STRATEGIES FOR MITIGATING THERMAL HEAT STRESS IN CENTRAL EUROPEAN CITIES: THE PROJECT KLIMES

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Abstract

Regional climate models predict that extreme heat waves become more frequent and more intensive in Central Europe due to climate change. The situation within cities with their own reinforcing microclimate (urban heat island) calls for new strategies in urban planning in order to mitigate the negative effects of climate change on human thermal comfort and health. The BMBF funded joint project KLIMES investigated human thermal comfort within urban spaces, combining human-biometeorological measurements with interviews of pedestrians and state of the art microclimate and multi-agent modeling. The knowledge gained by these measurements and simulations was then used by urban planners to redesign quarters in a way to maximize human thermal comfort.

Key words: KLIMES, thermal comfort, urban planning, adaptation strategies

1. INTRODUCTION

With global warming becoming an unavoidable fact, summerly heat waves in central Europe are going to become more frequent and more intensive over the next decades. The situation is aggravated in cities with their own complex micro climate, normally referred to as the urban heat island effect. The BMBF funded joint research project 'Development of strategies to mitigate enhanced heat stress in urban quarters due to regional climate change in Central Europe' (KLIMES, www.klimes-bmbf.de) had the goal to quantify the effects of the summerly urban microclimate on human thermal comfort and to develop possible countermeasures in urban planning.
For this purpose studies in the city of Freiburg, the city with the highest heat load in Germany, were conducted by research groups form the universities of Freiburg, Kassel and Mainz.

2. THE KLIMES PROJECT

The general aims of KLIMES include: (i) update of human-biometeorological methods available to quantify the perception of heat by people in urban environment under current and future climate conditions, (ii) quantifications of the perception of human thermal (dis)comfort in different urban quarters during extreme summer heat, (iii) development and verification of urbanistic strategies to mitigate the negative impacts of climate change and extreme weather conditions on the human thermal comfort, (iv) synthesis of all results in a guideline for urban planning in the face of climate change in Central Europe.
Different methods were applied within the KLIMES project to achieve these goals: (i) measurement of all biometeorologically important parameters in summerly conditions within the city of Freiburg (SW Germany) which is the warmest city in Germany (University of Freiburg) (Mayer et al, 2007) , (ii) interviews with people about their current perception of heat (University of Kassel), (iii) model based simulations of static (ENVI-met) and dynamic (BOTworld) human thermal comfort within different quarters of Freiburg under current and future summerly weather conditions (University of Mainz), (iv) development of human-biometeorologically based strategies for urban planning in order to mitigate the effects of global warming in central European cities (University of Kassel).

3. SIMULATIONS PERFORMED WITH ENVI-MET AND BOTWORLD

Within the KLIMES project the Environmental Modelling Group (EMG) of the Johannes Gutenberg University of Mainz modeled four quarters within the city of Freiburg with the three dimensional microclimate simulation ENVI-met (Bruse and Fleer, 1998) and used these results for a dynamic simulation of the human thermal comfort with the multi-agent system BOTworld (Bruse, 2007).
The four model areas were selected due to their development and building structure and their representativeness of quarters that can be found in typical central European cities. All model areas were first run with boundary conditions of present climate conditions (27.07.2007) and with boundary conditions that simulate a heat wave with maximum air temperatures of more than 35°C, low wind speeds (<0.5m/s in 2m above ground), low humidity (initial humidity of 46% in 2m above ground at 7 CET) and very dry and hot soils (10% relative humidity, 25°C initialization temperature at 7 CET). In order to simulate maximum incoming solar radiation a cloudless June 21st

