Climate change and heating/cooling degree days in Freiburg

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Abstract

The discussion of climate change is strong related to an increase of air temperature on global and local scale. The air temperature of Freiburg will increase by 3.5 °C to the end of the 21st century. The mean annual air temperature in Freiburg is currently about 10.8 °C. The urban conditions and the urban heat island are a phenomenon of the changed energy balance in cities and warmer conditions means changes in the exhaust warm by heating or cooling. Nowadays, in the midlatitudes or mild climate regions, e.g. Freiburg, the consumption of energy is more for heating than for cooling. For many regions, it will be of interest if there is a gain or loss in energy demand for heating or cooling in the future.

1. Introduction

Heating degree day (HDD) and cooling degree day (CDD) are quantitative indices being designed to reflect the demand for energy requirements to heat or cool a home, business or other issues. These indices are derived from daily air temperature observations. Generally, a degree-day fixes the value that expresses the adding temperature of the air. It gives the value of quantity and duration when the air temperature becomes lower or higher than a determined threshold value, which is known as the basic temperature (Hitchen, 1981; Martinaitis, 1998; McMaster and Wilhelm, 1987). In order to estimate heating costs, this value is given as the total deficit of outdoor air temperature in relation to the basic temperature.

The heating (or cooling) requirements for a given structure at a specific location are considered to be directly proportional to the number of heating degree days at that location. For Freiburg, the city with a long tradition in urban climatology in the southwest of Germany, the expected climate conditions for the future indicate an increase in air temperature and therefore a change in the demand of cooling and heating requirements.

Concerning urban climate and urban planning purposes, it is not only of interest to have the increase in air temperature in an annual mean but also in form of frequencies of thresholds and number of days. The question is how to quantify the heating and cooling energy demands. This can be carried out by the use of degree days and the annual amount of them. The advantage of them is that they are based only on air temperature and the final results are given in °C.

2. Methods and data

Based on daily values of mean, maximum and minimum air temperature (T_a) the heating and cooling degree days have been calculated. For heating degree days the thresholds of 15 °C, 14 °C, 13 °C and 12 °C have been used. 15 °C is the standard heating value for Freiburg. For cooling degree days the thresholds of 18 °C, 18.3 °C, 20 °C and 22 °C have been applied. Recommended is the 18.3 °C threshold. Three different periods and two different kinds of data have been analysed. The period 1961-2007 corresponds to the measured period of the German Weather Service data (DWD).

Based on existing measurement stations of the German Weather Service (DWD) and regional climate simulations (REMO) for two different scenarios (A1B, B1) the heating and cooling conditions have been analysed (Jacob, 2001; Jacob et al., 2007).

3. Results

The REMO data for the area of Freiburg (9 grid points have been used in order to get the mean conditions for the area of Freiburg) have been processed for the A1B-scenario from 1961 to 2100 and for B1 from 2001 to 2100, respectively. Figs. 1 and 2 show the heating and cooling days for A1B. The period 1961 – 2000 is the control period for REMO data. The heating degree days and cooling degree days for DWD data, A1B, and B1 are shown in Fig. 3 and 4. The heating and cooling days are presented in Fig. 5 and 6, respectively.

