nudging location. You clearly show this in Figure 6 (small changes in RMSE and MAE for the LEG and EPL lidars).

Response:

This is indeed an important conclusion. In the text, we refine Line 360 as follows:

"Finally in Fig. 6, at the more distant EPL and LEG LiDAR comparison locations (approximately 110 km away from the assimilation at WHi LiDAR), wind speed fields remain largely unaffected. At EPL and LEG, a small influence is captured only when the horizontal radius of influence reaches 50 or 60 km."