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THERMAL COMFORT CONDITIONS IN AN E-W ORIENTED STREET CANYON IN FREIBURG (GERMANY) DURING THE EUROPEAN SUMMER HEATWAVE 2003

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1. INTRODUCTION

A record-breaking heatwave affected the European continent in summer 2003. Within cities its negative impacts on well-being and health of people have been intensified by the specific meteorological conditions within the urban canopy layer. To quantify the impacts of the thermal environment on people, thermophysiologically significant indices were developed in the modern human-biometeorology (e.g. Mayer and Höppe, 1987; Spagnolo and de Dear, 2003). Depending on the objectives, they can be determined by direct measurements of all required meteorological variables or modeling.

By use of the first method, the aim of a two day (14 and 15 July 2003) experimental case study was to analyze the thermal comfort conditions for people within a street canyon (fig. 1) in Freiburg, a medium-sized city in the southern upper Rhine plain (southwest Germany), during the summer heatwave 2003.

Figure 1. E-W street canyon in Freiburg (left: North).

2. METHODS

The physiologically equivalent temperature PET (Mayer and Höppe, 1987; Matzarakis et al., 1999) served as an adequate thermal index. Continuous measurements of all meteorological data necessary to calculate PET, i.e. air temperature T_a, vapor pressure VP, wind speed v as well as short- and long-wave radiation flux densities from the three-dimensional surroundings of a standing person (fig. 2), were carried out at the human-biometeorologically significant height of 1.1 m a.g.l. at the northern sidewalk of an E-W oriented street canyon (height/width = 1.0) in the downtown of Freiburg.

Figure 2. Pyranometers for measuring short-wave radiation from the three-dimensional surroundings of a standing person.

3. RESULTS

The diurnal cycles of T_a, VP, and v as well as relative humidity RH show patterns (fig. 3), that are typical of extremely hot summer days in Freiburg. The increase of v around 10 p.m. was caused by a regional circulation system from the Black Forest (“Hoellentaeler”) occurring in most cloudless nights.

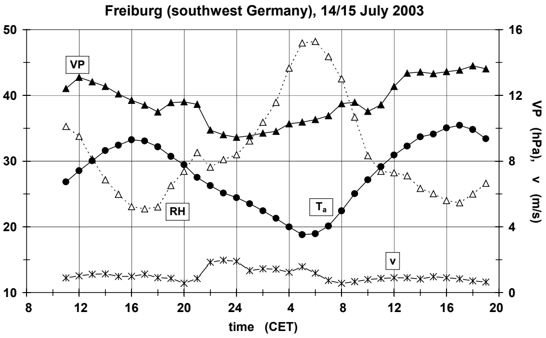

Figure 3. Air temperature T_a, vapor pressure VP, relative humidity RH, and wind speed v at the northern sidewalk (1.1. m a.g.l.) within an E-W street canyon in Freiburg on two hot summer days.

The results for the net short-wave radiation K* (fig. 4) reflect the local measurement conditions at the northern sidewalk of the E-W street canyon. K*(E-W) reached the highest values in the morning, when the site was sunlit from East, and the lowest values in the late afternoon, when the site was sunlit from West. The diurnal amplitude of K*(S-N) was approximately half as large as for K*(↓-↑), which usually represents the two-dimensional net short-wave radiation in a horizontal position.

As expected, the net long-wave radiation L*(↓-↑) was negative during the whole investigation period (fig. 5), whereas L*(S-N) reached positive values in

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the late afternoon, when the South oriented wall of the street canyon at the northern sidewalk was sunlit.

As the three-dimensional net all-wave radiation Q* is composed of corresponding values of K* and L*, the pattern of Q* (fig. 6) in the daylight hours is essentially comparable to K*. At night, the pattern of Q* is identical to L*.

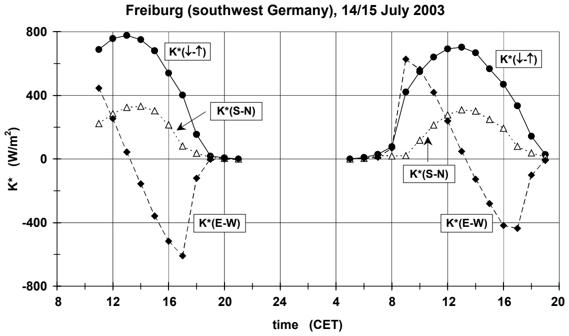

Figure 4. Net short-wave radiation K*, related to different positions of the radiation sensors, at the northern sidewalk (1.1. m a.g.l.) within an E-W street canyon in Freiburg on two hot summer days.

