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Geoscientific Model Development Discussions

Interactive comment on "A priori selection and data-based skill assessment of reanalysis data as predictors for daily air temperature on a glaciated, tropical mountain range" *by* M. Hofer et al.

M. Hofer et al.

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Reply to the review of Anonymous Reviewer # 2 on our manuscript:

"A priori selection and data-based skill assessment of reanalysis data as predictors for daily air temperature on a glaciated, tropical mountain range"

Revised title:

"An empirical-statistical downscaling method for data-sparse, glaciated

mountain ranges: application to reanalysis data predictors for daily air temperature

(Cordillera Blanca, Peru)"

We would like to thank the editor for obtaining the reviews, and for accepting the delay of our response due to the lead author's maternity leave. We would also like to thank the two anonymous referees for providing very helpful and constructive comments on our manuscript. Without doubt, the comments of both referees helped to improve our manuscript significantly, and we were able to address each of their remarks. We have restructured and reformulated large parts of the manuscript, for more clarity, and to facilitate reading. Note that we have also modified the title of the manuscript (see above). Please consider our detailed responses below, where we refer to our original manuscript (reviewed by the referees) as the "original manuscript", and to the new, modified manuscript as the "revised manuscript".

Marlis Hofer, Ben Marzeion, and Thomas Mölg

General comments by Anonymous Reviewer # 2

"*For a number of mountainous areas, the climate data are of high importance to study, for instance, the impact of the climate on available water resources. However, it is difficult to obtain long and continuous observational records - especially in glaciated areas - where data are usually affected by instruments dis-functionalities due to complex topographical features. Thus, empirical or statistical downscaling methods can be seen as a simple and promising alternatives to fill these gaps. Nevertheless, ESD model applications to short time series have been neglected by the scientific community during the last decade making this work relevant to overcome this limitation.*

The paper presents an ESD model tailored for short observational time series (less

than ten years of daily data) and discusses various aspects related to ESD calibration and evaluation purposes. In the ESD model, predictand are daily air temperature at automated weather stations located at the Cordillera Blanca, Peru (local scale). The predictors are outputs from global reanalysis data (large scale). Seasonality, predictor selection and model skill estimation procedure are also discussed in the paper. The main finding of this paper is the estimation of the minimum length of observational records which is required to provide a statistically significant model skill. This can definitely help in measuring new climate data at specific sites for shorter periods with minimum cost.

The several analyses performed here are innovative and have the merits to be published. There is, however, a need to reorganize the paper differently which will definitely help the the reader. In addition, the authors must clearly distinguish between results from previous studies and the new key main point findings of this work. The several hypothesis must be discussed and argued in more detail to avoid confusions. Also, in some sections, the titles are not appropriate."

Reply: We agree with the referee that the structure of our original manuscript needed improvement. We have accordingly done a revision. We have also renamed some sections, and put efforts into clearly distinguishing between the primary results of our article, and findings from earlier studies. For more details, please see our responses to your specific and technical comments below.

"*Section 4.3 seems to be the main core of the paper but appears late in the manuscript. The model calibration and cross-validation seems to be the innovative part of the work and need more highlights. However, my big concern is whether the authors are aware about the Jackknife method commonly used for parameter estimation errors and cross-validation purposes. It is stated from the wikipedia page that "The basic idea behind the jackknife variance estimator lies in systematically recomputing the statistic estimate leaving out one or more observations at a time from the sample set. From this new set of replicates of the statistic, an estimate for the bias and an estimate for the variance of*

the statistic can be calculated." (please refer to the following WIKIPEDIA link for more details about the method http://en.wikipedia.org/wiki/Resampling28statisticsincludes a list of useful references). It seems like the "JackKnife" method has been used here to give a better estimate of the Skill Score (SS) compared to the r2 statistic. The authors must definitely discuss on how their methodology is different from a Jackknife method."

Reply: In fact, leave-one-out cross-validation (applied in our study) is often mistakenly referred to as "jackknifing", because it is technically the same resampling method. However, the "jackknife" has a different purpose than cross-validation, namely, to compute the sampling distribution of a statistic nonparametrically. Cross-validation, by contrast, seeks to estimate model performance (as in our study, e.g., by means of the skill score). In the revised manuscript, we have added a quick note to avoid confusion.

