

Response to Anonymous Referee #1, wes-2020-134

The authors would like to thank the referee very much for the extensive feedback and the numerous and valuable comments. We consider these very helpful and are sure that they will help to improve the quality of our paper. In the following, we present how we considered and incorporated the remarks into the revised manuscript (responses in [blue](#)).

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General comments

The preprint “Seasonal effects in the long-term correction of short-term wind measurements using reanalysis data” by Alexander Basse et al. deals with Measure-Correlate-Predict (MCP) methods in the context of a shorter-than-standard measurement periods (3 month instead of 1 year).

The long-term correction of in-situ measurements is an important step of any wind resource assessment for developing a wind farm. Thus, the topic is very relevant for the wind energy industry. In particular, this focus on 3-month measurements could help make a better use of preliminary or incomplete measurement campaigns.

Among the variety of MCP methods, the authors investigate 2: the Variance Ratio and the Linear Regression with residuals. This choice is relevant as they are amongst the most used MCP methods. The question is addressed on a theoretical level and using a large set of wind-speed measurement data (18 sites) and a set of 6 relevant reanalyses as long-term reference data.

Despite those qualities, some flaws in the theoretical analysis impair the argumentation and conclusions. The major issue being that the role of the correlation between measurements and references is not enough considered nor investigated. The measurement data set is also under-exploited as site differences (arising from various terrains, various correlations to the reference data, or various measurement years) are not taken into account to analyse the results.

Sections 4 & 5 are too long, difficult to follow, for little conclusion. They could be written much more concisely. The reading is also impaired by grammatical mistakes and awkward phrasings.

[Thank you for your appreciation of our paper as well as the general remarks, which we considered below in the responses on the specific comments.](#)

Specific comments

Title. The title does not make clear that you are dealing with non-standard MCP, using only 3 months of data, not 1 year. Maybe rephrase it?

[We agree that the title does not refer to 3-month periods. However, we assume that our main conclusions are valid relatively independent of the measurement duration \(we mention that in, e.g., lines 233-237 of the revised manuscript\). Moreover, we feel that the term “seasonal” in the title already gives a sense of periods less than one year. We therefore would like keep the title as it is.](#)

§1 Introduction

L25: I don’t think that a “combination of observations and numerical models” is a fair definition of reanalysis.

[We agree and changed the explanation of the reanalysis in the revised version to “Reanalysis data sets are produced using numerical weather simulations with a fixed state-of-the art model and assimilating historical weather data. In contrast to models used for weather prediction,](#)

which are often updated and changed during operations, they therefore provide temporally consistent data sets over periods of up to several decades.” (lines 25 ff. in the revised manuscript).

§2 Data

L80 “an entire year”. Could you precise (in Table 1 or elsewhere) which year is available at each site? Are they all from the same year or from various years? You should also add some information about the average wind speed at each site and the correlation coefficient with each reference data set. All of this is important to understand the results.

In the description of Table 1 we write “The measurements were carried out between May 2013 and April 2019”. We agree that more information on the measurement periods would be helpful. Unfortunately, we are not allowed to give further information on the exact period nor the wind conditions at the individual sites as this is commercially sensitive (data partly obtained from wind industry). The one-year periods are distributed relatively homogeneously between May 2013 and April 2019; only the year 2016 may be judged slightly over-representated (with eight of the 18 sites covering at least a few months of the year 2016). We added these information on the temporal distribution of the measurements in the revised manuscript (lines 83 ff.). Regarding the correlation coefficient we added some further information as well (see below, §3.3).

L93: MERRA-2 is also available as instantaneous values (at hourly resolution). Why not use this data set instead of the time-averaged one?

We think that it is consistent to use the time-averaged MERRA2 data and not the instantaneous values, since the measurements represent averaged values as well. Moreover, we face the scale difference between measurement and reanalysis data (point values versus grid cell data). This impairs comparison of spot values, while temporal averaging will help at least a little. Therefore, we preferred time-averaged reanalysis where available. We agree that investigating the instantaneous vs. averaged MERRA-2 data could be interesting as well, but is beyond the scope of this work and would not contribute to the main conclusions drawn from the analysis.