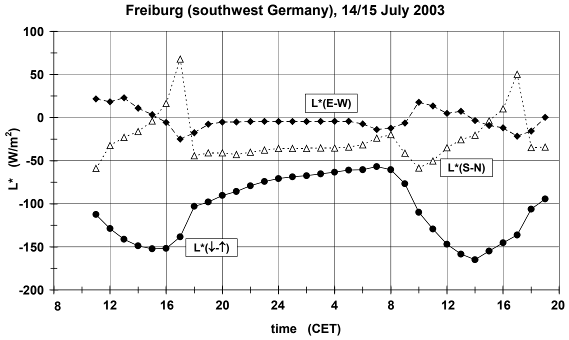

Figure 5. Net long-wave radiation L*, related to different positions of the radiation sensors, at the northern sidewalk (1.1. m a.g.l.) within an E-W street canyon in Freiburg on two hot summer days.

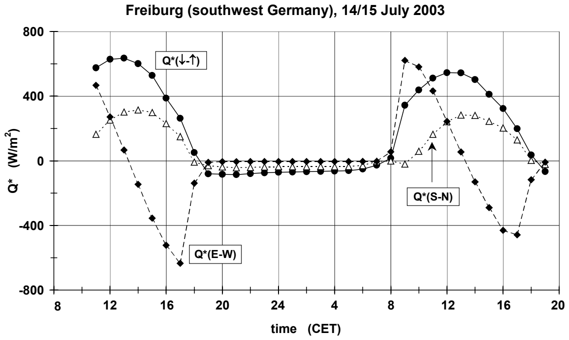

Figure 6. Net all-wave radiation Q*, related to different positions of the net radiation sensors, at the northern sidewalk (1.1. m a.g.l.) within an E-W street canyon in Freiburg on two hot summer days.

The mean radiant temperature T_{mrt}, which is the most important meteorological variable in the calculation of daytime values of PET, was directly determined from the measured radiation flux densities using the method by Höppe (1992). The results for T_a (fig. 3) and T_{mrt} (fig. 7) show highest values of T_{mrt}-T_a between 2 and 3 p.m. on both days. They amounted to 34 °C on 14 July 2003 and 30 °C on 15 July 2003. At night, T_{mrt} was nearly equal T_a.

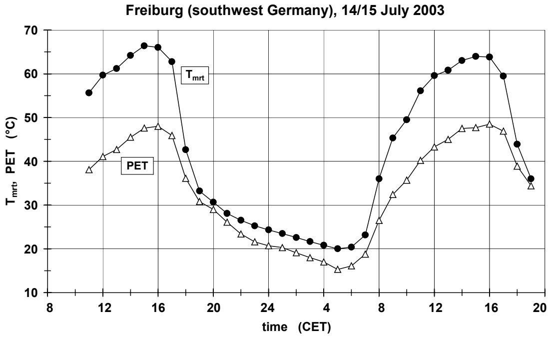

Figure 7. Mean radiant temperature T_{mrt} and physiologically equivalent temperature PET at the northern sidewalk (1.1. m a.g.l.) within an E-W street canyon in Freiburg on two hot summer days.

The thermal index PET was calculated according to the method reported by Mayer and Höppe (1987). PET reached peak values around 48 °C between 3 and 4 p.m. (fig. 7), which represents an extreme heat stress for people. The linear relationship between PET and T_{mrt}, which is indicated by fig. 7, has the form:

$$PET = 0.648 * T_{mrt} + 5.36; \qquad r^2 = 0.956$$

4. CONCLUSION

As the results for PET are based on measurements of meteorological variables and the street canyon has a comparatively simple dimension, the meteorological variables and calculated values for T_{mrt} and PET are qualified to validate human-biometeorological models for the simulation of T_{mrt} and PET.

5. REFERENCES

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