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Heat waves, urban climate and human health

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Heat waves, urban climate and human health

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Abstract. The European heat wave of 2003 was an outstanding weather event. The months of June and August have been nearly everywhere in Germany the warmest months since the start of registrations in 1901. The registered mean air summer temperature was 19,6 °C, that is 3,4 K higher than the mean value. At August 9 and August 13, 2006, the highest maximum temperatures ever registered in Germany, 40,2 °C, have been measured in Karlsruhe and in Freiburg. This extreme weather was caused by a blocking action of the westerly circulation due to a stationary wave forming a so-called Omega-weather type. High pressure systems with cloudless sky conditions permitted extreme sun radiation and caused repeatedly record temperatures. In southern Germany 53 hot days with maximum temperatures higher than 30 °C have been registered. This heat wave concerned not only Germany, but large regions of Western Europe with France and Great Britain. Other European countries like Switzerland, Spain, Portugal and Italy have been concerned, too.

The questions are (1), if this extreme event is in relation with the human impact on the climate system via the emission of greenhouse gases and (2), if such events will be more frequent in the future

Keywords. Heat Waves, Urban Climate, Human Health.

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TABLE OF CONTENTS

Global climate change and heat waves

The European heat wave of 2003 was an outstanding weather event. The months of June and August have been nearly everywhere in Germany the warmest months since the start of registrations in 1901. The registered mean air summer temperature was 19,6 °C, that is 3,4 K higher than the mean value. At August 9 and August 13, 2006, the highest maximum temperatures ever registered in Germany, 40,2 °C, have been measured in Karlsruhe and in Freiburg. This extreme weather was caused by a blocking action of the westerly circulation due to a stationary wave forming a so-called Omega-weather type. High pressure systems with cloudless sky conditions permitted extreme sun radiation and caused repeatedly record temperatures. In southern Germany 53 hot days with maximum temperatures higher than 30 °C have been registered. This heat wave concerned not only Germany, but large regions of Western Europe with France and Great Britain. Other European countries like Switzerland, Spain, Portugal and Italy have been concerned, too.

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Based on a climate change simulation the distribution of the maximum temperatures of the summer 2003 indicate that this extreme summer is expected to be a normal one by the end of this century in Central Europe (Beniston 2004, Schär et al. 2004, Meehl & Tebaldi 2004; Fig. 1)!

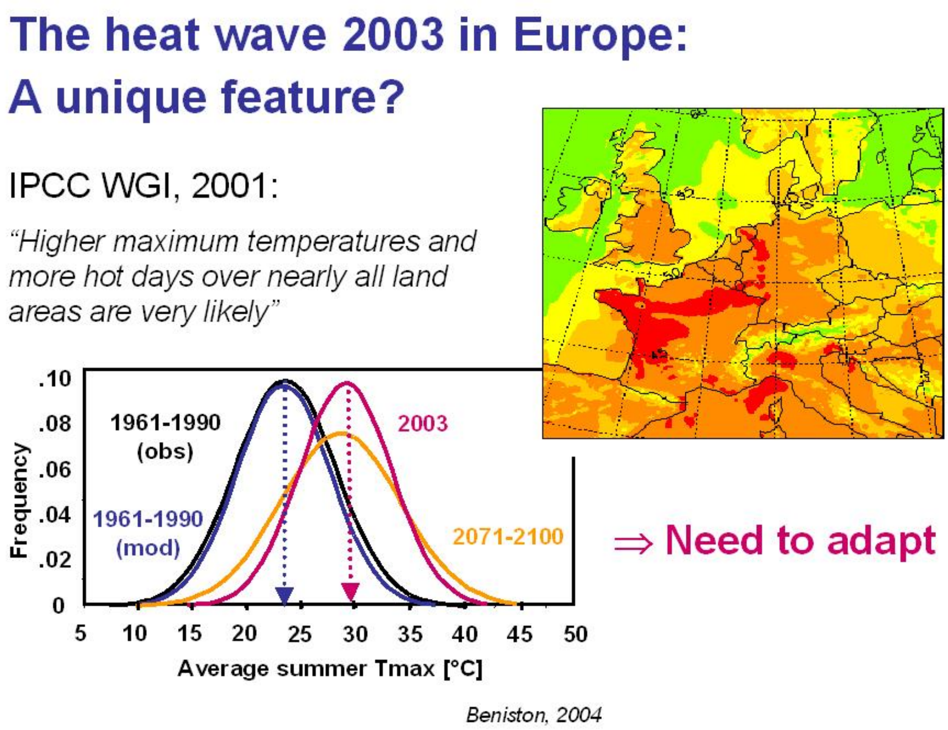

Figure 1: The heat wave 2003 in Europe: Actually a unique feature, but a normal event in 2071-2100

This is in good accordance with the IPCC (2001) statements that in the future extreme weather events are very likely and that more hot days over nearly all land areas are very likely, too.

