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Dear Editor,

We would like to submit the revised manuscript entitled “**New insights into the reconstructed temperature in Portugal over the last 400-years**”, with reference number cp-2014-146, by the authors J. A. Santos, M. F. Carneiro, A. Correia, M. J. Alcoforado, E. Zorita and J. J. Gómez-Navarro, for considering publication in *Climate of the Past*.

We thank the two reviewers for their careful reading of the manuscript and for their comments in the two revisions. We believe they have significantly improved our manuscript. Please see our point-by-point replies below. The corresponding changes in the manuscript are also highlighted in blue.

Looking forward to receiving your decision on this manuscript.

Vila Real, 30 April 2015

Yours sincerely,

J. A. Santos
(The corresponding author)

Editor Decision: Publish subject to minor revisions (review by Editor) (27 Apr 2015) by Stefan Bronnimann

I have two reviews of your paper. As you can see, reviewer #1 is now happy with the manuscript but not reviewer #2, who recommends rejection.

Please consider the review comments carefully in your revised version.

Specifically, comment 7 of reviewer #2 deserves attention (the error in the Luterbacher et al. reconstruction). Also, with respect to comment 6, I think what you are showing in Fig. 5 is basically the good agreement between the Luterbacher et al. 2004 reconstruction and the documentary index (which is to be expected) because the SSA-filtered series does not affect the interannual variability on such a short time window.

Finally, there are still some (few) instances where the tone of the manuscript should be more balanced (e.g., L.263: "...the Lut2004 reconstruction needs to be adequately adjusted for climate research purposes..."), as mentioned by the reviewer in the general comment.

Please submit a revised version of the manuscript, along with a point-by-point reply to the reviewers' comments.

Reply: We have revised the manuscript following all of your recommendations above.

Please see our point-by-point replies to the reviewer's comments below, including our replies to comments 6 and 7 of reviewer #2.

As suggested, we have also revised the text at some specific sentences. The example provided above was changed to:

Lines 262-264: *"As such, the low-frequency variability of the Lut2004 reconstruction are herein adjusted to be more coherent with the borehole data and simulations."*

Other similar changes are highlighted in blue in the revised text.

Reviewer #1

I think the paper has improved considerably and can now be published. However, I would avoid the use of "ensemble" for only two simulations, because this concept suggests that there is a statistical quality (number of samples, representativity) of some kind.

Reply: We thank the reviewer for his careful reading of the manuscript and for his very constructive and supportive comments throughout the revision process.

Regarding the comment above, we have changed the sentence “*An ensemble of two paleoclimate simulations (Sim1 and Sim2)...*” by “*Two paleoclimate simulations (Sim1 and Sim2)...*” (Line 166).

All the other sentences in the text using the term “ensemble” are in the formulations “ensemble mean/size”, i.e. related to a statistical measure.

Reviewer #2

The revised version of the paper is confusing, inconsistent and from different points of view not fully correct. The reader gets the following main interpretation of the research reading the paper: ‘we have a ‘bad’ reconstruction for Portugal, but perfect borehole and model data and need to readjust the reconstruction. This is definitively the wrong message that should be conveyed. Therefore I suggest rejecting the paper.

Reply: We would like to thank the reviewer for his/her comments. Unfortunately, the reviewer was not satisfied with the revision of the paper. However, we disagree that we are conveying a wrong message, as we wish to clarify in our point-by-point replies below.

1. The authors argue to present a (new) correct low frequency temperature estimation for Portugal for the past 400 years without giving convincing reasons why this is necessary and for what purpose such a new estimate is needed.

Reply: We believe that the purpose for this kind of calibration is already stated in the manuscript:

Lines 35-37: “The series resulting from this post-reconstruction adjustment can be of foremost relevance to improve the current understanding of the driving mechanisms of climate variability in Portugal.”

Lines 87-91: “In effect, this calibrated time series may help understanding past climate variability in Portugal and its main driving mechanisms, namely the role of external vs. internal forcing mechanisms on temperature variability. This attribution analysis provides critical information for model validation and for assessing the reliability of regional climate change projections.”

Lines 363-365: “CalT adjusts the low-frequency variability in the Lut2004 reconstruction so as to be more consistent with local borehole measurements and regional climate simulations. It can thus be of foremost relevance in forthcoming research on climatic variability in Portugal.”

We have also added the following sentence to better clarify this issue:

Lines 365-368: “A reliable representation of the low-frequency variability of temperature in Portugal, including its long-term trends, is critical for understanding the role played by external vs. internal forcings on the regional climate variability and change.”

