Earth Syst. Dynam. Discuss.,
doi:10.5194/esd-2016-52-AC1, 2017


Earth System Dynamics Discussions

# *Interactive comment on* "Addressing the assumption of stationarityin statistical bias correction of temperature" *by* Manolis G. Grillakis et al.

**Manolis G. Grillakis et al.**

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Received and published: 21 February 2017

Authors would like to thank Reviewer #1 for his valuable comments and the discussion about the manuscript. All the major and minor comments were carefully taken into consideration in reviewing the manuscript. The revised version will be more scientifically sound and better positioned within the discussed subject. Reviewer #1 also indicated the noteworthy work of (Maraun, 2016) that was not available to the authors at the time that this manuscript was finalized. Reviewer comments (denoted as R1) are transferred here, while after each comment and answer is provided by the authors (denoted as A)

R1: Major comments: 1. Conceptual issues and added value to previous literature a) "stationarity of biases" vs. "preservation of trends" The authors state in the abstract a



generality about bias correction techniques, namely that "various methodologies have been developed, their majority assumes that the statistical characteristics of the biases between the modeled data and the observations remain unchanged in time." (l. 27-29) and further state that they would develop "a method to overcome the assumption of stationarity and its drawbacks". (l. 30-31) These statements are mirrored multiple times in the manuscript. However, the authors' method does NOT address the issue of biases that are (or could be) changing over time (or in a changing climate) due to changing feedbacks, changing climatic patterns, etc. Quite to the contrary, the authors' method assumes a quite strict stationarity of the biases that are being corrected by their method (i.e. through a normalisation procedure that normalises yearly time series to the reference period, where only "stationary" (i.e. "stationarised") parts are being bias corrected); and non-stationary parts of the time series are not accounted for. This preserves the trend (as intended by the authors), but ultimately would fall short if "statistical characteristics of the biases" would change over time (see Boberg and Christensen, 2012, NCLIM, for an example of temperature-dependent biases, where due to non-stationarities in biases one might NOT want to preserve the original trend). Therefore, I believe the statements made in the paper regarding a "stationarity of biases" vs. "preservation of trends" could lead to a severe misconception among the readers, and I believe a substantial revision/clarification of these statements and discussion (including title) would be necessary to emphasize that the aim of the authors was to develop a trend-preserving bias correction technique, rather than a technique that addresses the "assumption of stationarity in statistical bias correction of temperature" (title). See e.g. Maraun (2016) for a more thorough discussion, including implicit assumptions, of using a "trend-preserving" bias correction vs. "state-dependent biases" (where one would expect time-dependency in the biases).

A: In the first major comment, Reviewer #1 correctly mentions a major misinterpretation in the manuscript. The presented methodology does not correct, but preserves the changes (stationary or not) relatively to a reference period, in order to avoid a correction that is based on the stationarity assumption. Hence, the methodology that is presented “overcomes the assumption of stationarity and its drawbacks” in the sense that the non-stationary parts are not corrected under any assumption, and not that it corrects the nonstationary parts. This is clearly stated from the abstract section, as “The methodology separates the stationary and the non-stationary components of a time series, in order to adjust the biases only for the former and preserve intact the signal of the later.” However the title of the paper may be misleading. In order to make clear the purpose of the manuscript, the title will be changed to “Suppression of long term signal distortion during bias correction of climate model temperature”. Additional clarification remarks will be added to end of the introduction section. Another clarification point that should be made in the manuscript and here is that (as previously mentioned) the purpose of the paper is to present a method that cancels the need of a stationarity assumption, by avoiding the correction of the potential non-stationary parts of temperature signal. As all the changes relatively to a reference period are excluded from the correction, the method preserves multiple statistical aspects of the original data, including the long term trend. The preservation of the trend may be a useful feature depending on the application and the robustness of the raw data signal. Changes are performed accordingly to the Reviewers #1 indication across the manuscript. Moreover, the terminology is changed across the manuscript from stationary and nonstationary, to normalized and residuals. Regarding the work of (Boberg and Christensen, 2012, NCLIM), they apply a bias correction conditioned on temperature. As they state, this is justified by the fact that temperature dependence of biases indicates limitations in interpreting regional temperature projections when temperatures in the warmest months are substantially above present-day conditions. Hence they chose to separate the monthly mean temperature biases into a cold period (NDJFMA) and a warm period (MJJASO) in order to discriminate the cold period biases from the warm period biases. In the present work, a similar discrimination is performed, as each calendar month data are separately bias adjusted after the “stationarization” of the data. However, due to the separation of the data, the long-term trend is not changed as it happens in the (Boberg and Christensen, 2012) work or in a classical quantile mapping. Appropriate discussion is added in the



introduction section.