2. Thermal climate in cities: the urban heat island

The most important „local climate change“ due to human building activities is the so-called urban heat island (UHI). Since about half a century many investigations have shown the importance of this phenomenon which is caused by the storage of short wave solar energy in the buildings during the day and its liberation by long wave radiation in the evening and night. The larger the city and the denser its build-up structure the more intense is the city’s heat island or heat archipelago. Maximum differences of about 10 K and more between city centers and rural areas (Δ(max)T_{urban} – T_{rural}) have already been registered in large agglomerations. Fig. 2 gives an example of the relation between the size of a city and its maximum heat island.

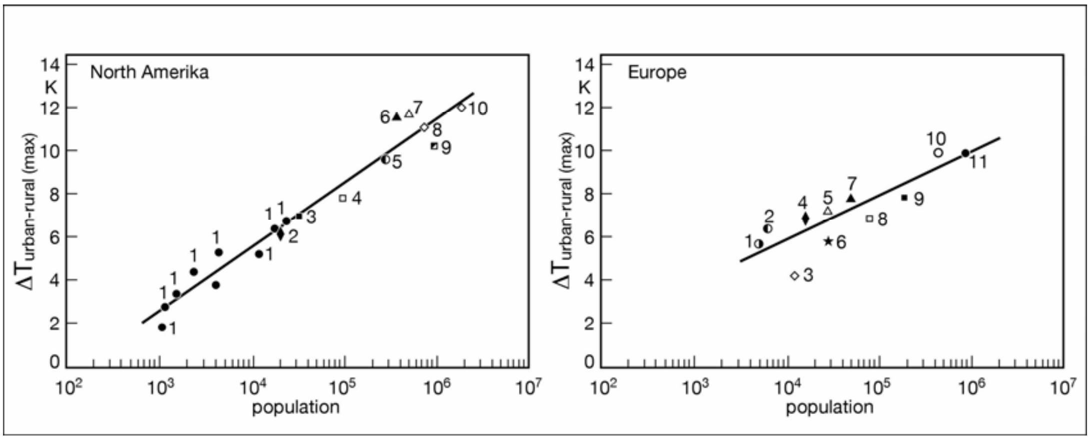

Fig. 2: European and North American Maximum Urban Heat Islands; relation between Δ(max)T_{urban} – T_{rural} and log population (Oke 1973); a) North America – 1 Nine Quebec settlements, 2 Corvallis, 3 Palo Alto, 4 San Jose, 5 Hamilton, 6 Edmonton, 7 Winnipeg, 8 San Francisco, 9 Vancouver, 10 Montreal; b) Europe – 1 Lund, 2 Uppsala, 3 Reading, 4 Karlsruhe, 5 Utrecht, 6 Malmö, 7 Sheffield, 8 Munich, 9 Vienna, 10 Berlin, 11 London (data from literature published between 1929 and 1972).

For sure the UHI is largest in the radiation rich seasons – e.g. the European summer months – or tropical and subtropical climates (e.g. summer dry subtropics of the Mediterranean coasts). Until this point there was only the question of global and local air temperature change. The climatic environment, however, includes much more elements which have to be taken into account, if we like to bring together climatic conditions and human health.

3. The Thermal Environment

One of the fundamental issues in human biometeorology is the assessment and forecast of the thermal environment. This is due to the need for human beings to balance their heat budget to a state very close to his/her thermal environment in order to optimise his/her comfort, performance and health. This means to keep heat production and heat loss in a equilibrium in order to keep the body core temperature at a constant level. Heat is produced as a result of the metabolic activity required to perform activities. The body can exchange heat by convection (sensible heat flux), conduction (contact with solids), evaporation (latent heat flux), radiation (long- and short-wave), and respiration (latent and sensible).