"*The overall linguistic quality of the paper is acceptable. There is a need to 1) shorten long sentences (see detailed comments), 2) avoid unnecessary extensive use of parentheses, be consisitent with definitions and acronyms, and review missing and wrong references in the text (e.g. page 2906 – L1 : Sect. 9!) and figure's caption. This will facilitate reading the paper*."

Reply: We have put particular effort into shortening long sentences, and eliminating relative sentences, wherever this could improve the fluency. We have also double checked the manuscript for consistency in the use of abbreviations and acronyms.

"*To summarize, the paper could be considered for publication provided major modifications and quality improvement of the text by addressing the several concerns previously mentioned and taking into account the following specific and detailed comments*."

Specific comments by Anonymous Reviewer # 2

"*Sections 2 and 3 must be combined together and shortened. A distinction between the Study site, the Predictand, and Predictors would be appreciated.* "

Reply: We have put sections 2 and 3 into one main section (Sect. 2), which consists

of three subsections describing the study site (Sect. 2.1), target variables (Sect. 2.2), and large-scale predictors of the case study (Sect. 2.3).

"*ESD model Architecture (Section 4). In this section, there is a need of an introductory paragraph before the subsection 4.1 starts. The general framework of the ESD should be first reviewed, from a general aspect, then details can be given later on in the paper giving specific adaptations to meet with the short time series purposes.* "

Reply: We agree and have added an introductory paragraph to this section (Sect. 3 of the revised manuscript). Please see also our response two comments below.

"*Downscaling process (Section 4.3). The statement on Page 2894 L26 needs some clarification. What would the author suggest as an alternative for using their model to downscale precipitation.* "

Reply: In the revised manuscript, we discuss possible measures for including precipitation (and non-Gaussian variables in general) into the ESD modelling procedure in Sect. 5.

"*ESD model Architecture (Section 4). This section should start with subsection 4.3. The authors need to start with general aspects and move to more specific ones, which seems to be reversed here. Also, part of subsections 4.1 and 4.2 refer to earlier results and do not introduce new material. I suggest to split these subsections partly in sections introduction and discussion. Also, subsection 5.1 "Downscaling parameters" should be displaced inside Section 4 as it is part of the ESD framework and not the application. Finally, I can hardly see how the title in section 5 can be appropriate here as it corresponds more likely to the results.*"

Reply: We have renamed Sect. 5 of the original manuscript according to the referees suggestion (i.e., "Results and discussion", Sect. 4 in the revised manuscript). Further, we introduce the downscaling parameter R_σ in Sect. 3.3 of the revised manuscript ("ESD model training and validation"). We have considerably shortened Sect. 4.1 and

Sect. 4.2 (section numbers correspond to the original manuscript), in order to focus on the important elements of the here presented ESD modelling procedure. However, we prefer to keep Sect. 4.1 and Sect. 4.2 in advance of Sect. 4.3 (original manuscript), although in the opposite sequence: thus in the revised manuscript Sect. 4.1 becomes Sect. 3.2, and Sect. 4.2 becomes Sect. 3.1. This is because predictor selection is generally the first step of any downscaling approach, and the "a priori" predictor selection is one of the primary steps of the here presented ESD modelling procedure. Furthermore, the treatment of seasonal periodicity is an important element of data preprocessing, which also needs to be addressed in advance of the main modelling procedure.

"*Moreover, Sub-sections 5.3 to 5.3 can be combined together and presented in the discussion.* "

Reply: We assume that the referee here means Sect. 5.3 and Sect. 5.**5**. We have shortened the two sections and put them together into Sect. 4.4 (revised manuscript). This way, the reader can find the primary results first (with focus on the daily time scale, Sect. 4.1 to 4.3, revised manuscript).