R1: b) Previous work on trend-preserving bias correction The authors motivate their study with an example of a model-based and observed time series, where a statistical bias correction method (quantile mapping) induces an additional warming signal of 1.5âŮęC by the end of the century due to the shape of the transfer function. However, the fact that bias correction can change the trend signal is not new, and in fact has been highlighted in a number of publications (see e.g. Maraun 2016 for a discussion).

A: In the second major comment, Reviewer #1 correctly indicates that the idea of trend changing is not new and this is also stated in the manuscript. Additional discussion motivated by the Reviewer #1 and the work of (Maraun, 2016) was added to the introduction section. “As transfer function (TF) of the bias correction is estimated between the reference period observations and climate model data, it indicates the different magnitude of correction for the different parts of the probability distribution function (PDF). Considering that the PDF of the climate data is actually time-dependent , the TF gradually changes its response on the climate data, providing unequal bias correction in different periods as Hagemann et al. (2011) and Maraun, (2016) also notice.” As of the manuscript Figure 1 and the video example in the manuscript, it is provided as video illustration to benefit potential readers understanding the issue of time dependency of the bias that was a motivation for this study.

R1: Moreover, several papers have investigated the issue raised in detail, and various methodologies to preserve trends have been developed. Unfortunately, the authors do not even refer to previous papers that already developed tools to address this issue (except for Hempel et al., 2013, ESD). For example, see: Li H, Sheffield J, Wood E., J Geophys Res., 2010. Maurer, E.P. and D.W. Pierce, Hydrol. Earth Syst. Sci., 2014. Pierce D, Cayan D, Maurer E, Abatzoglou J, Hegewisch K., J Hydrometeorol., 2015. Maraun D, Curr. Clim. Change Rep., 2016.

A:In the revised version of the manuscript, a more thorough discussion is performed, including findings of the aforementioned works and methodologies. “Maraun, (2016) discuss on whether the change in the trend is a desired feature of bias correction, concluding that it is case specific, depending on the skillfulness of a model to simulate the correct long term signal. In the case of a CCI study this implies that climate model output is assessed for its skill to well represent the trend. A possible but indirect solution to this is described in Maurer and Pierce, (2014) who study the change in precipitation trend over an ensemble of atmospheric general circulation model (AGCM). They concluded that, while individual quantile mapping corrected AGCM data may significantly modify the signal of change, an 11-member ensemble estimation diminished the problem due to the cancel out of the individual model trend changes. Li et al. (2010) present a quantile mapping method to adjust temperature biases taking into account the differences of the future and reference period distributions. A drawback of the method is that the difference between the two periods’ distributions depends on the future period length. In their work, Hempel et al. (2013) also propose a possible solution to the trend changing issue, by preserving the absolute changes in monthly temperature, and relative changes in monthly values of precipitation. The obvious conceptual drawback of this approach is that non-stationarity does not always coincide with a deterministic trend component (Lins, 2012). A similar additive for temperature and multiplicative for precipitation approach was also followed by (Pierce et al., 2015) ”

R1: 2. Technical Technical implementation of non-stationarity module (NSM) of bias correction and underlying assumptions of NSM In their manuscript, the authors separate "stationary" and "non-stationary" components of the time series by transforming each annual time series to the reference period using a transfer function (calibrated for each year separately). However, several implicit assumptions, choices, and potential in-consistencies seem to underlie this procedure, which to my mind are not or only very shallowly addressed in the present manuscript. For example: a. The procedure seems to be prone to conceptual in-consistencies that need to be addressed: For example, consider the following case: Imagine you want to bias-correct a climate model that has very strong positive biases in summer due to land-atmosphere feedbacks that



take off in the warmest, say, 30 days in each summer, and small biases for other seasons (a scenario that is not uncommon for regional climate models). Further, imagine a volcano goes off in any one particular year, leading to inter-annual variability in the climate system and a cold year without these hot 30 summer days. If I understand the procedure correctly, this unusually cold year without hot ("biased") days would still be bias-corrected following the reference period (i.e. "stationarized" time series), and thereby potentially large, unwanted side effects would be introduced.