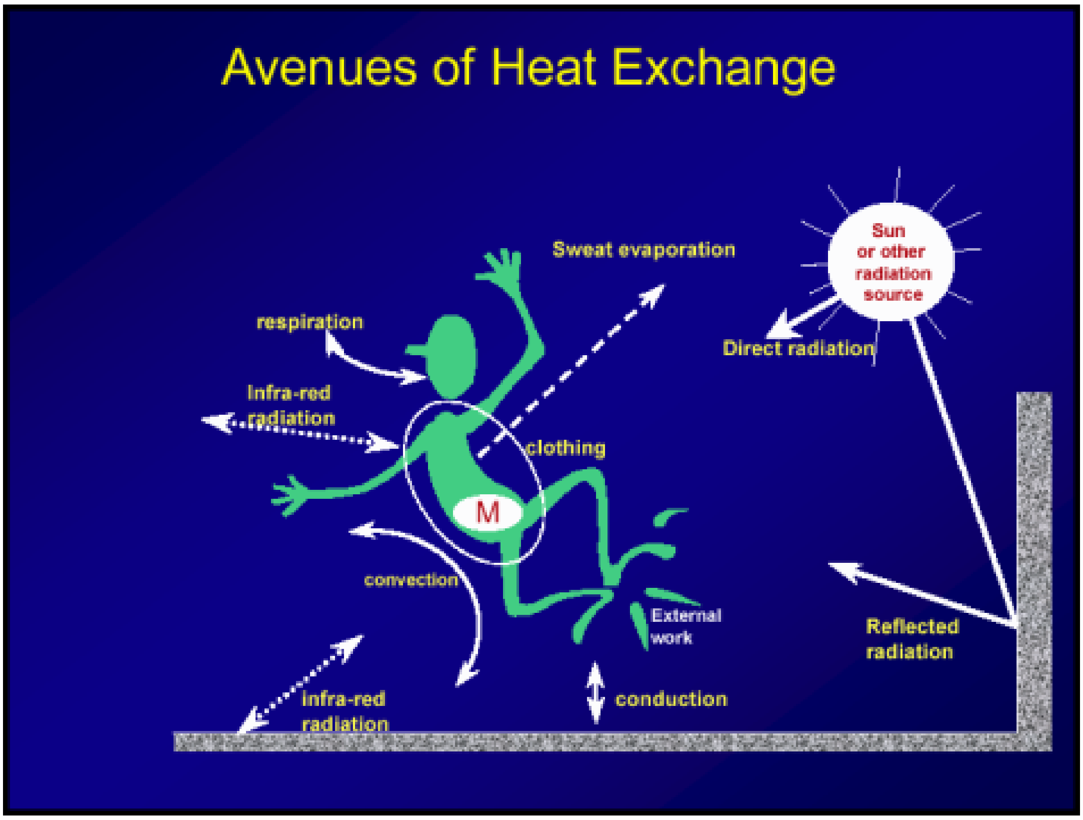

Figure 3: The human heat budget (Havenith, 2003, in Koppe et al. 2004)

The heat exchange between the human body and the thermal environment (Fig. 3) can be described in the form of the energy balance equation which is nothing but the application of the first fundamental law of thermodynamics:

$$M + W + Q^* (Tmrt,v) + QH (Ta,v) + QL (e,v) + QSW (e,v) + QRe (Ta,e) + S= 0 \qquad \text{Eq. 1}$$

M	Metabolic rate (activity)
W	Mechanical power (kind of activity)
Q*	Radiation budget (short wave and long wave radiation fluxes)
QH	Turbulent flux of sensible heat (convection)
QL	Turbulent flux of latent heat (diffusion water vapour)
QSW	Turbulent flux of latent heat (sweat evaporation)
QRe	Respiratory heat flux (sensible and latent)
S	Storage

The meteorological input variables include air temperature Ta, water vapour pressure e, wind velocity v, mean radiant temperature Tmrt including short- and long-wave radiation fluxes, in addition to metabolic rate and clothing insulation. In eq.1 the appropriate meteorological variables are attached to the relevant fluxes.
It is important to take into account all these variables for the complete description of the thermal conditions, thermal comfort or discomfort.
Thus, consequently dealing with the thermo-physiologically significant assessment of the thermal environment requires the application of a complete heat budget model that takes all mechanisms of heat exchange into account as described in eq. 1. Such models possess the essential attributes to be utilised operationally in most biometeorological applications in all climates, regions, seasons, and scales. Fanger's (1970) PMV-(Predicted Mean Vote) equation can e.g. be considered among the advanced heat budget models. This approach is the basis for the operational thermal assessment procedure Klima-Michel-model (Jendritzky

et al., 1979; Jendritzky et al., 1990) of the German national weather service DWD with the output parameter "perceived temperature, PT" (Staiger et al., 1997) that considers a certain degree of adaptation by various clothing.

