HUMAN THERMAL COMFORT WITHIN URBAN STRUCTURES
IN A CENTRAL EUROPEAN CITY
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Abstract

The joint research project KLIMES has the objective to develop urbanistic concepts, which mitigate the negative impacts of extreme heat on citizens. The basis is a combination of experimental investigations, questionnaires and numerical simulations on human thermal comfort. They are performed on typical summer days in different urban quarters within the city of Freiburg (SW Germany). To quantify the level of human thermal comfort, the physiologically equivalent temperature PET is used as assessment index. The results point to urban planning methods to reduce the effects of regional heat on the local urban scale by a suited human-biometeorologically based design of urban structures.

Key words: human thermal comfort, urban design, KLIMES project

1. INTRODUCTION

Cities are embedded in specific topographic and regional atmospheric background conditions. For example, the city of Freiburg in the southwest of Germany is located in the eastern part of the N-S oriented southern upper Rhine plain close to the slopes of the Black Forest. The Vosges mountains border the southern upper Rhine plain in the west. Due to its specific location and the relatively low latitude, Freiburg represents the warmest city in Germany.

Urban building structures and urban processes modify the atmospheric background conditions by a “±Δ”, which can be regarded as a function depending on different factors like weather, time of day and year, urban land use, street design and type of building structure. By this modification, a specific urban climate consisting of different urban microclimates within the urban canopy layer is formed.

Large-scale heat in summer (e.g. 2003) represents one of the worst atmospheric background conditions for cities in Central Europe, because this regional stress is intensified within cities. Results of regional climate simulations indicate the reliable likelihood that extreme heat waves in summer will be more intense, more frequent and longer lasting in Central Europe. Human thermal stress caused by this climate evolution will be strengthened within cities by their different dynamics. As a result of both developments, efficiency, well-being and health of citizens are affected in a crucial way that urban planning is defied to develop and apply strategies for the mitigation of extreme heat effects on citizens. They require a pronounced relation to citizens, i.e. they should have a human-biometeorological basis. In addition, they must consider the limited area of action due to the existing urban structures in Central European cities.

The joint research project KLIMES (www.klimes-bmbf.de) meets this demand.

2. JOINT RESEARCH PROJECT KLIMES

The joint research project “Development of strategies to mitigate enhanced heat stress in urban quarters due to regional climate change in Central Europe”, abbreviated by KLIMES, is carried out by four German research groups (Fig. 1) within the scope of the research initiative “klimazwei” funded by the German Federal Ministry of Education and Research (BMBF) from 2006 to 2009.

Based on an overview on the state-of-the-art in the planning-related urban human-biometeorology and identification of deficits, working hypotheses were derived, which lead to the general aims of KLIMES:
- update of human-biometeorological methods available to describe and quantify the perception of heat by citizens under current and future climate conditions,
- quantification of the perception of human thermal comfort (discomfort) in different urban quarters during extreme summer heat,
- development and verification of urbanistic strategies based on human-biometeorological results to mitigate the negative impacts of extreme weather on citizens in different urban quarters (optimisation of human thermal comfort under consideration of objectives of environmental protection, e.g. abandonment of electric air conditioning),
- synthesis of all results in a guideline for urban planning orientated to the challenges due to regional climate change in Central Europe.

To achieve the aims, a coordinated design of different methods is applied in KLIMES (for details see Bruse, 2007; Katzschner et al., 2007 a, b; Mayer, 2008; Mayer et al., 2008, 2009 a, b, c; Huttner et al., 2009):
Joint research project KLIMES

- Design of thermal index, experimental investigations on human thermal comfort: KLIMES ALUF-2
- Experimental investigations and questionnaires on human thermal comfort: KLIMES KAS-1
- Transformation of results on human thermal comfort into urbanistic concepts: KLIMES KAS-2
- Concept modules for urban planning aimed at regional climate change: KLIMES JGU

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Fig. 1: Schematic overview of the structure of the joint research project KLIMES (Mayer, 2008)

- a) experimental investigations on the perception of heat by citizens within different urban quarters in Freiburg,
- b) parallel to a), questionnaires on citizens' current perception of heat under consideration of their thermal history and their use of open spaces,

- model-based simulations of human thermal comfort in different urban quarters under current and future thermal conditions using the stationary model ENVI-met and the unsteady model BOTworld,
- development of human-biometeorologically based strategies for urban planning to optimise human thermal comfort against the background of predictions on extreme heat in the future,
- permanent dialogue with the planning practice and the public.

To quantify the level of human thermal comfort, the physiologically equivalent temperature PET (Fig. 2) is used as thermophysically significant assessment index.

Fig. 2: Schematic overview of the method applied in KLIMES to quantify the level of human thermal comfort by use of the thermophysiological assessment index PET (physiologically equivalent temperature), according to Mayer (2008)

3. RESULTS

Experimental investigations and numerical simulations on human thermal comfort were conducted at different sites in Freiburg on typical summer days in 2007 and 2008 as well as for comparison at two additional sites in Kassel (middle of Germany) in summer 2008. The sites are located within urban quarters of various building structures and vegetation types. They consist of urban street canyons, which differ in orientation to the sun, ratio of street width to building height, pattern of „green“ and sky view factor, as well as open spaces.

As example for the results obtained up to now, the effect of canopies of street trees on the level of human thermal comfort indicated by PET is analysed for a regional heat situation. The results are based on experimental investigations, which were conducted on a typical summer day in 2008 at two measuring points on a S exposed side-
walk of a street canyon located in the Vauban quarter of Freiburg. The horizontal distance between both measuring points - one unshaded and the other one shaded by tree canopies (Fig. 3) - was about 100 m.

Fig. 3: Fish-eye-photos from two different S exposed investigations sites in Freiburg, Vauban quarter (left: unshaded, right: shaded by tree canopies)

The results in Figs. 4-6 quantify the pronounced decrease of $T_{mrt}$ and PET (for PET: by about two steps within the verbal ASHRAE classification scale of heat perception by citizens), as the direct short-wave radiation is shaded by the canopy of street trees, whereas the shading effect on $T_a$ is relatively low.

4. CONCLUSIONS

The preliminary analyses yielded results on the influencing meteorological and site factors, which determine the level of human thermal comfort indicated by PET on a local urban scale during episodes with extreme regional heat stress (Mayer, 2008; Mayer et al., 2008, 2009 a, b, c; Holst et al., 2009; Huttner et al., 2009). On the basis of the results, design modules for urban planning are developed aiming on the mitigation of extreme heat. They consider (i) present knowledge, (ii) available scope for urban planning, (iii) experience from hot climate zones and (iv) compliance with aims of environment protection.

For Central European cities, extreme heat displays a summer phenomenon. The dominating number of daylight hours in summer primarily requires that the heat input from the atmosphere into cities is reduced in the daytime. Effective methods are: optimised design of streets and buildings, use of “cool” materials, promotion of „blue and green“ (roof gardens, green facades, street trees, front gardens, urban green spaces, larger water surfaces) and shading of rooftops by installations for solar energy systems. A sufficient ventilation, e.g. at night by local cold air drainage and mountain wind in cities located in complex terrain, represents an additional measure to maintain thermal comfort for citizens.

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References


**Fig. 4:** Air temperature $T_a$ at two adjacent sites in Freiburg, Vauban, on a typical summer day

**Fig. 5:** Mean radiant temperature $T_{mr}$ at two adjacent sites in Freiburg, Vauban, on a typical summer day

**Fig. 6:** Physiologically equivalent temperature PET at two adjacent sites in Freiburg, Vauban, on a typical summer day