"*Accounting for seasonal periodicity (Section 4.1). By estimating the model parameters separately for each month, the authors mentioned that the bias introduced by temporal dependencies is removed. By doing so, any dependency between the months, if it exists, will be also eliminated. What would the authors suggest to reconstruct reliable estimates of daily temperature time series based on their ESD model?*"

Reply: Thank you for this comment. After carrying out the cross-validation procedure for each calendar month individually, the complete air temperature time series is obtained by putting together in chronological order the final ESD models for each calendar month's model (equation 7, revised manuscript). We have added this information in the revised manuscript. Note further that the inter-monthly dependencies are introduced by the mean seasonal cycle that is transferred from the observation time series, and

through the inter-monthly correlation in the predictor time series.

"*For AWS1 predictand (Page 2920, Fig. 4), it is clear that ESD model parameter estimates for the wet season show a larger bias than for the other months, which is stated by the author on Page 2899, L22-23. This bias might be in the origin of the high minimum number of required observations as shown in Fig. 5 and for the SS difference between the two Periods 1 and 2 (Page 2900 L28 to Page 2902 L3), for AWS1 as shown in Fig. 6. It seems from the different figures that the wet season require larger sample data for the ESD model to be more stable than the other seasons. This issue might be included and discussed in the present paper.* "

Reply: It is true that the coefficient uncertainties of the ESD model are largest for the wet season months February to April (evident from Fig. 4, original manuscript). Note however that values of n_{min} are shown by the black filled circles in Fig. 5 (original and revised manuscript). These values are low for the months February to April, if compared to the maxima in July and November, thus not as the referee mentions above. The relatively low values of n_{min} for these months occur despite the large coefficient uncertainties evident in Fig. 4, and relate to the relatively high values of SS for these months (see Fig. 6). We have reformulated these lines for more clarity in the revised manuscript (Sect. 4.3, paragraph 4).

"*Results for different time scales (section 5.3). It is well known that the model skill increases with averaging the time scales because the variability is diminished in the aggregated values.*"

Reply: In the revised manuscript, we also mention that the increase in skill with increasing time scale is an expected result.

Technical comments by Anonymous Reviewer # 2

"*Page 2884 Line 2: delete the comma after "altitude". . .place a comma after "ESD model...". Line 10: place a comma after "Similarly" and remove the one after "temporal*

resolutions""

Reply: We have put a comma after "ESD model validation, ...", but we keep the comma after altitude.

"*Line 13-16: run on sentence Line: place a comma after "Ongoing developments in atmospheric modeling" and remove the comma after available choices of long term"*"

Reply: We have shortened this sentence.

"*Line 19-20: I would say "However, these data. . ."*"

Reply: Revised accordingly.

"*Line 21-23: Avoid starting the sentence with "especially". Sentence needs to be revised.*"

Reply: Revised accordingly.

"*Line 23: Please add "The" before "so-called. . ."*"

Reply: Since "downscaling" is introduced here the first time, it needs to appear without article.

"*Page 2885 Line 4: "have emerged" instead of "has emerged"*"

Reply: The verb "have" refers to the noun "variety" (singular), therefore "has".

"*Line 9: Place a period after "the last decades" and start a new sentence with "Concerning the choice. . ."*"

Reply: No more relevant, because the sentences have been changed.

"*Line 11 : in ". . ., and (iii) of . . ." remove "of"*"

Reply: Revised accordingly.

"*Line 21: Place a comma after "atmospheric sciences"*"

Reply: Revised accordingly.

"*Page 2886 Line 2-5: Run-on sentence*"

Reply: Thank you, we have shortened the sentence.

"*Line 4: put first letter of each word to upper case in "automated weather station (AWSs) . . ."*"

Reply: We prefer to keep "automatic weather station" lowercase, because this is the convention generally used in scientific journal articles.

"*Lines 6-7: avoid repetition of the word "study"*"

Reply: Revised accordingly.

"*Line 19: Put a comma between "agriculture" and "and households. . ."*"

Reply: Revised accordingly.

"*Line 23: remove extra "the"*"

Reply: Revised accordingly.

"*Line 29 and Line 1-2: Please rephrase*"

Reply: Revised accordingly.