4. Thermo-physiological modeling and urbanization

The importance of the described thermo-physiologic approach is evident. Simple indices taking into account only temperature and humidity are not any longer sufficient. An example from an urban street canyon shows it clearly (Fig. 4): Radiation received at the human body is totally different at the sunny and shadowed site of the street and so are the surface temperatures of the asphalt and the walls. Wind speed is highest in the middle of the street. Air temperature, however, is nearly the same at both sides of the street canyon. Only the modeled Perceived Temperature represent the thermal environment in a correct way (as we perceive when we cross the street from the sun to the shadow).

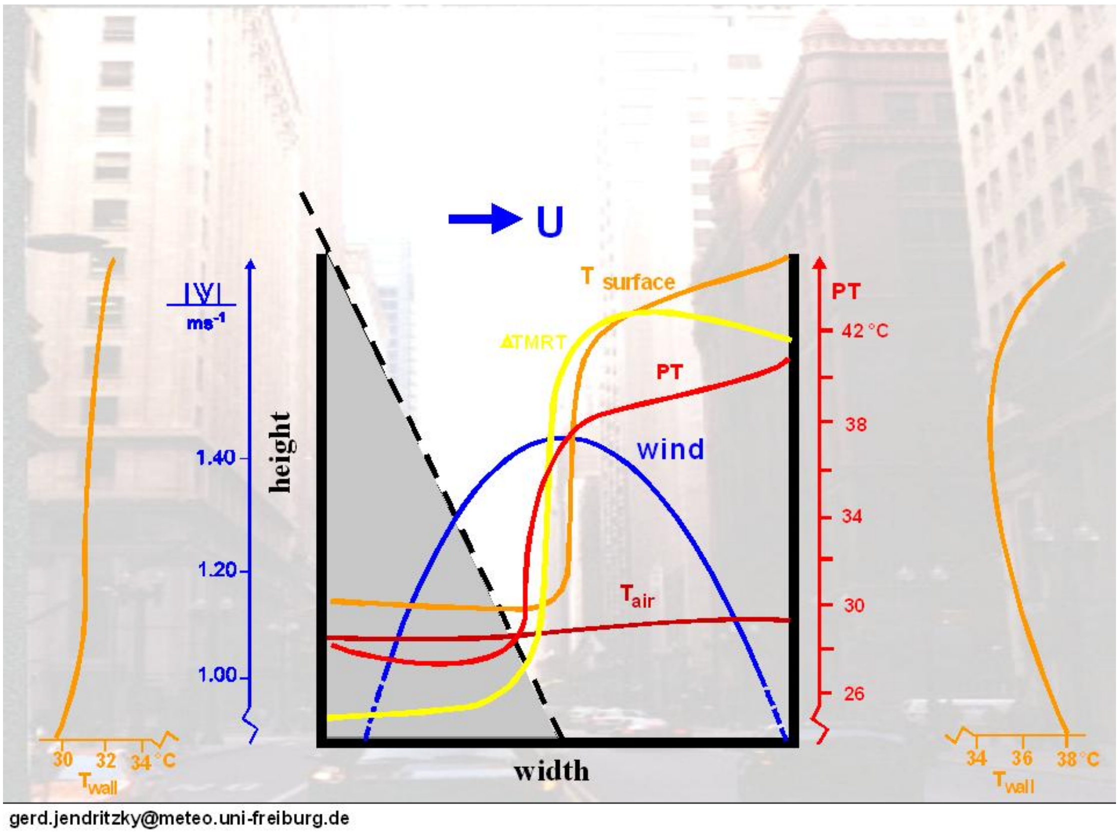

Figure 4: Meteorological and biometeorological conditions in a cross section of a street

In Berlin, the heat load in August 2003 has been modeled comparing 3 different neighbourhoods (Fig. 5): The open esplanade Alexanderplatz in the eastern city center with only a few trees, few shaded areas and a large sky view factor (a), the densely built-up.

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