How to Deal with the Urban Development - Urban Climate - Human Health Effect Relationship --- A Contribution to Methodology

Gerd Jendritzky, Angelika Graetz, Christina Koppe, Gudrun Laschewski
Deutscher Wetterdienst, Business Unit Human-Biometeorology, Freiburg, Germany

1 Introduction

The climate of a city presents some of the most impressive examples of man made climate modification that are on the whole a result of planned or accidental changes in land-use. From a health point of view air pollution, depending upon sources and atmospheric diffusion in urban structures, is the classical issue, especially in developing countries. Where air pollution is well controlled the urban heat island UHI as the other remarkable urban climate anomaly came more and more to the fore because numerous examples from different climates show adverse health effects from exposure to extreme thermal conditions. Time series data substantiate a marked increase in mortality rate during hot weather, especially in densely populated urban areas. The urban heat island has obviously an added effect on heatwave intensity, which may exacerbate the input of weather on heat-related mortality. In the absence of morbidity data, the use of readily-available mortality data permits evaluation of the impact of weather on this most serious health outcome. However, mortality data reflect only extreme health events. It can safely be assumed that thermal conditions are likewise significant predictors of morbidity and general human well-being.

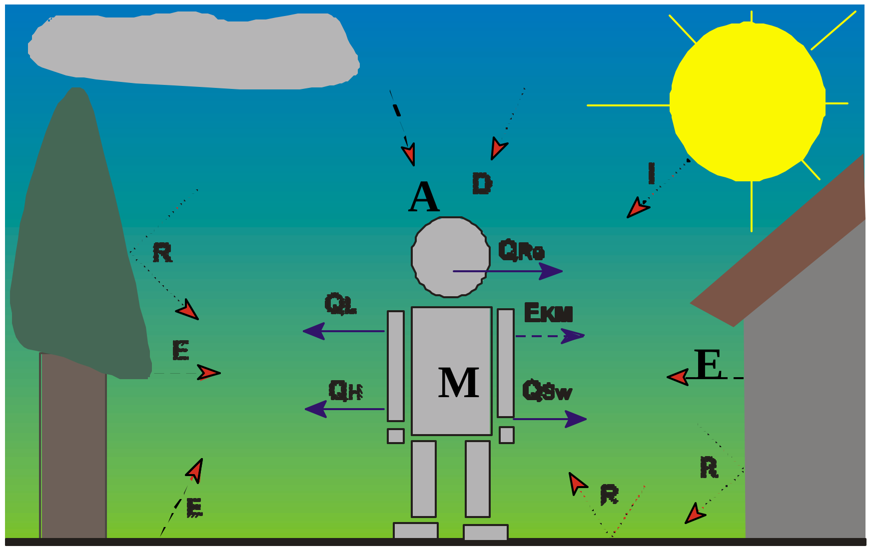
When looking for the range of issues in the urban climate and human health field numerous questions occur that require specific methods to deal with, such as the problem how to describe climate, weather, heatwaves from a health point of view or the issue of anticipatory (or proactive) adapatation/ mitigation measures both in short term and long term time scales. There is no generally accepted definition of a heatwave, the term urban heat island is based just on air temperature and not on the complex thermal conditions of human beings, there are different and not comparable thermal assessment procedures in operation, and in spite of the impressive increase in knowledge about urban climate there is still a gap between science and application in developing planning on an operational basis. So substantial progress in looking for comprehensive solutions can only be expected by multi-disciplinary and multi-organizational collaboration at least in the fields discussed in the following:

2 Heat related health effects

There is some good experience using simple thermal indices (such as the Heat Index that is based on the indoor Apparent Temperature AT) or even just air temperature in epidemiological investigations. However, due tomissing consideration of wind velocity (turbulent fluxes!) and the radiation fluxes that both play an important role in particular in the micro scale of the urban canopy layer, such indices are completely irrelevant for urban planning purposes.From a scientific point of view a thermal assessment of an urban area based on a simple thermal index would mean the same as dealing with the energetic basis of the urban heat island by just looking at air temperature and humidity without consideration the energy fluxes.

