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Climate of the Past Discussions

Interactive comment on "Non-linear statistical downscaling of present and LGM precipitation and temperatures over Europe" *by* M. Vrac et al.

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Responses to reviewers’ comments about “Non-linear statistical downscaling of present and LGM precipitation and temperatures over Europe” submitted for publication in Climate of the Past by M. Vrac, P. Marbaix, D. Paillard, and P. Naveau.

We first would like to thank the four anonymous reviewers for their detailed and constructive comments. Those were useful for improving the manuscript.

The manuscript has been remodeled according to the reviewers’ comments. For example, abstract and conclusion sections have been clarified. It has to be noted that the “Monthly GAMs” section has been completely removed from the manuscript in order to focus this article on the main results brought by the annual

GAMs for precipitation and temperature. We think that this modification (suggested by reviewer 2) of the present submission improves the manuscript by making it clearer and easier to follow.

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Condensed responses to reviewer 1:

The abstract and conclusion have been written more precisely.

About the direct comparison of the downscaled values with the 'raw' CLIMBER data, this was done in Fig. 9 of the previous manuscript. This comparison is kept in the new manuscript. Also, the stations 8 and 9 are not rejected anymore, and the comparisons are based on the 10 stations altogether. Remark that a “new” comparison with the interpolated CLIMBER (precipitation and temperature) values has also been added into the manuscript.

The figures have been remodeled according to all reviewers' comments. They all are in high-quality format.

The geographical and physical descriptors have been better described in the abstract. A geographical variable is described as using geographical or topographical information, while a physical predictor is considered as entirely simulated by an Earth System Model of Intermediate Complexity (EMIC), here CLIMBER.

The whole section about the description of GAM has been remodeled. More details are now given in the revised manuscript.

Longitude has been removed from the analysis and from the text. Also, remark that the “Monthly GAMs” section has been completely removed from the manuscript in order to focus this article on the main results brought by the annual GAMs for precipitation and temperature.

The interpolated temperature and precipitation CLIMBER values are now included into table 1 (i.e. old table 2). It is found that the mean GAM downscaled values are closer to the reconstructions than CLIMBER and the PMIP2 GCMs for July temperatures and January precipitation, while CLIMBER is the closest to reconstructions for January temperatures (with GAM projections better than the GCM's), and the GCMs are the closest to the reconstructed July precipitation. This last point is due to stations 8 and 9 with too large downscaled values for the July mean precipitation. This has been added into the manuscript. Remark that stations 8 and 9 are not rejected anymore and the comparisons are based on the 10 stations altogether.

All reviewer 1's technical comments have been taken into account and the associated corrections have been made.

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Condensed responses to reviewer 2:

The abstract and introduction have been re-written. In particular, the abstract states more clearly the main conclusions and the introduction has been remodeled to focus more on the points suggested by reviewer 2, i.e., the needs for downscaling (1) from low-resolution models (such as EMICs), and (2) on longer (past or future) timescales.

The notion of robustness used in this work has been better defined. A statistical downscaling method is said to be robust when this method remains valid when applied to large-scale climate conditions different from the one used for calibration. The main conclusion brought by our comparisons is that although the geographical predictors alone are not entirely satisfactory, they provide better projections (i.e. with smaller residuals) than physical variables alone in downscaling precipitation and temperature values under large-scale climate conditions strongly different from the calibration ones (i.e. they are more “robust” to the change of region for projection).

The introduction section has been remodeled and simplified.

We tried to improve the language and level of presentation all along this article. Moreover, the computation of the percentage of observed variance explained by the model (i.e. what was plotted in old Figure 2) is now expressed analytically in the (new) equation (6).

In this updated submission, the BIC is directly used to select the predictors for the annual GAMs. The BIC has to be considered as a tool for selecting models and predictors. However, this useful tool only gives indications (or help) on the objectively “correct” model. According to the application to be performed and the goal to reach, BIC results can be disobeyed. Here, the BIC indications helped to understand the main predictors to be retained. For example, the BIC choice of predictors is not respected for the temperature models with geographical variables for the reasons given in the manuscript. This has been clarified in the manuscript.

Our objective was to take into account obvious Climatological facts linked to geography (elevation, continentality, slope) without an explicit physical description. For example, it is obvious that mountains and wind strongly influence temperature and precipitation. But modeling these influences in an explicit physical way can be quite tricky. The main idea here is to let our model do this job in a statistical way. Figure 1 is just an example showing that a GAM can model both linearities and non-linearities when needed. In practice, the splines that we obtain are essentially linear and/or monotonic, confirming the underlying physical sense of the selected variables.

In this work, the CLIMBER outputs used for calibration of GAM are obtained from a control run stabilized after a few thousand years. The insolation, pCO2, and ice-sheet forcing are imposed as in Berger (1978), Petit et al. (1999), and Peltier (1994). This has been clarified in the text and the references have been added.