A: Let say for the sake of simplicity that all the simulated years are statistically similar and follow the described warm bias pattern in a summer month. Let also say that the eruption occurs in the projection period. In that case, the normalization of each year’s data individually, against the average modeled reference period climatology will give small differences that will be excluded from the correction. In the case of the eruption year, these larger “cold” differences between the eruption year and the average reference period climatology will be excluded from the correction. The separation of the timeseries in stationary and non-stationary components, provides the advantage to recognize “unusual” climate events in the sense that they are not interpreted in the average reference climatology, and exclude the unusual part of it from the correction. Hence, this unusual climate event would be excluded from the correction and should not cause any side effects on the corrected data. To support this claim, authors redone the experiment of correcting the MIROC-ESM-CHEM data using HadCET data as observations. However, this time a constant of 5 oC was added to all Augusts data (1850 - 2005) of MIROC-ESM-CHEM, except the last August of 2005 (modified TS). In this experiment the 2005 August resembles the volcanic eruption timing. The climate model data were corrected and the results are shown in the attached figure 1. The results between the original correction (BC) and the BC-NSM correction are very similar. Small discrepancies in the corrected original and the modified timeseries can be observed. These differences are due to the changes in the reference period climatology that affects the stationarization.

R1: b. The proposed method (BC-NSM) seems to underestimate variability on the annual time scale (Fig. 2c). I wonder whether this issue stems from the in-consistency outlined in (a), but in any case it seems to be a methodological problems that needs to be addressed.

A: The normal distribution that was used to depict the mean annual temperature has indeed small discrepancies between the raw data and the BC-NSM data. The difference in the data in terms of variance is 0.209 and 0.201 respectively. This small difference is random and is caused by the approximation error of data CDFs during the stationarization process. This approximation error also appears in the manuscript Figure 2a RAW normalized data annual averages which indicate almost but not an exact straight line. However, the annual variability is largely preserved in contrast to the quantile mapping without NSM. In order to investigate the difference in the annual scale standard deviation, authors expanded the experiment of calibration validation of manuscript Figure 2 on the CORDEX data that were used in the manuscript. Period 1951-1982 and 1983-2014 were used as calibration and validation periods respectively. Then we estimated the difference in the annual timescale standard deviation between raw and BC-NSM temperatures for the 1951 – 2014 years. The results are presented for each RCM model in the attached figure 2 (panels a to e indicate models 1 to 5 of Manuscript Table 2). As it can be observed, the difference in the annual timescale standard deviation may have positive or negative values. In any case, the absolute differences are low and the annual variability is certainly better preserved comparing to the quantile mapping approach.

R1: c. Why is the "recalibration" (Eq. 1 - Eq.3) performed on the annual time scale? How would it look like if this stationarity/non-stationarity separation would be conducted on other time scales? (for example for each season separately?) Regarding this point, the authors loosely refer to the annual cycle as the most dominant frequency of variation in the climate system, but for example in tropical regions this assumption does not necessarily hold. While I understand that a year seems to be an obvious choice, it is



subjective, and any of such choices will be (to some degree) prone to in-consistencies as outlined in (a).

A: Authors agree with Reviewer's #1 comment. The annual cycle is not so obvious in the tropical regions. However, neither other timescales, e.g. the mentioned seasonal scale. As indicated by the Reviewer #1, annual cycle was an obvious periodicity to use in the case of temperature, even if it is not so well defined in tropics. Beyond that limitation, annual cycle may be the best choice for the majority of the cases. Alternative timescales could be used under different assumptions. The rationale behind the separation of the stationary and the potentially non-stationary components is to leave aside the difference of each year's CDF relatively to a respective CDF derived from a 30-year climatic period of modeled data. Taking e.g. seasonal data rather than one year's period, would require that the stationary – nonstationary components would be separated relatively to the respective seasonal long term data. Technically, in the case that a seasonal (or even monthly) timescale was chosen, stationary component would exhibit a seasonal (or monthly) recurring periodic. This would separate a larger portion of the temperature as nonstationary, excluding a larger portion from the correction. In the attached figure 3, we present the manuscript's Figure 2a data, RAW Normalized timeseries (blue line) and the residuals (red line) but this time in monthly aggregates. It can be observed that, while the annual mean temperature in the stationarized (blue) data is almost constant (as shown in the manuscript's Figure 2), the intra-annual data have retained the relative variability. In the case of monthly separation, the normalized (blue) data would exhibit a uniform recurring monthly periodic, while the residuals that are excluded from the correction (red) would be larger.

