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Interactive comment on "Gridded climate data from 5 GCMs of the Last Glacial Maximum downscaled to 30 arc s for Europe" *by* D. R. Schmatz et al.

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Referee #1: This manuscript aims to bridge the gap between climate model output (from GCMs above all) and the needs of climate impact models. While GCMs typically have a resolution of 100-300 km impact models often require much higher resolution, c. 1- 10 km. One way to bridge this gap in resolution is to use the delta change factor method, which means that the the climate change signal is applied to an existing high resolved observational data set. Normally, this is a rather straightforward approach, but in the case of LGM things are more complicated since the land-sea mask in LGM and today is very different. The LGM sea level was about 125 m meters lower than

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today meaning that a lot more land was exposed during that time. For these regions there are no observations to use in delta change factor method. Schmatz et al. solve this by extrapolating existing data onto the LGM land surface asking the question "what would today's climate be if we had the LGM land surface?". By using linear regression modern day temperature and precipitation is adjusted for changes in elevation and distance to the coast. The difference in climate between pre-industrial (PI) time and LGM as simulated by a GCM is then applied to the extended observational data set to achieve a high resolved data set of LGM climate. The delta change factor method is not new, but I have never seen it applied on LGM. I'm sure there is a need for high resolved LGM data.

Response: We find the referee has summarized the intention of our manuscript very well. One point we wanted to raise here is that R. Hijmans and colleagues actually had applied the change factor method to LGM climates. This work is not published in the scientific literature, nor is the actual procedure documented, but the layers are available online (http://www.worldclim.org/paleo-climate). Similarly, several authors (e.g. Maiorano et al. (2013) and Pearman et al. (2008)) used the same method for Holocene climates but they only applied it to the current land mask. The problem with the current land mask is that it does not allow studying some of the important coastal migration routes of the early Holocene and certain putative LGM refugia that are crucial for understanding current biodiversity and population genetic patterns. - Maiorano L, Cheddadi R, Zimmerman NE, Pellissier L, Petitpierre B, Pottier J, Laborde H, Hurdu BI, Pearman PB, Psomas A, Singarayer JS, Broennimann O, Vittoz P, Dubuis A, Edwards ME, Binney HA & Guisan A, 2013. Building the niche through time: using 13,000 years of data to predict the effects of climate change on three tree species in Europe. Global Ecology and Biogeography 22: 302-317. - Pearman PB, Randin CF, Broennimann O, Vittoz P, van der Knaap WO, Engler R, Le Lay G, Zimmermann NE & Guisan A, 2008. Testing predictions of change in plant-species distributions across six millennia. Ecology Letters 11: 357-369.

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Referee #1: General comments I am sceptical about this work, it seems to me that a lot of effort is made to add un- certainty to something already uncertain, and the gain of all this is unclear to me. The manuscript doesn't do anything do convince me of the benefits of this method. The end product (high resolved data sets of LGM climate based on 5 different GCMs) is not showed at all.

Response: We realized only after publication the fact that the Pangaea link (http://doi.pangaea.de/10.1594/PANGAEA.845883) had disappeared in the published version. We do not know why, and would like to apologize for this. It is evident that the reviewer was not able to view or check the data visually. Nonetheless, the downscaled data are publicly available. Clearly, testing the method directly is impossible since there are no independent data of the LGM climate of the currently submerged land with which we could compare the values we report. In order to assess the uncertainty involved in extrapolating climate to these now submerged areas, the manuscript describes a test that is constructed by using the algorithm to extend the coastal climate inland, i.e., over areas that are also currently land. Subsequently, we assess the degree of interpolation uncertainty and potential bias generated by the extrapolation by comparing the test layers directly to the Worlclim layers. As we argue in the discussion, we believe that the interpolation uncertainty is low for areas in close proximity to current land. Further, the gain of having information is considerable, as it allows analyses of climate impacts to make inferences on areas that were terrestrial at the LGM but are now submerged. By providing the downscaled data layers, fully documenting our methods, and being transparent regarding our assumptions, we assist future impact studies in developing valid limits to their inferences.

Referee #1: My greatest concerns are: The gain of the method. On step in the delta change factor method is to interpolate GCM data to the higher resolution of the observational data set. This is the step that achieves the higher resolution. The next step, where the interpolated GCM data is applied to observation, adjusts the absolute values in the GCM climate so that any systematic biases are removed. This is the gain of the method. However, in central Europe LGM was 10-30 °C colder than today, depending on region and season. This is a huge difference in climate. If we lower the temperature with 20 °C, does it matter if we start from 16 or 18 °C in the present climate? Especially given the uncertainties in the GCM simulations. The inferred uncertainty from the delta change method may be of the same size as the bias in the GCMs. Since I'm not convinced of the method (see below) I'm not not sure if that is a risk I'm willing to take.

