

Title: On wake modeling, wind-farm gradients and AEP predictions at the Anholt wind farm

General comments:

The authors conducted a large number of simulations using a wide variety of models, and compared simulated values with observations from SCADA. These results can be of use to the scientific community, particularly in regards to the coupling of WRF and wake models, and to the effect of the nearby continent on the wind farm production. However, the abstract, methods, results, and conclusions are not well organized and the reader is left wondering what the real contribution of the work is, and what exactly was done when it comes to specific details of the results and their relevance to the scientific community. The manuscript can be greatly improved by overhauling the organization and text, at which point it can be considered for publication.

Specific comments:

Abstract: Very scattered text. Please rewrite. This is very confusing: “*accounting for the horizontal wind-speed gradient gives nearly the same results as averaging all the wake-free wind climates at the turbines’ positions or using the wind climate of a position in the middle of the wind farm*”. Results of what? AEP? CF? Can you be more direct with the “take home messages” you include in the abstract? This does not belong in the abstract but rather in the discussion section: “*These results are specific for this wind farm, the available dataset, and the derived inflow conditions.*” Can you be quantitative in the abstract, e.g. the model uncertainty is on average x%? What are the relevant results for the greater scientific community? The motivation on page 2, lines 20-26 should be included in a reduced manner in the abstract to give a greater context to why this work is relevant and needed. Below is a rewording that you can use as you rewrite your abstract.

In this work, a wide range of models is used to investigate wake effects at the Anholt offshore wind farm. Undisturbed atmospheric conditions are simulated with WRF for an entire year, and wake effects are simulated with two engineering models (Park and Larsen) and with a linearized Reynolds-Averaged Navier-Stokes solver (Fuga). For the engineering models, linear and quadratic approaches are considered for lateral merging of wake deficits. The effect of the horizontal wind speed gradient over the wind farm on the annual energy production and on the capacity factor is quantified by coupling the WRF and wake models and by comparing the derived predictions to SCADA. Additionally, the ability of the wake models in estimating power losses is evaluated, and the relative uncertainty of each wake model is quantified by bootstrapping the SCADA and to estimate the model-specific error distributions. We find that accounting for the horizontal wind speed gradient is important when estimating the annual energy production but not critical to estimating...? We propose methods for estimating freestream flow conditions based on SCADA, when no measurements are available upstream of the wind farm and quantify their relative performance using the turbines power curve...?

Similarly for the discussion and summary, be more specific with your take home messages. Even after carefully reading the entire manuscript, it is not clear to me by the end what your main results are, and what your contribution is. Results are fragmented and scattered.

“Background” is not a good title for section 2.

Please get rid of “Park1” and “Park2” , “Larsen1” and “Larsen2” and choose more descriptive names such as “Park_Linear” and “Park_Quadratic” , “Larsen_Linear” and “Larsen_Quadratic” .

Remove from all figure captions where you have something like “details in main text” .

Be consistent with your verb tenses – either present or past. Example of inconsistency, page 14 line 1: “we use and found” .

Technical corrections:

Section	Page/Line	Comment
Entire manuscript		Don't hyphenate “wind speed” and “wind direction”. You also use hyphens in other various terms that do not call for it, e.g. wind-farm.