§3 Methodology

L128: you should state more clearly in this paragraph that, in this paper, $ST=3$ month and $LT=1$ year, while, usually, $ST=1$ year and $LT=10-20$ years. You should consider adding a graph or something to better explain your notations and the connexion between the various series (a. finding correlation between u_{meas} and u_{ref} ; b. predicting $U_{corr,LR/VR}$ from U_{ref} ; c. verifying U_{corr} against U_{meas} ...).

We state the discrepancy to a “usual” LTC ($ST=3$ month and $LT=1$ year) in lines 142 ff. As recommended, we added a diagram for a better understanding of the notations and the procedure in the revised manuscript (Figure 1). We prefer to present these additional information after having explained the general procedure as we feel this facilitates the understanding for the reader.

§3.3

This section should contain the actual definition (formulas) of the scores. In fact, Err_{mean} and Err_{var} are never defined in the manuscript (except that Err_{mean} is given L250-251, but called “theoretical” there, why?). And the figures are given in %: % of what? How do you normalize?

We agree and added the definitions at the respective passages. The error scores are calculated as relative values, e.g., $Err_{\text{mean}} = \frac{\bar{U}_{\text{corr}} - \bar{U}_{\text{meas}}}{\bar{U}_{\text{meas}}}$, which is why they are given in %. We expect that this becomes clearer now that the formulas are given in the manuscript. We call $Err_{\text{mean,theo}}$ "theoretical" in order to make clear that this factor represents a theoretical, mathematically derived parameter (in contrast to the experimentally derived errors shown in the diagrams).

[major issue] You apply the MCP methods to all sites and periods with all references. Is the correlation between reference and measurements high enough in all cases? Linear MCP methods should not be used if the correlation is low. If some combinations of [site, period, reanalysis] do not meet this criterium (with a sensitivity analysis on the correlation threshold), they should be removed from the results.

We calculated the correlation coefficient of all combinations of site, reanalysis data set and short-term period. In most cases, the correlation coefficient was > 0.65 throughout the whole year despite the small amount of only 90 days of data. We feel that showing all of these is too extensive, but we give some numbers in the revised manuscript (see lines 158 ff.). In general, this work explores the use of MCP methods and the implications of their usage under non-ideal conditions – i.e. measurement periods, which are much shorter than a year. Therefore, we think that quality indicators like correlation coefficients are not expected to match the standard criteria.

The correlation coefficient certainly is an important measure when considering long-term corrections. Therefore, the influence of the correlation coefficient is explored in the analysis. Our results suggest, however, that it is not the decisive criterion for deciding whether a long-term correction using short-term measurement data can be performed; instead, the (expected) accuracy should be used - i.e., the errors which are presented in the respective figures. However, the temporal variation of the correlation coefficient (as shown in Fig. 5) is crucial especially when linear regression is applied.

All results are shown averaged over all sites. First, it is not always clear how you average the sites. It should be detailed in this methodology section.

We agree and added some information on that in the methodology section (lines 153 ff.).

[major issue] Then, what about the variability across sites? You address it only at the very end of the manuscript (and not in a satisfactory way). But in the first figures, we have no idea whether the "average" behaviour is representative of all sites and if the differences between references are significant or not. There should be some intervals associated with the mean curves. (+previous comment on the need of maybe removing some sites).

We agree that more information on the variability would be useful. Unfortunately, adding intervals (error bars) to the mean curves would make the diagrams cluttered and confusing.

Therefore, we had decided to address the variability in a dedicated section. In the revised manuscript, we added the standard deviation (as a measure of variability across the sites) of Err_{mean} in the respective figure (Fig. 11 in the revised manuscript). Furthermore, in lines 387-388 of the manuscript, we added a remark that analysis on the variability is presented in a later section.

We restricted the variability analysis on Err_{mean} and Err_{turbine} as we expect these parameters most useful for the wind industry. As shown and discussed, the error in variance generally can be regarded to be of minor importance for wind energy applications; the same applies to Err_{ED} . Hence, we feel

that showing all standard deviation values would make the paper too long with only little additional valuable information.

§4 Theoretical considerations

§4.1

This section is confused between the energy density (energy available in the wind, proportional to u^3) [let's call it ED] and the power production i.e. the output of a wind turbine (not proportional to u^3 because of the shape of the power curve) [let's call it PP]

- L221-222 “the wind power (...) target value of a WRA” . This is PP
- L224 “power in wind P”: this is ED, not PP

We apologize for the confusion. We corrected the respective passages.