Response: As stated above, our primary intent was to produce a data set that fulfills the needs of climate impact models, especially when analyzing LGM refugia of plants & animals and their subsequent migration after LGM. For this purpose, determining the areas where life was still possible commands the greatest importance, not determining the coldest regions of LGM. In identifying areas still suitable for life, differences of as little as 2°C can be decisive, creating large impacts in models of plant geographic distributions. Of course, there are several uncertainties inherent to GCMs. However, ignoring these additional 2°C differences would increase the uncertainty even further, by ignoring a potentially important bias that we were able to correct. Overall, we are fully aware of the considerable uncertainties in the spatial scaling of simulated LGM climate. We simply wanted to remove as much additional uncertainty as possible to produce the best possible downscaled climate models, from the perspective of assessing climate impacts on plant and animal life. In impact assessment models, larger uncertainties usually result in less detectable signal in the responses.

Referee #1: The representativity of “Worldclim extended”. Points near the present coast line (on land or off shore) will be adjusted to be consistent with the new land-sea mask when the sea level i lowered. This means that some of the data in “Worldclim extended” is not representing real conditions. In the GCMs the PI time is modelled with PI topography and LGM with LGM topography. This means that in a grid box the difference between PI and LGM is not only a result of the difference in climate itself, but also differences in surface characteristics (sea, ice, land), elevation, distance to the coast etc. For example one reason that Scandinavia was colder in LGM was that it was covered by ice. When the difference in GCM simulated climate is applied to “Worldclim extended” it is applied to something that is adjusted to these differences. As I see it the simulated GCM climate is therefore applied to observations that are biased from reality.

Response: We are not fully sure to what the Referee #1 refers to. Does s/he (1) question the anomaly application in general due to differences in surface characteristics between LGM and PI times or (2) point to the area between the LGM and PI coastline (the extended part) as being unrealistic? We have to assume that the surface characteristics (e.g. ice, sea, land, elevation, etc.) at PI time are the same as today. When we construct "preindustrial worldclim extended" we do not change the topography at all. (1) Of course, surface characteristics differ considerably between LGM and PI time. However, because the GCMs model PI time with PI topography and LGM with LGM topography, these differences are accounted for in a realistic fashion. Therefore also the anomalies (which are simply temperature or precipitation differences at a coordinate point) implicitly respect these topological differences. And because surface characteristics at PI time are assumed to be the same as today an application of such an anomaly to "preindustrial worldclim extended" is adequate. (2) The area between the LGM and PI coastline was modelled by the GCMs as ocean climate at PI time but we apply the anomaly to the extrapolated land climate of "preindustrial worldclim extended". However, we think that this has no significant effect since the GCMs have such a coarse resolution of 2.5°-2.8° ($\sim$300km). Cells near the coast cover huge areas of land and ocean alike, making coastal and inland climate indistinguishable. We will address this in the discussion section.

Referee #1: The results. The result of this study should be a high resolved LGM climate. Very little is shown of this, only two panels in Fig. 5, and they only show one month for one GCM. What do the reconstructed climate look like in all of Europe? How do the results compare to the original GCM results? How do they compare to other simulations (for RCM simulations of LGM see e.g Jost et al. 2005; Strandberg et al.,

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2011)? How do they compare to proxies? The lack of results make it impossible to estimate the value and correctness of the model. Furthermore the presented LGM climate in Fig. 5c and 5d seems to be wrong. In LGM a large part of the domain shown in Fig. 5 was covered by an ice sheet. I don't expect the mountains in Scotland and northern England to influence temperature or precipitation (as they seem to be in Fig. 5) when they are covered by a few hundred meters of ice.

Response: The results can be downloaded from the Pangaea link, which has the uploaded data: http://doi.pangaea.de/10.1594/PANGAEA.845883. Unfortunately, this link had disappeared from the discussion paper, but of course it has to be included since the link is still valid. We will also add figures in the main text to better show the results (see below). We did not mask out the area of the ice. But we will now improve existing figures by adding an ice mask at LGM. Also, we will upload the same ice mask to Pangaea so that users of our data can make their own decision about whether they want to use this mask or another.

Referee #1: To conclude, to make this manuscript acceptable the results must be better accounted for. And it has to bee shown why these results are better than the original GCM simula- tions and why this method is better than a simple bilinear interpolation of the GCM data. As it is now the title "Gridded climate data from 5 GCMs of the Last Glacial Maximum downscaled to 30arcs for Europe" is misleading.

Response: The results are described in detail, but only shown exemplarily in Fig. 5c & 5d, since input data sets and all results are available for download on www.pangaea.de. To better illustrate the final results and title we will include additional figures in the main text (few only) and in the appendix showing e.g. maps of annual sums and averages of precipitation and temperature for each of the GCMs for whole Europe. Then the title will be better reflected. The very coarse resolution of the GCMs prohibits their direct use in climate impact models. We therefore also do not find it interesting to compare a high-resolution (downscaled) LGM map with a coarse resolution GCM map for LGM. Also, a simple bilinear interpolation would not increase the real resolution and the model bias would remain. The change factor method corrects for this model bias.