2. The authors write in the text and answers to the reviewers that the Lutherbacher reconstructions has flaws in the low frequencies and thus need to be corrected. They don't provide convincing evidence that this is the case and instead argue that the two simulations and boreholes are the adequate and correct data to perform such a correction. Unfortunately, the authors are not as critical with their data as they are with the reconstructions. The limitations of the RCMs for the area for instance are not reported and also not why the two simulations do not agree in different periods within the past 400 years and what implications this might have. Further, there is quite a large difference within the instrumental period between the observations and the two simulations (borehole data are not shown), thus also the SSA trend show a different sign as the observations for the 2nd part of the 20th century.

Reply: We would like to state that in no circumstance we have said that the Lut2004 reconstruction has “flaws”. In our study we simply highlight some discrepancies of this reconstruction with new data sources (local borehole data and regional simulations). These inconsistencies should be used as a tool for improving the quality of the existing reconstruction and not its refutation. We have indeed used this reconstruction as a basis for our study. Furthermore, in the revised manuscript we also provide uncertainty measures for both the

simulations and borehole data, as was suggested by the two reviewers. We are also well aware of the uncertainties and limitations inherent to borehole data and paleoclimatic simulations. This is also discussed throughout the manuscript, as e.g.:

Lines 227-236: *“The low borehole depths require a word of caution, as some authors have indicated that 200 m of depth may be too shallow for climate change assessments (Beltrami et al., 2011; Hamza et al., 2007; Majorowicz et al., 1999). The Global Database of Borehole Temperatures and Climate Reconstructions from the University of Michigan and the World Data Center for Paleoclimatology indeed consider a 200 m depth as a minimum requirement for past climate reconstruction (Pollack and Huang, 2000). Beltrami et al. (2011) also demonstrated that the maximum depth of borehole profiles can have a large impact on temperature-depth anomalies. Since no other geothermal-paleoclimatological observatory is available in Portugal, the conclusions derived from these borehole profiles may be provisional.”*

Lines 372-377: *“Unfortunately, there are only two available simulations covering Portugal with such high-resolution characteristics. Hence, it is not possible to increase the ensemble size of model simulations, though it would be very useful for uncertainty assessments. In forthcoming research, new regional paleoclimatic simulations over Portugal, also using different models, should be used to enhance the robustness and evaluate the significance of the current adjustment.”*

Lastly, we would like to mention that only the externally driven part of the climate variability is required to agree in the two simulations and in the reconstructions. The fact that the two simulations diverge in certain periods is indicative that those climate anomalies are not externally forced, and therefore observations and simulations are not required to agree in those periods. The main disagreement between simulations and reconstructions is rather the amplitude of variability and not so much the timing of ups and downs in the temperature records. Our study attempts to adjust this amplitude of variability in the Luterbacher reconstructions to make it more consistent with the simulations and the borehole data, precisely the frequency band where such datasets exhibit more reliability.

3. One striking feature is also that the borehole data are not plotted in Fig 2 b.

Reply: All borehole data are plotted in Fig. 2a. As we have not applied inversion methods to the borehole profiles, this data cannot be plotted in a chronogram such as Fig. 2b. This approach is clearly stated in the manuscript:

Lines 135-139: *“The borehole temperature-depth profiles are herein compared to synthetic temperature profiles (forward model), generated from both Lut2004 and annual mean near-surface temperatures from two paleoclimate simulations, rather than applying the conventional procedure of inverting temperature logs to reconstruct ground surface temperatures (e.g. Correia and Šafanda, 2001).”*

4. The main issues from the first review (see point 1) were not addressed. For instance the issue of the uncertainties of single reconstructions and (30 year averages) over Europe and Iberia in the Luterbacher reconstruction.

Reply: With respect to this uncertainty issue, we would like to mention, again, that assuming that the errors in the temperature for the grid point close to Lisbon are of the same order of magnitude as those for the European average, as is suggested by the reviewer in his/her first review, is not an accurate assumption. As we have previously referred, the error in the spatial average depends on spatial correlations between local errors. However, these local errors are not indicated in Luterbacher et al. (2004). Additionally, they do not provide errors for 30-year

averages. The errors at 30-year time scales also depend on the temporal autocorrelation of the annual errors, and this error autocorrelation is also not indicated in Luterbacher et al. (2004). Thus, it is not possible for us to establish the local uncertainty at the 30-year time scale in Lut2004.

5. From the SOM of Luterbacher there it is mention, that Lisbon temperature data back to the mid 1850 are used in their reconstruction. It is thus hard to believe, that the reconstruction back to that time has any serious issues, also in terms of variability, trends.