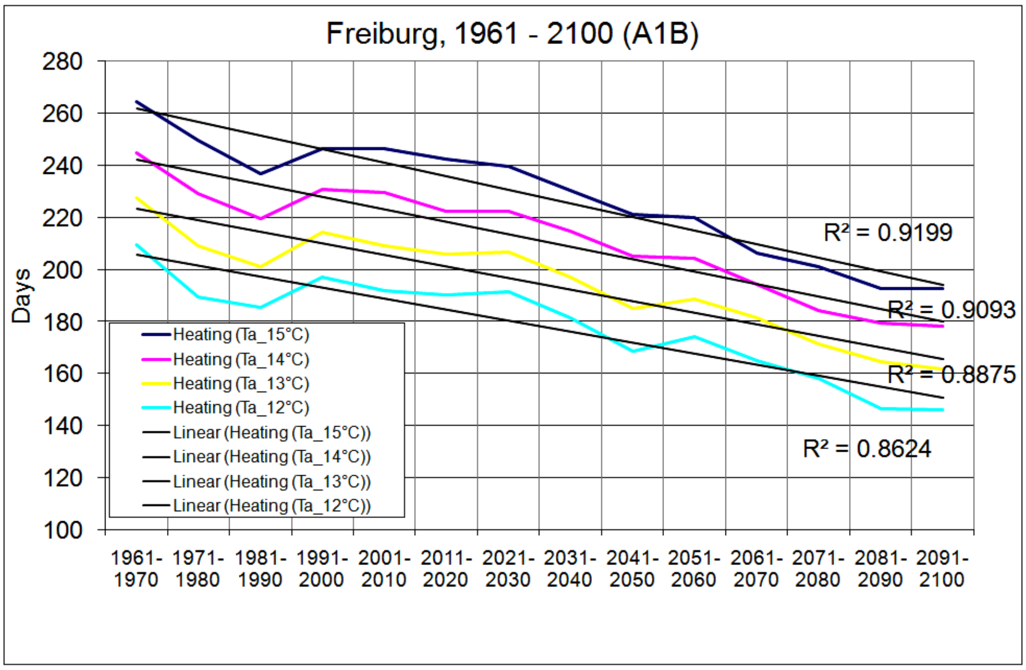

Fig. 1: Heating days in Freiburg for the A1B-scenario (REMO) (based on T_a: 12, 13, 14 and 15 °C) for 1961 – 2100

Fig. 1 shows the heating days of the A1B-scenario based on the threshold values 12, 13, 14 and 15 °C. Generally, there exists a decreasing trend over the decades from 1961 to 2100. In each case, the coefficient of determination shows a high statistical relationship in linear regression of the periods, in which the scenario with the threshold value of 15 °C creates the highest statistical connection with $R^2 = 0.9199$.

Fig. 2 shows the cooling days of the A1B-scenario based on the threshold values 18, 18.3, 20 and 22 °C. Discernible is the increasing trend of cooling days in the period from 1961 to 2100. As well as in Fig. 2 the coefficient of determination of all curves shows a high statistic connection to the linear regressions, whereas the scenario with a threshold value of 18 °C creates the strongest relationship with $R^2 = 0.9179$.

The heating degree days based on the air temperature data of the DWD data as well as the A1B- and the B1-scenarios (with a threshold value of 15 °C) are shown in Fig. 3. All included thresholds have a decreasing trend. In the second half of the 21st century, the A1B-scenario features much less heating degree days than the B1-scenario. This applies accordingly for the heating days (shown in Fig. 5). These results aren't surprising, because the A1B-scenario works on the assumption that there will be an increase in air temperature of maximal 4.4 °C until the end of the 21st century, whereas the B1-scenario only calculates with a maximum increase of 2.9 °C.

Fig. 4 shows the cooling degree days, Fig. 6 the cooling days based on the data from the DWD, the A1B- and B1-scenario at the threshold value of 18.3 °C. All curves show an increasing trend. From 2020 on, the A1B-scenario reveals higher cooling- and cooling degree days than the B1-scenario. This is as previously mentioned caused by the air temperature, which increases more intense in the case of A1B compared to B1.

In the 1990s and in the beginning of the 21st century, the measured values of Ta were generally higher than the Ta simulated in the A1B-scenario. In the decades of 1991 – 2000 and 2001 – 2010 the amount of actual heating- and heating degree days was clearly under the expected values of the A1B-scenario. Likewise there existed more actual cooling- and cooling degree days as expected by the scenario. The discrepancy between the simulated and the observed values was the result of mild winters and hot summers in this time span.

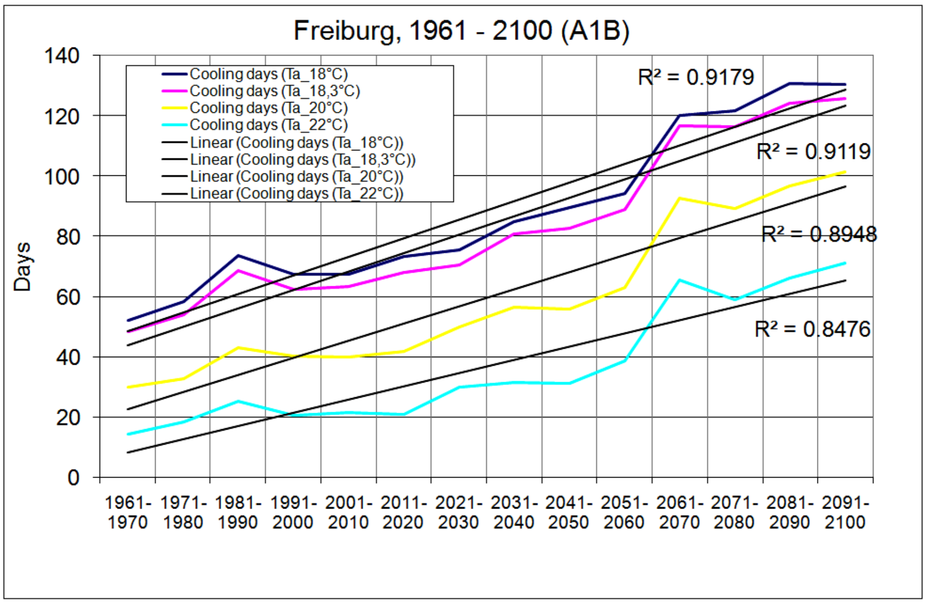

Fig. 2: Cooling days in Freiburg for the A1B-scenario (REMO) (based on T_a: 18, 18.3, 20 and 22 °C) for 1961 – 2100

