FLOWERS Reviewer Comments II

Michael J. LoCascio et al.

April 21, 2022

Comment 1

"Thank you for your corrections. I agree with most of the changes but I find it a missed opportunity to not report the difference between the analytical and the numerical approaches for a realistic AEP calculation (using a wind speed range of 4-25 m/s instead of just a single below rated wind speed), as pointed out in my first main comment. If I use PyWake to calculate the AEP of Horns Rev II using the standard setup as reported in my first review and an equivalent setup using a constant CT=0.8 and CP=0.44 for all wind speed then I get: AEP = 1096.37 GWh instead of 702.43515771906 GWh, which is an error of 56%. In terrm of wake loss the error is about 100%. Therefore, I think you need to report the difference in AEP for a realistic AEP case and not just a single wind speed below rated wind speed (where the constant CT and CP assumption is not tested properly)."

We appreciate the comment from the reviewer. We have added a more realistic AEP calculation as requested for a wind rose with higher wind speeds on a larger wind farm. The following text is now in the manuscript:

"For a more realistic wind rose, the discrepancies in AEP between FLOWERS and the Jensen numerical integration approach are more substantial. We consider a larger wind farm of sixty turbines with $6D$ spacing in the streamwise and spanwise directions and an offshore wind rose sampled from the WIND Toolkit draxl2015wind with higher average freestream wind speeds than those considered in the previous example. Figure 1 displays the resulting flow fields from the FLOWERS and Jensen integration models. The AEP computed with FLOWERS is about 17% lower than that from the Jensen model. This greater difference between the two approaches in this case can be attributed to the assumption that C_T and C_P do not depend on the local flow velocity at each turbine, which breaks down for larger wind farms with more heterogeneity in the flow velocity. Including the local flow velocity in the FLOWERS formulation is part of future work."

We also clarify the treatment of C_T and C_P. After our previous revisions based on the reviewer's first round of comments, C_T varies with the freestream wind speed, which is itself a function of wind direction: $C_T(U_\infty(\theta'))$. This definition means that C_T is the same for every turbine in the wind farm for a particular wind direction but still varies across different wind directions and speeds. C_P is computed as a function of the average wake speed (i.e. it does not vary for different wind directions): $C_P(\overline{U})$. While this definition of C_P is an approximation and does not exactly account for its dependence on the local flow velocity for different wind directions, it does incorporate the effect of wake velocity deficits on power production (since we use the wake speed and not the freestream wind speed). Both C_T and C_P are not defined as arbitrary constants—they do include the variation in wind speed over a realistic wind rose because both are computed as a function of $U_\infty(\theta')$ (directly in the case of C_T and indirectly via the average wake speed $\overline{U}$ in the case of C_P).

The following two sentences have been modified to make this point as clearly as possible:

- "We make two simplifications to compensate: C_p is calibrated as a function of the average wake speed $\overline{U}$ (which for each turbine is a constant across all wind directions), and we substitute $\overline{U}^3$ into Eq. 13 instead of evaluating $\overline{U^3}$."
- "C_T is the thrust coefficient which is realistically a function of the local inflow speed; we simplify it to be a function of the freestream wind speed U_∞ such that it is uniform across all turbines in the wind farm but still varies around the wind rose."

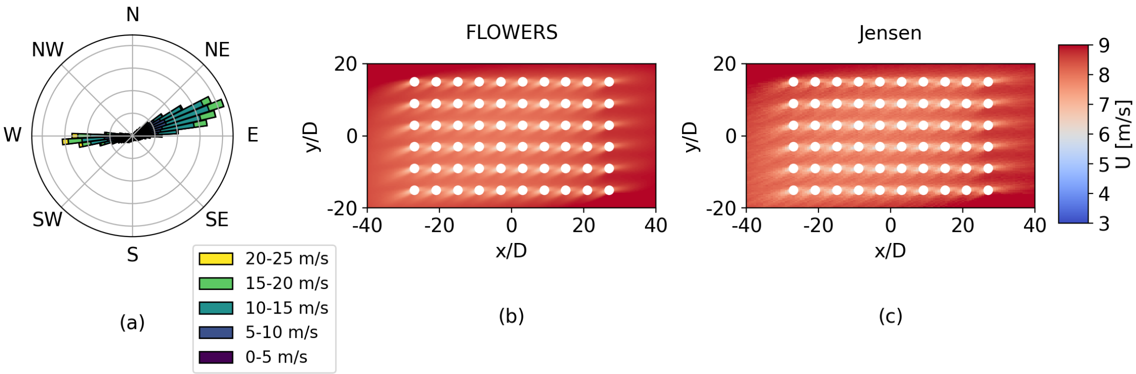

Figure 1: Flow field comparison for a sixty turbine wind farm with $6D$ spacing with a realistic wind rose (corresponding to an offshore site in the Northwest U.S.). Again, the number of wind direction bins B in the numerical method (c) is $B = 72$, and the number of Fourier coefficients in FLOWERS (b) is $N = 37$.

Comment 2

Minor point: What does s.t. stand for in equation (14). Is it 'subject to'? If so perhaps replace s.t. with subject to.

Thank you for pointing this wording out—the language of the equation is unclear. We have modified the equation to state that we are optimizing AEP subject to certain constraints:

$$\begin{aligned} \min_{x_i, y_i} \quad & -AEP\left(x_i, y_i, U_\infty(\theta'), f(\theta')\right) \\ \text{subject to} \quad & \text{boundary constraints} \\ & S_{ij} \geq 2D, \end{aligned}$$