

# ***Interactive comment on “Statistical downscaling of a climate simulation of the last glacial cycle: temperature and precipitation over Northern Europe” by N. Korhonen et al.***

## **Anonymous Referee #1**

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## **General description**

Korhonen et al. perform statistical downscaling of an EMIC simulation of the last glacial cycle climate evolution. A statistical downscaling method, Generalized Additive Models, previously used by e.g. Vrac et al (2007), is utilized. Previous studies rely on the assumption that the statistical relations are valid for the range of glacial to interglacial boundary conditions, whilst Korhonen et al include different explanatory variables in the statistical downscaling to account for the presence of an ice sheet. The inclusion of the shortest distance to an ice sheet margin as an explanatory variable is novel, and potent. The manuscript describes an interesting approach to downscaling low-

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resolution simulations of climate on glacial-interglacial time scales. The manuscript is however difficult to follow, and descriptions of the methodology and discussion of the results need to be substantially improved to meet the standards of the *Climate of the Past*.

## Major comments

- A general discussion on different techniques for statistical and dynamical downscaling is lacking. The discussion should include reference to the recent discussion on the added value of downscaling, e.g. Racherla et al (2012).
- The methodology is not well described. The climate model simulations used must be better described, and the choice must be motivated. Further, the use of two geographical regions must be better described and motivated. Also, the methodology used in determination of which explanatory variables should be used in the GAM and the benefits of including the shortest distance to the ice sheet (rather than the continentality used by Vrac et al, 2007) is not described or discussed.
- To avoid the problem of lacking observations (temperature, precipitation, ice sheet position) for the glacial climates, Korhonen et al. utilize results from global climate modelling and from dynamically downscaled global climate modelling. This choice is not discussed in the manuscript, although a number of issues warrant a discussion:
- The ice sheet extent and topography implemented in the RCA3, CCSM4 and CLIMBER-2 - SICOPOLIS simulations differ. How is this treated in the current work? How does it influence the results?
- In the text, the authors state that they use both the most recent CCSM4 LGM simulation and the RCA3 downscaling of a CCSM3 LGM simulation to represent

C1294

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9, C1293–C1300, 2013

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the LGM climate. The use of these two data sets is not clear. Are the two datasets combined, or used separately? In combination with a clear description of the use of the two data sets, the authors should briefly discuss the differences in the simulated climate between the two. The global CCSM3 simulation downscaled by Kjellstrom et al (Brandefelt and Otto-Bliesner, 2009) differs substantially from the standard CCSM3 simulation referred to in the manuscript (Otto-Bliesner et al., 2006), and presumably it also differs from the CCSM4 LGM simulation (Brady et al., 2013). These differences are important to discuss in relation to the usage of a combination of results from these simulations.

- The RCA3 and CCSM4 simulations are used here to replace observations. Why were these specific global (and dynamically downscaled global) simulations chosen? How does the simulated climate compare to other modelling of the LGM (PMIP2; Kageyama et al 2006, and PMIP3; Annan and Hargreaves (2013), Brandefelt and Otto-Bliesner, 2009) and MIS3 (van Meerbeeck et al, 2009)? How does it compare to proxy reconstructions (e.g. Annan and Hargreaves, 2013)?

### Minor comments

- Times should be given in a consequent manner, e.g. with kyr BP. 'kyr' should be defined the first time it is used.
- Abstract. The abstract reads very much as a listing of what was done without a statement of the aim of the study.
- Introduction; page 3373; lines 2-6. The authors state that GCMs cannot be used for simulations of full glacial cycles; Smith and Gregory (2012) however used an AOGCM in a transient simulation of the last glacial cycle. Further, the references to simulations of the distant past climate represent an odd selection. Please

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refer to some article describing PMIP2 and/or PMIP3 results. The ordering of the references is also odd, it is neither alphabetic nor based on publication year.

- Introduction; page 3373; lines 7-20. The division between AOGCMs and EMICs must be better described. What is meant by an AOGCM, which components of the climate system are dynamically modelled and which are assumed constant? Similarly for EMICs; these exist in many flavours, some e.g. including global bio-geo-chemical cycles. Please improve the description and discussion of differences and similarities between different types of models.
- Introduction; page 3373; lines 21-29. Please elaborate on the deficiencies of EMICs; both resolution and modelling simplifications (such as the use of statistical descriptions of the atmospheric dynamics) may influence the validity of the simulated climate and climate evolution.