R1: d. Why is the separation being done in an additive way? (Eq. 2) While this seems to be a reasonable choice at first sight, it is clearly subjective, and to me it is not at all evident why climatic time series could be separated into "stationary" and "non-stationary" components in an automated and additive way (given this is done on an annual basis, and not by subtracting long-term trends, etc. A: The idea behind the additive separation of the temperature data is not new, as it has been used elsewhere (Hempel et al., 2013; Pierce et al., 2015; Rutty and Scott, 2015) to remove the constant bias between the reference period observations and model data. Beyond the differences of the present methodology to those, the additive separation is an analog procedure. Alternative methodology would be the inverse mapping of the corrected stationarized data, using the transfer functions of Eq.1. However, this had been unsuccessfully tested in the early stages of the methodology development, adding new bias to the data, in a similar inflation–like way that the quantile mapping time dependency of the bias changes the trend (in manuscript Figure 1).

R1: e. The procedure is not sufficiently explained, and relevant sections seem to be very hastily written. For example, out of 3 equations, two appear to be wrong (wrong subscripts in Eq. 2, Eq. 3 does not make sense unless S NS i = 0). Furthermore, the reader is left to guess how exactly the transformations and methodology is implemented ("using linear functions instead of gamma functions", l. 192-193). If the authors would decide to move forward with their manuscript, I believe that the readability of the manuscript would benefit greatly from a substantial rewriting and a better illustration of the procedures.

A: Authors corrected the misprinted Eq. 3 as indicated correctly by Reviewer #1. The transformations described in l. 192-193 were not initially included to the manuscript as they are in detail (and with example) exhibited in ( Grillakis et al., 2013). The transformation is made using quantile mapping, where the CDFs are approximated by sequential linear functions. The number of the linear functions that are used are determined by Schwarz Bayesian information criterion (SBIC). The procedure is not new and a step by step example application of the MSBC can be found in the Appendix A of (M.G. Grillakis et al., 2013). The methodology section is expanded to better describe the methodology.

R1: 3. Comprehensive evaluation of procedure and comparison to previous trend preserving bias correction methods As stated already above, a couple of "trend-



preserving" bias correction methods already exist in the literature, which the authors tend to ignore (with one exception, see above). However, given that the authors' intention is to present a novel methodology, it would be crucial to see how a new method compares to established methods. Is there a large gain in performance compared to "less intrusive" methods, i.e. those that only preserve the trend (Hempel et al., 2013, ESD) or trends in individual quantiles (Li et al., 2010 JGR)? If not, what is the added value of yet another post-processing step? Furthermore, to my mind it would be crucial to explore how yet another additional bias correction step (in the form of a "prepostprocessing") would change statistical properties of the data. For example, I get the impression that BC-NCM reduces the variance on annual time scales (Fig. 2c). Is this an artefact that stems from the method or does it only appear to do so? For example, it might be beneficial to compute power spectra of the model data, observations, and the bias-corrected data in order to see how the various transformations distort or change variability at different frequencies (and both for the calibration and validation period).

A: Following Reviewer #1 indications, the introduction section was expanded to the comparison of the methodologies to further strength the scientific value of the manuscript. Regarding the effect of this additional step for the correction and whether it reduces the annual variability, it has been extensively discussed earlier.

R1: Minor comments: R1: l. 65-67 I do not believe that this is always the case. Climate models are indeed also tuned to specific variables.

A: The sentence was changed.

R1: l. 92 typo: flawed

A: the typo was corrected

R1: l. 96-99 A change in the model trend is not in all conceivable cases unwanted. See discussion above or Maraun (2016).

A: As indicated, the sentence was corrected to present the change in the long-term trend as a (not always unwanted) effect.

R1: l. 122-125: As described above, it is unclear to me why a change above or below the annual periodicity should distinguish between a stationarity and non-stationarity process. I would advise the authors to make their reasoning more clear here. A: Authors share Reviewer's #1 concern. Changes above or below the annual periodicity cannot distinguish between a stationarity and non-stationarity process, but include the potential non-stationary change in the data. A better description was implemented in the specific part of the manuscript.

