7.4 THERMAL SENSATION IN EXTREMELY HOT AND DRY URBAN ENVIRONMENTS

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1. Introduction

Thermal sensation of humans is often calculated by human energy balance models, which are defined for steady state conditions, where the human thermo regulation system has been exposed to the same climatic conditions for a considerable period of time. However, real live conditions in urban environments are often determined by frequent changes of the thermal environmental conditions and short-term thermal reaction and adaptation processes are required to maintain vital body functions.

2. Methods

The Yotvata experiment was a pilot study to an applied desert climatology project examining the effect of extremely hot and arid conditions on human thermal perception. One of the aims of this study was to assess human energy balance calculations under these conditions, by comparing the calculations with the subjective perceptions of the participants. The question of how the absence of steady state conditions would influence the observed thermal sensation as related to the calculated values was of special interest of this research.

The pilot study has been carried out in the Eilat region (Kibbutz Yotvata, Israel) in July 2000 with temperatures ranging up to 44°C and humidity below 10%. Four climatic stations were set up at different locations in the area of the kibbutz. 36 students from Eilat College were examined during alternating exposure to hot outside and comfortable indoor conditions to compare the calculated and observed thermal stress levels.

Temperatures ranged from around 25 °C at night to almost 45 °C during the day with a relative humidity between 30% and 5%. The wind speeds in the biometeorological relevant height of 1.5 m were generally around or less than 1 m/s during the day, with the exception of the exposed station on the hill. Wind speeds increased during the evening and subsided at night. The calculated mean radiation temperatures ranged from around 25 – 30 °C at night to values above 70°C in the sun and above 40°C in the shade during the day. The calculations are based on measurements of ground temperatures and solar radiation.

Thermal perception was calculated by the Predicted Mean Vote (PMV) according to Fanger (1972) and the Discomfort Index (DISC) according to Gagge (1986), which applies especially to hot conditions, where the possibilities for interpreting the PMV values are limited.

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3. Results

Figure 1 shows the average thermal sensation votes and calculated Predicted Mean Votes during the course of the experiment at one of the locations in the shade, no significant differences were observed at other stations.

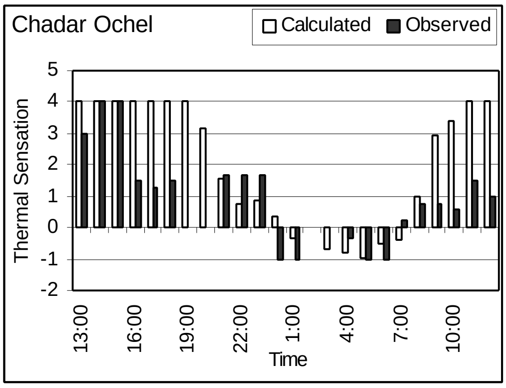

Figure 1: Calculated PMV and observed thermal sensation

The correlation between observed and calculated values is not very distinctive, the correlation coefficient (r^2) for all data takes on a value of. 0.49. Comfortable conditions are obviously registered quite correctly, whereas heat stress conditions are overestimated and cold discomfort is underestimated by the model calculations.

Figure 2 shows the average thermal sensation votes and calculated thermal sensation according to the DISC index during the course of the experiment at one of the locations

The correlation between the observed and calculated DISC values is obviously distinctively better then the correlation with the PMV values, the correlation coefficient (r^2) for all data takes on a value of 0.84. However, the observed heat stress shows continuously higher values than the calculated thermal strain. One reason for this could be the fact, that the calculation of the skin's wetness, which is a main indicator for the DISC coefficient, is not sufficient for the evaluation of thermal perception under the extremely dry conditions.

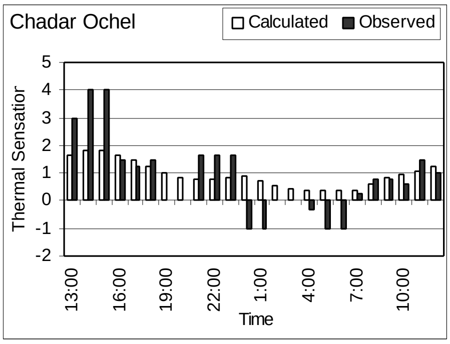

Figure 2: Calculated DISC and observed thermal sensation

It was noticed that the deviations between observed and calculated heat stress levels at all stations follow certain characteristics. Figure 3 shows calculated stress levels, deviations from observed stress levels and air temperatures at one of the stations.

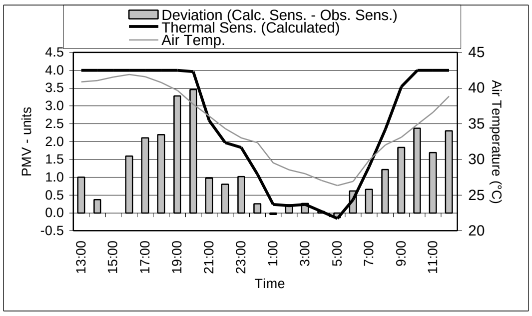

Figure 3: Calculated stress levels, deviations from observed stress levels and air temperatures

The deviations show a distinctive temporal course with an increase of values during the afternoon to 20.00 hours. From 21.00 to 23.00 hours all calculated and averaged sensations values are still slightly higher than observed values. The observed relatively comfortable conditions, from midnight to 5.00 hours, are calculated quite accurately by the energy balance model. The deviation between observed and calculated values, increases with the heat stress from 6.00 to 10.00 hours, whereas afterwards we notice a slight decrease of the deviations from11.00 to 12.00 hours at maximum heat stress levels.

A detailed analysis of the data led to the determination of a significant regularity in the diurnal development of the calculated differences. The two factors "short-term thermal adaptation" and "thermal expectation" serve to explain the differences qualitatively (Figure 4).

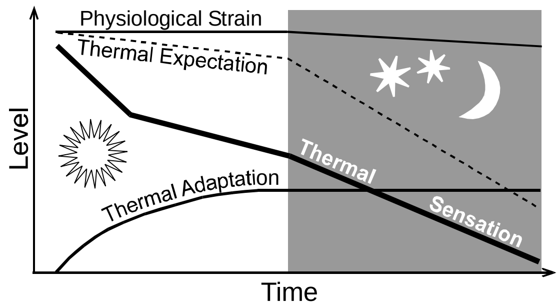

Figure 4: Schematic course of thermal sensation factors during the experiment

The physiological strain remains on a high level all during the late afternoon and decreases only slowly after sunset. The increasing thermal adaptation and to a smaller extend the thermal expectation of a cooling towards the evening, leads to an interpretation of decreasing heat stress in the course of the afternoon. After sunset it is mainly the thermal expectation which leads to another decrease in the observed heat stress levels.

The database is not yet sufficient to quantify the influencing factors, but as can be seen from the examples, they can lead to an interpretation of the thermal environmental conditions, which differs considerably from calculated values or the actual physiological strain.

4. Conclusions

The calculations of human thermal stress according to steady state energy balance models seem to be inadequate to evaluate human thermal perception in extremely hot conditions and for short term variations of thermal environmental conditions.

The presented pilot study has revealed some new aspects regarding the thermal perception of humans in a hot and arid urban environment, where the impact of the frequent short term changes of the thermal environmental conditions cannot be calculated adequately by the steady state human energy balance models. Future research projects are under preparation to further examine these aspects.

5. References

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Gagge, A.P., Fobelets, A.P. and Berglund, L.G., 1986: A standard predictive index of human response to the thermal environment. *ASHRAE Transactions*, Vol.92, 709 – 731.