Assimilation of palaeoclimate proxy data into GCMs using ensemble member selection

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Abstract

Quantifying and understanding natural climate variability on long time scales is key to distinguishing natural and anthropogenic variability during the 20th and 21st century, and to predict the future climate. Climate variability in the pre-instrumental period can be estimated either from climate proxy data, e.g. tree rings, ice cores or stalagmites, or from numerical simulations. Palaeoclimate simulations have been performed so far mainly by prescribing climate forcings such as solar radiation and atmospheric composition. However, as a consequence of internal climate variability, the temporal evolution of the climate states is not completely determined by the forcings. In principle this problem can be addressed by combining empirical information from proxy data with numerical simulations. This approach is used operationally in meteorology and is known as data assimilation, but adapting it to palaeoclimatic applications is challenging.

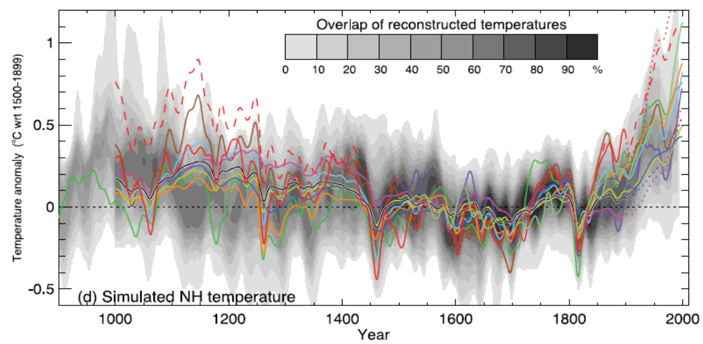
This project proposes to use ensemble simulations with General Circulation Models (GCMs) and to select ensemble members that are closest to palaeoclimate proxy data to obtain a simulation that is both consistent with the model physics and with the empirical knowledge. This approach has been already successful with Earth System Models of Intermediate Complexity. The increase in computing power now allows to attempt this for the first time using more complex GCMs.

The project gives the chance to work on cutting-edge problems in palaeoclimate modelling using supercomputers, state-of-the-art climate models, and advanced statistics.

Applicants should have a background in a related field such as meteorology, climatology, geosciences, or physics. Sound mathematical and statistical skills, as well as programming experience are essential. Working experience with UNIX, FORTRAN, and climate modelling would be beneficial. For further details please contact M. Widmann (m.widmann@bham.ac.uk).

Introduction

Understanding of and distinguishing between natural and anthropogenic climatic changes requires a realistic estimation of climate variability over long periods. Instrumental meteorological records are too short for this purpose and low-frequency climate variability needs thus to be estimated either from climate proxy data or from numerical simulations. The supervisors have been active in both areas (Jones and Widmann, 2003, Baker et al. 2007, Wagner et al. 2007).



Proxy-based (greyscale) and simulated (colour) reconstructions of Northern Hemisphere temperatures (IPCC AR4).

When simulating past climates with GCMs climate forcing factors such as solar radiation, atmospheric composition, or the Earth's orbit are prescribed. These simulations can be expected to represent the response of large-scale and temporally averaged aspects of the climate. However, as a consequence of internal climate variability, the temporal evolution of the climate states, in particular on regional scales, is not completely determined by the forcings, and even a perfect model with all forcing mechanisms included, would yield only one out of many possible climate realisations that are consistent with the forcings. This realisation will in most cases be different from the realisation in the real world.

As a consequence, one of the emerging topics in palaeoclimate modelling is the combination of empirical information from proxy data with numerical simulations. This approach is known in meteorology as data assimilation. Adapting it to palaeoclimatic applications is not straightforward, and M. Widmann is part of a small group of scientists that has suggested various approaches to the problem (Widmann et al. 2010). So far for GCMs only a simple pattern nudging method has been used and investigating the feasibility of more sophisticated and computationally expensive approaches is crucial to progress in this research area.

Aims and methods

The aim of this PhD project is to explore the feasibility and usefulness of using GCM ensemble simulations and selection of ensemble members that are close to palaeoclimate proxy data as an approach to data assimilation. This method has been pioneered and successfully used by Goosse et al. (2006) using an Earth system Model of Intermediate Complexity (EMIC). As the atmospheric circulation in GCMs is more complex than in EMICs it is not clear a priory to what extent the available proxy data will constrain the atmospheric states. The very high computational demands of GCMs are an additional challenge for ensemble approaches, but the computing power is now high enough to attempt ensemble-based data assimilation with low-resolution GCMs. Determining the optimal compromise between resolution and ensemble size is one of the questions that should be answered in this project.

After a successful data assimilation method has been developed it will be used in this project to obtain improved climate reconstructions for key periods during the last millennium, for instance the medieval warm period or the Maunder Minimum cold period.

Training

The supervisory team will provide training in all aspects of the project such as climate modelling, palaeoclimatology and statistics. I also brings multiple national and international links. The project gives the chance to work on cutting-edge problems in palaeoclimate modelling using supercomputers, state-of-the-art climate models, and advanced statistics.

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