"*Page 2887 Line 5: add "located at" to ". . . AWSs at and nearby glaciers. . .". Line 6: Period after "installed" and start a new sentence with "Primarily. . ."*"

Reply: We have reformulated this sentence.

"*Line 16- 19: The sentence is too long; try splitting it in two parts.*"

Reply: Revised accordingly.

"*Line 19: I would say "methodology that is based on single. . ." instead of "methodology, based on single"*"

Reply: Revised accordingly.

"*Line 29: Be consistent: replace (hereafter AWS3) by (hereafter referred to as AWS3)*"

Reply: Revised accordingly.

"*Page 2888 - Line 10: replace "described by . . ." by ". . ., as described by . . ."*"

Reply: Revised accordingly.

"*Page 2889 Line 7 : capitalize first letter in each word in ". . . numerical weather prediction . . ."*"

Reply: We prefer keep "numerical weather prediction" lowercase, as it is usually found in atmospheric science articles.

"*Line 14 : Please be consistent with names and acronyms as "the National Centre for Environmental Prediction (NCEP) . . . "*"

Reply: Revised accordingly.

"*Lines 20-25 : please rephrase and shorten the sentence . . .Line 23 : move CFSR inside the parentheses*"

Reply: No more relevant, because this paragraph has changed in the revised manuscript.

"*Lines 25-28 : rephrase sentence and define "interim" as first occurrence. Line 27 : replace "who" by "which"* "

Reply: No more relevant, because this paragraph has changed in the revised manuscript.

"*Page 2891 Line 3 : to which model the authors refer to ?*"

Reply: No more relevant, because this paragraph has changed in the revised manuscript.

"*Page 2892 : Line 17 : replace "model" by "reanalysis" to be consistent*"

Reply: No more relevant, because this paragraph has changed in the revised manuscript.

"*Line 19 : start the sentence with "However, . . ."*"

Reply: No more relevant, because this sentence has been removed in the revised manuscript.

"*Line 20 : remove "s" in levels*"

Reply: Revised accordingly.

"*Page 2893 Lines 18-21 : The authors must argue their choice here.*"

Reply: No more relevant, because this comment has been removed in the revised manuscript.

"*Line 24 : what does "at the grid points located closest to the study site" means. Do the authors refer to the average of the closest grid points taken from the different re-analysis, respectively?*"

Reply: As the referee correctly mentions, *rea-ens-air* consists of the average of the closest grid points of the three reanalyses. In the revised manuscript, we describe this more clearly to avoid misunderstanding here.

"*Line 26 : remove "s" in "550 hPa levels"*"

Reply: No more relevant, because this sentence has been removed in the revised manuscript.

"*Page 2894 Line 3 : the verb "is" is missing in "More precisely, the coarser the large scale"*"

Reply: No more relevant, because this sentence has been removed in the revised manuscript.

"*Line 8 : replace "best" by "better" and capitalize "limited area . . .models", and avoid the use of "certainly" . . .*"

Reply: No more relevant, because this sentence has been removed in the revised manuscript.

"*Line 18 : replace '10-fold" by "N-fold* $(N > 1)$*" to be more general.*"

Reply: However, here we intend exactly 10-fold cross-validation, because this is in fact the frequently used choice (see, e.g., Hastie et al., 2001).

"*Lines 19-21 : I would say, ". . .because the estimated coefficient of regressions or model parameters are not affected by temporal dependencies ..."*"

Reply: Revised accordingly.

"*Line 24 : I would use ". . .for each month in the time series" instead ". . .month's time series. . ."*"

Reply: We have replaced "...each month's time series..." by "...each calendar month's time series...". However, the reformulation suggested by the referee has a different meaning. More precisely, there are twelve time series for the twelve calendar months, and the modelling procedure is repeated for each of the twelve time series.

"*Line 26: please move this sentence to the conclusions and perspective section and give alternatives of regression relationship to use with non-Gaussian variables such as precipitation.*"

Reply: We discuss the more general application of the ESD model for non-Gaussian target variables in Sect. 5 of the revised manuscript.

