Climate Variability within the climate model ECHO-G during the Dalton Minimum

Sebastian Wagner
Institute for Coastal Research, GKSS-Research Centre, Germany*

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Introduction

Due to the lack of historical climate data around the world prior to the mid-19th century, climate model simulations are used to study climate in the past in a global context. In this study the output of the climate model ECHO-G is analysed concerning the climate variability during a time with reduced solar activity and enhanced volcanic activities at the beginning of the 19th century, known as the Dalton Minimum. The climate model ECHO-G constitutes of the atmospheric model ECHAM4 (T30-resolution) and the global ocean circulation model HOPE-G (T42-resolution), both developped at the MPI in Hamburg. The model is forced with solar irradiance and volcanic dust indices as well as with greenhouse gas concentrations in order to simulate external conditions of the past in an appropriate way (Fig. 1).

Winter temperatures

The averaged winter temperatures during the period 1700-1990 are given in Figure 2. The northern hemisphere north of 30°N reveals an increased temperature range compared to the tropics and the southern hemisphere south of 30°S. This is due to the relatively huge continental influence on the northern hemisphere. Furthermore the temperature in this part of the globe shows a marked resemblance to the external forcing, whereas the southern hemisphere deviates in some periods. Within the first part of the Dalton Minimum there is also a marked contrast in the temperature development on both hemispheres with cooling in the northern hemisphere and the tropics and a warmig tendency in the southern hemisphere. This trend is reversed after 1810 when temperatures in the southern hemisphere eventually also decrease. Another interesting fact between the external forcing and temperature is the time lag between the minimum of the solar activity around 1815 and the minimum of the temperatures around 1840. This phenomenon probably involves a lagged oceanic response to the external forcing.
In the section above only averaged temperatures are analysed. A question further to discuss is the regional - or continental - temperature impact. Figure 3 shows the leading EOFs of northern hemisphere winter temperatures (T2m) and sea level pressure (SLP) north of 30°N together with their Principal Components (PC) explaining 16% and 27% of total T2m and SLP variance,respectively. EOF 1 T2m shows the seesaw between Eurasia and Greenland as well as between central North America and Alaska. The PC of EOF 1 T2m reveals that during certain periods within the Dalton Minimum above normal temperatures prevail in Greenland and Alaska. The first SLP-EOF is connected to the Arctic Oscillation (AO). The SLP-PC indicates negative values or values close to zero connected with weak or inverse AO during the Dalton Minimum. A physical explanation for this phenomenon is probably the reduced temperature gradient between high an low latitudes due to reduced solar irradiance. This leads to an enhanced meridional circulation due to weakened zonal winds as seen in PC 1 of SLP.

Acknoledgements
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*Corresponding author address: GKSS-Forschungszentrum, Max-Planck-Str.1, 21502 Geesthacht, Germany; e-mail: swagner@gkss.de

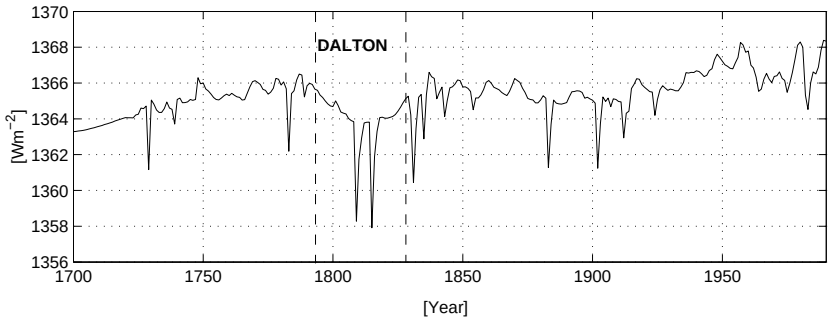

Figure 1: Solar and volcanic climate forcing form 1700-1990. The Dalton Minimum lasts from 1790-1840 with volcanic eruptions, e.g. Tambora 1815.