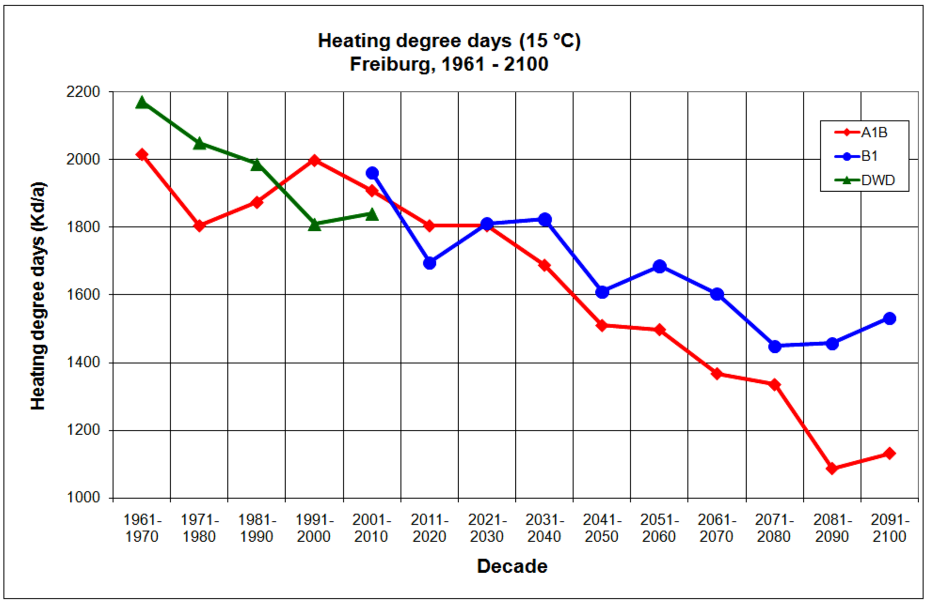

Fig. 3: Heating degree days in Freiburg for DWD, REMO A1B and B1 (based on T_a: 15 °C) for 1961 – 2100

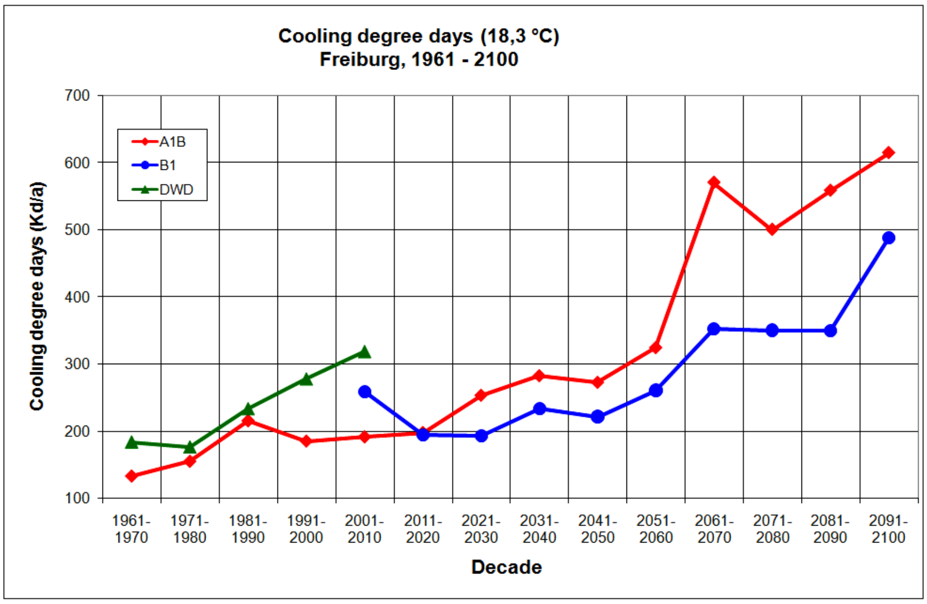

Fig. 4: Cooling degree days in Freiburg for DWD, REMO A1B and B1 (based on T_a: 18.3 °C) for 1961 – 2100

