CLIMCYC: Modeling of the Last Glacial Cycle: Response of Climate and Vegetation to Insolation Forcing Between 132-112 ka BP

U. Mikolajewicz[1], M. Gröger[1], E. Maier-Reimer[1], G. Schurgers[1], M. Vizcaino[1] and A. Winguth[2]
[1]Max-Planck-Institut für Meteorologie, Bundesstraße 55, 20146 Hamburg, Germany; groeger@dkrz.de
[2]Center for Climatic Research, Department of Atmospheric and Oceanic Sciences, 1225 W. Dayton St., Madison, WI 53706, USA

The last ice age is known for high frequency climate fluctuations that cannot be explained by astronomical forcing alone. Therefore, an accurate simulation of internal feedbacks between individual climate subsystems is absolutely necessary. In the set of experiments presented here, the model's ability to simulate climate feedbacks from the land biosphere has been verified by transient simulations with both the ECHAML/LSG and the ECHAM/LSG/LPJ model. The experiments were performed with a time-varying insolation from 132 ka proceeding to 112 ka. This time frame covers the transition from the last interglacial to the following glacial and is therefore ideal for the study of climate feedbacks. Figure 1 shows the response of near surface summer temperature to the astronomical forcing in the northern hemisphere. The stronger cooling of the northern hemisphere in the model version with included vegetation model LPJ is mainly due to the replacement of forest with lighter grass or even snow areas in the higher latitudes. This effect is important for the establishment of continental ice sheets and the inception of glacials. since it increases the albedo, thus amplifying the astronomical forcing.

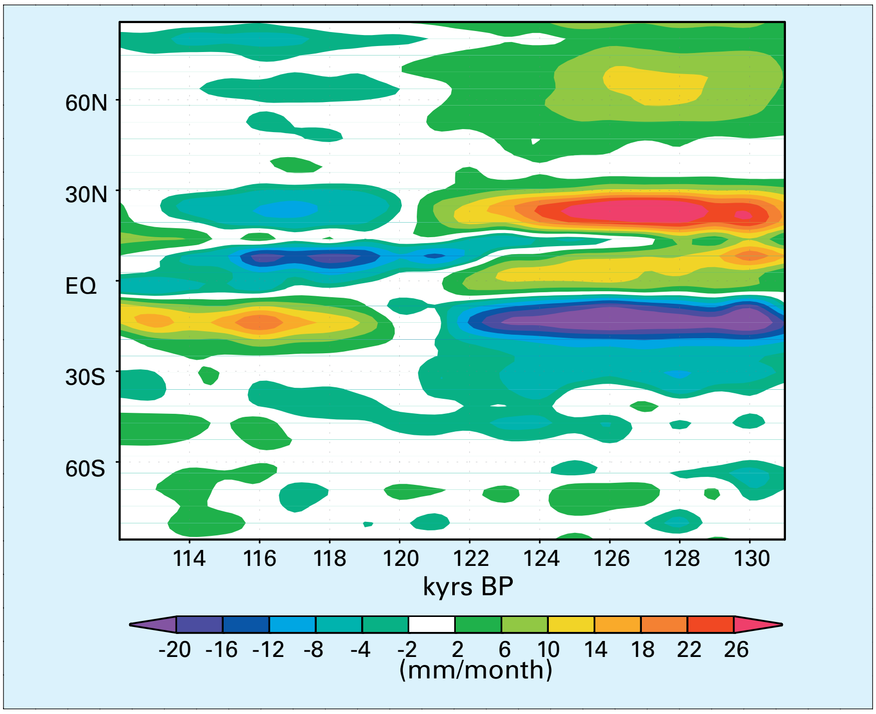

Fig. 2: Global zonal mean precipitation anomalies [mm/month]