was selected as simulation day. In order to simulate the effect of irrigated soils another simulation with initial soil humidity of 40% was run for two of the model areas.
Based on the discussion of these results conversion scenarios for these model areas were developed by urban planners at the university of Kassel and run in ENVI-met, using the boundary conditions of the extreme heat wave. As greening is an essential part of these conversion scenarios these conversions were only run with an initial soil humidity of 40%, simulating irrigated natural soils within the model area.
The results of the simulations were used to calculate the thermophysiological assessment index PET (physiological equivalent temperature) (Höppe, 1999) in order to quantify the human thermal comfort. As every other static comfort index PET unfortunately is in most cases not in good accordance with the thermal comfort of pedestrians that walk through the quarter, because it does not take the thermal history of the pedestrian into account. For this purpose the multi-agent simulation BOTworld was used. This software uses virtual agents (bots) in order to simulate the human thermal comfort of pedestrians moving through the model area while e.g. going shopping or going to the bus stop. The motion patterns of the virtual agents were set according to the use and the structure of the model areas. I.e. shopping areas, recreational areas, bus stops etc. were designated accordingly within the model. As atmospheric background conditions the model output of ENVI-met was used. The results were compared to the interviews of pedestrians within the model areas.

4. RESULTS

4.1. Climate scenarios

The comparison between the simulations with present day and heat wave boundary conditions shows that the general distribution of zones with high heat stress is in both scenarios roughly the same. If natural soils are not irrigated during heat wave their effect on the microclimate is roughly the same as of asphalt. As the soils dry up their heat transfer coefficient is reduced, leading to a stronger warming of the upper layers. Furthermore due to the change in albedo of the soil (and also grass) more shortwave radiation is reflected into the environment, leading to a higher radiative temperature of humans standing/ walking on these surfaces

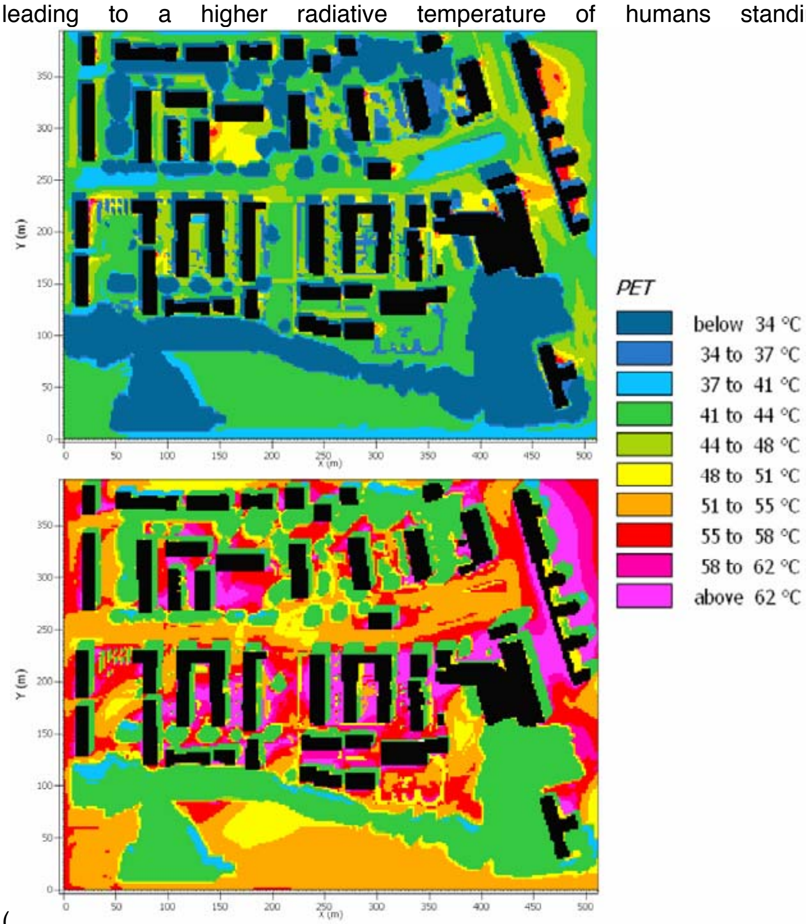

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Fig. **1**) (Huttner et al., 2008).

