Estimation of human-biometeorological conditions in southwest Germany for the assessment of mitigation and adaptation potential

Dominik Fröhlich and Andreas Matzarakis
School for environment and natural ressources, contact: dominik.froehlich@venus.uni-freiburg.de

Introduction

Human thermal perception is influenced by a lot of meteorological parameters like air temperaure (T_a), wind speed (v) and the different radiation fluxes summarized as the mean radiant temperature (T_{mrt}).

Thermal Indices

The impact of the individual meteorological parameters on thermal bioclimate can be best estimated by applying thermal indices, e.g. the Perceived Temperature (**PT**), the Universal Thermal Climate Index (**UTCI**) or the Physiologically Equivalent Temperature (**PET**).

To assess thermal stress for humans, the results can be evaluated using thermal stress classifications, which are available for different indices and regions. For Freiburg, the thermal perception classification introduced by [1] was selected (tab. 1).

Data and Method

This study is based on meteorological data recorded by the German Weather Service at the station Freiburg (southwest Germany) covering the years 1981 - 2013 in 1h resolution.

To approximate the future conditions REMO regional modelling outputs for the same location have been used covering the years1950 - 2100 in 1h resolution.

The model RayMan [2, 3] was applied for calculating the three thermal indices.

Conclusions

For the assessment of thermal stress, PET still appears to be the best choice, as it can be calculated for situations with low v and high T_{mrt} and shows a plausible distribution (fig. 1).

PET for REMO data shows a general increase in heat stress (PET >= 35°C) by 0.5%. Increased heat stress is found to be the largest in summer at daytime (2.8%) but also some increase at night time is evident.

References

[1] Andreas Matzarakis and Helmut Mayer. Another kind of environmental stress: Thermal stress. **WHO Newsletter**, (18):7–10, 1996.

[2] Andreas Matzarakis, Frank Rutz, and Helmut Mayer. Modelling radiation fluxes in simple and complex environments - application of the RayMan model. **Int. J. Biometeorol.**, 51(4):323–334, March 2007.

[3] Andreas Matzarakis, Frank Rutz, and Helmut Mayer. Modelling radiation fluxes in simple and complex environments: basics of the RayMan model. **Int. J. Biometeorol.**, 54(2):131–139, March 2010.

[4] Peter Kampstra. Beanplot: A boxplot alternative for visual comparison of distributions. **Journal of Statistical Software, Code Snippets**, 1(28):1–9, 2008.

Aknowledgement

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Sensitivity of the Thermal Indices

Six modified datasets have been created to show the impact of the different input parameters on the thermal indices. The indices were calculated and evaluated for additional four datasets with modified T_a of +/-2 K and modified v of +/-2 m/s (+/-3 m/s for UTCI, as v in 10 m required). Additionally, two input datasets with reduced T_{mrt} were calculated: one with T_{mrt} = T_a ("shaded") and T_{mrt} = 0.5 T_a + 0.5 T_{mrt} ("half-shaded"). The results for the modified datasets have been compared to those for the default data set (modified by 0 K, 0 m/s and T_{mrt} = T_{mrt} ("sun")).

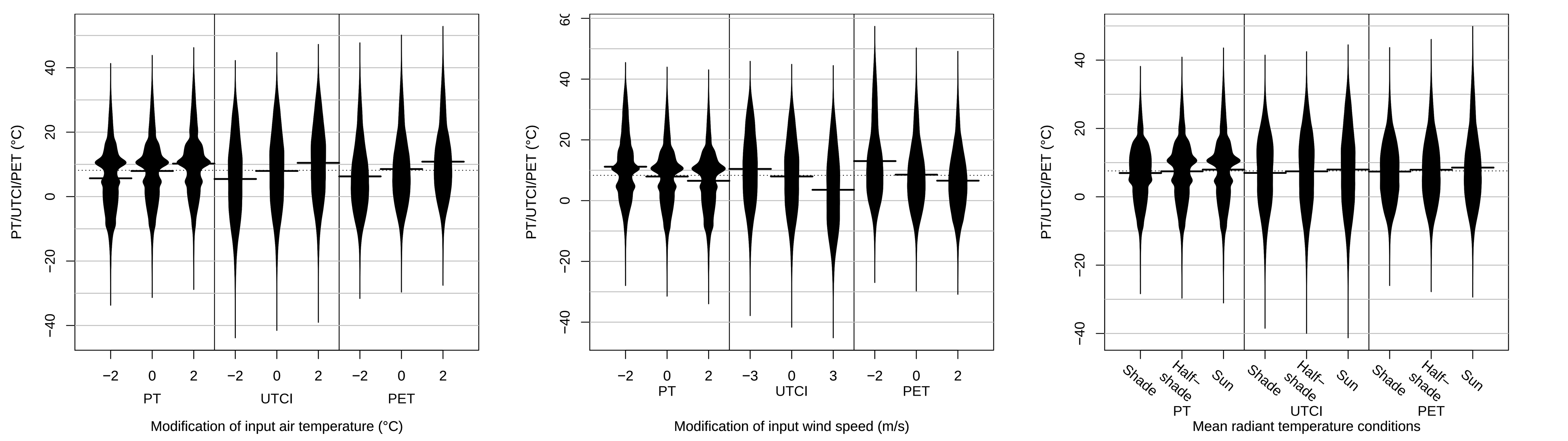

Figure 1: Results of the sensitivity analysis presented as Beanplots [4]. In each plot, the distribution of PT can be found in the left section, UTCI in the central part, and PET in the right section. Each of the indices is calculated with modified input T_a (left graph), v (central graph) and T_{mrt} (right graph). The modification of the default input dataset is shown on the x-axis.