"*Page 2896 Line 2 : What does index "s" stands for in Equation (1). I guess "standard-ized".*"

Reply: $y_{\mathsf{s}}(t)$, and $x_{\mathsf{s}}(t)$ are the standardized predictand, and predictor time series,

respectively. We state this both in the original, and the revised manuscripts. In the revised manuscript, this explanation can be found in the text immediately after Eq. (1).

"*Line 13 : define the right hand side of equation (2). Does it stand for estimated values ? Please give details.*"

Reply: We have revised this section and added more explanations to the text, trying to be more comprehensible.

"*Page 2897 Line 2 : replace "step" by "repetition"*"

Reply: Revised accordingly.

"*Line 20 : I think that it would be relevant for the authors to give the expressions of the two penalty terms, here, instead of referring to the work of Murphy (1998).*"

Reply: We agree. In the revised manuscript, we explicitly show the decomposition of SS.

"*Line 25 : please define n and p*"

Reply: Revised accordingly.

"*Line 25 : The authors must explain and argue this sentence. Otherwise, this sentence has to be removed.*"

Reply: We have reformulated this paragraph, and added more explanation.

"*Page 2898 Line 10 : replace "round" by "repetition to be consistent with the previous sections.*"

Reply: Revised accordingly.

"*Line 24 : I would say, "Part of the results in Fig. 3 are also discussed later in Sect. 5.2.*"

Reply: Revised accordingly.

"*Page 2898 Line 1 : Please add an introductory sentence to this section.*"

Reply: Revised accordingly.

"*Page 2899 Line 9 : Start a new sentence with "consequently".*"

Reply: Revised accordingly.

"*Line 11 : remove parentheses and start new sentence with "For instance, the AWS1 March as well as July time series consists of 186 values . . ."*"

Reply: Revised accordingly.

"*Line 15 : The R(sigma) parameter should be defined in the model framework (section 4.3)* "

Reply: We agree. We have moved the definition of R_σ into section "Downscaling model training and validation" (Sect. 3.3 of the revised manuscript).

"*Line 23 : What does "The largest coefficient uncertainties" mean ?*"

Reply: In the revised manuscript, we point out that the coefficient uncertainties are estimated based on the ESD model uncertainty using the cross-validation procedure (defined by Eq. 9 of the original, and Eq. 7 of the revised manuscript).

"*Line 25 : Please add "the" prior to "largest"*"

Reply: Revised accordingly.

"*Page 2900 Line 8 : rephrase the sentence*"

Reply: Revised accordingly.

"*Line 16 : start a new sentence with "However,"*"

Reply: Revised accordingly.

"*Line 23 : "ENSO" must be defined as first occurrence.* "

Reply: We define the abbreviation ENSO on p.2888, l.27 (original manuscript), where it appears for the first time in the manuscript.

"*Page 2901 Line 3 : remove the second "for" in "...for April and for September ..."*"

Reply: Revised accordingly.

"*Line 12 : This sentence is too long. Please rephrase and try to split the sentence. Also, in "we suggest that variability must..." should be used with precautions. The sentence seems to be more likely a hypothesis than a suggestion*"

Reply: We have split up the sentence into three shorter sentences. We agree that they include a hypothesis of why the values of SS are low during the dry season. In the revised manuscript, we replace "must" with "might" and use the verb "hypothesize".

"*Line 20 : It is not evident from Fig. 3 that the day-to-day variability is smaller for dry season than wet season.*"

Reply: We understand what the referee means. The within-month day-to-day variability is not obviously smaller in the July time series (Fig. 3, upper versus lower panels). With this regard, the sentence (p. 2901, l.19-20, original manuscript) is not meaningful. However, day-to-day variability also comprises year-to-year variability, and this overall variability is evidently smaller for the July time series, than for the March time series. We have revised this sentence, replacing "... Year-to-year as well as day-to-day variability in the observational time series are evidently smaller..." (p. 2901, l.19-20, original manuscript), by "... Variability in the observational time series is evidently smaller... " (revised manuscript).

"*Line 27: please avoid repetitions further in the text "of where data is available for all three AWSs" and use Period 1, instead. Also capitalize "p" in period 1.*"

Reply: Revised accordingly.