R1: l. 132 / Fig. 1: Generally, the transfer function for bias correction is a function of the modelled data, i.e. f(xmod). Wouldn't is be more natural to put the model data on the x-axis?

A: Reviewer #1 is right, but it was chosen so as it is better presented with observations on X-axis.

R1: l. 132/Fig. 1: It seems that in your example, you've bias-corrected to station data? This induces a scale-mismatch, and I wonder whether this scale mismatch might contribute to the fact that the trend change is so large. The induced changes in the trend are not as large in Fig. 5, are they? Would it change if the bias correction is conducted on a seasonal basis?

A: Reviewer#1 correctly indicated that the bias correction was performed against station data. Instead of performing the bias correction on seasonal basis, authors run the experiment again on similar spatial scale data (of the same point location). In the revised version of the manuscript we used temperature data interpolated (nearest neighbor) on the same location, from the EOBSv14 dataset, which spatial resolution is 0.25 o comparing to the 0.11o degrees of the ICHEC-EC-EARTH r12i1p1 SMHI-RCA4_v1 Euro-CORDEX data, covering large portion of the scale mismatch.

R1: l. 161/162 Sentence not understandable. Please rephrase.



A: The sentence was rephrased to be more clear.

R1: l. 168 each year's data

A: The sentence was corrected.

R1: l. 192/193 Why linear here? Please be specific. A: Gamma function is usually used to fit precipitation data and is inappropriate for temperature for a series of reasons, with the most important to be the negative temperature values that gamma functions cannot facilitate. Linear functions have also been successfully used elsewhere (Themeßl et al., 2011) in quantile mapping. Moreover, using linear functions, the methodology is able to work with other variables.

R1: l. 197 "The bias correction methodology modification has been already used in the Bias Correction Intercomparison Project..." - but by modification you do not mean the BC-NSM in this paper, do you?

A: No, by modification authors mean the "BC", not the "BC-NSM".

R1: l. 215 Has the data quality of the observations been assessed? One might expect that observations-related uncertainties are largest in the early period, therefore using the first 50 years for validation might not be an ideal choice.

A: Reviewer #1 is right about the uncertainty in the records that augments as time series goes back. However, It has to be mentioned that (Parker et al., 1992) took into account such issues with the early years of the records when they compiled the dataset (1659 to 1722). (Parker and Horton, 2005) present a discussion about the uncertainties of the HadCET dataset. Furthermore, in this study, we further omitted the 1722 to 1850 data to meet the climate model's simulation length.

R1: l. 221 This statement is trivial in that it does reconstruct the initial raw data time series by construction, doesn't it?

A: The statement was removed as redundant.

R1: l. 234-237: I do think that BC-NSM underestimate variability in annual averages. Given that inter-annual variability is very important for climate impacts (for example in the carbon cycle), I would consider this is something that is crucial to get right.

A: Authors agree with Reviewer #1 about the importance of preserving the interannual variability of temperature. The issue of the change in the inter-annual variability was discussed earlier.

R1: l. 339-341: I do agree that this is the case for statistical bias correction, but biases can also be overcome by using bias correction scheme that preserve the physics (e.g. ensemble-resampling methods, Sippel et al., 2016, ESD).

A: Authors agree with Reviewer #1, as there are methods that preserve the physical consistency between a set of variables. However not the entire spectrum of the simulated variables and fluxes. Additional clarification was added to the manuscript.

R1: References: Boberg, Fredrik, and Jens H. Christensen. "Overestimation of Mediterranean summer temperature projections due to model deficiencies." Nature Climate Change 2.6 (2012): 433-436. Hempel, S., et al. "A trend-preserving bias correction–the ISI-MIP approach." Earth System Dynamics 4.2 (2013): 219-236. Maraun, Douglas. "Bias Correcting Climate Change Simulations-a Critical Review." Current Climate Change Reports 2.4 (2016): 211-220. Maurer, Edwin P., and David W. Pierce. "Bias correction can modify climate model simulated precipitation changes without adverse effect on the ensemble mean." Hydrology and Earth System Sciences 18.3 (2014): 915-925. Li, Haibin, Justin Sheffield, and Eric F. Wood. "Bias correction of monthly precipitation and temperature fields from Intergovernmental Panel on Climate Change AR4 models using equidistant quantile matching." Journal of Geophysical Research: Atmospheres 115.D10 (2010). Pierce, David W., et al. "Improved Bias Correction Techniques for Hydrological Simulations of Climate Change." Journal of Hydrometeorology 16.6 (2015): 2421-2442. Sippel, Sebastian, et al. "A novel bias correction methodology for climate impact simulations." Earth System Dynamics 7.1



(2016): 71.