Further, I wonder if c. 50 km horizontal resolution is really representative of regional climate simulations, or if this is just the resolution of the RCA3 simulations utilized in the present study.

- Introduction; page 3374; line 12. AP is not defined. Further, the articles by Martin et al. describe the future 1000 yr, rather than the future 100 yr.
- Introduction; page 3374; lines 20-25. Since the simulated regional climate is strongly dependent on the global climate simulations, the global climate simulations used by Kjellstrom et al and Strandberg et al should also be cited.
- Section 2. It is not clear which type of data from the different models /observations are used; what is meant by temperature - T2m or something else?, are the variables included in the calibration of the statistical model monthly means for each grid point (giving 12 values for each variable and grid point)? How many years were the RCA3 data averaged over?

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- Sect. 2. Two regions are mentioned in Sect. 2, western Eurasia and northern Europe. The purpose of using two different regions is not described. Please motivate the definition of these regions, why were these particular regions chosen, why are there two regions, how are these incorporated in the analysis?
- Equation 3. Does log mean natural logarithm or base 10?
- Sect 2.2. Page 3378 The description of the CLIMBER-2-SICOPOLIS model is not detailed enough. Please detail the different components somewhat more, and relate to the discussion in the introduction on different types of models.
- Sect. 2.3.1. The authors must comment on the choice of CRU (land-only) data in combination with very low resolution data over the ocean. Why is not NCEP or ERA re-analysis data, which has much higher resolution, used?
- Sect. 2.3.2. To avoid mis-understanding, please refer to the articles describing the CCSM3 simulations used as boundary conditions to the RCA3 simulations. In the current writing, one may conclude that the LGM boundary conditions were those reported by Otto-Bliesner et al, 2006.
- Sect. 2.3.2. Line 13. What is meant by historical climates? Is this a simulation of the pre-industrial or recent past climate or what?
- Equations 6-10. The equations are somewhat confusing. Please indicate which variables are functions of the location and which are not.
- Sect. 3. For clarity, please divide the results section into subsections.
- Sect. 3. The results, skill scores etc. are given one after the other with very little discussion on how they relate to observations and other studies. E.g. how do the skill scores related to the results of Vrac et al (2007) and Martin et al (2013)? Any improvements?

- Sect. 3. As mentioned earlier, it is not evident why two different regions were studied and how the different simulations were used for the different regions. This description must be improved.
- Sect. 3. The spatial patterns may be relatively well captured by the GAMs, but the absolute values are off in large regions. Please comment on this and discuss the results in relation to other studies of statistical and dynamical downscaling. What is the use of downscaling in a region where the temperature is several degrees off from the observed?
- Sect. 3. and Fig. 6. You have not explained the difference between GAM Western and GAM Northern,, and also, you do not discuss the 1-3 degree difference between the temperatures in these!
- Sect. 3. Page 3382; Lines 8-10. I do not agree on the interpretation of Fig. 2a. The spline function plotted reduces the precipitation (regardless of the location I suppose) in months of low precip simulated with CLIMBER, and enhances the precipitation in months of high CLIMBER-simulated precip. This means that the spline function increases the amplitude of the precipitation annual cycle (which is reasonable since CLIMBER-2 has such low horizontal resolution and thus simulates smoothed precipitation variability in time and space).
- Sect. 3. Page 3382; Lines 15-17. I am a bit curious about the shape of the elevation component of the GAM in Fig. 2c. It shows that precip is higher than the CLIMBER-2 precip for moderate elevations, but lower than CLIMBER-2 for an intermediate elevation range of c. 1000-2200 m. Can this be explained in meteorological terms? Is it somehow connected to the inclusion of glacial climates with thick ice sheets? What does the cpline function lookk like if only present observations are included?
- Figure 2. Please incert a thin black line at s equals 0 in subplots 1,c and d to

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illustrate above and below CLIMBER-2 simulated precipitation. Also, in subplot d. it may be easier to read the plot if the directions were indicated with S, N, E and W.

## References

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