

HEAT STRESS IN BERLIN (GERMANY)

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Abstract

Three sample sites with different urban structures were chosen for studies of thermal sensation during the heat wave year 2003 in the City of Berlin. Meteorological, urban morphology and personal data were used for the modelling of the thermal index physiological equivalent temperature and the mean radiant temperature using the program RayMan.

During summer 2003 air temperature values were higher than the average of the years 1998-2004, with summer days and hot days already in June. Analyses of the Physiological Equivalent Temperature show clear differences between the different sites due to varying shading and radiation effects following from building structure and vegetation.

Key words: Physiological Equivalent Temperature, Thermal comfort, Berlin

1. INTRODUCTION

Street canyons, sealed surfaces and the lack of green spaces are of interest during heat waves because of their strong contribution to the urban heat island. Extreme weather conditions have a prejudicial effect on the urban population, especially on risk groups, e.g. ill and elderly persons. Meteorological data and information about building structure and vegetation of specific urban structures have been used in order to quantify thermal stress on human beings in a humanbiometeorological manner. Of special interest for this investigation are the summer months of the year 2003 because of their extraordinary impact on population with tens of thousands of deaths all over Europe.

2. AREAS OF INVESTIGATION

In the City of Berlin different types of land use and urban structure can be distinguished: e.g. late 19th-century block and block-edge development in the city center, villa development with park-like gardens, low buildings with yards, parks, large woods and lakes.

Heat stress conditions on urban population have been examined and compared at three locations with differences in building structure and vegetation.

2.1 Alexanderplatz

It is an esplanade situated in the city center of Berlin. The surrounding buildings are between 12 m and 128 m high. This place is characterized by its completely sealed surfaces and the lack of vegetation. Only few trees can be found here. As can be seen in Figure 1a), only small areas are shaded at noon in August.

2.2 Potsdamer Platz

Area of interest is the Quarter of DaimlerChrysler, a densely built-up area situated in the city center. The generally 35 m high buildings are overtopped by two higher constructions. The streets and pavements are completely sealed. The radiation fluxes are mostly influenced by narrow street canyons and trees of different heights that create extended shadowed areas during most of the day, as can be observed in Figure 1b). Arcades protect pedestrians against climatic influences like wind, solar radiation and rain. Potsdamer Platz is located close to the biggest park of the city, the Tiergarten, which exerts an influence on this quarter by generating cold, fresh air at night.

2.3 Dahlem

Dahlem is a suburb region situated in the southwestern part of Berlin. It can be characterized as an area with villa development and park-like gardens, where buildings and trees are about 10 – 12 m high. The high amount of vegetation in form of trees (coniferous and deciduous trees), bushes and lawn is characteristic for this

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neighborhood. Figure 1c) shows one street in this suburb with its typical building structure and the shaded areas at 1 pm in August.

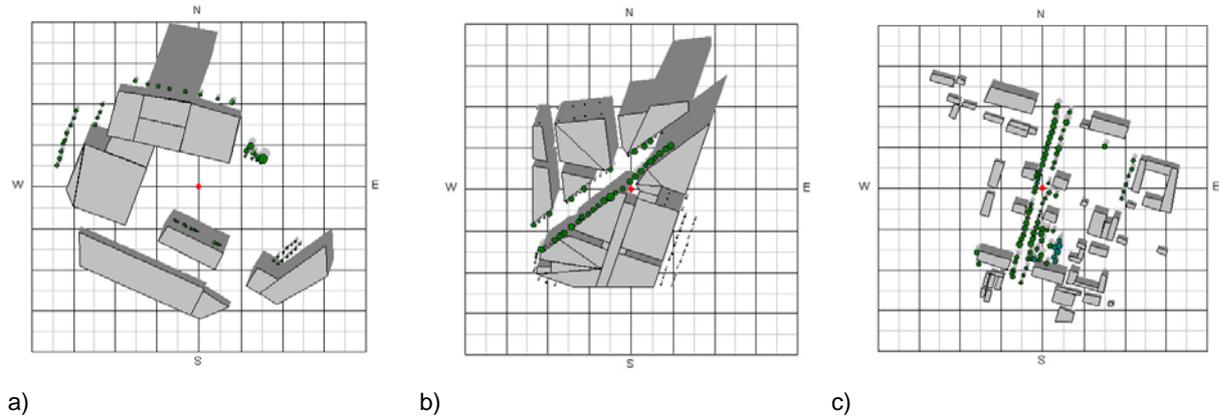


Fig. 1: Shaded areas (13:00 h, 13th August) at Alexanderplatz (a), Potsdamer Platz (b) and Dahlem (c)

