Climate change and urban bioclimate: Adaptation possibilities

Andreas Matzarakis and Christina Endler

Meteorological Institute, University of Freiburg, D-79085 Freiburg, Germany

andreas.matzarakis@meteo.uni-freiburg.de

Abstract

Climate change will affect climate in urban areas and also urban bioclimate. Therefore, there is a demand on adaptation strategies and possibilities in the urban structures and microclimate. The performed simulations are based on changes in parameters which have the biggest variation in urban structures: mean radiant temperature and wind speed. REMO data for A1B and B1 one have been used.

Key words: RayMan, PET, Freiburg, REMO, Adaptation

1. INTRODUCTION

Freiburg is a medium sized city in the south west of Germany with a population of more than 200.000 inhabitants. Freiburg states an interesting study site for urban bioclimate research located at the foothills of the Black Forest. Additionally, Freiburg is one of the most important and visited cities in the Black Forest. Based on the IPCC scenarios an increase in air temperature of more than 3 °C is expected to the end of the 21st century for the A1B scenario. The physiologically equivalent temperature (PET) and its variations in Freiburg build the basis for the analysis of future bioclimatic conditions in order to access the climate for adaptation possibilities in urban areas. For this purpose, the PET has been applied in order to quantify the urban thermal bioclimate and the influences on urban structures and green areas.

2. DATA AND METHODS

To assess the urban climate in a physiologically significant manner it requires the application of methods of modern human-biometeorology which deals with the effects of weather, climate and air quality on human organism (Mayer, 1993).

The physiologically equivalent temperature is based on the human energy balance and describes the effects of the meteorological conditions (short and long wave radiation, air temperature, air humidity and wind speed) and thermo-physiological conditions (clothing and activity on humans) (Höppe, 1999, Matzarakis et al., 1999).

For this study, the A1B scenario carried out by REMO (Jacob, 2001, Jacob et al., 2007) is initially used. The model region covers Germany and the Alps. The data has a spatial resolution of 10 km and a temporal resolution of hours. The data is available from 1950 until 2100. Thereby, the period 1961-1990 of the A1B scenario is used as reference period for future climate changes ranging from 2021 to 2050 as well as from 2071 to 2100.

We have chosen the time span from 1961 till 1990 for comparison. The following parameters of REMO data are the basis for the computation of physiologically equivalent temperature (PET) being background for thermal comfort and discomfort (Höppe, 1999, Matzarakis et al., 1999):

- Date,
- Longitude, latitude and altitude,
- Air temperature,
- Vapour pressure,
- Wind velocity,
- global radiation.

PET is computed by RayMan (Matzarakis et al., 2007). Additionally, precipitation and snow cover are also included in the analysis. The values refer to 14 CET.

3. RESULTS

In order to get any information about adaptation possibilities to climate change conditions two options have been included. Based on the assumption that, in urban structures, the parameters modified at most are radiation fluxes (here expressed by the mean radiant temperature) and wind speed, we made several runs with modified *Tmrt* (mean radiant temperature, which includes the effect of short and long wave radiation fluxes on the human energy balance) and wind speed. These two parameters are also the possibilities that can be modified or changed by urban planning measures.

Based on the assumption that, if *Tmrt =Ta* (more or less shady conditions) changes in heat stress are very high. If wind speed is modified by increasing of 1 m/s then the days with heat stress are decreasing compared to original PET conditions.

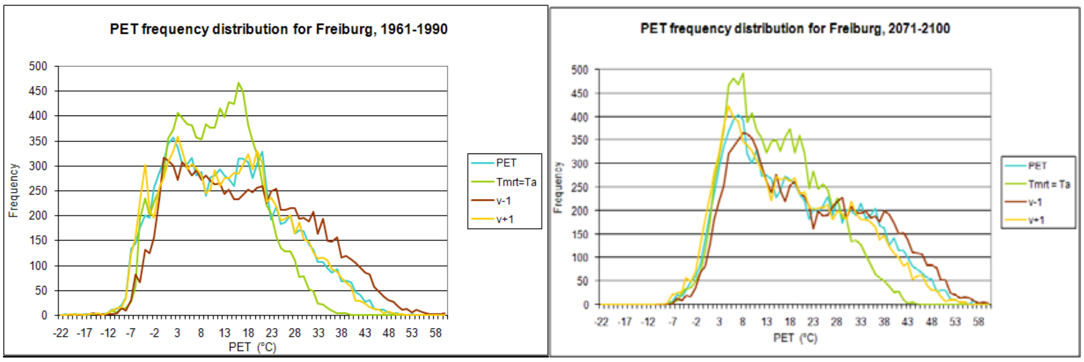

Fig. 1. Distribution of PET conditions for the period 1961-1990 (left) and 2071-2100 (right). Conditions with *Ta=Tmrt* and modified wind conditions with wind-1 m/s and wind+1 m/s. Data: REMO and A1B Scenario.