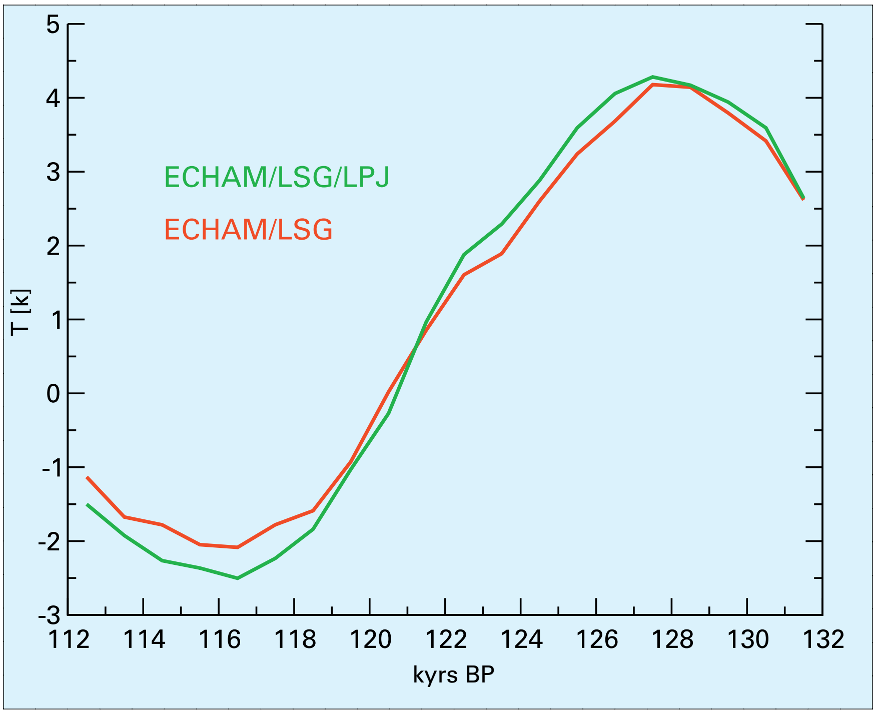

Fig. 1: Mean summer temperature anomaly (exp-ctrl) over land 45-65°N.

In both model versions, intensified insolation during the interglacial stage 5e leads to higher precipitation over most of the continents. The maximum response is registered in the tropics and the African-Asian monsoon belt (Fig. 2), due to higher land-sea temperature contrasts. Vegetation is established in the western part of the Sahara desert. This reduces the local albedo, which further amplifies the land-sea temperature contrast, thereby strengthening the summer monsoon. The resulting change in monsoonal precipitation exceeds the response simulated by the model with non-dynamic vegetation by more than two-fold in this area.

Changes simulated by the dynamical vegetation model are most pronounced in the boreal regions of northern Asia, North America, in the tropics, and in the African-Asian monsoon belt. In the latter regions, an increased (decreased) vegetation coverage is modeled at around 125 ka (115 ka), due to changes in monsoonal precipitation (see above). By contrast, a more direct response is observed in boreal areas. Here, the temperature effect due to higher (lower) insolation triggers a northward expansion (southward retreat) of the vegetation, leading to large anomalies compared to a control run with present day climatology.

The simulated changes in vegetation are in good agreement with paleoclimatic evidence from proxy records. In particular, the greening of the western part of the Sahara desert at 125 ka is supported by reconstructions from pollen records (van Andel and Tzedakis, 1996). Furthermore, the results are in qualitative agreement with findings from proxy studies evidencing drier vegetation during glacial periods in the African tropics (Jahns et al., 1998). The results for 125 ka agree well with equilibrium simulations produced by the higher resolution model ECHAM4/HOPE-G (EEM Subproject 2, this issue) and with transient simulations of the lower resolution Climber model, which actually includes more components but of less complexity (EEM Subproject 7, this issue).

So far, the model has simulated strong climate feedbacks, justifying the use of more expensive complex 3-D models. With the inclusion of continental ice sheets via SICOPOLIS, a much stronger response to insolation forcing, necessary for the simulation of glaciation, is expected. Finally, the coupling to HAMOCC will permit the simulation of the long-term response of marine biogeochemistry such as carbon storage/release in the ocean and/or sediment.

References

Greve, R., 1997: Application of a polythermal three-dimensional ice sheet model to the Greenland Ice Sheet: Response to steady-state and transient climate scenarios. *Journal of Climate* **10 (5)**, 901-918.

Jahns, S., Huls, M. and Sarnthein, M., 1998: Vegetation and climate history of west equatorial Africa based on marine pollen record off Liberia (site GIK 16776) covering the last 400,000 years. *Rev. Paleobot. Palynol.* **102**, 277-288.

Maier-Reimer, E., Mikolajewicz, U. and Hasselmann, K., 1993: Mean circulation of the Hamburg LSG OGCM and its sensitivity to the thermohaline surface forcing. *Journal of Physical Oceanography* **23**, 731-757.

