Report on manuscript: Swell Impacts on an Offshore Wind Farm in Stable Boundary Layer: Wake Flow and Energy Budget Analysis

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Summary

The paper quantifies the effect of swells (waves traveling faster than the local winds) using a wave-induced stress parameterization. The parameterization is implemented in an open-source Large Eddy Simulation (LES) code and used to study the impact of wave-induced stress in the wake flow and power output of a real offshore wind farm under a stable atmospheric boundary layer. Two cases are investigated, namely, wind following swell and wind opposing swell, and a detailed kinetic energy budget analysis is performed to quantify the direct and indirect wave-induced components. The paper is sufficiently detailed, and the discussions are a valuable addition to the community. In particular, the results showing the wind velocity profiles, wind direction, and budgets are interesting and the paper can be published in WES. I have a few major concerns regarding the wave model, and minor comments on adding some useful references to recent papers for wave-modeled LES simulations and ML methods for offshore wind farms.

Major Comments

- My major concern lies with the wave model. To parameterize the wave-induced stress, the authors use an empirical wave damping rate from Ardhuin et al. (2010), in conjunction with a given wave spectrum. Are there any validation studies, without wind farms, where such an approach is valid? There seem to be two tuning constants, 1) the parameter f_e, and the decay coefficient for the wave surface stress $a = 1$. From potential theory if $\tau_w \sim < u'w > \sim < u_{orb}w_{orb} >$, where the orbital velocity decays as $(u, w)_{orb} \sim \exp(-kz)$, shouldn't the most obvious choice of a be 2? What is the thought process behind choosing $a = 1$?

- By limiting the integral to ω_c the higher frequency wave contributions are accounted for in a roughness length. Why not have a similar growth rate (instead of a damping one) to account for this? There are also recent models such as [1] that calculate the stress due to wind waves. Maybe, a Charnock model is sufficient for the current work, but this is an area to consider.

- The Charnock constant α is another free parameter chosen here. Is there any rationale behind this particular value? For instance, see *Liu et al (2012)*[2] where they discuss the different values used for the constant in different models.

- Is the wave model turned on at the same time as the cooling rate, or with the neutral flow?

- In line 160, $z_0 = 0.0002$. Previously it was mentioned that z_0 is calculated using the Charnock model. This seems inconsistent. Or is the above z_0 only for the pre-runs?
- Stable boundary layer simulations are generally quasi-steady. What is the averaging window for the simulations? Is the window chosen over a range where u_* is a constant? Maybe a plot of u_* as a function of time, with the averaging window highlighted will be useful.
- If I understand the wave stress correctly, it is independent of the flow characteristics, and the wave shape is fixed. However, with the introduction of wind turbines, u_* decreases, and the wave effect should be more pronounced as the wave age increases.
- In Figure 7, can anything be said about the wake decay, i.e. does the presence of waves result in longer wakes? Is the velocity deficit formally defined somewhere in the text (is it normalized?)?

Minor Comments

- In the introduction, while discussing CFD papers for offshore wind farms, I think it is worth adding a reference to a recent review paper by *Deskos et. al 2021* [3]
- In line 45, the two Yangs in *Yang et al. (2014) and (2022b)* are different. The authors should add a citation to *Xiao S & Yang D. 2019*[4] which is relevant.
- Above line 45, the authors point out that the shortcomings of the wave-averaged (roughness length) approach can be addressed using the wave-phase resolved approach. However, there exist wave phase-aware models that lie between these two approaches [1, 5], and ML-based approaches [6, 7] that are relevant.
- Can the rationale behind multiplying the Donelan Spectrum with the exponential factor be explained?

References

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