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Comment on wes-2022-21

Anonymous Referee #2

Referee comment on "An investigation of spatial wind direction variability and its consideration in engineering models" by Anna von Brandis et al., Wind Energ. Sci. Discuss., https://doi.org/10.5194/wes-2022-21-RC2, 2022

This paper covers an important topic, namely how spatial variability in wind direction affect the evolution of wind farm cluster wakes and how this can be implemented in engineering wake modelling tools. I do however have some substantial concerns that need to be address before I can recommend the paper for acceptation in wind energy science. The improvements necessary are detailed below:

Major comments:

“spatial variability in wind direction” covers better the content of the paper than “mesoscale wind direction changes” and should in my opinion be used throughout the paper. First of all, the systems that are discussed here are often larger than what is traditionally described as mesoscale systems. Moreover, the paper focusses on variability in space and not in time (streamline instead of lagrangian approach).

The qualitative comparison with synthetic aperture radar (SAR) is the center of the paper, but the setup of the model experiments and comparison with data should be improved. To produce this figure, the wake model parameters were adjusted to minimise wake recovered and to achieve slowly decaying wakes. However, the authors argue that this does not yield a goods agreement with real production data and they propose other parameters for realistic simulations. It would therefore be much fairer to produce the maps and the comparison with SAR for realistic coefficients of the wake models. Moreover the current comparison is not straightforeward to interpret since SAR data in figure 8 are displayed as the backscatter value of the normalised radar cross section. It would be much better to use here the geophysical quantity wind speed which also improves the ability to compare the observed versus the modelled far wakes.

I am not convinced with the use of the term “reduction in uncertainty” in the paper. In my opinion what the authors propose here is rather an attempt to include a process, namely the curved propagation of cluster wakes as a result of spatial variability in wind direction and thereby improve existing wake models. Even though this improvements cannot be quantitatively demonstrated in the current framework. For example in line 440 where you state that applying the proposed model reduces uncertainty by up to 0.7% when estimating the interaction between neighboring wind farm clusters. This is just referring to a sensitivity where curvature of the path is included versus a situation where this is not included and is not a metric for reduced uncertainty. Please go through the entire paper to critically reflect on the use of the term uncertainty and reduction of uncertainty.

In Section 5.1.1, I do not understand the logic of taking the mean of the medians. If I understand it correctly, you first take for every time frame the difference in wind direction compared to FINO. Then you take for each pixel the yearly median of this difference. Subsequently you average over a 30 year period. Why making it so complex and not just taking the median of all the timeframes for each pixel (or the mean if you prefer)?

In the same section, I do not understand why your value does not become zero when looking at the FINO grid point for 25th percentile and the 75th percentile. Per definition, the direction difference with reference to FINO should always be zero at FINO. Moreover, there is little discussion anyway on the 25 and 75th percentile so it is perhaps better to remove this.

In the same section, I am not sure if it does make sense to take the median (or the mean) of a direction (which is a circular metric). The average wind direction of -179 deg and +179 deg is not 0 deg. Am I missing something on how you exactly did the data processing (and then you can perhaps explain it better). Of course if the difference in the direction is in between -90deg and +90deg it is okay, but I would expect that larger differences can occur over distance of 200km or so? Even if you scale it back to 100 km there might be similar issues. Please check.

Figure 7 and 8: add the positions of the wind farms to this figure. Moreover, make a map using a lat/lon grid similarly to the other figures that you created. Make Figure 8 so that you can directly compare the model with SAR by using the same map and also by plotting windspeed in both the model and SAR.

Figure 9: you plot the standard deviation of the relative difference. I am a bit puzzled why this is an interesting metric. Why not simply plot the relative absolute difference which is a much easier metric to intuitively interpret. The standard deviation will also never be a negative number so what you plot in the figure cannot be a standard deviation, since negative numbers appear in the figure.

Overall after reading your paper, although I'm not an expert on wake modelling, your results seem to imply that turning of the wakes in relation to spatial variability in wind direction is relevant, but that the current engineer models of the wind farm wakes are perhaps not appropriate yet to firmly demonstrate this. Your conclusion on line 486 is that "it is concluded that the new model can represent the flow with the fact greater fidelity then becoming baseline approach." This statement is much too strong given the limitations of the analysis currently done and discussed above.

Also the line 488 doesn't clearly follow from the results where you state that "the new model should consistently outperform the baseline approach that neglects wake turning." Well perhaps in principle it should (because in reality the wakes move with the flow) but the paper does not firmly demonstrated that.

A related question: are there better ways to model the wake of a wind farm than adding up the wakes of the individual turbines? In figure 7, the wakes of the individual turbines remain visible over a long distance and I wonder whether there is observational evidence for this: Individual streaks remain visible in the model as far as 50 km downstream. Is this realistic? I therefore would like to see a brief discussion on this together with a discussion on how wakes of farms are implemented in current engineering models, how this model relates to other approaches and whether the approach presented here is accurate enough to study wind farm wakes and interaction between wind farms.

Minor comments

It would be good to add a short description how the wake expansion is related to the atmospheric conditions. From the equation 6, it is clear that the wake deficit is in turn function ambient turbulent intensity which is in the a function of meteorological conditions. A paragraph explaining how this relation is exactly formulated would add strong value to the paper. Later in the paper this can be used to describe how the wake expansion relates to meteorological conditions in the cases that are presented (low pressure system).

Section 2.2 on the implementation of direction changes into engineering models should be improved. It is unclear what x exactly means. Moreover, r(t) is the path as a function of time whereas s is distance along a path. The distinction should be better explained . More details should be given on the determination of the coefficients of the engineering model for the realistic situation. This is not a detail of the paper, because the extent of the wake and consequently the turning of the wake, is very much determined by these parameters therefore the potential impact of spatial variability in wind direction is very much dependent on these parameters.

In Section 5.1.1 it is shown and discussed that wind direction are large for very high wind bins. Can you analyse the cause of this? Are these situations where the location is close to the central point of a deep low pressure system with strong windspeed but also strong curvature?

Please look again figure 5 on what you plot on the x-axis. You take the logarithm of a variable and then you plot this on a logarithmic scale.