Variability on time scales of decades up to a century in a AOGCM simulation with realistic time-variable forcing

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Two multi-century simulations with a state-of-the-art AOGCM have been made using reconstructed solar, volcanic and GHG forcing. Significant variations in large scale air temperatures are generated, with a marked medieval warming, an extended Little Ice Age punctuated by extra cool periods during the Dalton and Late Maunder Minimum, and a fast increase of temperature during the last century. The low-frequency variations of temperature in China are well reproduced; the variations of the large-scale storm tracks on the Northern Hemisphere are mostly independent of the radiative forcing and its associated temperature variations.

Two multi-century integrations have been performed with the climate model ECHO-G, which is a combination from the ocean model HOPE-G in T42 resolution and the atmospheric model ECHAM4 in T30 resolution both developed at the MPI in Hamburg. Two runs, named “Christoph Columbus” (CC) and “Erik den Røde” (EdR) were executed, one over 500 years and another over 1000 years. The runs were exposed to time-variable external forcing related to solar and volcanic activity and changing atmospheric concentrations of greenhouse gases. The CO_2 and methane atmospheric concentrations were derived from air trapped in Antarctic ice cores. The variations of solar output and the influence of volcanic aerosols on the radiative forcing were determined from the number of sun spots after 1600 AD and concentrations of cosmogonic isotopes in the atmosphere before 1600 AD. The forcing due to volcanic aerosols was estimated from concentrations of sulphuric compounds in different ice cores, located mainly over Greenland. These forcing factors were then translated to effective variations of the solar constant in the General Circulation Model (GCM) taking into account the corresponding geometric factors and the mean earth albedo. Changing loading of industrial aerosols has not been incorporated in the simulation. Figure 1 shows the history of the effective solar activity, greenhouse gas and volcanic-aerosol concentrations used to force the model. In addition, the global mean near-surface temperature is shown.

We compared Wang et al.’s reconstruction of regional temperatures in China since the 16^{th} century with the model output. The reconstructed temperatures are simulated reasonably well. The similarity is good on time scales of a century, while the model generates variability on shorter time scales without a counterpart in the reconstructions. The development of regional temperature in the recent decades of the industrial period is towards significantly elevated levels – where the significance is assessed by comparing against a pre-industrial “normal” and “noise level”. Thus, the presence of non-normal external factors must be assumed. Using the GCM simulations to assess the relative importance of the solar and volcanic as well as greenhouse gas forcing, we find that only the greenhouse gas forcing can account for the recent warming.

For the assessment of extreme wind speed events, long time series of maximum 10 m wind speed data were analyzed. This variable is computed every 30 minutes – and 12-hourly maxima are determined. As thresholds for extreme wind speed events, we selected the two lower limits on the WMO Beaufort wind speed scale for gales and storms, 8 Bft (17.2-20.7 ms^{-1}) and 10 Bft (24.5-28.4 ms^{-1}) respectively. The seasonal frequency of maximum wind events of 8 or 10 Bft is determined by adding up all days with wind-speeds reaching at least once one of the two thresholds. For each Northern Hemisphere winter one map of these frequencies is derived; the principal component of the first EOF of this quantity is a kind of storm index. Figure 2 shows this index for both simulations during the overlapping, pre-industrial period (1550-1850). Clearly, the series are unrelated even though the temperature variations in the two simulations (Figure 1) are closely related to each other. We conclude that the historical variations of the storm track are not in any simple way related to the variations of the historical forcing or the temperature variations.

