Review of WES-2023-79

Gaussian wake model fitting in a transient event over Alpha Ventus wind farm
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Overview:

The work described in "*Gaussian wake model fitting in a transient event over Alpha Ventus wind farm*" endeavors to address one of the major shortcomings of analytical wake models—that they are built on the assumption of stationarity and cannot be expected to reflect changes in forcing conditions or in turbine operation. However well understood that assumption is, this does lead to misleading predictions, or high uncertainty, from many engineering models when compared to operational data. That said, this work does not attempt to update the underlying assumptions used to build the wake models. Instead, the authors simply highlight several details about the discrepancies between some wake models and high-fidelity simulations.

The work in this manuscript is interesting but does not by itself merit publication. If the authors wish to describe model errors with any statistical certainty, they would need to review a large sample of dynamic conditions (open-cell convection, and weather fronts, morning/evening transitions), and ensure that they sample wakes from turbines at different points in their operating curves. Otherwise, the most that can be said about the wake models is that, "they did not match the wakes predicted by LES in this case." Expanding the sample size would also help indicate whether there may be straightforward means of improving the models to accomodate these sorts of dynamic events. Such model improvements would be enormously valued in the wind energy industry and would be much more valuable for wind plant design, optimization, and prediction.

Major Comments:

The wakes predicted by WRF-LES and by Gaussian models are compared for only a single OCC. How sure can the authors be that the results in the manuscript are a good representation of the disagreement between models? I would hesitate to draw any real conclusions about the possible benefits of model parameter tuning or the underlying cause for differences in wake model predictions from a single sample.

Similarly, the study looks at a small region of the flow in Alpha Ventus, containing two wakes that interact strongly. The study design does not take into account that there are several possible superposition methods that could be used for analytical wake models, or the possibility of added prediction uncertainty introduced by superposition (see ref 1, below) . Other engineering models exist that do not rely on a superposition scheme. Have the authors considered using those to limit uncertainty to only the definition of the wake itself? (see refs 2—4).

> *Figure 1 . The cross-section of the inner*
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> What do the small makers downstream of AV1 indicate? Sometimes they overlap AV4 and other times they do not. Do these point out measurement areas? This does not match the 17 cross sections from the simulations described in the text.

> *Figure 2. 10-minute averaged inflow chara*
>
> I would be interesting to include AV2 in the subplots of Figure 2. AV2 is already called out in Figure 1 and comparing it to AV1 may highlight the spatial variability in turbine performance as well as inflow characteristics.

> *khoday-Paskyabi et al., 2022b). The Weather Research and Forecasting (WRF) model output acts as a dynamicdriver input for the large-eddy simulation (LES) PALM model system (Maronga et al., 2020). The LES consists of twonested d*
>
> Is PALM a normal LES framework to use within the WRF model? It would benefit the readers to explain a bit more of the details in the simulation scheme. For example, how is turbulence information exchanged between the WRF simulation and PALM? Do you use the cell-perturbation method? Have you tested sensitivity? Is the WRF simulation driven with reanalysis data? If so, what is the source?

> *Figure 3. RMSE of the Gaussian models cal*
>
> This is an interesting figure and appears to be the main result of the study. However, trying to compare results from the various models and model tunings based on the colors of each cell in the figures makes the actual data feel somewhat arbitrary and qualitative. Perhaps the figure could be replaced with trend lines comparing either the different models or the different tuning strategies. I think this would also provide a better opportunity to discuss the surprising result of the peaks in RMSE for the different models.

Minor Comments:

> *per-Gaussian model proposes two method of finding n(x): root-solving a*
>
> should be plural, "methods"

> *= 0.2√β, β = 121 + √1 −CT√1 −CT (4)
>
> Combine fractions to make equation (4) more readable.

> *as= 0.17, bs= 0.005, cs= 0.2by the direct hit from AV1 wake . Overall, this similarity allow*
>
> Rephrase.

References

1. Hamilton, Nicholas, et al. "Comparison of modular analytical wake models to the Lillgrund wind plant." *Journal of Renewable and Sustainable Energy* 12.5 (2020).
2. Martínez-Tossas, Luis A., et al. "The curled wake model: a three-dimensional and extremely fast steady-state wake solver for wind plant flows." *Wind Energy Science* 6.2 (2021): 555-570.
3. Bastankhah, Majid, et al. "A vortex sheet based analytical model of the curled wake behind yawed wind turbines." *Journal of Fluid Mechanics* 933 (2022): A2.
4. Bay, Christopher J., et al. "Addressing deep array effects and impacts to wake steering with the cumulative-curl wake model." *Wind Energy Science* 8.3 (2023): 401-419.