Impact of volcanic eruptions on the climate of the 1st millennium AD in an Earth System Model simulation

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Sebastian Wagner, Eduardo Zorita

Institute for Coastal Research, Helmholtz-Zentrum Geesthacht – Contact: sebastian.wagner@hzg.de

1. Introduction

The climate of the 1st millennium AD shows some remarkable differences compared to the last millennium concerning variation in external forcings: Together with an orbitally induced increased solar insolation during the northern hemisphere summer season and a general lack of strong solar minima, the frequency of large tropical and extratropical eruptions is decreased. Here we present results from a simulation with the fully coupled Earth-System-Model MPI-ESM-P (Giorgetta et al., 2013) starting in year 100 BC.

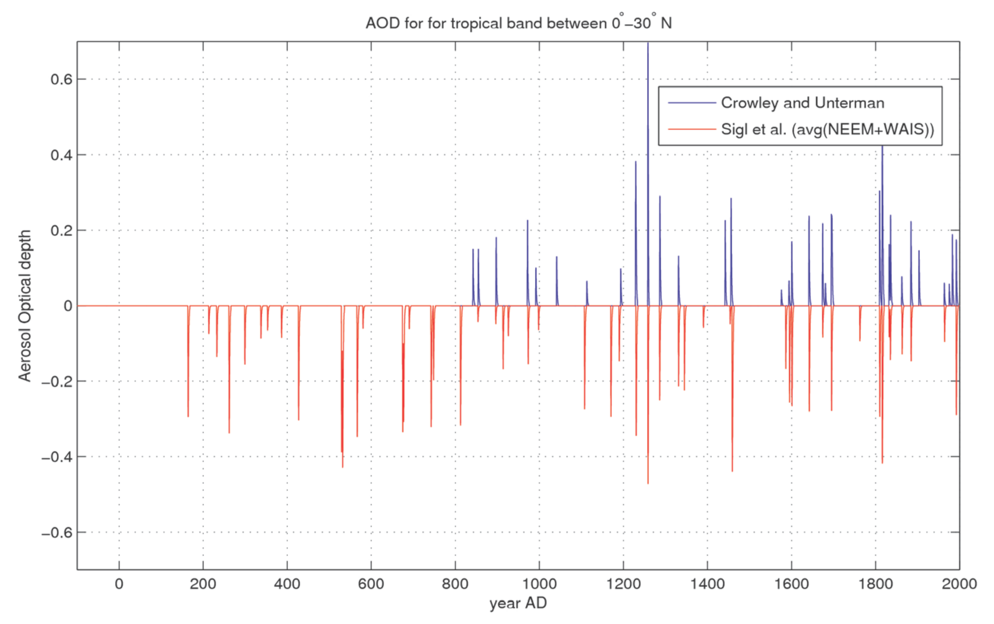

Figure 1: Aerosol optical depth of volcanic eruptions for the tropical latitudinal band. The sulfate records are based on the NEEM (NH) and WAIS (SH) ice cores by Sigl et al (2013). For comparison the Crowley and Unterman (2012) reconstruction is provided.

2. Reconstruction of solar and volcanic activity

The reconstruction of the volcanic forcing is based on the sulfate data set of Sigl et al. (2013) using the NEEM and WAIS record. The sulfate records are scaled to the Crowley and Unterman (2012) reconstruction used within PMIP3 for the period 800–2000 AD for different latitudinal bands. Eventually the algorithm of Crowley and Unterman (2012) is applied to the sulfate records yielding AOD estimates back to 100 BC (cf. Fig. 1). In contrast to the second millennium AD, volcanic activity in the first millennium is generally reduced.The solar forcing is based on the reconstruction of Vieira et al. (2011). Long-term changes represent a 0.1% difference between the Maunder Minimum and present-day values (1950–2000 AD). The synthetic 11-year solar cycle is implemented after Schmidt et al. (2011).