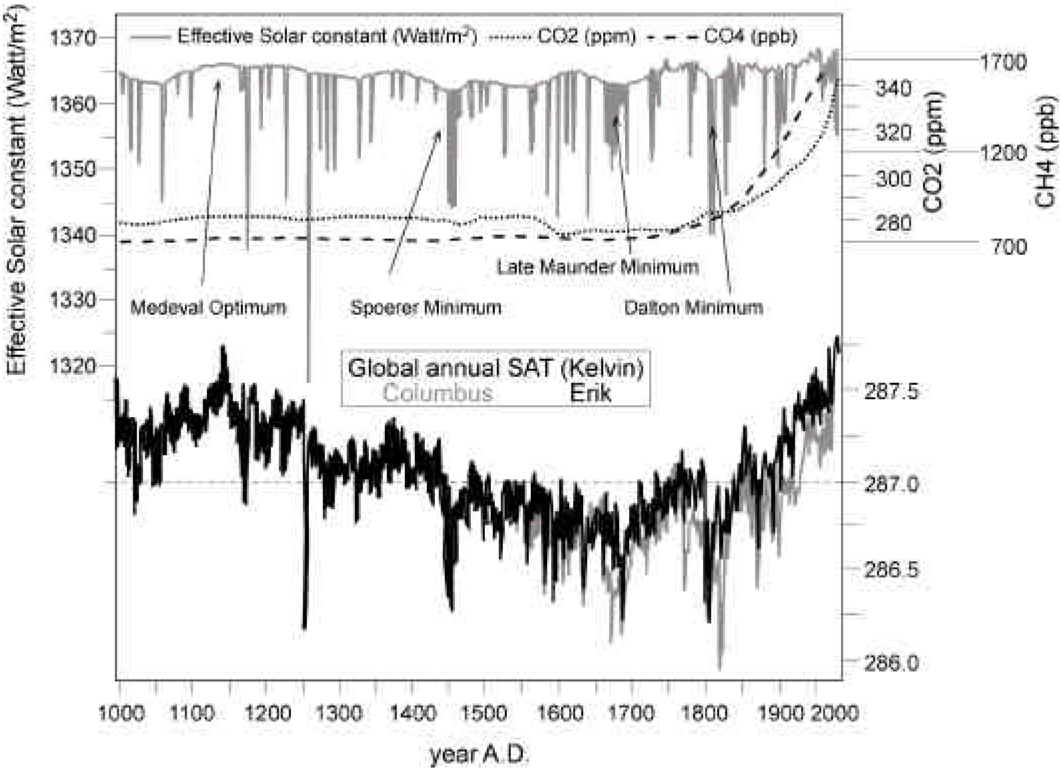

Figure 1 Time series of simulated global mean temperature (bottom) in a 500-year simulation (CC, black) and in a 1000-year simulation (EdR, grey), and time variable forcing (top) of atmospheric methane (dashed), carbon dioxide concentration (dotted) and effective solar constant (solid grey curve), mimicking the presence of volcanic aerosols and a variable solar output used in both CC and EdR. .

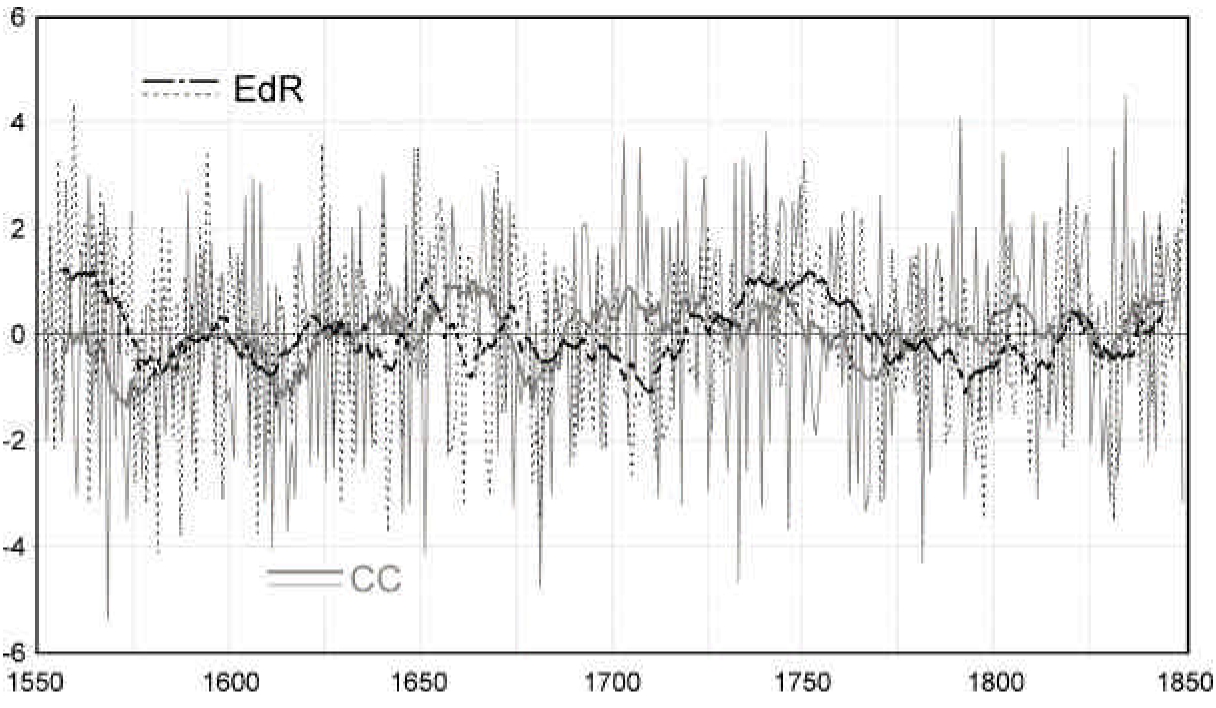

Figure 2 Time series of the PC of the first EOF of the frequency of extreme winds per Northern Hemisphere winter in the overlapping pre-industrial period 1550-1850 of the two simulations EdR and CC.