Referee #1: Specific comments P. 2586, l. 4-6: “Another shortcoming of available datasets on past climate is that the effects of sea level rise and fall are not considered.” This is not true, PMIP2 uses LGM topography (see e.g. Braconnot et al., 2007).

Response: Here we refer to very high-resolution datasets available for LGM, not the GCMs as those used in PMIP2. The sentence will be changed to: "Another shortcoming of available high resolution datasets on past climate is that the effects of sea level rise and fall are not comprehensively considered."

Referee #1: P. 2586, l. 16: “we calculate 19 ’bioclimatic’ variables”. These variables are mentioned here and once in section “Summary and conclusions”. What are these variables? How where they calculated, and why?

Response: We thank the reviewer for pointing to this lack of clarity. The bioclimatic variables are variables that are biologially more meaningful, derived from Tmax, Tmin, Tave, Prec. They are often used in climate change impact studies or ecological niche modeling. Examples are “isothermality”, “precipitation of the warmest quarter” and “mean diurnal temperature range”. They are described in detail at worldclim.org/bioclim, including the program code. We already refer to the original Hijmans et al. (2005) publication in the text but we will augment the text accordingly.

Referee #1: P. 2590, l. 1-3: “we assumed physical processes like air pressure, weather patterns, exposition, and geographic trends in solar radiation are unaffected by the exposure of additional terrestrial land area during LGM.” It is not easy to answer the highly theoretical question “What would today’s climate be if we had the LGM land surface?”. Probably the general circulation would change which would effect temperature and precipitation.

Response: Of course the referee has a point here, and is correct that it IS a complex situation. However, we have made simplifying assumptions because other less restrictive assumptions would require us to employ physical downscaling by means of RCMs to a 1km spatial resolution. While this might change coastal climate patterns quite considerably this is not what we present here. The effect of changed land masses on general circulation would probably be stronger where big areas of land were exposed (e.g. in the North Sea due to the increased distance to the ocean) than on the steeper continental rims, which actually represent the majority of the areas that are now submerged. We will extend the description of this assumption accordingly.

Referee #1: P. 2595, l. 6-7: "Even though we intended to present downscaled climate data for Europe we used the area of the Yucatán Peninsula (Gulf of Mexico) to develop our method". I see the point of testing the model for different areas, but the reader of this paper is probably mostly interested in how the model performs for Europe. Why don't show that?

Response: Also here we should be more precise and will adapt the text. We only developed the extrapolation method for precipitation to the LGM coast in the Yucatán area. In order to cover all cases, an area with variable topography and precipitation patterns is best suited to develop the extrapolation method. The major reason to use the Yucatán area was that it contains steep coasts in the south and extremely flat regions in the north. Lowering the sea level by 125 meters has very different effects on these coastlines. Also, the precipitation gradient in this area was an important criterion. Finally, we intended to apply the method to other continents, too. However, in this paper, we simply present the method and offer access to the data from Europe, as it has been processed based on the here presented approach.

Referee #1: P. 2596, l. 26-27: "We therefore have to assume that the precipitation difference be- tween current and preindustrial times is negligible." I see why this is necessary, but it is not true and adds to the uncertainties in the method.

Response: That is correct and it is a clear, but unavoidable weakness. We mention this issue in the discussion, but do not feel it should be dwelt upon. As soon as monthly

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precipitation data become available (they currently are not) this difference can be estimated and the results improved still further.

Referee #1: P. 2597, l. 5: “the following GCMs”. References to models and simulations are missing. References Braconnot, P., Otto-Bliesner, B., Harrison, S., Joussaume, S., Peterchmitt, J.-Y., Abe-Ouchi, A., Crucifix, M., Driesschaert, E., Fichefet, Th., Hewitt, C. D., Kageyama, M., Kitoh, A., Laîné, A., Loutre, M.-F., Marti, O., Merkel, U., Ramstein, G., Valdes, P., Weber, S. L., Yu, Y., and Zhao, Y.: Results of PMIP2 coupled simulations of the Mid- Holocene and Last Glacial Maximum – Part 1: experiments and large-scale features, Clim. Past, 3, 261–277, doi: 10.5194/cp-253-261-2007, 2007. Jost, A., Lunt, D., Kageyama, M., Abe-Ouchi, A., Peyron, O. and coauthors. 2005. High-resolution simulations of the last glacial maximum climate over Europe: a solution to discrepancies with continental palaeoclimatic reconstructions? Clim. Dyn. 24, 577–590. Strandberg, G., Brandefelt, J., Kjellström, E., and Smith, B.: High-resolution regional simulation of the last glacial maximum climate in Europe, Tellus A, 63, 107–125, 2011.

Response: We thank the referee for this information. However, Braconnot et al. (2007) is already cited. Jost et al. and Strandberg et al. downscale to 50-60km resolution, which is too coarse for our purposes. Yet, we now edit the manuscript to include them as examples in the introduction. Thank you for this suggestion.

Interactive comment on Clim. Past Discuss., 11, 2585, 2015.