

General comments

The highlight of this paper is the integration of a POD approach to model the low-frequency energy content of the wake, with a homogeneous turbulent field in the center of the wake to model the high-frequency flow fluctuations. The work is innovative and of high value to the scientific community, particularly in that it can potentially be combined with existing wake models which consider other features (e.g. large-scale meandering) that are not present in this framework. Additionally, the authors present three different methods of estimating the coefficients of the POD modes. These results lay out the framework necessary to extend the model to a wider range of atmospheric stability conditions, which is necessary in order to generalize the model so that it can be used for long-term studies and controls applications as suggested in the conclusion.

The main weakness of the paper is its length -- there is a lot of information packed into it and although the content is very interesting, it gets a little tedious after a while due to the repetitiveness of the figures and the organization of the results. A suggestion: can you give another review of the text and figures to ensure that there is no way to compact it a bit? Some figures are there but only one sentence is given about them, are they really necessary?

Finally, by the end of the paper it is still not clear what a good model performance is i.e. what are the authors aiming for with this model?

Specific comments

P5

L5: What are the criteria to define satisfactory performance? If you get to them later, just say here that you will get to them later. Same issue P7 L29.

P6

L2: "temporally local": can you elaborate a bit more on what this means and how it affects your analysis? ie, at each snapshot the wake-defining vd value is different? Can you say how much this value changes over time? Since it depends on the max vd , which is a very unsteady quantity, this could criterion could also oscillate a lot depending on your TI?

At this point I am confused as to why "the stochastic modeling approach, presented in the following, does not principally rely on the chosen preprocessing procedure" but I assume it will be clear as I continue reading the manuscript.

P12

L15: "The POD modes also reveal this non-symmetric behavior of the wake." Would this also be the case if you were looking at a downstream distance $> 3.5 D$?

L18: "As discussed in Bastine et al. (2015b), mode 1 is related to the horizontal large-scale motion of the wake." What is meant by horizontal here, its downstream advection or its cross-stream meandering? Because your cross-stream component is zero here, right? OK you briefly discuss this in P15 L7-10 but have a think about whether the controller also may be driving this.

P14

L19: why are a lot fewer modes needed to reproduce the torque? could this be just a consequence of how your variable speed controller works, ie it is driven by your hub height wind speeds and does not respond to small scale fluctuations?

P23

L25-26: and what does this mean in terms of fatigue loading / premature failure? Would you be able to add a sentence commenting on this, if not quanti- then at least qualitatively?

P26

Figure 20: why is torque so off in your stochastic models, while it is the best for the truncated POD? Also why standard errors for the spectral model only are given? In one of my comments above I wondered about the variation in the uncorrelated model, can you include that?

P31

L16: your work didn't really reveal this but just confirmed it. It is pretty well known that small-scale fluctuations are extremely relevant for fatigue loading.

Conclusion

"models which are as complex as necessary", but what is necessary for fatigue life estimation? After your discussion this question of how much we care about these high frequencies really remains unanswered?

Do you have any ambition to validate these spectra or TKE values with measurements? If so, mention it here perhaps where you have the LiDAR comment.

Technical corrections

* After defining an acronym, always use it instead of spelling out the acronym again several times.

* Check carefully punctuation, extra spaces, extra empty lines.

* Remove use of non-scientific terminology, e.g. "we suspect", "grasp", "lumped"

P1

L6: for->to

L11: procedure, how to -> procedure to
L14-15: it still remains an open question which features of the wake flow have to be taken into account-> which features of the wake flow to take into account remains an open question.

P2

L25: PIV-Data -> PIV data

P3

L3: Calman-filter -> Kalman filter

L15-16 : not sure what you mean by words "principle" / "principally"

P4

L11: "a medium rough sea surface" word medium sounds weird here, you mean moderately rough?

Figure 1 caption: please say whether looking up or downstream; should you really put the units [ms^{-1}] before (a), (b), (c) if it's not the unit for all frames? ie (c) is different unit

P5

In Figure 2 you are using $\langle u \rangle$ to represent your means but you did not say in the text what the angled brackets mean? Is it temporal mean over the 7050 s, ie 23500 snapshots? (OK you define this P6 L14 so maybe move the definition up or have it twice so it is given before Figure 2, or in the caption).

Figure 3 caption: please say whether looking up or downstream.

L4: LES Data -> LES data

L5: satisfying -> satisfactory

L10: similarly -> remove this word

L11: upstream the -> upstream of the

P6

L5: remove both commas; again confusing use of the word "principally"

L7: have been -> either "were" or "are"

L8: lead -> led

Figure 4: I don't understand why ν_d is not given in the conventional definition where it is a fractional value normally between 0 and 1?