A: References Boberg, F., Christensen, J.H., 2012. Overestimation of Mediterranean summer temperature projections due to model deficiencies. Nat. Clim. Chang. 2, 433–436. doi:10.1038/nclimate1454 Grillakis, M.G., Koutroulis, A.G., Tsanis, I.K., 2013. Multisegment statistical bias correction of daily GCM precipitation output. J. Geophys. Res. Atmos. 118, 3150–3162. doi:10.1002/jgrd.50323 Grillakis, M.G., Koutroulis, A.G., Tsanis, I.K., 2013. Multisegment statistical bias correction of daily GCM precipitation output. J. Geophys. Res. Atmos. 118. doi:10.1002/jgrd.50323 Hagemann, S., Chen, C., Haerter, J.O., Heinke, J., Gerten, D., Piani, C., Hagemann, S., Chen, C., Haerter, J.O., Heinke, J., Gerten, D., Piani, C., 2011. Impact of a Statistical Bias Correction on the Projected Hydrological Changes Obtained from Three GCMs and Two Hydrology Models. http://dx.doi.org/10.1175/2011JHM1336.1. Hempel, S., Frieler, K., Warszawski, L., Schewe, J., Piontek, F., 2013. A trend-preserving bias correction – the ISI-MIP approach. Earth Syst. Dyn. 4, 219–236. doi:10.5194/esd-4-219-2013 Li, H., Sheffield, J., Wood, E.F., 2010. Bias correction of monthly precipitation and temperature fields from Intergovernmental Panel on Climate Change AR4 models using equidistant quantile matching. J. Geophys. Res. 115, D10101. doi:10.1029/2009JD012882 Lins, H.F., 2012. A Note on Stationarity and Nonstationarity. WMOCHy-AWG. Maraun, D., 2016. Bias Correcting Climate Change Simulations - a Critical Review. Curr. Clim. Chang. Reports 2, 211–220. doi:10.1007/s40641-016-0050-x Maurer, E.P., Pierce, D.W., 2014. Bias correction can modify climate model simulated precipitation changes without adverse effect on the ensemble mean. Hydrol. Earth Syst. Sci. 18, 915–925. doi:10.5194/hess-18-915-2014 Parker, D., Horton, B., 2005. UNCERTAINTIES IN CENTRAL ENGLAND TEMPERATURE 1878–2003 AND SOME IMPROVEMENTS TO THE MAXIMUM AND MINIMUM SERIES. Int. J. Climatol. Int. J. Clim. 25, 1173–1188. doi:10.1002/joc.1190 Parker, D.E., Legg, T.P., Folland, C.K., 1992. A new daily central England temperature series, 1772–1991. Int. J. Climatol. 12, 317–342. doi:10.1002/joc.3370120402 Pierce, D.W., Cayan, D.R., Maurer, E.P., Abatzoglou, J.T., Hegewisch, K.C., Pierce, D.W., Cayan, D.R., Maurer, E.P., Abatzoglou, J.T., Hegewisch, K.C., 2015. Improved Bias Correction Techniques for Hydrological Simulations of Climate Change*. J. Hydrometeorol. 16, 2421–2442. doi:10.1175/JHM-D-14-0236.1 Rutty, M., Scott, D., 2015. Bioclimatic comfort and the thermal perceptions and preferences of beach tourists. Int. J. Biometeorol. 59, 37–45. doi:10.1007/s00484-014-0820-x Themeßl, M.J., Gobiet, A., Heinrich, G., 2011. Empirical-statistical downscaling and error correction of regional climate models and its impact on the climate change signal. Clim. Change 112, 449–468. doi:10.1007/s10584-011-0224-4

Interactive comment on Earth Syst. Dynam. Discuss., doi:10.5194/esd-2016-52, 2016.



