

Referee report on “Dynamic response and loads analysis of a large offshore wind turbine under low-frequency wind fluctuations” by Syed, Hannesdóttir and Mann

The manuscript provides a comprehensive assessment of offshore wind turbine loads under the influence of low-frequency wind field fluctuations within a recently introduced extension of the Mann inflow turbulence model [Syed, A. H., Mann, J., Bound.-Layer Meteorol. **190**, 1 (2024)]. This extension accounts for potential anisotropic wind-field structures at low frequencies by superimposing an additional two-dimensional wind field on the standard Mann wind field box. The inflow turbulence model parameters for each wind bin, which, in addition to the standard parameters (integral length scale L , variance of wind field fluctuations, and shear distortion parameter) include an anisotropy parameter ψ , a correlation length of two-dimensional wind field fluctuations, and a high-frequency cut-off z_i , are extracted from ultrasonic anemometer measurements recorded at FINO1. Using aeroelastic simulations, it is explicitly demonstrated that including low-frequency components in the wind field increases the damage-equivalent loads (DELs) of an IEA 15 MW turbine compared to the standard 3D model and primarily affects thrust-related moments, such as the tower base fore-aft and blade root flapwise moments. A third wind field is also introduced, based on the original Mann model and matching the variance of wind-field fluctuations in the extended (2+3)D model, with increased kinetic energy at high frequencies. The aeroelastic simulations are also repeated for a floating wind turbine setup.

The manuscript is well written and certainly of general interest from both an academic and an industrial perspective, as it provides a more realistic load assessment and modeling of wind turbines that are susceptible to long-lived, anisotropic wind-field structures offshore. I recommend publication in Wind Energy Science after the following comments have been taken into account:

General comments:

1. Although the results presented in Fig. 5 are rather interesting, I have some difficulties with their interpretation and the study’s overall design: Intuitively, adding an additional 2D wind field to an existing 3D field increases the kinetic energy content of the wind field, as shown in the variance plots of the u - and v -components in Fig. 4. Therefore, one might actually expect that damage-equivalent loads are increased for both the new (2+3)D wind field model and the rescaled 3D model. I would suggest strengthening this main part of the manuscript to make the study clearer: It seems that the rescaled 3D model (green) in Fig. 5 only shifts the DELs and does not result in any shape change, unlike the extended model (orange). How can the higher variability in DELs for the (2+3)D wind field model in Fig. 6 be explained? How do the wind field structures change? As mainly thrust-related moments are affected, it might make sense to depict slices through the rotor planes of or even isosurface volume renderings of the u -components which produce high-amplitude events, e.g., in the tower base fore-aft or blade root flapwise moment time series.
2. If I understand correctly, the model parameters are determined for each wind bin using the FINO1 measurement data, i.e., they vary across wind bins. For the anisotropy parameter ψ , for instance, it appears that deviations from isotropy are rather small except in the low- and high-wind speed regimes. This could also be attributed to a lack of statistical convergence (see Fig. 1 (a)). To assess this, it would be beneficial to i.) include error bars (e.g., from the least-squares of the spectral fits), and ii.) determine the total length of the time series in neutral conditions in FINO1.
3. In synthesis of points 1. and 2., it appears that, at least in the test case of FINO1, anisotropic two-dimensional wind field structures appear only as slightly oblate spheroids (see also [Syed,

A. H., Mann, J., Bound.-Layer Meteorol. **190**, 1 (2024)). Do the authors have any intuition or perhaps even preliminary studies for what systematic changes in ψ would imply for the damage-equivalent loads?

Specific comments:

1. In l. 45, the acronym TIMESR is not defined, and it is not clear to which of the references this model belongs.
2. Concerning the generation of the three different wind fields, for comparability, I assume that the authors used the same random seeds for the wind field generation of the underlying 3D Mann wind field box, correct? If yes, I suggest adding a sentence on this issue in Section 2.2.
3. In l. 164, it is stated that the rescaled 3D Mann field has higher PSD at high frequencies, and the authors refer to Fig. 7 corresponding to the tower fore-aft moment. However, in this plot, I only see deviations at low frequencies. Perhaps this sentence refers to Figure 8?