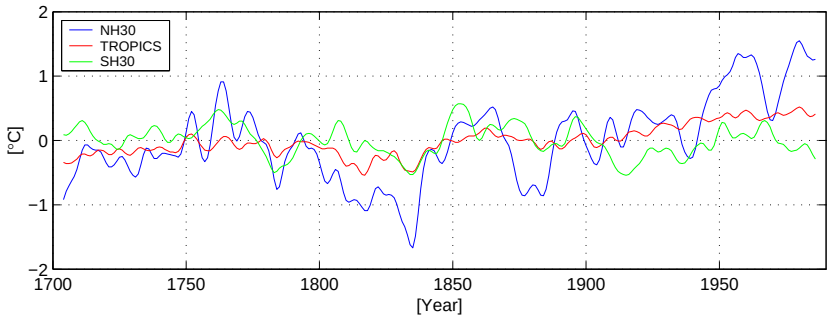

Figure 2: Winter temperature anomalies 1700-1990 in the northern (NH30) and southern hemisphere (SH30) north and south of 30°, respectively, and the tropics smoothed with a 10 years Gaussian filter. Notice the strong resemblance of NH30 temperatures with the external forcing as well as the time lag to the external forcing at the time of the Dalton Minimum.

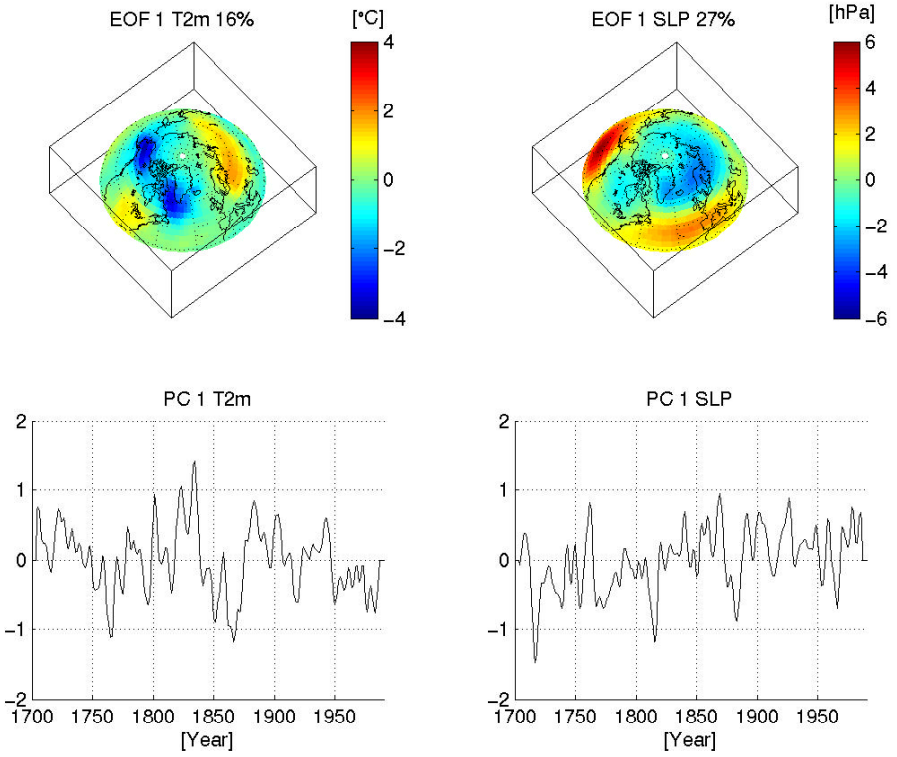

Figure 3: Leading EOFs of temperature and sea level pressure and appendant Principal Components (PC) for the northern hemisphere north of 30°N smoothed with a 10 years Gaussian filter. Notice the regional different temperature impacts due to atmospheric circulation anomalies.