3. METEOROLOGICAL DATA AND DATA EVALUATION

As meteorological input data were used: air temperature T_a ($^{\circ}\text{C}$), relative humidity RH (%), wind speed WS (ms^{-2}) and global radiation G (Wm^{-2}) of the weather stations Berlin-Alexanderplatz and Berlin-Dahlem, provided by the German Weather Service (DWD) and the Institute of Crop Science of the Humboldt-University of Berlin. These data are available as daily values and as measurements at 07:00 h and at 13:00 h for the years 1998-2004.

Due to missing global radiation values at the sample site Alexanderplatz, data measured in Dahlem were used for this study area.

These meteorological data, together with urban morphology and personal data, were used for the calculation of the Mean Radiant Temperature T_{mrt} and the Physiological Equivalent Temperature PET with the program RayMan (Matzarakis et al., 2000). The obtained PET values were evaluated regarding the frequency of the different grades of thermal stress in the summer months May to September 2003.

4. SUMMER 2003

A stable and exceptional persistent high pressure system over Western Europe was responsible for the heat waves that affected many countries and caused tens of thousands of deaths all over the continent. The following two chapters have a look on the air temperature and on the thermal index Physiological Equivalent Temperature (PET).

4.1 Air temperature

Comparing the air temperature at noon of the months May to September of 2003 with the mean values of the years 1998 till 2004 the anomaly of this year can be seen easily. Already in the first half of June, some summer days ($T_a > 25^{\circ}\text{C}$) and even a few hot days ($T_a > 30^{\circ}\text{C}$) have been registered. In July as well a longer period of warm days has been observed. Outstanding are the first two weeks of August with daily maximum temperatures exceeding the 25°C .

The figure 2 shows as well the differences between the air temperature in 2003 and the mean values calculated for the years 1998 till 2004. Although some cooler days were measured, differences up to 10°C were reached during most part of the investigation period.

