Climate simulations of the past millennium with the global model ECHO-G: results for the Baltex area

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1. Introduction

Climate reconstructions of the past few millennia may provide useful information of the amplitude of climate variations at centennial timescales and help to put the recent 20th century global warming into the perspective of natural climate variations. Several simulations covering all or parts of the past millennium have been conducted with the global climate model ECHO-G driven by estimations of past external forcing (*Storch et al.*, 2004; *Zorita et al.*, 2005). Here, the main results of the simulated climate in the Baltex area will be presented. The simulations differ only in their initial conditions, and thus allow for a rough estimation of the internal variability at multidecadal and regional timescales, which is presently poorly known.

2. Climate model and simulations

The global coupled climate model ECHO-G consists of the spectral atmospheric model ECHAM4 and the ocean thermodynamic/dynamic sea ice model HOPE-G. Both sub-models were developed at the Max-Planck-Institute of Meteorology in Hamburg. In the present setup, the atmospheric model has a horizontal resolution of T30 (approx. 3.75 x 3.75 degrees) and 19 vertical levels.

The ocean model HOPE-G has an effective horizontal resolution of approximately 2.8 degrees with 20 vertical levels. In the tropical regions a grid refinement is employed with decreasing meridional grid-point separation, reaching a value of 0.5 degrees at the Equator. This increased resolution allows for a more realistic representation of ENSO events. The climate model is flux-adjusted to avoid climate drift. The flux adjustment is held constant in time and its global average is set to zero.

Note that the resolution of both atmosphere and ocean models is too coarse to reasonably resolve the Baltic Sea. The results of the simulations cannot, therefore, be interpreted at small regional scales. Here, the emphasis will be put on larger-scale climate patterns of relevant for the Baltex region.

The model was driven by the following external forcings: total solar irradiance, volcanic forcing, and well-mixed greenhouse gases. The solar forcing was derived from the data provided by *Crowley* (2000) through transforming effective solar forcing to Total Solar Irradiance (TSI) units to drive the model. There still exists a large uncertainty in the amplitude of past TSI at centennial timescales. In this simulation the Crowley data were re-scaled so that the differences between the Late Maunder Minimum (1680-1710) and present (1960-1990) are 0.3 % of the TSI. The volcanic net radiative forcing was translated to changes in an affective solar constant. The volcanic forcing is thus implemented in this simulation as a global annual reduction in the solar constant. The values provided by Crowley already take into account an e-folding time in the years following a volcanic eruption. The concentrations of atmospheric carbon dioxide and methane were derived from ice-core measurements. Concentrations of N2O were used as in previous scenario experiments with this model: fixed 276.7 ppb before 1860 and the historical evolution from 1860 to 1990 AD adjusted from Battle et al. (1996). Figure 1 shows the past forcings used in all simulations together with the global temperature response in two of them.

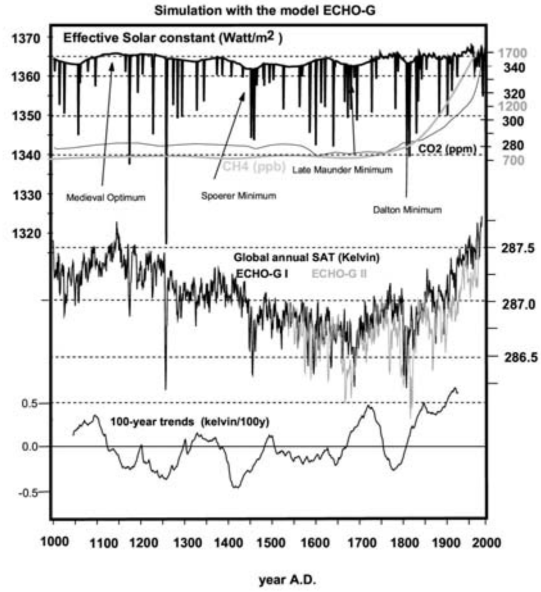

Figure 1. External forcing used in the climate simulations (upper panel), global temperature response in the simulations starting in 1000 A.D. and 1500 A.D. (middle panel) and 100-year running temperature trends (lower panel)

3. Comparison with climate reconstruction

In general the simulated global and Northern Hemisphere air temperature agrees with the reconstructions that indicate large temperature variability at multidecadal and centennial timescales, e.g. derived from boreholes or from dendroclimatological methods designed to preserve low-frequency variability. The simulations clearly indicate temperature deviations larger than reconstructed by *Mann et al* (1999).

On regional scales, the agreement with long early-instrumental records and some long temperature reconstructions is remarkable. For instance, Figure 2 shows a comparison between simulated grid-point values and the Central England temperature record and a summertime Alpine temperature reconstructions. A reasonable agreement is also found between modeled and reconstructed summer Alpine temperature (not shown) (*Büntgen et al*, 2006).

