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Interactive comment on "Understanding and mitigating the impact of data gaps on offshore wind resource estimates" *by* Julia Gottschall and Martin Dörenkämper

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We thank Reviewer 2 for the positive words about our manuscript and the thorough evaluation. We address every point raised by the reviewer separately below.

Specific Comments:

[RC2SC1]: P1L6-7: sentence unclear "mitigation of the gaps' impact by a factor of ten ..."

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Thank you. In the revised version of the manuscript, we have changed this sentence to "We find a mitigation of the data gaps' impact, i.e. a reduction of the observed biases, by a factor of ..."

[RC2SC2]: P1L12: wind resource also is often re-assessed based on the WTG and sometimes a met-mast, all of which also may have gaps.
We have added the following sentence to account for the comment of the reviewer: "During the lifetime of a wind farm re-assessments are also typically done that can be based on wind turbine or further wind measurement data."

[RC2SC3]: P1L15-16: would be interesting to quantify the impact of the uncertainty in terms of the wind project value, e.g. a 1% uncertainty in the wind speed that results in 2% or more uncertainty of the wind farm production which is almost directly related to the earning and compared to an expected return of investment of e.g. 8%.
Good point. We have added the sentences "Consequently, uncertainties and a possible bias in the wind resource estimate propagate up to the financing of a wind project with the percentage uncertainty value increasing from uncertainty in wind speed to uncertainty in wind farm production to uncertainty in the expected return on investment. Thus to reduce these uncertainties starting from the wind measurements is of high interest and relevance." Sorry we could not find a suitable reference for explicit numbers.

[RC2SC4]: P4L3-11: Filling gaps with data from below scaled by the ratio of mean wind speeds is unnecessarily rough. Luckily the wind speed gaps in the raw measuremetns at the considered heights of 92 m are very short so this probably does not have a significant impact to the outcome of the whole wind speed analysis. Nevertheless, if possible, it would be necessary to apply a more refined method (e.g. using the extrapolated wind profile from two data points below on a 10-minute basis).

As shown in Figure 2 the data sets were very complete even before the gap filling applied here. In case of FINO3 and Ijmuiden the filling was less than 0.5 % of the values. The measurement period selected was also based on consideration of the availability of the mast data. We didn't aim for having a precise filling of these small gaps here but rather tried to generate a complete time series for the methodology in the later steps.

[RC2SC5]: Table 1: The wind distribution parameters A and k are presented, but what are their confidence intervals (Weibull fitting is not perfect because the wind is not entirely Weibull distributed)? Further analysis in the paper should then take these confidence intervals into account when the impact of the gaps, and of their mitigation, is presented and discussed. (e.g. P10L30, the error of the k is reduced from 0.017 to 0.007, but what if the uncertainty of the computed k is e.g. 0.1 in the first place?).
We agree that the confidence intervals should be considered when integrating such an analysis in a WRA study (in particular, when assessing the final uncertainties of the wind resource estimates) but for our study it is out of scope. For offshore conditions, the Weibull distribution is a pretty good approximation.

[RC2SC6]: P7L3: Please use the common terminology for NWP and climate modelling: "longitudinal" → zonal, "lateral" → meridional
Changed Accordingly. Thanks.

[RC2SC7]: P9L6-7: "start state" or perhaps "start date"?
It should be "start" only. We removed the "state". Thanks.

[RC2SC8]: P10L14-15: while I agree that it would not add much to the study to use a sectorwise approach in the linear correction, it is probably not completely true that

50 km is a sufficient distance (from the coast) that such an approach would not be necessary. Please delete this claim.
Deleted as suggested by the reviewer. Thank you.

[RC2SC9]: Please show the magnitude of the noise applied. Applying a random noise in such a way poses a risk that the resulting time-series loses its physical consistency.
Thanks for pointing this out. For clarification we have added the sentence “The noise factor ensures that the generated time series does not lose its physical consistency." after "... a noise factor is derived as standard deviation of the data per bin, and combined with a white-noise process in the prediction step." to the revised version of the manuscript.

[RC2SC10]: Figure 6 (and associated analysis): is there any dependency of the gap-filling success on the WRF errors (as compared with the non-gapped met mast data)? I.e. there is a certain match between the gap impact itself (red line) and the error of the corrected series (blue), but what makes this correlation not perfect? Model error, or another (stochastic) effect?
We have investigated the bias between the original numerical (WRF) data and the observations and could not identify any significant dependency (cf. RC1SC7). Instead, we believe the varying “success” of the gap-filling procedure depends on how representative the correlation period is for the gap, i.e. the period that needs to be predicted within the MCP framework. If the gap corresponds to a significant part of a season, this part will not be well represented in the data basis used for correction. A refined MCP approach may balance this deficit at least to some extent.

[RC2SC11]: P11, section 3.2.1.: please clarify if WRF is also used for gap-filling when ERA5 is used for the long-term extrapolation?
Thanks for pointing this out. We have added the half-sentence “.., while the gap-filling

is still based on the mesoscale model data as before."

[RC2SC12]: P11L10: Using ERA5 directly for MCP is authors' choice and should be stated like this. Typical case is to use downscaled e.g. ERA5 (Windpro/ConWX, Vortex, ...).
We agree that at onshore sites, downscaled data are more commonly used. For offshore sites, newer studies showed that ERA5 data already provide very good results, see e.g.

Dörenkämper, M., Olsen, B. T., Witha, B., Hahmann, A. N., Davis, N. N., Barcons, J., Ezber, Y., García-Bustamante, E., González-Rouco, J. F., Navarro, J., Sastre-Marugán, M., SÄńle, T., Trei, W., Žagar, M., Badger, J., Gottschall, J., Sanz Rodrigo, J., and Mann, J.: The Making of the New European Wind Atlas – Part 2: Production and evaluation, Geosci. Model Dev., 13, 5079–5102, https://doi.org/10.5194/gmd-13-5079-2020, 2020.

[RC2SC13]: Table 3: again, these results should be accompanied by the underlying uncertainty in the calculation of the statistical parameters.
Thanks. We have added the sentence: "Uncertainties or standard errors in the estimation of the parameters are not further considered here and in the following as they are small compared to the reduction of the gap impact which is the focus of this study." at the end of 3.2.

[RC2SC14]: P18L5: why do you say that gap-filling should be an integral part of wind resource assessment?
According to MEASNET Guideline "Evaluation of Site Specific Wind Conditions" data gaps should in general be filled, although the recommendations therein focus on filling

those with data from other heights or different sensors and are thus more related to the classical onshore approach of met mast measurements. We show in our study, that the gap filling does not improve the long-term assessment. However, our data gaps were rather short, which could change for gaps that cover e.g. periods of a whole season or when not only the long-term statistics are relevant but average time series, e.g. diurnal wind speed changes are of interest. Thus, we suggest to modify the sentence the reviewer referred to: "We believe that a specific gap-filling approach should be an integral part of the wind resource assessment process that is applied by a specific consultant for a specific site as it improves the wind statistics of the measured period and can potentially also reduce the uncertainty of the long-term assessment."

[RC2SC15]: Figure 11 shows that gap-filling or not has no impact on the long-term wind assessment.
This is correct. After a comment of Reviewer 1 (see [R1SC10], we put more emphasis on this (quite central) finding.

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