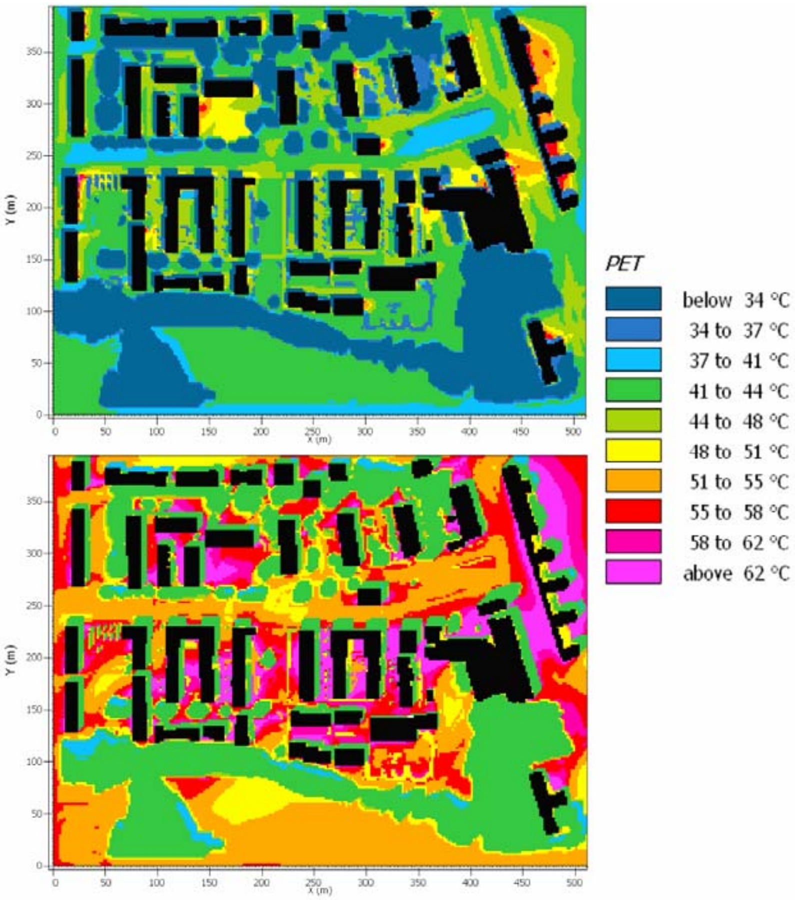

Fig. 1: Comparison of PET in 2m above ground at 15CET between present day (above) and heat wave (below) conditions in the Freiburg quarter Vauban.

4.2. BOTworld

The results from all ENVI-met simulations were used to start corresponding simulations of the dynamic human thermal comfort, i.e. the thermal comfort of pedestrians that move through the quarter. The results show that a qualitative comparison between BOTworld and onside-interviews is possible (Fig. 2). In heat sensitive areas the results from the interviews and the bots show the same pattern, like on squares or under trees. The second output of BOTworld is that taking into account the thermal history of each bot leads to different results than the calculated static PET in ENVI-met. The bots do not reach the high values of static PET due to their movement inside the model area and the possibility of e.g. clothing adaptation. The qualitative analyses of BOTworld and the onside-interviews allow assessing a threshold for human heat stress.