And since PP (what we want) is not proportional to u^3 , I do not find this analysis very relevant. Using u^3 puts way too much weight over high wind speeds that finally do not produce power (>cut-out) or only the nominal power.

In this remark as well as in remark to § 5.4.3, the following issues are addressed

- a) a lack of representativity when one power curve is selected (error score Err_{turbine})
- b) a lack of relevance for the wind industry when u^3 is considered (error score Err_{ED}).

On aspect a): As suggested below, we tried two further power curves (significantly lower and higher rated wind speeds than the power curve being used in the study so far). The results differed slightly with regard to the amplitude of Err_{turbine} , but the essential conclusions remained the same. We added a remark on that in the revised manuscript (lines 228-231 in Sect. 3.3).

On aspect b): We agree that the accuracy in energy density is not of primary interest for the wind industry. However, its strength lies in the general validity (independent of a power curve). Therefore, we decided to use

- 1) Err_{ED} as a power-curve independent error score for the energy in the wind (moreover, Err_{ED} might be interesting for different aspects of research, if not for industry)
- 2) Err_{turbine} as an error score which depends on the selected power curve but shows a high relevance for wind industry. We used the same power curve also in an earlier publication (see <https://doi.org/10.3390/rs12071091>) successfully and therefore think it is advantageous to keep 1) and 2).

§4.2

Eq 13: I do not find this decomposition so relevant. It is difficult to interpret because it is a difference, not a sum, of 2 terms.

The goal of this formula was to reveal the different influencing factors on the bias in mean wind speed when a long-term correction of short-term wind measurements is performed. In our opinion, it delivers the mathematical background for understanding the seasonal biases. We are not convinced that a sum would make it easier to interpret than a difference. In contrast, we would expect that the difference allows a better understanding that both terms act in different directions.

§4.3

L282-284: I am not sure that this is the right conclusion.

If we want $\text{var}(U_{\text{corr}}) = \text{var}(U_{\text{meas}})$, Eq 15 gives: $\text{var}(u_{\text{meas}})/\text{var}(U_{\text{meas}}) = \text{var}(u_{\text{ref}})/\text{var}(U_{\text{ref}})$

Hence, what is important is that the ratio ST-variance over LT-variance should be similar

in the reference and the measurement. So, if a reference is always under/over-dispersive, it could OK (regarding this particular aspect). Also note how this relates to the parameter d_{var} introduced later in §5.3.

We agree that the whole passage is a bit misleading and, therefore, rephrased it in the revised version. Furthermore, we changed the order of the terms in Eq. 15 (Eq. 14 in the revised manuscript) to

$$\text{Var}(U_{\text{corr}}) = \text{Var}(u_{\text{meas}}) \cdot \frac{\text{Var}(U_{\text{ref}})}{\text{Var}(u_{\text{ref}})},$$

hoping that this further facilitates understanding the conclusion.

L290-292: You did not explain how the residual distribution is fit, i.e. how σ_{ε} relates to the other properties (and I could not access the reference paper). Hence some questions:

- Is it possible to really distinguish between effects 2 & 3?
- Isn't effect 3 important and worth investigating? You do not mention it ever again.

We added some information on how σ_{ε} is calculated (lines 194-198). Furthermore, we agree that $r_{\text{ref,meas}}$ and σ_{ε} are strongly connected (higher scatter around the fitting line generally results in lower correlation and higher σ_{ε} values) and can/should not be treated independently. We added a remark on that in the respective passage. Because of this relation between $r_{\text{ref,meas}}$ and σ_{ε} , we restrict the analysis on effects 1. and 2. (lines 310-313 in the revised manuscript).

§ 5 Experimental results

§ 5.1 to § 5.4.1

L313: it is unclear why you introduce this particular parameter d_{mean} , not directly related to the previous theoretical considerations.

In fact, you could have linked d_{mean} to Err_{mean} . If you go further from Eq (13), you would see that:

$$\text{Err}_{\text{mean}} = \text{mean}(U_{\text{corr}}) - \text{mean}(U_{\text{meas}}) = -\beta_1 U_{\text{ref}} d_{\text{mean}} + \dots$$

This explains what you see in the experimental section.