As mentioned earlier, “monthly GAMs” section has been completely removed from the manuscript in order to focus this article on the main results brought by the annual GAMs for precipitation and temperature. In this updated submission, the BIC is directly used to select the predictors for the annual GAMs. Here, the BIC indications helped to understand the main predictors to be retained but are not an absolute rule. For example, the BIC choice of predictors is not respected for the temperature annual models with geographical variables (for the reasons given in the manuscript) and only the second best BIC was retained. This has been clarified in the manuscript.

Stations 8 and 9 are not rejected anymore, and the comparisons are based on the 10 stations altogether. Remark that a “new” comparison with the interpolated CLIMBER (precipitation and temperature) values has also been added into the manuscript.

The figures are now in high-quality format. Units are now indicated in all captions.

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Condensed responses to reviewer 3

Reviewer 3 is right about the role of two of the purely geographical predictors, i.e. latitudes (LAT) and longitudes (LON). These two predictors remaining unchanged under past or future climate, they are not meaningful with respect to the goal of this work and, hence, have been removed from this study. About the change of elevation at the LGM, it is true that our statistical model will interpret this elevation change as a mean cooling of the region, but we have to remember that elevation is not the only predictor used in our model: other predictors can influence the change in temperature (or precipitation) in the same way as the elevation predictor but also in the opposite way. In other words, in our model, the elevation variable plays only a partial role in the cooling at LGM, other variables are also taken into account to characterize the changes in temperature (and precipitation).

More technical details and references about the statistical model and its inference are now given in the manuscript. Three cubic splines are used for each predictor. Hence, we have 12 free parameters per predictors (a cubic polynomial has four parameters), leading to 96 free parameters for 8 predictors. However, the number of CRU gridpoints in the Western Europe region is not 200 but is around 13000 (only non missing values). Consequently, the ratio number of parameters to sample size is quite acceptable. Moreover, the overfitting question is treated by the Bayesian Information Criterion (BIC), that is a classical criterion used for model selection. The retained variables were selected according to BIC, avoiding overfitting of the data by our model. See also our response to next comment.

BIC was not properly written. This has been corrected in the manuscript. We should now read

where d is the dimension of the model (i.e. number of parameters), n the sample size, and RSS the residual sum of squares from the estimated model. This has been clarified in the text and all definitions needed (e.g. RSS) are given in the manuscript.

The main conclusion of the comparisons in North America is that, although the geographical type predictors cannot be considered as satisfactory, they provide local projections “better” than those obtained based on physical type predictors, in the sense that the residuals (obs – predictions) are smaller from geographical variables than from physical ones. This has been clarified in the manuscript. Units have also been precised in the text and figures captions.

The two locations 8 and 9 are not excluded from the analysis anymore. Hence, the comparisons are now based on the ten locations available. The interpolated CLIMBER precipitation and temperature values have also been included in new table 1 (previous table 2) to perform a more complete comparison. It is found that the mean GAM downscaled values are closer to the reconstructions than CLIMBER and the PMIP2 GCMs for July temperatures and January precipitation, while CLIMBER is the closest to reconstructions for January temperatures (with GAM projections better than the GCM’s), and the GCMs are the closest to the reconstructed July precipitation. This last point is due to stations 8 and 9 with too large downscaled values for the July mean precipitation. This has been added into the manuscript.

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The introduction has been slightly shortened (condensed considerations about statistical downscaling methods). More details about differences between our model and more usual ones are also added. Moreover, more descriptions about the statistical model are now provided in Section 2.3.

In the toy model, the LAT predictor is found to be uninformative since it is constantly equal to zero, hence not participating to describe July precipitation, nor explaining its variance. This has been clarified in the text. Since this toy model is just an example presented for illustration of how GAM works, no BIC have been used for this model. In other words, first, some of the predictors used can make no sense relatively to July precipitation, and second, it is possible that the resulting GAM overfits the example data. Remark also that LAT is not used as predictor in the following.

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Condensed responses to reviewer 4:

The description of the Generalized Additive Models has been improved. Also, the fact that arbitrary functions, not only splines, can be used in GAM is now mentioned in the manuscript.

More details about the method have been added to the description of the GAM. For information, our model has an identity link function. Although this is not mentioned in the manuscript (to avoid uninformative details), equation (1) and the details given should make it implicitly clear. The way to select the knots, as well as the number of degrees of freedom has also been described in the section 2.3 about the presentation of GAM.

The correct formula for BIC is now included in the text and the associated analysis have been performed again in consequence. Interpolated CLIMBER values are now used for comparison with the GAM downscaled LGM temperatures and precipitation. The results are presented in Fig. 8 and in table 1. We see that the mean GAM downscaled

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values are closer to the reconstructions than CLIMBER and the PMIP2 GCMs for July temperatures and January precipitation, while CLIMBER is the closest to reconstructions for January temperatures (with GAM projections better than the GCM’s), and the GCMs are the closest to the reconstructed July precipitation. This last point is due to stations 8 and 9 with too large downscaled values for the July mean precipitation.

The figures should now been in high-quality format. Their size can nevertheless be variable and are left to the appreciation of the production staff.

As a final answer, we would like to thank the four reviewers for their detailed and constructive comments.

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Interactive comment on Clim. Past Discuss., 3, 899, 2007.

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Interactive Comment