Reply: We would like to state that we have not found any “serious issues” over the instrumental period. As is stated in the manuscript:

Lines 99-100: *“From 1901 onwards this dataset is based on instrumental data from New et al. (2000)”*.

Therefore, as expected, the Lut2004 reconstruction is in good agreement with the instrumental data, as is also apparent in our Fig2b. In fact, there is a clear superposition between CalT and Lut2004 over the 20th century. The long-term variability is not fully captured only before 1901.

6. Another issue is that the indexed temperature data from Portugal for the LMM were included in the reconstruction of Luterbacher et al. (see their SOM). If they were to be ‘correct’ then also for that period it cannot be argued that the reconstruction has flaws and in my opinion it would be difficult to ‘beat’ the performance of that reconstruction for that period by any other reconstruction (method).

Reply: We agree with this reviewer’s comment. In fact, Fig. 5 also hints at a good agreement between the Lut2004 reconstruction and the annual temperature index during the LMM. Therefore, the following sentence was added to the manuscript:

Lines 331-333: *“However, as the SSA-filtering does not significantly modify the interannual variability within this relatively short time period (LMM), the aforementioned agreement also applies between Lut2004 and the annual temperature index (not shown).”*

7. Page 11: The uncertainties in the CalT series are the combination of the original uncertainties in the Lut2004 dataset plus additional uncertainties related to the non-linear trend used in the adjustment. To my knowledge, the uncertainties for each grid point of the Luterbacher et al. data are not discussed in their publication I am also not aware that those would be accessible online. Uncertainties are given for the mean European reconstruction, therefore I cannot understand why the authors state differently and what kind of uncertainties they are using.

Reply: We also agree that uncertainties in the Lut2004 reconstruction are not available at a grid point level, neither in Luterbacher et al. 2004 nor online. Only European average errors are available. This is now explicitly stated in the manuscript.

Lines 302-306: *“The uncertainties in the CalT series are a combination of the original uncertainties in the Lut2004 dataset plus additional uncertainties related to the non-linear trend used in the adjustment. The former are discussed in Luterbacher et al. (2004), but are only available for the European mean reconstruction. Hence, it is not possible to have a local estimate of these uncertainties.”*

However, bearing this in mind, the reviewer also asks for an analysis of the uncertainties at local/regional scale (see point 4 above and point 1 in the first revision). These suggestions seem to be contradictory.

For sure it is not correct to use the SSA filtering separately from Sim1 and Sim2. The author mix two different data set that cannot be combined/interchanged and thus this analysis is not correct. All subsequent analysis thus do not have merit to be presented as they are based on wrong assumptions. Further, as the authors state themselves, the estimated uncertainty is a lower bound, since it does not explicitly consider uncertainties related to the simulation itself, which are difficult to assess due to the limited number of available simulations with similar characteristics.

Reply: Regarding the SSA filtering, we cannot understand the reviewer's point. SSA can be applied to each simulation separately, as they are two different time series. The reviewer's comment is too unspecific in this regard.

The uncertainty in the simulations may have different origins. Here, we can only address the uncertainty due to internal climate variability, as explained in the text:

Lines 308-310: *“The mean absolute difference between the two non-linear trends obtained from Sim1 and Sim2 provides a measure of the uncertainty related to the simulations. It has an approximate value of 0.05°C.”*

We believe that this is currently the best possible approach to estimate the uncertainty, taking into account the lack of simulated data from RCMs. Furthermore, the structural uncertainty originating in the possible models that could have been used cannot be addressed here since there is only one model available.

8. The authors mention that data are only available until the end of the 20th century. It is hard to believe that the authors do not have updated data from Lisbon going to 2014.

Reply: We understand this comment, but in truth we do not have data after 1999. As we mention in the manuscript, data for the Lisboa-Geofísico meteorological station was supplied by the European Climate Assessment & Dataset project (ECA&D) and the current available period is 1901-1999, as is also referred in the manuscript:

Lines 202-205: *“The consistency of the Lut2004 reconstruction with the corresponding instrumental series (InstT) for the available period of 1901–1999, recorded at the Lisboa-Geofísico meteorological station and supplied by the European Climate Assessment & Dataset project (Klein Tank et al., 2002), was also assessed.”*

We would also like to state that a homogeneity testing was carried out for the temperature series recorded at the Lisboa-Geofísico station by the ECA&D project. On the other hand, the Lisbon-airport weather station, maintained by the Portuguese Meteorological Office (IPMA), has a much shorter time period and its homogeneity was not tested.