Fig. 1 presents the distribution of PET standard conditions and the applied adaptation options (*Ta=Tmrt, v-1 and v+1*) for the periods 1961-1990 (left) and 2071-2100 (right). Furthermore Fig. 1 reveals that not only minimum and maximum conditions are shifting and changing but also that there are changes in the medium and less thermal stress levels.

In general, the distribution of the PET values shows a shifting to higher values till the end of the 21st century (2071-2100). Very cold (less than 0 °C PET) as well as comfortable conditions (18 to 23 °C) are decreasing. The frequency of PET values greater than 35 °C is increasing esp. for the period 2071-2100. The distribution for values higher than 30 °C is rapidly increasing for the period 2071-2100 as well.

For the *Ta=Tmrt* conditions, the distribution is shifting also to higher PET conditions for the two examined periods of the 21st century. The conditions have a general increase with a more intense shifting in the cold conditions and thermal comfort ranges. The very high conditions will also increase for PET values higher than 30 °C.

Due to modifying wind conditions (reducing the wind speed by 1 m/s, here declared with *v-1*) the distribution of PET will become wider esp. in the level of heat stress. Changes in PET frequencies are higher under consideration of reducing wind speed compared to increased (+ 1 m/s, here declared with *v+1*) wind speed.

The changes are much higher considering the modifications in the radiation fluxes (here *Ta=Tmrt*) that can be done by plantation of specific and relevant vegetation types producing shade in summer and types allowing to let short wave radiation passing the surface or the areas where human spend their time in winter. For the modifications by wind the influence is not so high but relevant to know that increased wind speed can reduce thermal conditions of hot conditions in complex structures.

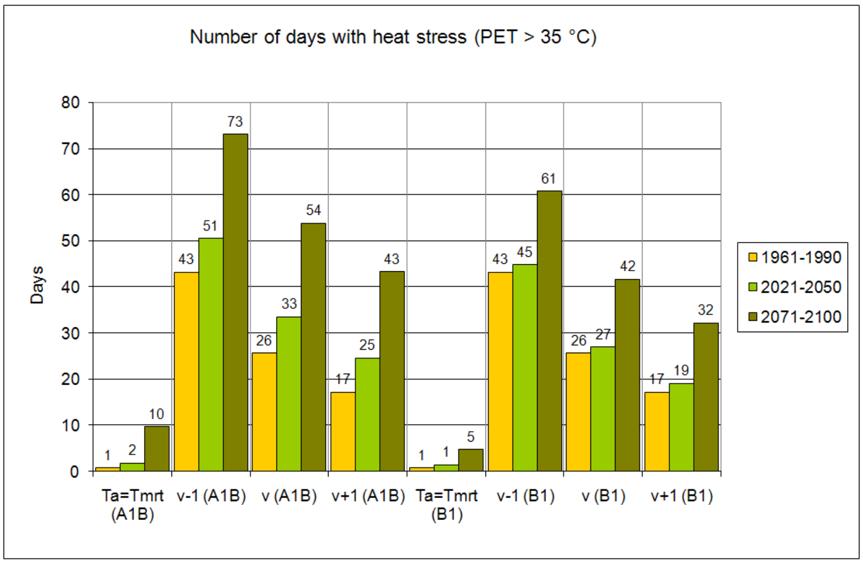

Fig. 2. Number of days with heat stress (PET > 35 °C) in Freiburg for the periods 1961-1990, 2021-2050 and 2071-2100 under following simulations: *Ta=Tmrt, v-1, v, v+1*. Data: REMO A1B, B1.