Roeckner, E., Arpe, K., Bengtsson, L., Brinkop, S., Dömenil, L., Esch, M., Kirk, E., Lunkeit, F., Poneter, M., Rockel, B., Sausen, R., Schlese, U., Schubert, S. and Windelbrand, M., 1992: Simulation of present-day climate with the ECHAM model: impact of the model physics and resolution. Max Planck Institute for Meteorology, Hamburg, Rep. **93.**

Sitch, S., Smith, B., Prentice, I.C., Arneth, A., Bondeau, A., Cramer, W., Kaplan, J.O., Levis, S., Lucht, W., Sykes, M.T., Thonicke, K. and Venevsky, S., 2003: Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ Dynamic Global Vegetation Model. *Global Change Biology* **9 (2)**, 161-185.

Van Andel T.H. and Tzedakis, P.C., 1996: Palaeolithic landscapes of Europe and environs: 150,000-25,000 years ago: an overview. *Quaternary Science Reviews* **15**, 481-500.

Winguth, A., Archer, D., Maier-Reimer, E., Mikolajewicz, U. and Dupplessy, J.-C., 1999: Sensitivity of the paleonutrient tracer distribution and deep-sea circulation to glacial boundary conditions. *Paleoceanography* **14**, 304-323.

GHOST (Global Holocene Spatial and Temporal Climate Variability): Combination of Paleotemperature Records, Statistics and Modeling

R.R. Schneider[5], J.-H. Kim[1], N. Rimbu[2], S. Lorenz[3], G. Lohmann[2], U. Cubasch[4], J. Pätzold[1] and G. Wefer[1]

[1]FB5 Geowissenschaften, Allgemeine Geologie & Meeresgeologie, Universität Bremen, Klagenfurter Straße, 28359 Bremen, Germany
[2]FB5 Geowissenschaften, Erdsystemmodellierung & Analyse, Universität Bremen, Klagenfurter Straße, 28359 Bremen, Germany
[3]Max-Planck-Institute für Meteorologie, Modelle & Daten, Bundesstraße 55, 20146 Hamburg, Germany
[4]Institut für Meteorologie, FU Berlin, Carl-Heinrich-Becker Weg 6-10, 12165 Berlin, Germany
[5]Dept. de Géologie et Océanographie, UMR5805-EPOC, CNRS/Univ. de Bordeaux1, 33405 Talence Cedex, France; r.schneider@epoc.u-bordeaux1.fr

In the GHOST project, we explore the evolution of Holocene sea-surface temperatures (SSTs). Our perspective consists of two baselines: the archiving and statistical evaluation of worldwide distributed existing, reedited, and newly collected marine alkenone-derived paleotemperature records and the use of actual but low-resolution general circulation models with high computational efficiency, designed for long-term paleoclimate studies.

We consider SST records solely based on the alkenone method in order to avoid potential bias due to using different SST proxies (Kim and Schneider, 2004). Our novel modeling strategy uses a technique for transient simulations with state-of-the-art climate models on paleoclimate time scales. By accelerating the very slow time scale of the Earth's orbital parameters within a fully coupled atmosphere-ocean circulation model, we are able to investigate the influence of the slowly varying annual distribution of solar radiation on the climate of the Holocene (Lorenz and Lohmann, 2004).

Statistical analysis of alkenone-derived SST records indicates a transition from relatively cold to relatively warm conditions in the tropics from the middle to late Holocene (Rimbu et al., 2004). This tropical warming was accompanied by a SST decrease in the Northeast Atlantic, as well as in the western Mediterranean Sea, and a warming in the eastern Mediterranean Sea and the Northern Red Sea (Fig. 1a and 1b, Kim et al., 2004). This SST distribution pattern resembles the modern AO/NAO-related SST pattern from this region, suggesting a transition from a more positive to a more negative phase of AO/NAO-like atmospheric circulation from 7 cal. kyr BP to the present. An analogy with the instrumental period suggests that this Holocene SST pattern is due to a decrease (increase) of southwest (northwest) wind strength over the eastern North Atlantic (the northern Red Sea) (Fig. 2c, Rimbu et al., 2003). Model experiments (Lorenz and Lohmann, 2004) confirm the results of statistical analysis of alkenone SST data and show that the phase and amplitude of AO/NAO is controlled by the variation in solar insolation over the tropics