Another very successful procedure, utilized in the WMO/WHO/UNEP Interagency Network on Climate and Human Health Showcase Projects on Heat Health Warning Systems (HHWSs) uses a synoptic-climatological (holistic) approach (air mass types) to identify those meteorological conditions that lead to statistically significant increases in mortality (Kalkstein and Green, 1997). But there is also no relationship to urban planning. So only complete assessment procedures give the chance to study cause-effect relations which must be the base for decisions in urban planning.

Fig. 1: The Thermal Environment. M metabolic rate, I direct solar radiation, D diffuse solar radiation, R reflected solar radiation, A atmospheric longwave radiation, E longwave emission of the ground, E_{KM} longwave radiation from the surface of the human body, Q_H turbulent flux of sensible heat, Q_{SW} turbulent flux of latent heat, Q_L turbulent flux of latent heat due to water vapour diffusion, Q_{RE} turbulent respiratory heat flux (sensible and latent)



Thermophysiologically relevant assessment procedures that combine the above listed meteorological variables with metabolic rate with due consideration of the insulation of clothing require the application of complete heat budget models. There are some such state-of-the-art approaches available since 20-30 years. In the German Weather Service (DWD) we use the Klima-Michel-model (see e.g. Jendritzky and Nuebler,1981) with the outcome Perceived Temperature PT that is originally based on Fanger's (1972) PMV equation and later modified for better consideration of the role of humidity. PT represents the temperature of a standard environment (wind calm, relative humidity 50%, tmrt=ta, walking 4 km/h, adapted clothing).

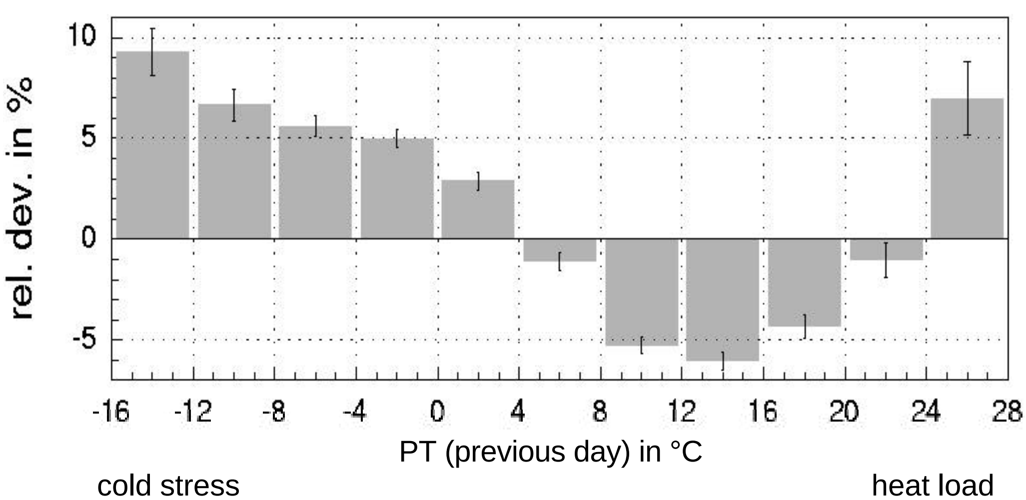


Fig. 2: Mean relative deviation of MR for classes of mean PT of the previous day (class width: 4 K, range bars: confidence interval at the 0.05 significance level)

The application of the PT-model on 30 years time series of mortality data MR (2.7 mill cases) provides impressive results (Laschewski and Jendritzky, 2002). During the seasonal minimum of MR in summer (Fig. 2), death rates sharply increase with increasing heat load, reaching highest values – of about 14% above the seasonally expected MRs - during heat episodes even in the temperate climate of southwest Germany (Fig. 3).

