Authors' Response to Reviewer 2

General Comments. Overall, the manuscript gives a very good overview of many research questions and aspects and clearly shows that a good understanding of wind direction variability is crucial in many fields of wind energy application and that this understanding is still incomplete. This also shows the need for further research and provides a good introduction to the topic, especially for new scientists. Overall, I therefore consider this paper to be an important contribution.

Response: Thank you very much for your feedback.

We appreciate the attention you paid to our paper and the insightful suggestions for improvement. Your expertise in the subject area is clear, and we are grateful to have benefited from your knowledge.

Comment 1

line 25: "EC 61400-1" Here, the "I" for IEC is missing.

Response:

Thank you, this error will be corrected.

Comment 2

line 59: "as as" is a typo.

Response:

Thank you, this error will be corrected.

Comment 3

line 206: "the maximum horizontal resolution of these models is too large to allow them to accurately investigate intra-wind farm effects"; I assume you mean that the resolution of a mesoscale model like WRF is not high enough to resolve intra-wind farm effects, is that correct?

Response:

Yes, the current maximum resolution of mesoscale models like WRF is in the order of kilometres in space and in the order of minutes in time so are not useful for resolving the flow around turbines. They are useful in studying general wind farm flow effects, for example inter-wind farm wakes and the development of wind farm boundary layers. We decided to exclude discussion on that topic since it strayed a little far away from the control-oriented part, but a paragraph or so in the revised manuscript would make the point more explicit here.

Comment 4

line 285 eq(1). The definition for the absolute minimum distance according to (Farrugia2009) is fine, although I agree with RC1 that additional parentheses can be helpful. As stated in the author's comment, this will be updated.

However, the equation given in (Farrugia2009) is not complete, in my opinion. (Note that Farrugia substracts the second variable from the first, which is the opposite of eq1 of this paper). E.g. (in degrees for simplicity): $\Delta(190°, 0°)$. The result should be $-170°$. This case is not covered in Eq1 of Farrugia2009 in the "if cases".

To simplify things, I suggest the shift trick from Rott2018: $\Delta(A, B) = ((B - A + \pi) \bmod 2\pi) - \pi$

The only difference is that with the shift trick per definition if the distance of A and B is precisely π, the result is $\Delta(A, B) = -\pi$, which is equivalent to a rotation of π, but in opposition to the definition of the sign in Farrugia2009. But this allows us to define the Δ operator directly, without if cases. And from this, the absolute can be defined, and not vice versa.

Response:

There seems to be a few different ways of calculating this signed angular distance, we also arrived at one independently of both Farrugia2009 and Rott2018. We must have missed the definition from Rott2018 but it appears to be a more succinct and probably computationally faster calculation compared to both our approach and Farrugia2009. We will include this in the revised manuscript with a short discussion about each approach.

Comment 5

line 298: Eq3 calculates the "regular" variance (or variance "on the line", which is the term that Fisher uses), which is the expected quadratic difference of the individual samples to the "arithmetic" mean. The circular variance is defined in Fisher1995 (Statistical analysis of circular data) and also in (Cremers and Klugkist, 2018) (`https://www.frontiersin.org/articles/10.3389/fpsyg.2018.02040/full`) as $v = 1 - \overline{R}$, where $\overline{R}$ is the mean resultant length (dashed line in Figure2 divided by n). The circular variance is a measure of the variability of the data, like the variance "on the line", but it is bounded between 0 and 1 and is mathematically different from the variance "on the line". Calculating the circular standard deviation is also more complicated than the standard deviation "on the line". The problem with the "on the line" statistics arises because distributions on the circle wrap around; therefore, the interpretation of the statistics is not the same (see Note 2 in Fisher1995).

However, for the application of short-term wind data, the widths of wind direction distributions are comparatively very small, and the chances of wrapping around are basically 0. Therefore, it makes sense to use the common terminology like variance and standard deviation, although this is mathematically not 100 % correct. In this review paper, however, the difference should be emphasised very clearly.

Response:

Thank you for pointing this out, we suspected this section needed more careful consideration. While researching the paper, we came across both the "on the line" description and the bounded circular definition. Only the "on the line" method was included for brevity. However, it is clear that there is a deeper discussion to be had here around the points you raised and the various ways the mean and variance of circular variables can be defined. We will address these points in the revised manuscript to give a complete picture.

Comment 6

line 589: "Wind Direction Forecasting" is an essential topic for many applications that significantly differ in time scales. Long-term forecasts, short-term forecasts, and shortest-term forecasts (nowcasts). Since this is a paper about Control-oriented modelling, it should be clear that the forecasts are in the shortest-term range, but the reader could be reminded at the beginning of this section to avoid confusion.

Response:

Agreed, there are different time-scales over which you might want to forecast the wind direction which correspond to various applications. We briefly introduce forecasting in the bullet points of section 6, however it is a short sentence and it is not clear why we are focusing only on the short-term range. We will correct this in the revised manuscript.