From our perspective, it is useful to introduce a figure, which enables to identify differences in the seasonal courses of reanalysis and measurement data. In our opinion, this figure can only be defined in a sensible way by either a difference or a ratio of wind speeds in short and long-term period.

Hence, as an alternative to our approach it would be possible to define d_{mean} as

$$d_{\text{mean}} = \frac{\bar{u}_{\text{ref}} - \bar{U}_{\text{ref}}}{\bar{u}_{\text{meas}} - \bar{U}_{\text{meas}}}$$

In this case, Eq. 13 could be transformed to contain d_{mean} as suggested in the comment. For the original definition in the paper ($d_{\text{mean}} = \frac{\bar{u}_{\text{ref}}}{\bar{U}_{\text{ref}}} - \frac{\bar{u}_{\text{meas}}}{\bar{U}_{\text{meas}}}$), rewriting Eq. 13 as $\text{Err}_{\text{mean}} = \text{mean}(U_{\text{corr}}) - \text{mean}(U_{\text{meas}}) = -\beta_1 U_{\text{ref}} d_{\text{mean}} + \dots$ is not easily possible.

However, the formulation of d_{mean} above brings other problems. In periods of similar wind speeds in short and long-term period (i.e., $\bar{u}_{\text{meas}} \approx \bar{U}_{\text{meas}}$), the denominator takes values close to 0 and d_{mean} becomes very large (positive or negative). This cannot be depicted in a diagram appropriately, which is why we had decided against this option.

Therefore, we decided to introduce d_{mean} as a measure for presenting and intuitively understanding the differences in the seasonal courses of reanalysis and measurement data - despite the fact, that it cannot directly be included in the theoretical analysis in a sensible way.

The same applies for the parameter d_{var} accordingly.

L330-341 (§ 5.2): it feels like you are discovering that $\beta_{1, \text{VR}} > \beta_{1, \text{LR}}$ while this is central and should be obvious from the start.

We rephrased the text in the revised manuscript to avoid this impression.

L345: again it is unclear why you introduce this particular parameter d_{var} , and how it relates to the theory in §4.3.

Please see our response above regarding d_{mean} .

L381: of course the differences between LR and VR arise from β_1 . This should be stated much earlier and investigated thoroughly.

Considering that $\beta_{1, \text{LR}} = r^2 \beta_{1, \text{VR}}$, the correlation coefficient is very important and should be considered way before §5.4.2

We agree and therefore had addressed these differences in β_1 in a distinct section (Sect. 5.2). In the revised manuscript, we moved the parts regarding the correlation coefficient to this (earlier) section.

You should also try to understand the differences between seasons and sites originating from β_1 :

- $\sigma_{\text{meas}}/\sigma_{\text{ref}}$: whether the reference is under/over dispersive: how does this vary spatially, temporally and among reanalyses?
- [for LR only]: r^2 : how does the correlation vary across the sites and across the year? Why is the correlation lower in spring? Is it a general conclusion or is it linked to one/some particular(s) year(s)? (Are all the measurements from the same year or very different years? cf. Data section)

The temporal variation as well as the variation among the reanalyses is shown in Fig. 3 (a) (β_1 equals $\frac{\sigma_{\text{meas}}}{\sigma_{\text{ref}}}$) and Fig. 4 (in the revised manuscript: Fig. 4 (a) and Fig. 6). We added a corresponding remark in Sect. 5.3 to make this clearer to the reader (lines 371-372).

We decided to exclude the discussion about the spatial variation of the statistics $\beta_{1, \text{LR}}$, $\beta_{1, \text{VR}}$, and the correlation coefficient as it would extensively increase the scope of the paper instead of keeping the focus on the systematic biases in an LTC. Furthermore, our data basis of 18 sites is not sufficient to derive reliable results when trying to separate the influences of seasonality, spatial variation and different years. We therefore restrict the analysis here to average behavior.

Regarding the correlation coefficient, please see our comments above (§2 and §3.3). Additionally, we added a remark on possible reasons for the lower correlation for spring/summer periods (atmospheric stability, lower wind speeds). We certainly think that the conclusion can be drawn generally for Central Europe / Germany as the measurement periods originate from different years and sites (see comment above, §2).

L406-431: some literature review that might be better in the introduction?

We agree that this literature review would also fit well in the introduction. On the other hand, we feel that a direct comparison of the results obtained in Sect. 5.4.1 with results from literature is helpful for the reader to judge the validity of the results at this point. We therefore left this passage in this paragraph.