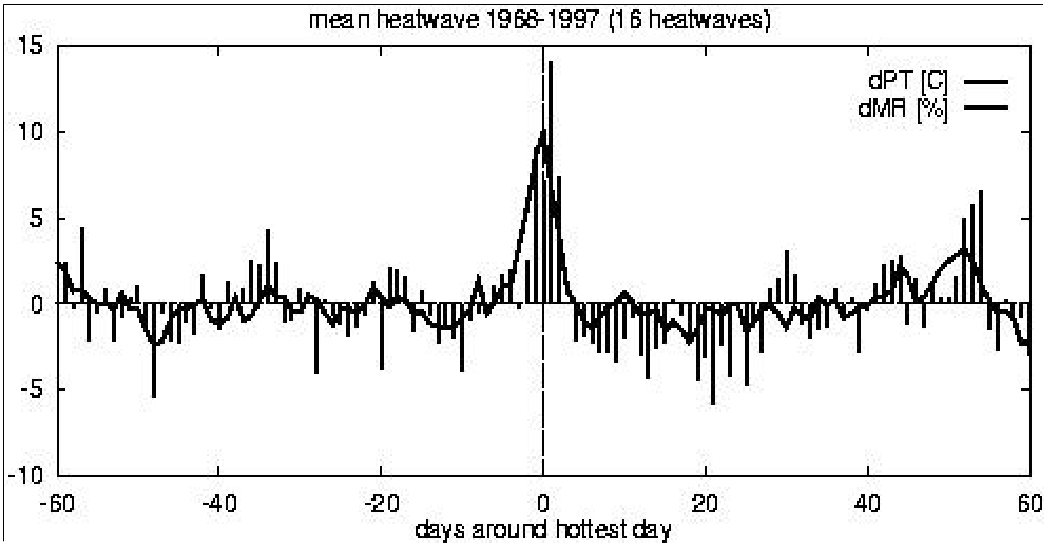


Fig. 3: Mean deviation of perceived temperature dPT and mortality rate dMR from the smoothed time series of PT and MR for the 16 most severe heat waves between 1968 and 1997

Increasing heat load means more demands on the cardiovascular system to enable better thermal regulation. Events of high PT values in relation to the seasonally expected values (heat waves) show an increase in MR with no delay. The mean increase of MR (+3.9%) during heat waves is about twice as high as during cold spells. The increase of MR above expected values lasts for a shorter period and is followed by a mean period of 19 days of below normal values of MR. This possibly indicates effects of short-term mortality displacement, i.e. people die who would have died short-term anyway. Obviously there is no uniform behaviour in the time series concerning the residue of mortality attributable to a heat wave (integral of dMR over the time period of two months following the heat episode; a positive value is also referred to as *net* excess mortality). It seems to depend on the intensity of the heat wave as to whether or not net excess mortality occurs. The 16 most severe heat waves result in a small value (0.2%) of mean net excess mortality, i.e. a total number of 30 additional deaths occurred in association with heat waves in southwest Germany.

The results allowed to derive a forecast procedure for daily MR based on intensity and duration of the thermal load. The procedure is directly linked to the numerical weather forecast model of DWD for Europe in 7 km resolution that provides data for every hour..

3 Short Term Anticipation: Intervention Strategy

The simple evaluation of heat-health relationships is insufficient for local planners to deal with heat-related problems. Rather, a forecast procedure must be derived that couples with a locally specific mitigation strategy developed and established by the responsible health authorities that will be in place whenever a warning is called in order to save lives. The development of an appropriate intervention strategy that takes into consideration local needs, such as political and urban infrastructure, is the most difficult step in the development of HHWSs. However, the numerous successful systems established by Kalkstein and collaborators, some as WMO/WHO/UNEP Showcase Projects, are the best examples for the value of this approach.

4 Long Term Anticipation: Urban Planning

From a bioclimatological point of view the atmospheric fields determining the thermal environment are significant in the urban canopy layer, i.e. the settlement structure (including its interactions) as the result of planned or free development. At least for urban planning purposes with the aim of creating and safeguarding healthy conditions modelling seems to be the appropriate method. But unfortunately urban climate models with high resolutions, that cover urban districts as well as towns and cities as a whole inclusive of its varying urban structure, are computationally demanding. Thus for practical applications in urban planning the Urban Bioclimate Model UBIKLIM (Graetz et al.,1992; Friedrich et al., 2001) was developed as an expert system that utilizes available knowledge in urban climate science in an objective procedure. Using GIS-techniques UBIKLIM simulates the thermal environment in the urban boundary layer at a given location in an urban area that depend on the kind of land use, i.e. the settlement structure (these are the planning variables to be transformed into boundary layer parameters). Interactions between neighbouring structures, topography (local scale), and meso and macroscale climate are taken into account.

