Title: Long-term variability of heat waves and cold spells in Central Europe
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Abstract: Heat waves and cold spells have serious impacts on natural environment and society. The main aims of this thesis are to examine past variability of Central European heat waves and cold spells, to assess severity of recent events in a long-term context, to evaluate simulation of heat waves in climate models, and to construct their scenarios for a possible future climate. Heat waves and cold spells were primarily investigated as spatial events, using gridded data sets. E-OBS gridded data was utilized to assess past variability of heat waves and cold spells and to evaluate regional climate model (RCM) simulations from the ENSEMBLES and EURO-CORDEX projects. An extremity index that captures joint effects of temperature, duration, and spatial extent of individual heat waves and cold spells was proposed and tested. The persistent 1994 heat wave was found to be the most extreme over Central Europe in the 1950–2012 period, and the summer of 2013 was unprecedented at several Central European stations according to seasonal heat wave characteristics. The severity of cold spells was largest in the winters of 1955/1956 and 1962/1963, and the winter of 2011/2012 was ranked as the 6th most severe since the mid-20th century according to seasonal sums of the extremity index. Reproduction of heat waves in Central Europe was examined in an ensemble of RCMs driven by the ERA-40 reanalysis. The multi-model mean reflected the characteristics of heat waves quite well, but considerable differences were found among the individual RCMs and deficiencies were identified also in reproducing interannual and interdecadal variability of heat waves. Magnitude of the 1994 heat wave was underestimated in all RCMs and this bias was linked to overestimation of precipitation during and before the heat wave. Projections of heat waves for a possible future climate were studied using RCM simulations driven by global climate models forced by three different concentration scenarios. In the near future (2020–2049), heat waves are projected to be twice as frequent compared to the historical period and a similar increase was found under all concentration pathways. By contrast, the projected frequency of heat waves in the late 21st century (2070–2099) depends largely upon concentration scenarios. Three to four heat waves per summer are projected in this period (compared to less than one in the recent climate) and severe heat waves are likely to become a regular phenomenon. These projections may be potentially useful for stakeholders and policymakers, however, an interpretation has to be carried out with caution due to substantial uncertainties originating mainly from concentration scenarios and different responses of climate models to altered radiative forcing. The thesis contributed also to better understanding of RCMs' strengths and weaknesses with respect to simulation of heat waves that might eventually lead to improvements of climate models.

Keywords: heat waves; cold spells; climate change; climate models; Central Europe