Authors' Response to Reviewer 1

General Comments. I have several comments to help clarify some points throughout the text (considering the increased length of a review paper). Regardless, I think this manuscript is a comprehensive review of its stated objectives and should be accepted for publication.

Response: Thank you very much for your feedback.

Allow us a moment to express our gratitude for the time and effort you invested in reviewing the paper. Your comments are insightful and constructive. They are extremely valuable in improving the quality and clarity of our work.

Comment 1

Line 73/103: There are several points throughout Section 2 where descriptions like "long term," "small scale," "low frequency," etc., are used to describe certain regimes of physical processes. Section 2.1 ties the definition of some of these descriptors to specific length and time scales, but I'm not sure if those definitions are consistent throughout Section 2. I think it could be helpful to specify what these descriptions of scale mean when they come up, or clearly summarize them at the beginning.

Response:

Section 2 is meant to paint a picture of the relevant phenomena that need to be considered and therefore broad categories are introduced. We agree that more precise language is needed and words like "long term," "small scale," "low frequency," are quite vague, especially when not in the context of micro, meso and synoptic scale, introduced at the start of section 2.1. We will review this section in the manuscript and adjust accordingly.

Comment 2

Line 121: This clockwise rotation with height is only true in the Northern Hemisphere.

Response:

Thank you for pointing this out, it is a simple edit which we will make to the manuscript.

Comment 3

Line 132: This sentence suggests that time scales of 10 minutes are significant for wind farm flow control. Can that be explicitly stated/summarized somewhere? The authors argue that a range of length and time scales are important for modeling wind direction variability, but the control problem itself is rooted in a specific range of length and time scales. I think that added context could be helpful to the reader.

Response:

We had a discussion about this and more context is needed here. It is an implication of the control architecture and yaw rates of modern wind turbines (in the order of minutes), therefore direction changes with enough magnitude in the order of minutes could elicit a control response. The wording needs to be changed here to convey that idea properly. We will update the manuscript with these changes.

Comment 4

Line 161: What is meant by "current developments in high-fidelity farm flow models" that are out of reach to the majority of the research community? Are the authors referring to direct numerical simulations? And then the argument is that large eddy simulations are more practical and within reach? I think this wording is slightly confusing because "high-fidelity" is linked to large eddy simulations at Line 171.

Response:

The sentence refers to LES with concurrent precursor simulations which are used to model dynamic wind direction changes in the wind farm LES which are less accessible than LES with preset initial and boundary conditions. We will change the manuscript to emphasise that here and make it clear and consistent with the rest of the paper.

Comment 5

Eq. 1: Some parentheses could be added to clarify order of operations in this equation.

Response:

Thank you for highlighting this, we will edit the equation in the manuscript to fix this. We also plan to add the calculation of the signed minimum angular distance to complement this equation.

Comment 6

Fig. 2: This figure needs labels and more context to provide value to the reader; I personally didn't understand much from these vector diagrams. Related: how is the vector defined in the complex plane (Line 290)?

Response:

The idea was to make the diagram as minimal as possible but we definitely lost interpretability along the way. We will review this figure and add more text to it. As for your other question, in the complex plane, the wind direction angles are cast as the argument of complex numbers in exponential form with unit radius, which makes calculation of the mean angle a little more intuitive. If you imagine the vector summation of the complex numbers and then measuring the angle of the resultant vector as in the figure, you arrive at the circular mean, which is demonstrated in the figure. That connection needs to be more explicit and we will edit this part in the manuscript.

Comment 7

Line 346: Yaw misalignment is mentioned before this point, but I'm not sure if it is clarified that is in reference to the hub height time-averaged wind direction. There is certainly instantaneous misalignment at any time, but the focus is on error relative to time-averaged (over the relevant time scale of the control problem) wind direction.

Response:

Yaw misalignment is not well defined in general. We take it to mean any (instantaneous or time-averaged, static or dynamic) difference between the rotor axis angle and the hub height wind direction. However, as you point out, the instantaneous yaw misalignment is not useful for our purposes by itself and we are much more interested in the time-averaged misalignment (in the order of minutes). We will review the wording to make sure it is clear what we are talking about at all times. We will also make sure other related terms like yaw error and yaw offset are consistent and well defined.

Comment 8

Line 393: Is there a reason why the Heck, Johlas, and Howland (2023) citation is not used here in addition to the Howland et al. (2020) citation? The 2023 paper also derives a physics-based model for the power ratio/power reduction factor from first principles, assuming that the thrust force characteristics as a function of yaw misalignment are known.

Response:

We noted the Heck, Johlas, and Howland (2023) paper while writing the review but must have overlooked it when writing this section (perhaps it was published after this section was completed). We will add this paper to the manuscript.

Comment 9

Line 421: Rotating the rotor to the "right" is unclear - does this refer to clockwise rotation?

Response:

We agree that rotating to the right is not clear and depends on the readers perspective. From a top down view of the turbine we meant clockwise rotation. We will change the wording here to reflect that.

Comment 10

Line 506: Why are the yaw signals "mostly wrong?" Based on the description of the Draxl paper in the next sentence, I would think it's more appropriate to say that the signal is wrong at start-up?

Response:

Draxl wrote about the wind direction measurements at Horns Rev being mostly wrong, but only when the turbines are not operating, which is different from what we have said here. We will change this part in the manuscript to make it accurate.

Comment 11

Line 564: Could slightly more description be given for these measurement-free yaw control methods? Based on the text here, I can't wrap my head around how these techniques could work.

Response:

The general idea is to infer the wind direction signal from other more reliable measurements. There are only a couple of examples of this in the literature and so it's not given much space in the text. It is skipped over somewhat to focus more on the other techniques. However, you're right that it warrants more explanation since these techniques are not widely known and might be of interest to a lot of people.