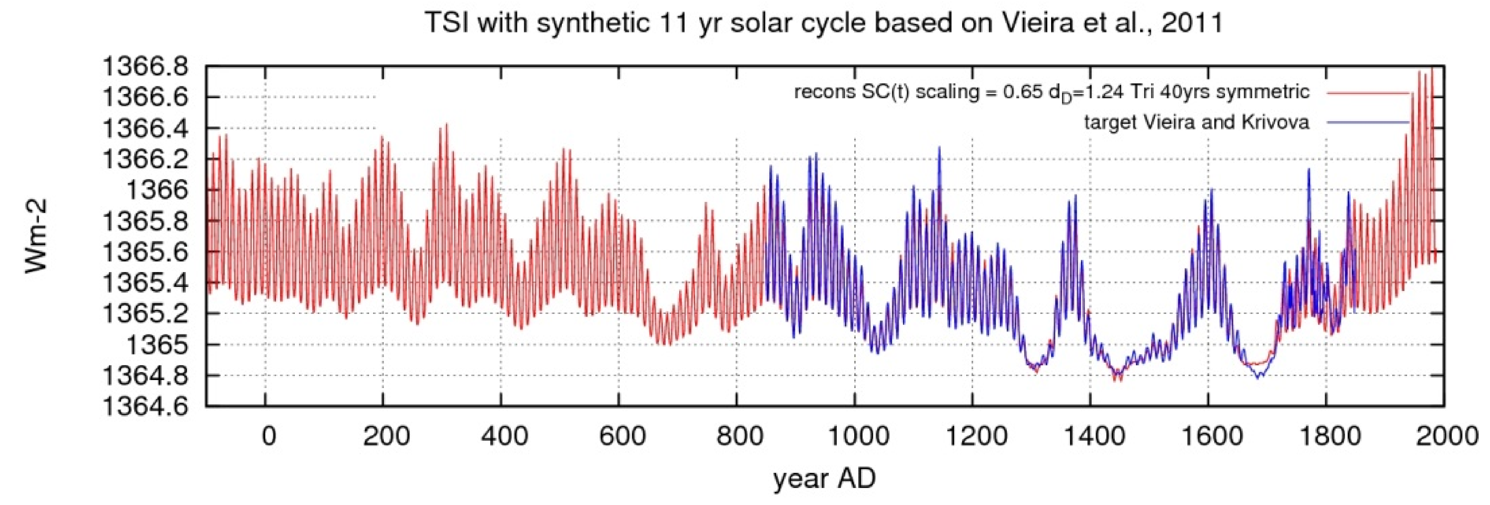

Figure 2: Changes in Total Solar irradiance (TSI) based on the reconstruction of Vieira et al. (2011). The 11-year solar cycle is estimated based on the method outlined in Schmidt et al. (2011).

3. Evolution of global 2m temperatures

Global mean temperatures show a slight gradual decline. Volcanic outbreaks are reflected as negative peaks in the temperature curve, the most prominent around 530 AD and 1250, 1452 and 1815 AD (cf. Fig. 3). The historical prominent eruption related to Mount Vesuvius 79 AD is not reflected in global temperatures.

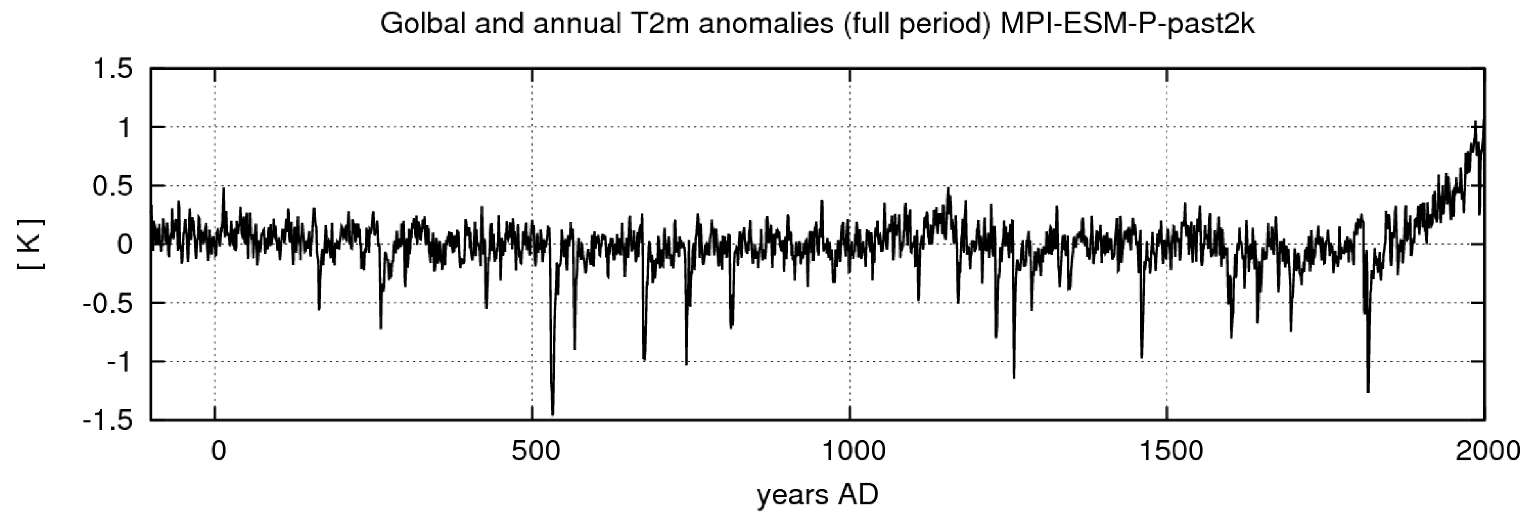

Figure 3: Global and annually averaged near-surface temperatures for the period 100 BC until 2000 AD.