"*Page 2902 : Line 8: what do the authors mean by "positive" in "... the cross validation*

results are more positive." Do they mean less biased? "

Reply: With "cross-validation results" we mean the values of SS. We reformulated: "...and values of SS are higher."

"*Line 27 : replace "time length" by "duration"* "

Reply: Thank you for this suggestion. However, "duration" does not have the correct meaning here. We replace "time length" with "length of the time series" instead.

"*Page 2903 : The authors must define r2 at first use.* "

Reply: In the revised manuscript, we define the Pearson correlation coefficient r in Sect. 3.3, Eq. 3, and introduce r^2 at its first appearance as squared Pearson correlation coefficient.

"*Line 8 : The authors must discuss this issue in the concluding section rather than here.*"

Reply: We agree. We have accordingly removed this sentence.

"*Line 13 : replace "available" in "observations n available" by "required" observations "*"

Reply: The referee's suggestion would change the meaning of the sentence. Here we want to say exactly that "for lower temporal resolutions, the number of observations *available* for the model set up decreases". We do not want to make the hypothesis that the "number of observations *required* for the model set up" decreases.

Line 25 : replace "time scale" by "temporal resolution" to be more consistent with the text.

Reply: We replace "temporal resolution" with "time scale" instead, since we use "time scale" more often in the manuscript.

"*Page 2904 Line 1 : To what values the authors refer to ? I guess SS values ! And be consistent, use "SS values " instead of "values of SS". -*"

Reply: We instead replace "SS values" by "values of SS" (as we use it in the entire manuscript).

"*Lines 13-15 : This is a well-known behavior from previous studies !*"

Reply: In the revised manuscript, we mention that this is an expected result.

"*Line 22 : please use italic font type for abbreviated variables.*"

Reply: We also prefer italic for the abbreviated variables. However the journal typesetting team changed this, because after the journal conventions, abbreviations are not set in italic. If the manuscript will be edited again, we hope that the the abbreviated variables will be shown in italic.

"*Line 24 : I am concerned about this choice because in the rea-ens-air the authors have chosen the closest grid point to the study area instead of the 4 surrounding grid points. This may introduce difficulties in comparing the results as the main hypotheses differ.*"

Reply: We have reformulated this paragraph in the revised manuscript. We state more clearly that it is necessary to consider the ERA-interim at their optimum scale (thus the average over the four surrounding grid points), in order to reduce numerical noise. For the "a priori" predictor *rea-ens-air*, by contrast, numerical noise is reduced already by computing the average over the three different reanalysis models. Please also note that the results of the ERA-interim predictors (Sect. 4.4, revised manuscript) are discussed independently of the results of *rea-ens-air* (Sect. 4.3, revised manuscript).

"*Line 28 : How can the authors "observe" inhomogeneity. Use "found" instead of "observe"*"

Reply: In the revised manuscript, we have reformulated: "...there are inhomogeneities...".

"*Page 2905 Line7 : I could not find the results. What is the statistical test used here?*"

Reply: We applied the statistical test of the skill assessment described in Sect. 4.3 of the original manuscript (Sect. 3.4 of the revised manuscript). We added a quick note along these lines.

"*Line 24 : Please correct the reference here. "Sect. 9" does not exist! Page 2906 Line 1: Again, "Sect. 9" wrong reference*"

Reply: Revised accordingly.

"*Lines 16-20 : long sentence. Please split it in two*"

Reply: Revised accordingly.

"*Page 2907 Line 3 : remove "s" in "emphasizes"*"

Reply: Revised accordingly.

"*Line 5 : be consistent, use "the model skill" in "...differences in skill..."*"

Reply: We have reformulated: "...differences in the ESD model skill..."

"*Lines 15-17 : What does "model surface" means ?*"

Reply: With "model surface" we mean the surface of the large-scale model. In the revised manuscript, we have reformulated the sentence as follows: "if the topography of the large-scale model is not representative for the real topography".

"*Page 2914 Use ERA-interim instead of ECMWF interim.*"

Reply: Revised accordingly.