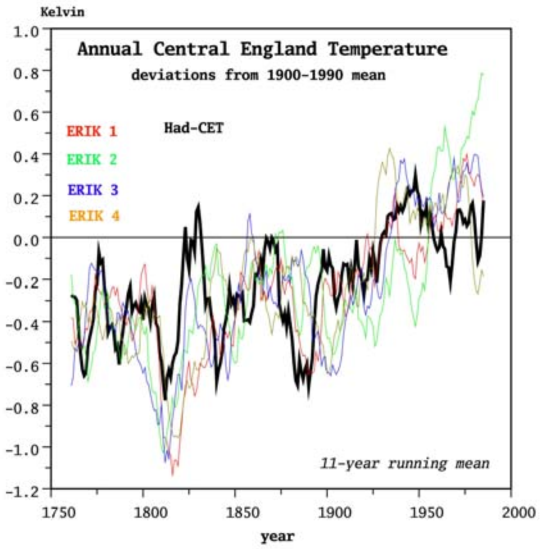

Figure 2 Observed and simulated (grid-point values) records of the Central England annual mean mean temperature

4. North Atlantic Oscillation

The simulated evolution of the North Atlantic Oscillation index in past millennium and in the last 250 years is displayed in Figure 3.

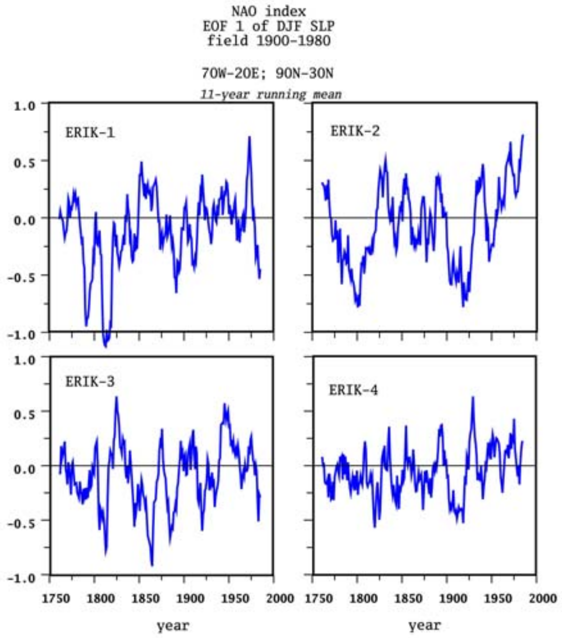

Figure 3 The simulated North Atlantic Oscillation Index in four simulations with the global model ECHO-G in the period 1750-1990.

At centennial timescales the NAO index seems to follow a similar evolution as the globally averaged temperatures, i.e. also following the external forcing. At shorter timescales, for instance multidecadal, clear deviations among the simulations can be observed, indicating that the internal variability of NAO at these timescales is larger than the possible influence of the external forcing. The modeled NAO, however, clearly responds to the external forcing when this forcing is strong enough, as in the last decades of the 21rs century under scenario A. This result may indicate that the observed evolution of the NAO in recent centuries does not necessarily has to be explain by the effect of external forcing, either natural or anthropogenic.

5. Air temperature in the Baltic Sea region

Figure 4 shows the simulated evolution of the annual mean air temperature averaged in n extended Baltic Sea area in the period 1000-2100 in one of the simulations.

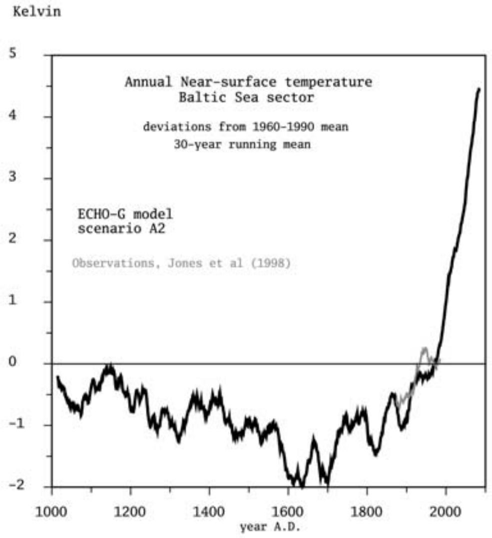

Figure 4 Simulated mean annual near-surface air-temperature in an extended Baltic Sea region in the past millennium and in the 21st century. Observational record is also included.

The simulated temperature shows one maximum around 1150 A.D. possibly corresponding to the so called Medieval Warm Period, followed by a temperature decrease with and clear temperature minima around 1700 A.D., which also corresponds to the Little Ice Age and Late Maunder Minimum periods. The temperature Medieval Warm Period reaches roughly the same level as in the late 20th century. The projected temperature increase in the 21ts century, however, clearly stands out of the range of natural variability simulated by the model.

References (style: non numbered headline)

Büntgen, U., D.C. Frank, D. Nievergelt, and J. Esper, Summer temperature variations in the European Alps, A.D. 755-2004. *J. Climate* 19, 5606-5623, 2006.

Crowley, T.J., Causes of climate change over the past 1000 years. *Science* 289, 270-277, 2000.

Mann, M.E.,R. Bradley, and M. K. Hughes, Northern Hemisphere temperatures during the past millennium; inferences, uncertaintes a, and limitations. Geophys. Res. Lett., 26, 759-762, 1999.

Storch, H. von, E. Zorita, J. M. Jones, Y. Dmitriev. F. González and S. F. B. Tett, Reconstructing past climate from noisy data. *Science* 306, 679-682, 2004.

Zorita E. , F. González-Rouco, H. von Storch, J.P. Montavez and F. Valero, Natural and anthropogenic modes of surface temperature variations in the last thousand years. *Geophys. Res. Lett.* 32, L08707 (2005).