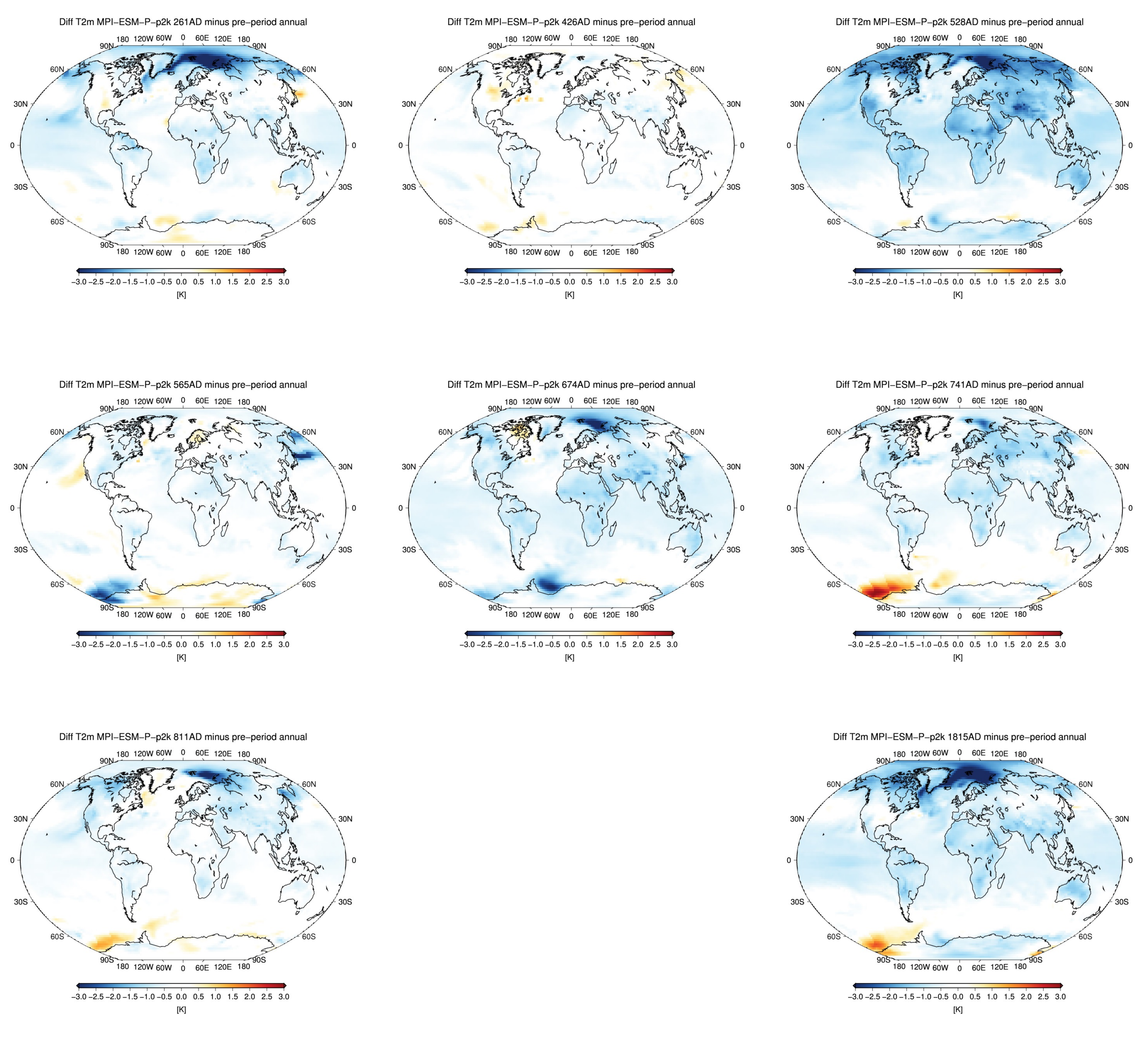

Figure 4: Spatial near-surface temperature response after the large tropical volcanic eruptions in the 1st millennium AD. For comparison also the 1815 AD Tambora event is given in the lower right.

4. Spatial temperature response

Fig. 4 shows the spatial temperature response of the different volcanic eruptions in the 1st millennium AD for the *annual* mean. The Figures are based on the difference between the 10 years after the eruption minus the 20 years before the eruption. Most eruptions show a clear cooling, mostly pronounced over the continents. Largest cooling is evident over the Northeastern Atlantic, possibly due to changes in sea ice coverage. Over the high latitude SH the temperature response is more heterogeneous.

5. Summary

Despite the comparatively low frequency of tropical volcanic eruptions during the 1st millennium AD the modelled response shows on continental scale a clear-cut impact. The spatial response to the individual eruptions differs in the spatial extent and magnitude. Future studies addressing Holocene climate change should therefore take into account reconstructions of volcanic forcing, especially for providing a better basis for comparisons with proxy data and tests for earth system models simulating past climates.

6. Technical details

The simulation was carried out on a IBM-Power6 "blizzard" at the German Climate Computing Center (DKRZ). The simulation consumed approx. 500000 CPUh including a 500 year spin down with constant external conditions set to 100 BC. The simulation of the period 100 BC to 2000 AD took 14 months (~5 simulated years/day).

The storage of the 2100 year long simulation (including atmosphere, ocean and land output) consumed 79 TB in the tape archive HPSS at DKRZ.

Helmholtz-Zentrum Geesthacht • Max-Planck-Straße 1 • 21502 Geesthacht / Germany • www.hzg.de
Contact: Sebastian Wagner • Phone +49 (0)4152 87-1862 • Fax +49 (0)4152 87-2832