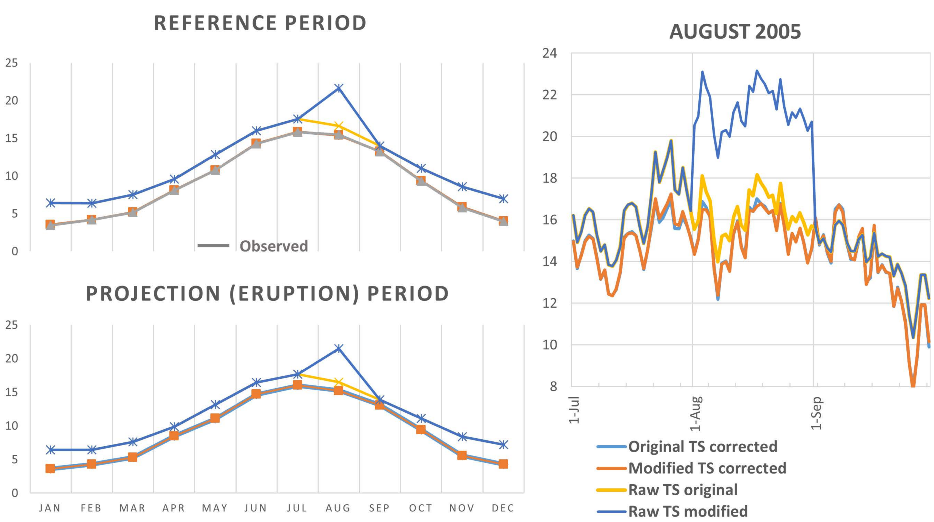


**Fig. 1.**

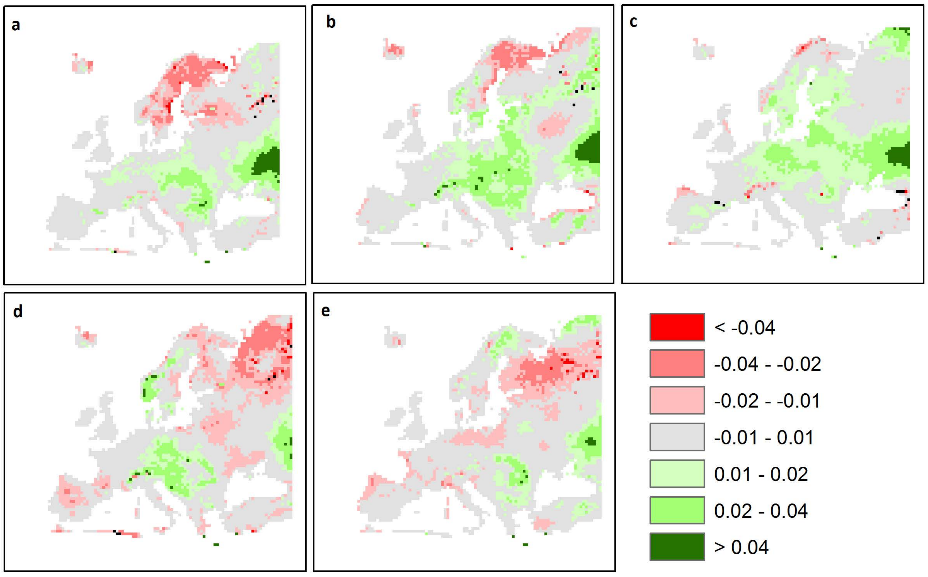
a
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**Fig. 2.**



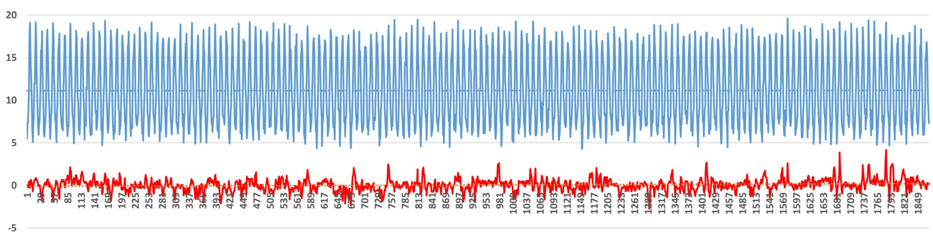
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**Fig. 3.**