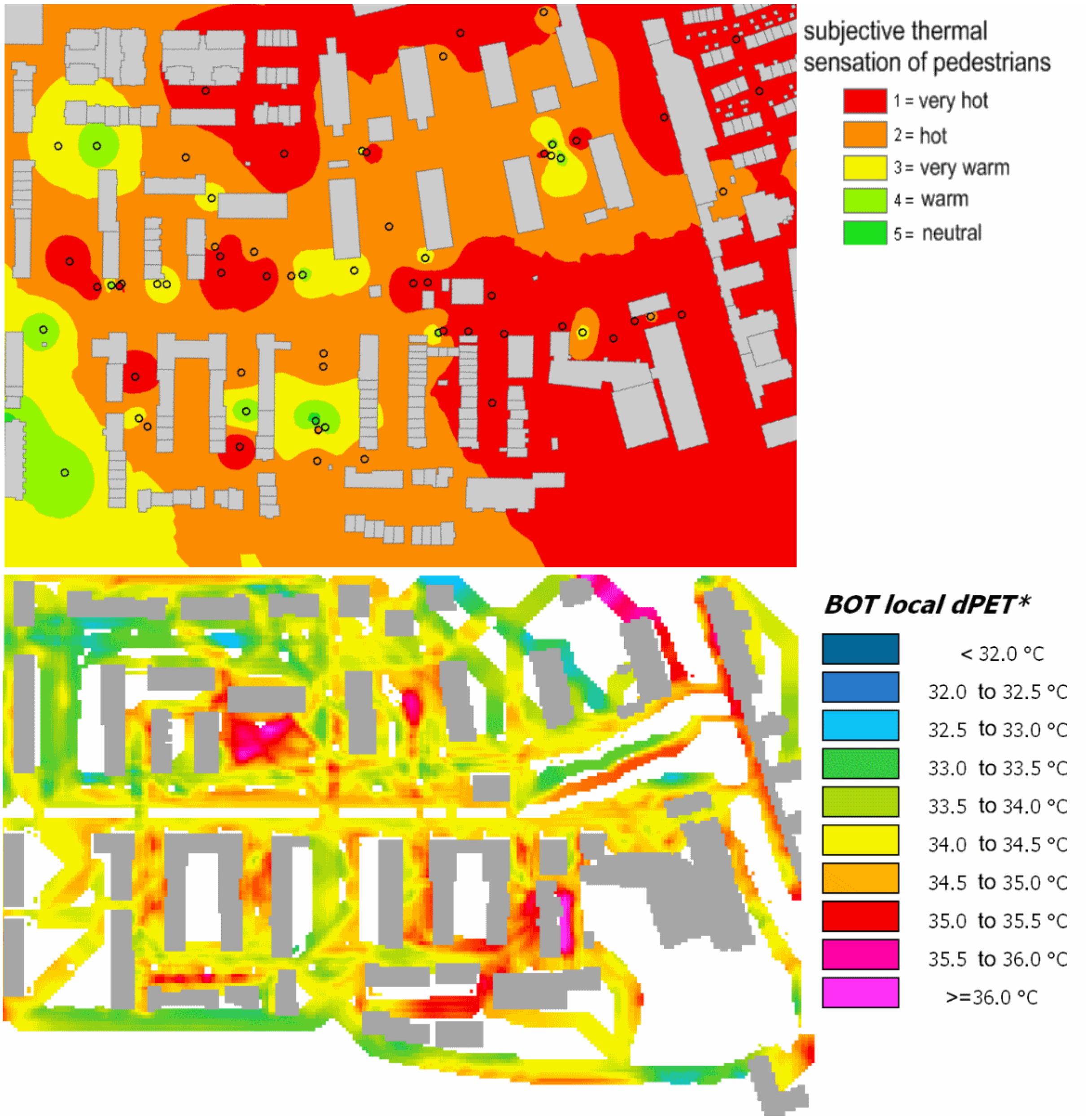

Fig. 2: The upper figure shows the subjective thermal sensation derived from onside-interviews. The lower figure shows the BOTworld simulation for the same environmnetal conditions like the onside-interviews. In heat sensitive areas pedestrians and Bots show the same pattern like on squares. With these results an assessment of the threshhold for heat stress for people can be estimated.

4.3. Urban planning scenarios

The redesigns of the quarters that were composed by urban planners from the University of Kassel show that urban greening is an easy way to drastically reduce thermal heat stress in urban spaces. Trees reduce solar access in the summer and thereby effectively lower the thermal discomfort within their vicinity.

While it is sufficient to provide shadowy places along the route of pedestrians in order to increase their thermal comfort, places where people stay over a prolonged period of time, like market places or playgrounds, have to be shaded large-scale.

Fig. 3: Concept for the human thermal comfort based redesign of the quarter Vauban

5. CONCLUSION

The results of the KLIMES project show how climate change is going to effect urban structures in central Europe and how urban planning can profit from modern simulation tools like ENVI-met and BOTworld when looking for ways to mitigate these negative effects on human thermal comfort.
For central European cities an effective greening of urban spaces is the easiest way to ameliorate human thermal comfort in the summertime. Trees can provide effective screening from short wave solar radiation and thus lower the radiative temperature in their vicinity. Simulations with BOTworld show that a clever distribution of shady places throughout the quarter can effectively lower thermal heat stress for pedestrians, even if their route includes passages with high radiative temperatures and PET values.

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