§ 5.4.3

For the "ED" score: why not use $\text{mean}(u^3)$ directly?

We use Eq. (10) for calculating Err_{ED} in order to directly present the influences of Err_{mean} and Err_{var} on Err_{ED} and to compare the results to Err_{turbine} .

As we write in lines 464-466 (lines 494-496 in the revised manuscript), we tested $\text{mean}(u^3)$ directly. We decided against showing both ($\text{mean}(u^3)$ and Err_{ED} from Eq. (8)) for means of the length of the paper.

And relevance for the industry (cf. §4.1)?

The results of the "turbine" score may depend a lot on the turbine's choice (especially its rated wind speed, here 14 m/s, and, to a smaller extent, its cut-in wind speed). Did you conduct any sensitivity analysis? If not, you should try several power curves having different rated wind speeds.

Please see our response above (§4.1).

§6 Conclusions

L541: "Short-term wind measurements are recommended to be conducted in periods of representative wind conditions", but the whole point of a MCP method is to correct the fact that the ST period is not representative of the LT!

In practice,

- how would you know that a ST period is representative enough?
- given the very high inter-annual variability in wind speed, even if the ST period is in spring or fall, it does not seem that you could guarantee that they would be close to the LT mean, does it?

We admit that the question of "representative periods" is rather opened than answered. Of course, you cannot know in advance what a representative period really is (nor guarantee representativity). However, from our study we learned that transitional seasons (spring, fall) are most likely to give the best results while showing representative wind conditions (in terms of mean wind speeds similar to the average mean). We rephrased the respective passage accordingly.

Have you considered the possibility of non-contiguous 3-month periods? For example if a LIDAR is moved around 3 or 4 sites, changing place every month?

We agree that this would be an interesting aspect to analyze with a good chance to gain more accurate estimates (while, on the other hand, too extensive for this paper, we assume). Additionally, from our experience in practice, splitting the (already short) measurement periods in two campaigns is not very attractive for the wind industry (probably because of the relatively high effort and costs for moving the lidar).

Technical corrections

Maybe use different notations for residuals in Eqs 1 and 6.

We accounted for that in the revised manuscript.

Subscript labels (meas, ref, LR, ...) should be typeset upright, not italicized (use $\mathrm{\}$ in LaTeX). Idem for mathematical function "var". And "Err" in italics is weird, maybe use a symbol instead, e.g. δ or Δ ?

We considered this in the revised manuscript. We prefer "Err" versus δ or Δ as the latter are commonly used for (absolute) differences, not for relative deviations.

L182: you could say "zero mean" instead of "mean μ " (confusing)

We considered this in the revised manuscript.

L345 (Eq 18): the subscripts say "tar" instead of "meas"

We corrected this in the revised version, thank you.

English:

- Revise the use of "which": missing commas (e.g. L 28, 45, 144-145, ...) ; improper structures (e.g. "relationship are derived which trace..." L8, "studies have been presented which ..." L47, "is given which" L153 ...)
- Revise the position of frequency adverbs, which should be placed after a form of the verb to be ("often" (L 56, 144), "generally" (L 28, 111, 154, 494), "usually" (L 140, 251) ...)
- Revise the use and positioning of "therefore"
- Revise punctuation. Consider adding some commas: some are absolutely necessary (e.g. L33 before "providing", L180 before "giving" etc.) ; some would be useful in long sentences (e.g. L144 around "in practical applications", L147 after "For... periods" etc.)
- L44: round-robin (no capital, I think)
- L105: time inconsistency "have replaced (...) did"
- L114 and later: "annual/seasonal course": wouldn't "seasonal cycle" be a better term?
- L135, 305 etc.: 90-day periods (not 90-days)
- L187: the VR method is proposed as ... (verb position)
- L235-236: rephrase (a value is not "present" at a site)
- L251, 257 and other places: when speaking of bias, maybe use terms such as "difference" instead of "deviation"
- L259: remove ",hence,"
- L279: redundancy "respective (...) respectively"

- L279 and later: uncommon abbreviations “cmp.” and ‘s.’: maybe use “cf.” or “see”
- (...)

Thank you very much for this comprehensive list of language improvements, which we really appreciate and considered when revising the manuscript.