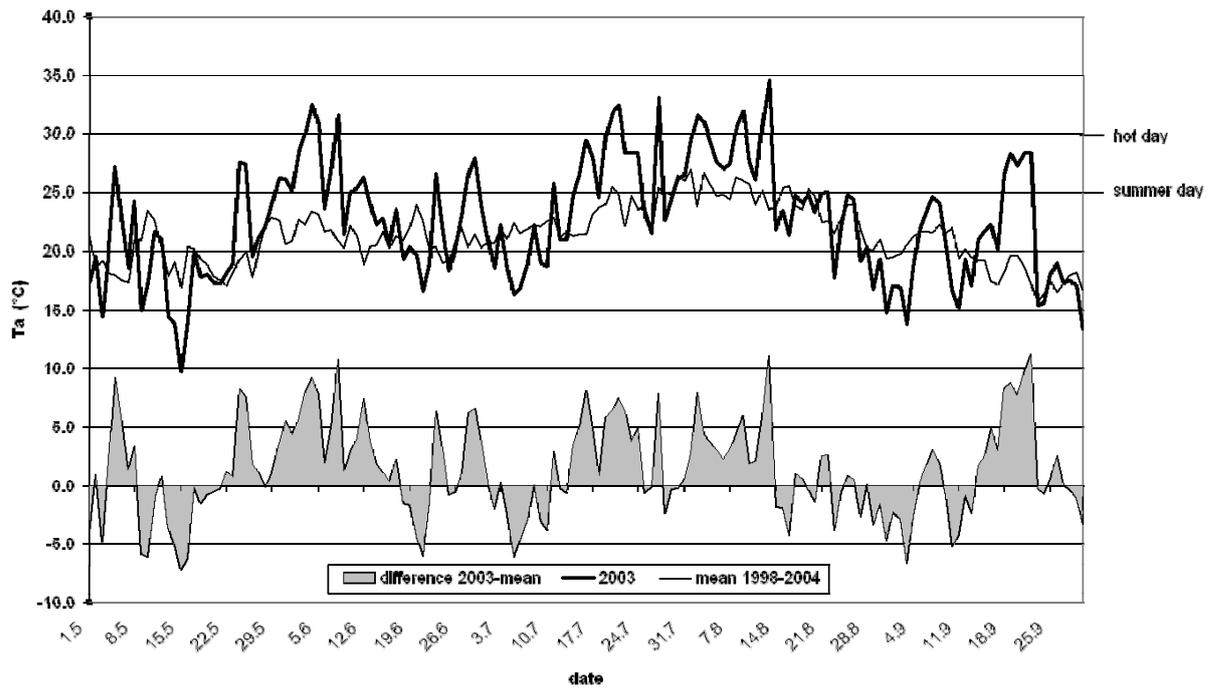


Fig. 2: Maximum air temperature at Alexanderplatz in 2003 and mean of 1998-2004

4.2 Physiological Equivalent Temperature

Figure 3a) illustrates the number of days the modeled PET exceeds at 07:00 h. Only few days lay within the range of thermal comfort ($18\text{ °C} < \text{PET} < 23\text{ °C}$). For the majority different grades of cold stress ($\text{PET} < 18\text{ °C}$) were calculated. The number of days exceeding different PET at noon is shown in Figure 3b). Strong differences between the sites regarding the development of PET during the morning hours can be observed.

Alexanderplatz shows in the morning highest values in all categories. This is due to the high amount of irradiation during these hours. Additionally, the heat storage in walls and streets contribute to the higher temperatures. For 13:00 h about 36 days with moderate and strong heat stress were calculated.

At Potsdamer Platz the input of insolation during the day is only low. But the shading effect of the buildings is cancelled out by the heat storage in the narrow street canyons, resulting in some days with thermal comfort in the morning. During the day only few days with heat stress result out of these effects.

The most significant changes are observed in Dahlem. The high amount of thermal radiation at night, the evapotranspiration and the shading effects of the trees resulted in cool and cold sensations at 07:00 h. Especially during sunny days the irradiation increased noticeably during the morning, leading to high T_{mrt} (during some of the days higher than at Alexanderplatz) and higher relative humidity, deriving from the evapotranspiration. The human body in this area was exposed to moderate and strong heat stress on 25 % of the days.

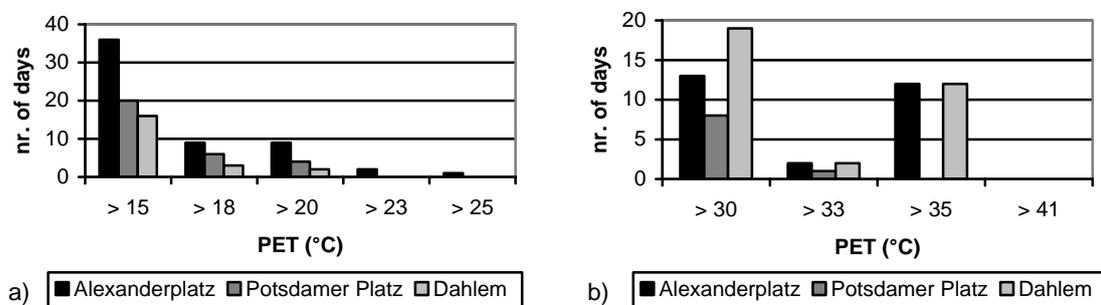


Fig. 3: Exceedance of different grades of thermal sensation in the morning (a) and at noon (b)

As seen above, the diverse urban structures have varying influences on the development of PET. Figure 4 shows the calculated values of PET at noon during summer 2003 at the sample sites Alexanderplatz and Potsdamer Platz. Clear differences up to 10 K could be observed between the open place with its unrestricted radiation on

the one hand and the shaded street canyon on the other. The values of T_{mrt} , as the most important input for the energy balance during sunny weather conditions, show even more significant differences. These were as high as 15 K – 20 K, due to the different irradiation.

