Geophysical Research Abstracts
Vol. 16, EGU2014-392, 2014
EGU General Assembly 2014

On-line and Off-line data assimilation of palaeoclimate proxy data into GCMs using ensemble member selection

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Estimates for the climate of the past are usually derived either from climate proxy data using statistical techniques or from forced numerical simulations. However, both approaches are associated with substantial uncertainties in the reconstructions. In principle the best state estimates can be expected by employing data assimilation (DA) techniques, which systematically combine the empirical information from proxy data with the representation of the processes that govern the climate system given by climate models. Although DA is a very mature field in numerical weather prediction, the specific problem in palaeoclimatology is different and the methods cannot be directly transferred. DA can be considered as one of the key challenges in palaeoclimatology and has recently become an emerging research area (e.g. Widmann et al., Clim. Past, 2010; Hakim et al., PAGES news 2013; Bronnimann et al., PAGES news 2013).

Here, we compare two different types of ensemble member selection DA methods, namely the so-called off-line and on-line approach. In the off-line DA one ensemble for the entire simulation period is generated first and then the ensemble at a given time is used in combination with empirical information to produce the analysis. In contrast, in the on-line DA the ensembles are generated sequentially based on the previous analysis. A fundamental question that can be addressed from the comparison is whether the slow components of the climate system, such as the ocean or the cryosphere, lead to enough memory to propagate the information contained in the assimilated proxy data forward in time on decadal timescales. If the answer is yes, the technically more demanding on-line approach would be justified. If, on the other hand, the chaotic nature of the system dominates, the simpler off-line method can be sufficient.

We employed ensemble simulations with a low-resolution version (T31, L31) of the MPI-ESM CMIP5 model, and simulated the period 1600-1700 AD, which leads into the Maunder Minimum. We select the ensemble members that are the closest to the northern hemisphere continental temperature averages of the PAGES2K proxy data base (PAGES 2K Consortium, 2013).