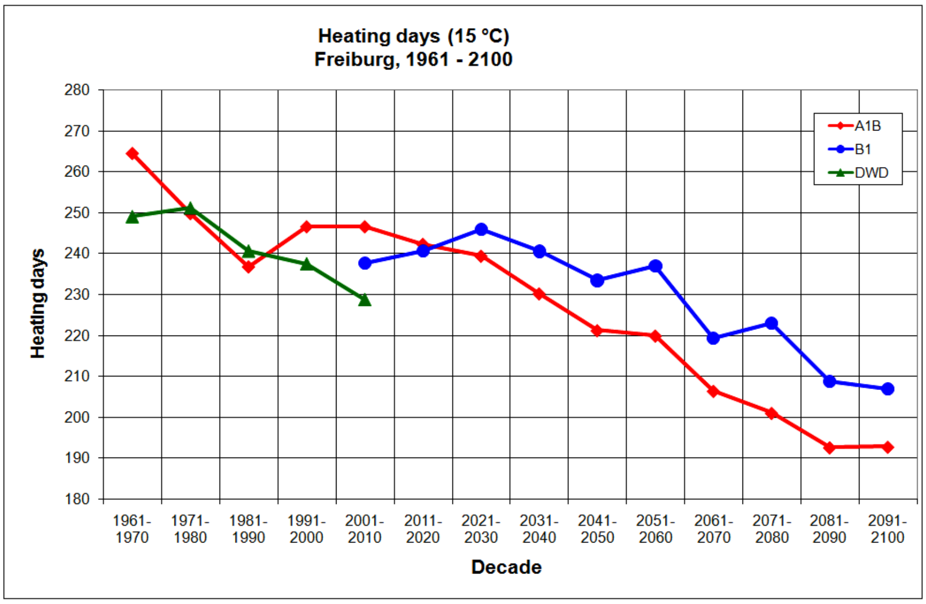

Fig. 5: Heating days in Freiburg for DWD, REMO A1B and B1 (based on T_a: 15 °C) for 1961 – 2100

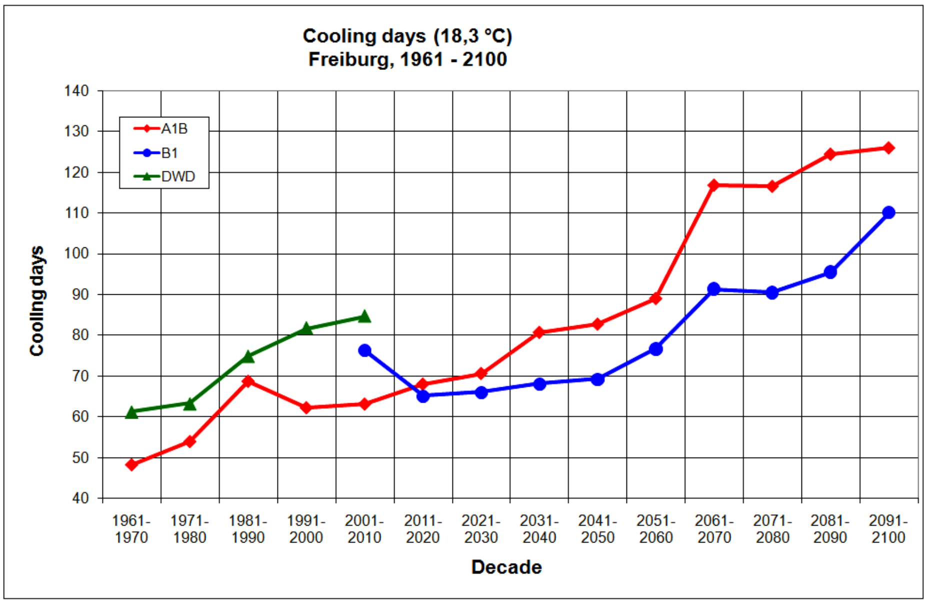

Fig. 6: Cooling days in Freiburg for DWD, REMO A1B and B1 (based on T_a: 18.3 °C) for 1961 – 2100

5. Conclusions

The analysis based on the measured DWD data shows a decrease of heating of more than 20 days for the period 1961 – 2007. The cooling days rose up from 60 to 85 days. For the REMO simulated data the A1B-simulation shows a decrease for the period 2001 – 2100 from 240 to 190 days and to 220 days for B1. The cooling days increase for

2001-2100 for A1B from 90 to 130 and for B1 to more than 100. The examined conditions by the use of heating and cooling days for a city in moderate climate and the expected climate conditions for the end of the 21st century build valuable information about the regional and local climate.

Based on the present calculations and the analysis, the energy as well as heating and cooling demand for future climate conditions can be quantified. There are, of course, open questions for future heating or cooling degree days, if human will have an adaptation to higher air temperatures in winter, resulting to lower heating requirements. For summer, residents will accept higher thermal loads and avoid cooling devices e.g. air conditioning.

For urban areas the knowledge of heating and cooling requirements for present and future climate conditions play a significant role not only for the formation and influence on urban heat island but also for thermal perception or comfort conditions as well as thermal adaptation of humans in a future climate.

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