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Climate simulation for the period 1500-2100 with all relevant natural and anthropogenic forcings

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We present results of a climate simulation for the last five centuries and a projection throughout the 21st century with a state of the art coupled atmosphere-ocean general circulation model. The model, ECHAM4-OPYC3, has been driven with all relevant forcings, both natural (solar variability, volcanic aerosol) and anthropogenic (greenhouse gases, sulfate aerosol, land-use changes). In contrast to previous studies, we have taken into account the latitudinal dependence of volcanic aerosol as well as changes in land cover.

A clear signature of large volcanic eruptions in the simulated temperature record is evident. The model is able to simulate individual extreme events such as the “year without a summer” 1816 following the eruption of Tambora. Strong warming is simulated since 1850, in particular over land, along with a secular zonalisation trend. Simulated multidecadal circulation anomalies resemble observations and reconstructions, e.g. during the Late Maunder Minimum (LMM), and the model is able to reproduce some of the regional patterns. Cooling during the LMM and at the end of the 18th century is smaller than in other studies, due to the relatively small variations in solar activity and the relatively modest volcanic forcing applied here. Cooling events are not restricted to Europe and North America, but cover most of the Northern Hemisphere.

Colder than average conditions go along with a decrease in pressure difference between low and high latitudes and a decrease of the North Atlantic Oscillation, thus favouring positive sea ice anomalies off Greenland and around Iceland, leading to widespread negative temperature anomalies over Europe. We also find characteristic blocking patterns over Western Europe, in particular during autumn which contribute to the advection of cold air.