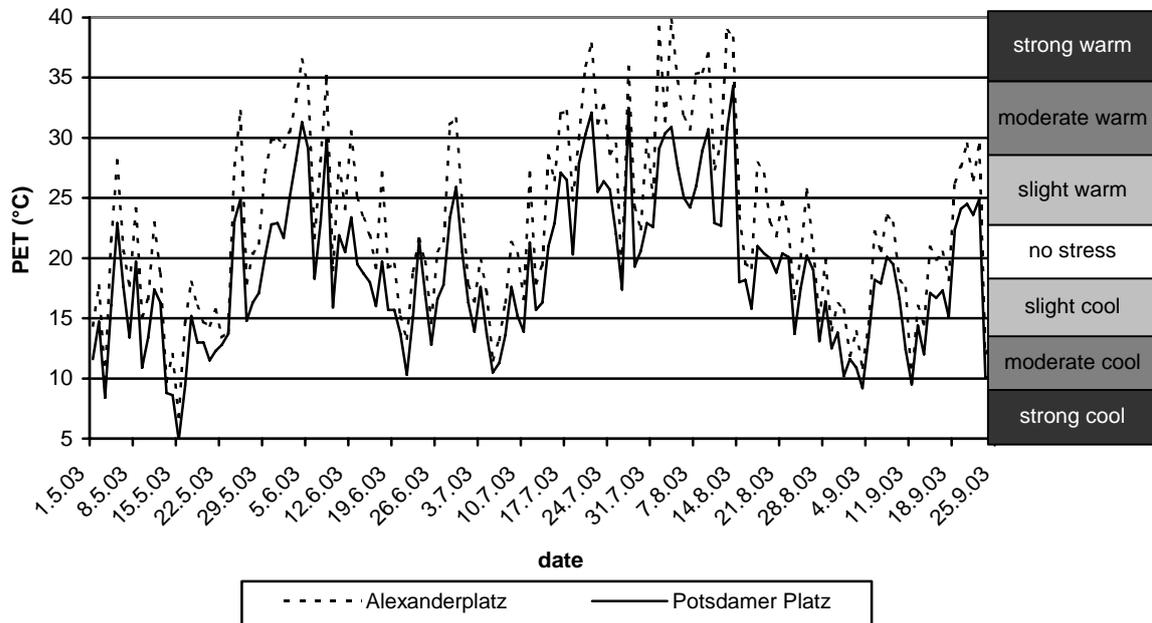


Fig. 4: Physiological Equivalent Temperature in the months May till September of 2003 at Alexanderplatz and Potsdamer Platz and the grade of thermal stress

5. CONCLUSION

Study area	Date	T_a max. (°C)	PET max. (°C)	T_{mrt} (°C)	RH (%)	Wind (m/s)
Alexanderplatz	03/08	30,9	39,8	52,3	44	0,9
	13/08	34,6	38,3	50,8	21	6,7
Potsdamer Platz	03/08	30,9	30,9	32,2	44	09
	13/08	34,6	34,3	35,3	21	6,7
Dahlem	03/08	31,0	40,8	54,0	42	0,9
	13/08	33,7	37,7	52,1	33	6,7

Table 1: Examples of PET and T_{mrt} values at the different investigation sites at two days in August 2003

Examples of the resulting PET and T_{mrt} , using the given meteorological input data, of two days in August 2003 are illustrated in Table 1. Large differences between air temperature, T_{mrt} and consequently PET can be found in the open or only partly shaded places like Alexanderplatz and Dahlem, whereas shaded places (Potsdamer Platz) show only insignificant differences.

The calculated differences of PET and T_{mrt} at Alexanderplatz and Potsdamer Platz, two sites located close to each other, are evidence for the high influence of the building structure and the resulting shading effects on the human biometeorological comfort.

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