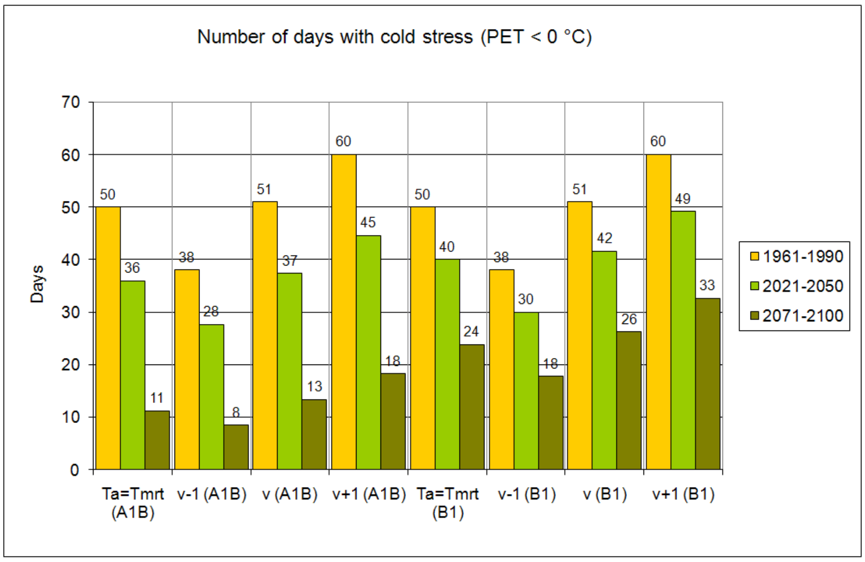

Fig. 3. Number of days with cold stress (PET < 0 °C) in Freiburg for the periods 1961-1990, 2021-2050 and 2071-2100 under following simulations: Ta=Tmrt, v-1, v, v+1. Data: REMO A1B, B1.

In Fig. 2, possible changes of heat stress days (PET > 35 °C) are shown for both scenarios (A1B and B1). The three bars show the amount of days for the examined climate periods. The first four groups of bars show the A1B scenario runs and the last four the B1 results. The bars marked with *v* are the original calculated conditions for PET. The *Ta=Tmrt* conditions show the conditions with modified *Tmrt* and have to be seen in comparison to the bars marked with *v*. The same applies for *v-1* and *v+1* which represent the conditions with modified wind speed (*v-1* and *v+1*). The individual bars have to be interpreted in comparison to the original calculated conditions of *v*. Reducing the radiation (here *Tmrt=Ta*), heat stress days will be only about 10 till the end of the century for A1B. For B1, only an increase of 5 days will occur. Reducing the wind speed, heat stress days increase in all cases with highest changes for A1B for the period 2071-2100 with an amount of 30 days. The increase in heat stress days is similar for B1. In the case of increasing the wind speed by only 1 m/s, a decrease of days with heat stress occurs. For both scenarios, the amount of days with heat stress drops about 10 days (Fig. 2)

For cold stress conditions (PET < 0 °C), the results show a decrease (Fig. 3). Only small changes occur in cold stress days with the assumption of *Tmrt=Ta*. Decreasing the wind, changes in days with cold stress are less than five days (producing better PET conditions). By increasing the wind speed of 1 m/s, the days with cold stress decrease slightly.

4. CONCLUSIONS

The present analysis for Freiburg shows that, in general, the days with heat stress will increase and days with cold stress will decrease in the expected future climate conditions. In general, the results of B1 are lower compared to A1B.

Based on the results, reduction possibilities due to modified air temperature, global radiation and wind speed have been applied in order to validate the sensitivity of these parameters on physiologically equivalent temperature and expected future climate conditions. It is not relevant to know only about the expected air temperature changes of future climate but about also the thermal bioclimate conditions for urban dwellers.

With less modifications of meteorological conditions in urban structures, i.e. increasing the shadow by planting and providing big leaf trees, huge modifications of thermal bioclimate are possible. But also possibilities of less modifications of wind conditions can sustainable modify the thermal bioclimate conditions in the micro scale.

Simple and less expensive adaptation strategies esp. in areas where humans spend their time in urban areas have not only to be seen from the point of view of climate change discussion but also generally for improved climate conditions in urban areas.

ACKNOWLEDGEMENT

This research study is supported by the Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF) in the allowance of „Klima*zwei*“ (01LS05019).

References

Höppe, P., 1993. Heat balance modelling, *Experientia* 49, 741-746.

Jacob, D., 2001. A note on the simulation of the annual and inter-annual variability of the water budget over the Baltic Sea drainage basin, *Meteorology and Atmospheric Physics,* 77, 61–73.

Jacob, D., Andrae, U., Elgered, G., Fortelius, C., Graham, L. P., Jackson, S. D., Karstens, U., Koepken, Chr., Lindau, R., Podzun, R., Rockel, B., Rubel, H.B., Sass, R.N.D., Smith, B.J.J.M., Van den Hurk, X. Yang, X., 2001. A Comprehensive Model Intercomparison Study Investigating the Water Budget during the BALTEX-PIDCAP Period, *Meteorology and Atmospheric Physics* 77, 19-43.

Matzarakis, A., Mayer, H., Iziomon, M. G., 1999, Applications of a universal thermal index: physiological equivalent temperature. *Int. J. Biometeorol.* 43, 76-84.

Matzarakis, A., Rutz, F., Mayer, H., 2007. Modelling Radiation fluxes in simple and complex environments – Application of the RayMan model, Int. J. Biometeorol. 51, 323-334.

Mayer, H., 1993. Urban bioclimatology, *Experientia* 49, 957-963.

Zebisch, M., Grothmann, T., Schröter, D., Hasse, C., Fritsch, U., Cramer, W., 2005. Climate change in Germany – Vulnerability and adaptation of climate sensitive sectors, *Climate Change 10/05*. Umweltbundesamt, Dessau. 2005.