		Remove the figure references that are left/right and top/bottom and instead use (a), (b), ...
Introduction	2/22	“relatively close by” – be quantitative, how many km?
Background	3/9	Even after being done reading your manuscript, I still don’t understand what is the “ensemble” that you are using for your average. Please explain more clearly: is it an ensemble of turbines? Of grid points? Of models? Of runs?
	3/14-16	Please give range of wind turbine spacings within the farm, to make it easier for the reader to understand what your model grid spacing means later on. I was left wondering how much spatial interpolation is being done on a 2 km grid, when you place your turbines on the model grid.
	3/21	The dataset exclude periods where “any” turbine was parked/idling/etc.? Or only where at least some n number of turbines was parked/idling/etc.?
	22	The “;” is confusing, please make two sentences there. I don’t understand this: “power is 5% above rated power for turbines nr. 1, 36, 65, and 68.”
	23	How many of these 10-minute time stamps are in 2014, which is the portion you consider in your analysis?
	26-27	This is really confusing. Can you have a more lengthy explanation or an equation for $u_{\text{equivalent}}$? Also, you say how the “inflow reference wind speed” is estimated but what is it defined to be? How about it is defined as ... , estimated as ... , and used for ...?
	4/Fig. 1	Can you color the turbines that are used in those groups you define in Tables 1 and 2, to estimate the “inflow wind speed” and direction? Is this what you call the “inflow reference wind speed”? Does “reference” stand for undisturbed, freestream wind speed?
	4	Please explain why a group of 4 turbines is used to estimate the wind speed, and only a group of two is used to estimate wind direction? And why are the sectors defined differently? Can you please combine these two tables in one?
	5/2-12	How long was the simulation run for?
	5/10	Is the model output linearly or logarithmically interpolated to hub height? Please explain. “(the mean wind speed is 9.23 m s ⁻¹)” over these sectors or over the entire rose? How does that compare to the “inflow reference wind direction” estimated with your method and your two turbines by region?
	6/1-6	Why would you do Park1/Larsen2 for quadratic, and Park2/Larsen1 for linear? Confusing! This entire paragraph is just hard to follow, please rewrite. “We consider three different wake models: the Park wake model with the commonly-used offshore value of $k = 0.04$; the G. C. Larsen model (Larsen, 2009); and Fuga (Ott et al., 2011). Two methods of laterally merging the wake deficits are considered in the first two models: a linear sum and a quadratic sum.”
	6/7	What is “a time series basis”? Rework.
	6/9	What is a “free” wind speed/direction? Rework.
	6/11	“(≈160/340 and 45/235 deg)” confusing – write in words.
	6/15	Remove this bit starting with “;for the Anholt...AEP analysis”
	7/1-12	These two paragraphs are very confusing. Please rewrite the whole thing, even if you need to be more wordy and/or use equations.
	7/10	What is a gradient-based AEP analysis?
	7/10-12	I don’t understand this last sentence...
	7/20	I assume you can reference this pdf in a better way...
Results	7/23	Why 2014? Why is half of the year in 2013 for which you do have data, ignored here?
	8/2	By information you mean the WRF simulated wind direction at hub height? Be specific.
	8/5-7	Be quantitative – how small is the effect of the small island relative to the Djursland effect in percentage?
	8/9	Everywhere in the manuscript change “all directions” to “omnidirectional” “wind gradient” change to “wind speed gradient”
	8/10	How does the magnitude of the WRF gradients compare to those in Paul’s RANS work?
	9/1	“a effect” change to “an effect”
	9/1-4	You need to rewrite this to make it sound a bit more scientific/less speculative. It seems like you are giving a justification for the wind farm wall effect justification for this, but it is poorly worded. Also, this “similar effect” that you are using in your justification is not

		shown, so maybe say that?
	9/Fig. 5	Left panel: add small markers to points where each turbine is; Do not connect line as we move from one row to the next (e.g. turbine 30 to 31). Legend... “omnidirectional flow”
	9/7	“that that” change to “that which” “assuming a horizontally homogeneous”
	9/9	“highest impact” of what on what?
	9/6-9	This sentence is long and confusing.
	9/13	“larger than 1%” – by how much?
	9/14	“significant” may be not the best term – is this statistical significant? I’m guessing not.
	9/12-17	In Section 2 (which may be best called “Methodology”) please explain the choices of these turbines #1, #54, #65 in your analysis, as it seems very arbitrary.
	10/1	Change to “although accounting for the wind farm gradient is important, it does not”
	10/3-4	This sentence doesn’t belong here?
	10/5	This sentence is too informal, please use scientific writing practices.
	10/8	By “simulated wind climate” you mean the WRF simulated wind climate? Since you are using so many models, please be very specific when referencing your results.
	10/15-18	So confusing! Reword.
	10/footnote	I still don’t understand what your ensemble is... time series at each wind turbine location? At all the WRF grid points in the innermost domain?
	11/Fig. 6	Don’t use these abbreviations “grad” and “homo” – just spell out the entire term, there is space. What is the SCADA standard “error”? I assume this is the same as “standard deviation” but the term “error” is not usually used in this context, especially when error means something else here (simulations-observations).
	11/1-12	Why, if the flow is from the west? I don’t understand the P3<P31. Is this circling back to your blockage comment earlier on? If so, please remind the reader.
	11/5	Why this weird number, 168.7? Explain. Be more specific on which information from Table 1 is used, which group? I still don’t understand your entire process of estimating these “reference” inflows, when they are used and what for.
	12/3	Yes you do, you can use WRF output to estimate stability. Please comment on why not do it?
	12/4	Why is this interesting? Why are the differences so large?
	12/15	“performing the best” – reword this.
	12/15-17	Confusing, reword. Why is it not “fair”? Maybe “fair” is not an adequate word here?
	13/3	Instead of having these numbers in the text can you add them as another column to Table 4, just noting that for PL estimation WRF is not used just the wake models?
	13/7-13	I’m not sure about this paragraph – it sounds like a justification of your methodology and not really a result. Does it belong elsewhere, maybe Section 2?
	13/17-20	What does this mean for your analysis?
	14/2-3	It is counter-intuitive to say that positive values mean under-estimation, so reword this a bit: “where positive ϵ values denote a model that overestimates the power (i.e. underestimates the wake loss)”
	14/3	“mean $\langle \epsilon \rangle$ and standard deviation σ_{ϵ} of the distributions”
	14/Table 5	Get rid of this table and add these numbers to Fig. 9.
	16/1-5	This paragraph is completely irrelevant.
Conclusions	16/7	We “confirm” or “reiterate” – you don’t really “show” since previous work had already shown this.