"*Page 2915 In the table caption, the authors must be consistent with the text in defining the different periods. Period 1 and Period 2 should be clearly defined in the text and referred to in the table caption.*"

Reply: Revised accordingly

"*Page 2916 There is no section 9.* "

Reply: Revised accordingly.

"*Use ERA-INTERIM instead of interim.* "

Reply: Revised accordingly.

"*And please provide information about the optimum spatial domain in the table and refer to the work of Hofer et. Al (2012)*"

Reply: Revised accordingly.

"*Page 2917 The authors must provide a title in the caption figure first. Then give details after. Please add "as" to "mentioned in the text"*"

Reply: Revised accordingly.

"*Page 2918 Please replace "for each moth of the year" by "Monthly statistics of daily temperature..."*"

Reply: Revised accordingly.

"*Page 2919 Replace "in March" by "for March". The authors should be aware that the shaded area is a moving area and precise to what cv values the figure correspond. I do not see from the figure how the vertical dashed lines indicate the minimum number. It is confusing to have one line between 2007 and 2008 in March (top) and between (2010 and 2011) in July (bottom).*"

Reply: The dashed line in Fig. 4 (original manuscript) indicates the minimum number of observations to obtain statistically significant skill for the ESD model, n_{min}, as follows: if both the March and July time series would be cut off at the date indicated by the dashed line, the time series would still be of length n_{min}. However, we have removed the dashed line in Fig. 4, since this information has not been understood by both anonymous referees, and because n_{min} is shown again in Fig. 5 (original and revised manuscript). As also evident in Fig. 5, n_{min} differs considerably for the different calendar months. Therefore the dashed line does not appear at the same dates for the

different calendar months' time series in Fig. 4 (original manuscript).

"*Page 2920 The caption of the figure must read "Box-plots of the downscaling model parameters. . .). Then, explain the different components in the caption detail.*"

Reply: Revised accordingly.

"*Page 2921 The x-label must be n_{min},n_{eff} [days] to be consistent with notations in the main text. The authors may also include the results for the other AWSs using different colors and line types.*"

Reply: We have replaced n by n_{min} for consistency. However, we prefer to show the results only for AWS1, because putting the results of all AWSs into Fig. 5 makes the information very difficult to read. Moreover, the AWS1 time series is the longest time series of all AWSs, and we have use the results of AWS1 for demonstrative purposes throughout the entire manuscript (Fig. 4, Fig. 5, Fig. 6, Fig. 7, Fig. 8, and Fig. 9).

"*Page 2922 Period 2 has not been defined in the text! And remove "respective"*"

Reply: Period 2 has been defined in the original manuscript (p. 2901, l.1), and we define it in the revised manuscript at its first occurrence (Sect. 4.2).

"*Page 2923 The color scale bar in this figure is confusing. I wonder whether the authors must use 12 different color instead of using a gradually color bar. It is really difficult to distinguish between the colors for Apri-May-June within the different time scales.*"

Reply: Thank you for this suggestion. We have accordingly changed the color scheme in Fig. 7.

"*Page 2924 Section number is missing!*"

Reply: Revised accordingly.

"*Page 2925 Same as previous figure, the section number is missing from the caption. Please replace figure x-label with r2 to be consistent with the text.*"

Reply: Revised accordingly.

References

Hastie, T., R. Tibshirani, and J. Friedman, 2001: *The elements of statistical learning: data mining, inference, and prediction*. 1st ed., Springer series in statistics, Springer, New York, 533 pp.

Madden, R. A., 1976: Estimates of the natural variability of time-averaged sea-level pressure. *Monthly Weather Review*, **104 (7)**, 942–952, doi:10.1175/1520-0493(1976)104.

Wilby, R. and C. Dawson, 2007: *SDSM 4.2 âĂŤ A decision support tool for the assessment of regional climate change impacts*. Leicestershire, UK, Loughborough University.

Wilks, D. S., 2006: *Statistical methods in the atmospheric sciences*, International Geophysics Series, Vol. 91. 2d ed., Academic Press, 627 pp.

Interactive comment on Geosci. Model Dev. Discuss., 6, 2883, 2013.