P7

L12: can you explicitly say what indices i, j will refer to throughout manuscript

L26: lumped into -> "described by" or some other term

L29: satisfying -> satisfactory

P8

L5: repetitive and confusing sentence

P9

L5: already defined PSD so no need to spell it out again

L21-22: sentence is missing a verb?

P10

L6-7: "In this paper, we use three of the multiple loads calculated by FAST, namely the rotor torque T , the rotor thrust F_t and the tower base yaw moment in z-direction t_z ." -> "In this paper, we focus on rotor torque T , rotor thrust F_t and tower base yaw moment in the z-direction t_z ."

L16: energies -> energy

L17: "since they are commonly used" -> remove this

L23: missing a period

L28: shown in Fig. 1a. -> shown in Fig. 1a. that

You say "turbulent kinetic energy" a lot before here, so define TKE when it first appears in the manuscript

P11

L13: hy- drodynamics -> fluid dynamics or aerodynamics

L18: since this will come back in your analysis, I think you should explain here how you came up with a $f_{rot} \sim 0.12$ Hz for your average value. Or explain it in second paragraph of chapter 2 where you give rotor characteristics

P12

L4: grasp -> reproduce

L10: "There is slight tendency from larger to smaller structures with increasing mode number", confusing sentence

L12: than the modes -> than those

L18: non-axisymmetry -> axial asymmetry

L19: " the fact that we do not find a similar mode representing the motion in another direction", not very clear what you mean

L23: In the spirit of -> please reword

P13

Figure 5: add punctuation to caption

Figure 6: again, looking upstream or downstream? is this one realization of your uncorrelated model, ie how were the weighted coefficients generated for these figures?

P14

L2: yielding truncated PODs -> remove this, redundant

L24: less -> fewer

L25: fix white space between paragraphs

L27: suspect -> hypothesize?

P15

L19: fix white space between paragraphs (this happens a lot in the manuscript is this a formatting requirement?!)

L22: for -> towards

P16

Figure 7 caption: can you add (a) through (f) labels (consistently with your other figures) and reference that in your caption accordingly ie Local TKE $\langle u' (y,z)^2 \rangle_t$ [$m^2 s^{-2}$] for original LES (f) and truncated PODs including different numbers of modes N (a-e). Also once again what is the direction of the x axis...?

Figure 8 and 9 (c) title Tower Base Yaw Moment, figures should be somewhat self-explanatory without reading the entire manuscript so it's important to say it's the tower base moment, if you don't want to repeat that all the time then define an acronym TB Yaw Moment

P18

Figure 11 caption: Rainflow counting histograms (RFCs) -> Rainflow counting (RFCs) histograms

P19

L21: does the best job -> reword this

L22: has been -> is

L23: three model parameters -> three parameters

P22

L1: for capturing -> to capture

L4: lead -> leads or led

L20: truncated POD -> the truncated POD

P23

L1: does the best job -> reword

L6-7: interesting that uncorrelated model looks better than OU...One wonders why

L14: less good -> reword

L23: lead -> leads

L26: perform weaker -> reword; perhaps underperform?

P24

Figure 16: I am not an expert in POD analysis but I do think you should try to appeal to a large audience and make this as clear as possible, so I must say I still don't understand whether these are a mean wake over those thousands of snapshots? Is TKE always averaged over the entire period in your paper, as one may assume from $\langle u'^2 \rangle$?

Figure 17: might want to stay away from green+red as some people can't differentiate these? Maybe the truncated POD (ref data) should be consistently black just like in previous figures you used black for the reference data set?

P25

Figure 18 caption: for capturing \rightarrow to capture

Since the uncorrelated model is random, does it produce different spectra every time you run the model, or is it robust in terms of mean spectra / mean statistics?

Figure 17-19: Tower Base Yaw Moment

Figure 18-19: this sentence is unnecessary here: "Note that we aim for capturing the behavior of truncated PODs here, as pointed out in the beginning of this section."

P26

L2: very \rightarrow remove

L3: damage equivalent loads \rightarrow DELs

P27

Figure 21: is (b) a snapshot?

Figure 22: OK it is very important here that you keep the same colorbar scale in all panels (a) through (c)

P28

L4-5: To enable direct comparison between Fig 23 and Fig 21, colorbar must be the same here too (going from 0 to 2).

L7: similar looking \rightarrow reword

L13: more high \rightarrow higher

L21: perform well or best \rightarrow reword

L22-24: didn't you just say this up above?

P29

L3: have problems \rightarrow struggle

L6-7: not sure what you are suggesting here?

Figure 23: add (a) through (f) sub captions here too.

Figure 24: Why is T time series much longer?

P30

Figure 26: Modify axes limits so as not to cut your data

Figures 24-26: Tower Base...

P32

L4: realistic \rightarrow remove word

L11: probably \rightarrow remove word