

Interactive comment on “The last glacial maximum locations of summer-green tree refugia using simulations with ECHAM3 T42 uncoupled, ECHAM5 T31 coupled and ECHAM5 T106 uncoupled models” by K. Arpe et al.

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In this manuscript, Arpe and collaborators evaluate simulations for the present and the Last Glacial Maximum with three ECHAM model versions (ECHAM T42 uncoupled model forced by Sea Surface Temperatures -SST- provided by CLIMAP, coupled ECHAM5-MPIOM T31 model and ECHAM5 T106 uncoupled model forced by SSTs, corrected for systematic errors, provided by the coupled model) and find that the ECHAM5 T106 provides the most realistic simulation for present-day climate conditions. Subsequently, they predict the location of summer-green tree (cold and warm-

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loving trees) refugia in Europe during the LGM, and show that summer precipitation, minimum winter temperatures and growing degree days are the most appropriate parameters to predict the location of summer-green tree growth in this region. They reach two interesting conclusions: a) they establish that the resolution applied to the model is more important than other parts of the model formulations and, b) they identify potential refugium zones for warm-loving summer-green trees such as southern Italy, not identified by data. Based on their conclusions, it becomes now possible to detect with increasing confidence LGM refugia for temperate trees. These results justify the publication of the manuscript submitted by Arpe and collaborators to *The Climate of the Past*. However, I have four main concerns that the authors should discuss before this work being published.

1- Atmospheric conditions in Europe during the LGM

The authors predict with the ECHAM T106 run a more southerly position of the main flow during the LGM over the Alps, a shift of the precipitation towards the Mediterranean Sea and an eastern Mediterranean region more humid during the LGM than now but with summer precipitations lower at the LGM than at present. These simulations would fit with several lines of evidence such as southern Alpine glacier advances (northeast-directed cyclone tracks) and high lake stand in the Dead Sea during the LGM. However, contrasting observations are presented by Kuhlemann et al. (2008, *Science* 321: 1338-1340). They document, based on a Mediterranean synthesis of palaeo-observations from the sea surface to alpine altitudes (Sea Surface Temperatures, SSTs, and Equilibrium Line Altitude, ELA), frequent cold polar air incursions channeled between the Alps and the Pyrenees associated with blocking moisture supply by the westerlies during winters alternating with more zonal circulation during warm seasons. Arpe et al. should discuss these data, which appear in contradiction with their simulations.

2- Contradiction between temperatures simulated by models and estimated by transfer functions

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Arpe et al. refer to the estimated coldest mean temperature (MTCO) and annual mean precipitation (Pann) for the LGM in Europe published by Peyron et al (1998) and find that these estimations predict colder and drier climate than that simulated by their models. They consider that it is difficult to judge whether the minimum temperature patterns are more realistic in the one or the other simulation. In my view this mismatch is likely due to the erroneous chronological attribution of a number of pollen spectra assigned to the LGM by Peyron et al. : only half of the European pollen sites generally attributed to the LGM (7 out of 15) have a reliable chronology and can be assigned to the LGM time interval ($18,000 \pm 2,000$ 14C years BP). The other pollen spectra are probably contemporaneous with Heinrich event 1 or 2. Since we know that the Heinrich events are drier and colder than the LGM (Turon et al., 2003, Kageyama et al., 2005; Naughton et al., 2007, Fletcher & Sanchez Goñi, 2008) the low temperature estimates proposed by Peyron et al. reflect in most of the cases the climate of Heinrich events. A critical analysis of the chronological attribution of the sequences considered by Peyron et al. is needed before any meaningful comparison between the two sets of estimates is made. My prediction is that if only the reliable LGM pollen spectra will be considered the temperature estimates obtained by the two methods will be more similar.

3- Temperature of the warmest month

Arpe et al. claim, based on the work by Van Campo (1984) that a limiting factor for summer-green tree growth is the value of 12°C for the warmest month. Van Campo refers to 12°C in the summer Sea Surface Temperatures of the North Atlantic, not to the warmest month temperature on land. Therefore, this paragraph should be either removed or modified to take into account SST instead of temperatures on the continent.

4- Marine pollen sequences versus vegetation in the adjacent continent

I agree with Arpe et al. in giving ± 3 grid points (3.75°) to the vegetation area represented by the marine pollen assemblages from western European margin and Mediterranean Sea sequences. However, based on several experimental studies performed

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in this region, it is unlikely that a significant amount of pollen can come from further away than this ± 3 grid points. Naughton et al (2007) have clearly shown that the top samples from two cores 5° far from each other, collected in front of Galicia and Lisbon, and representing the vegetation of the last centuries, discriminate the two kinds of vegetation that occupy at present south western and north western Iberia.

Minor comments

- Non-modellers would need a more detailed explanation of the differences between coupled and uncoupled ECHAM models.
- The authors say that the 4,000-yr time window between 23 and 19 ka is coeval with the lowest stand of sea level after Yokoyama et al.(2000). However, recent studies suggest an earlier date, 26 ka, for the maximum global ice extension (Peltier & Fairbanks, 2006).
- Please give the meaning of the following abbreviations: ECMWF and MPI.
- Authors should discuss results from the marine pollen sequence of the Galician margin, MD99-2331, presented by Naughton et al (2007). Data from this and the other Iberian sequences strongly support the occurrence of refugium zones for summer-green trees during the LGM, and this not only in the south but also in north western Iberia.
- In the conclusion, the authors encourage the usage of climate model simulations for identifying potential refugia in other regions of the planet. It would be appropriate here to emphasise also the need for new high quality data to constrain better the model simulations.
- Figure captions:
 - o Figure 1: Please replace “Annual mean SST differences between LGM” by “Annual mean SST differences between LGM and the present (NOW).”
 - o Figure 3: What does “dam” mean? And please replace “LGM<NOW” by “LGM-NOW”.

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o Figure 7: I do not see on the map the symbol Xs. I only identify circles, triangles and crosses.

References

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