The climate of past interglacials

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Preface:

Climates of past interglacials - a PAGES perspective

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The cultural evolution of humans has accelerated considerably during the Holocene interglacial. This explosion of civilization has probably only been possible under the mild and relatively stable climatic conditions that have prevailed for the last 11 000 years.

However, these conditions can not be taken for granted. This is one of the rather simple- but unequivocal and important lessons we have learned from the palaeoclimate record. All other interglacials terminated after a few thousands to a few tens of thousands of years. In fact, interglacial states similar to today, with little land ice and largely elevated temperatures at mid-high latitudes, prevailed during no more than 15% of the last half million years. These simple empirics already give clear evidence that interglacials are rather unstable on a 10 000-year timescale. Also on shorter timescales of millennia to decades, late Holocene climate fluctuations such as the Little Ice Age and those associated with the Maunder Minimum are proof that interglacial climate is not entirely stable on a regional scale but responds to even subtle changes in radiative forcing. Moreover, the discovery of the 8.2 kyr cooling event made it clear- that even the worst-case scenario (socio-economically speaking) of an abrupt change of climate within years is not just a theoretical possibility but has in fact happened in the prehistoric past. It is therefore clear that in principal it could happen again, once some perturbation exceeds a critical threshold of the climate system.

Given that humans are indeed becoming increasingly effective at perturbing the climate-environment system, learning about its sensitivity, thresholds and feedbacks should be in our best interest. An obvious way to do this is to study climate and environment in a suite of experiments where boundary conditions are similar but not identical to today. Through the quasi-cyclic reoccurrence of interglacials during the late Pleistocene, we have several such experiments at hand. The palaeoclimate community therefore holds an important key to scientific information on climate change that provides a basis for appropriate adaptation and mitigation strategies. The authors of this book have taken up this challenge and summarise their results in this special volume on climates of past interglacials. It presents state-of-the-art science on new reconstructions from all spheres of the Earth System and on their synthesis, on methodological advances, and on the current ability of numerical models to simulate low and high frequency changes of climate, environment, and chemical cycling related to interglacials. Most of the authors had been involved in the German DEKLIM programm (www.deklim.de) and have attended some of the five DEKLIM workshops and conferences between 2001 and 2005. The discussions started out quite controversial in the beginning, but step by step the dating, reconstruction and modelling of interglacial climate evolution came to a convincing synthesis. Not all open questions are settled, and there is not full consensus on all subjects, but the picture of past climates is now much clearer than it was 5 five years ago.

Beyond the pure scientific findings, DEKLIM will leave more (secondary) footprints in palaeoscience that are of equally high value in the perspective of PAGES because of their integrative character. Two fields of palaeoscience that did not often mix well with classic palaeoclimatology were deliberately and successfully incorporated as genuine counterparts of the project. Firstly, studies on palaeovegetation added important information on the regional expression of, and regional feedbacks to, global change. Secondly, numerical modelling of climate and environmental and geochemical parameters were an integral part of the project. It seems that a generation of modellers and data people has evolved who are capable of communicating effectively on mutual needs and complementary results. A great number of the papers of this volume reflect this successful data-model symbiosis. In addition, in spite of being funded by the German Federal Ministry of Education and Research, DEKLIM managed to cooperate successfully beyond national boundaries. The science community and the science consequently benefited greatly from the involvement of many renowned international scientists.

The lasting value of this project comes not only from its scientific results, which have led to an improved understanding of the operation of the climate system, but also from the identification of current scientific limitations and open questions. These provide orientation as to where researchers, funders, and programmes like PAGES might most effectively focus their resources and efforts for future research.

For example, one fundamental limitation is given by the uncertainties in the age control on pre-Holocene interglacials. They are out of reach of radiocarbon dating, not anywhere near the next palaeomagnetic reversal, and the relative smoothness of the climatic records leaves only minor characteristics for event stratigraphy. However, to enable modellers to prescribe forcings with a realistic phasing will require a sub-millennial chronological accuracy. Creative new approaches are needed, some of which are discussed in this volume.

A similarly high standard is demanded from the quality of the reconstruction of climatic and environmental parameters. The proxies used to reconstruct past interglacial conditions need to detect variations that are usually rather subtle compared to glacial or semi-glacial scenarios. This task imposes higher requirements on methods in terms of precision and accuracy. Hence, the ongoing improvement of analytics, and the development and refinement of proxies and their calibrations, is not just an academic obsession but a fundamental need to advance our understanding of past climate and ultimately the accuracy of prediction.

One limitation on model simulations is records of climate forcing, both natural (orbital, solar irradiance, volcanic, greenhouse gases) and anthropogenic (greenhouse gases, aerosols, land use). The validity of any climate simulation depends on the accuracy of the input parameters that generate climate change and environmental response. The above-mentioned improvements of chronological tools and proxies will contribute to the advancement in the accuracy of forcing records. Raising the awareness of its importance may be another measure to foster progress.

In previous years and decades, a lot of effort was concentrated on understanding the large-amplitude climate variations during glacials, and between glacials and interglacials, thereby somewhat disregarding interglacial global change issues. As a result, the spatial density and temporal resolution of records is presently insufficient to allow for firm conclusions on high-frequency or regional-scale climate variability during past interglacials. This becomes more and more acute the further back in time one goes due to the increased difficulty in obtaining good archives. The ambitious target for the coming years will be to reconstruct and simulate centennial-to-decadal scale variability of climate modes, not only for the Holocene, but also for the slightly differing boundary conditions of pre-Holocene interglacials. Since climate modes reveal themselves to be relatively patchy dynamic climate patterns, a critical density of data is necessary to map them. This will require concerted efforts focussing on particular regions and time intervals. The largest region identified as being underrepresented in the climate record and therefore a prime target of future research need is the entire southern hemisphere.

To be effective, concerted efforts, such as those described above, will require an infrastructure for data compilation, storage and accessibility. This will be important in order to exploit the full potential of numerical climate models. Another fundamental future challenge will be to further increase professionalism in both data management and the attitude towards data dissemination.

The challenges described above are among those also adopted by PAGES as being particularly worthy of support. These objectives will require excellent research by individual scientists and groups but also a high level of interdisciplinarity and organisational structure. While PAGES cannot influence individual scientific excellence, it will continue to facilitate integrative palaeoscience along the lines of the DEKLIM project. Meanwhile the community can build on many scientific results and datasets, an international network, and a comprehensive concept for an integrative global change research programme.