For the modifications in T_a (fig. 1, left) all three indices agree in the general trend to respond little about the same amount as the modifications in input T_a. It can also be seen, that the distribution of PT (left three beans) is very uneven both for the original, as well as for the modified datasets.

Comparison of the results for the modified v (center) shows that the indices agree in the trend, but disagree in the amount of their response. UTCI (central part) is based on less data as it requires 0.5 m/s $\leq$ v $\leq$ 17 m/s, which is not valid for many readings.

The modification in input T_{mrt} shows most comfortable conditions for the datasets with T_{mrt} = T_a ("shaded") for all indices.

Approximate the Future Conditions

The thermal conditions in the future have been assessed using REMO data. The data was separated into three groups: 1971-2000 ("now"), 2020-2050 ("2035") and 2070-2100 ("2085"). For the results of the sensitivity analysis, PET was selected for the assessment. Results were classified using the thermal perception classification after [1] (tab. 1).

PET	Thermal Perception	Grade of Physiological Stress	Color
< 4	Very cold	Extreme cold stress	
4 - 8	Cold	Strong cold stress	
8 - 13	Cool	Moderate cold stress	
13 - 18	Slightly cool	Slight cold stress	
18 - 23	Comfortable	No thermal stress	
23 - 29	Slightly warm	Slight heat stress	
29 - 35	Warm	Moderate heat stress	
35 - 41	Hot	Strong heat stress	
>= 41	Very hot	Extreme heat stress	

Table 1: Thermal sensation classes for human beings in Central Europe, modified after [1].

For each group of years, the fraction of the perception classes were calculated for all data, day- and night time (fig. 2 left). To analyse the development in heat stress, the months June, July and August are presented separately (fig. 2 right).

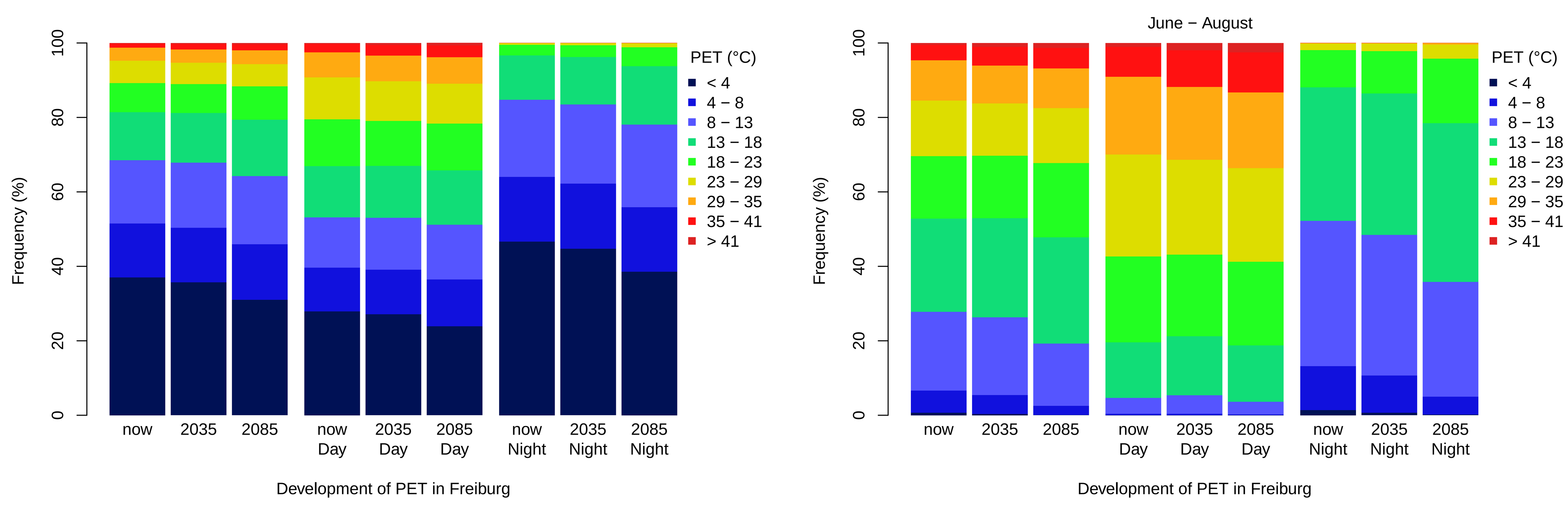

Figure 2: Comparison of the thermal bioclimate in Freiburg of the current state ("now") with the two future scenarios for the years 2020 - 2050 ("2035") and 2070 - 2100 ("2085") for the whole year (left graph) and the summer months (right graph). In each graph, results are presented for all hours, for daytime (7 - 18 LST) and night time (19 - 6 LST).

In all the diagrams, a strong trend towards the warmer classes can be seen. While the increase in hot classes is quite uniform for all the year, for the summer months it is strongest between "now" and "2035", while for night time there is a stronger increase from "2035" to "2085".