As input data UBIKLIM needs a digital height model with a 10 m resolution and appropriate land use information. Here it is sufficient when the urban area is divided into a limited number of districts, each characterised by its own land use type. The main types are water, forest, parks, meadows, paved and unpaved open spaces and built-up areas. In order to be able to work out the varying urban structure, the built-up area is divided up further. From an energy budget point of view (Oke, 1987) areas reacting in a similar manner were summarised according to the porousness approach (Gross, 1989) and characterised by certain parameters of the urban structure: building density, building height, relative building volume, cumulative wall surface index, sky view factor, degree of pavement, greenery interdispersion. Based on these land use data, it should be mentioned that the horizontal dimension can be parameterised by the parameters of the urban structure, while the vertical dimension is given by the discrete values of the building height. This input data enable to calculate the meteorological fields of air temperature, humidity, wind velocity and mean radiant temperature at the one meter level of the urban canopy layer for a high radiation day in summer (Fig. 5). After this the Klima-Michel-model can be applied.

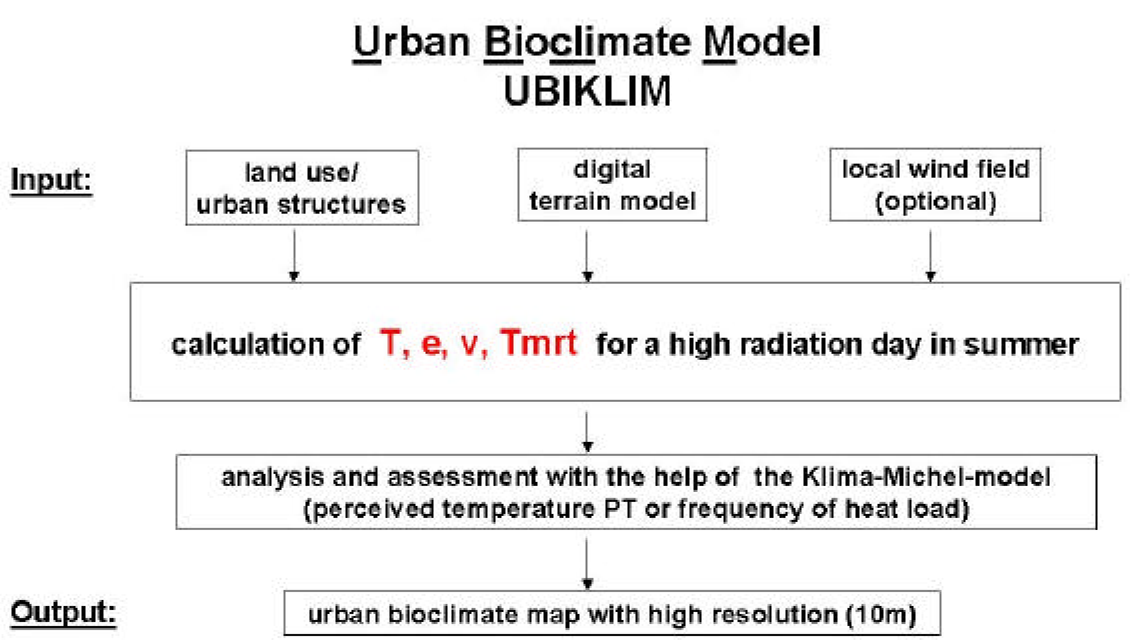


Fig. 5: Structure of UBIKLIM (T: air temperature, e: vapour pressure, v: wind speed, Tmrt: mean radiant temperature)

The result is a widespread and detailed bioclimate map on the horizontal heat load distribution with 10 m resolution. Altered planning situations can also be calculated and assessed easily by changing the land use input data. This provides necessary information for urban planners, health professionals, and other decision makers.

5 Conclusion

Ther is no doubt that the urban heat island is relevant for human health. It causes adverse health effects from exposure to extreme thermal conditions. The urban heat island has an added effect on heatwave intensity, which may exacerbate the input of weather on heat-related mortality. As the urban heat island is the result of urban planning it is correspondingly also sensitive to future urban planning. But in spite of the impressive increase in knowledge about urban climate there is unfortunately still a need to bridge the gap between science and application. This requires specific methods to deal with that depend on time scales. In short term time scales HHWS intervention strategies are useful tools for mitigating adverse effects due to heatwaves. In long term time scales there is a need to create urban development standards (VDI,1997), to make existing knowledge available and to develop tools for urban planning. That support urban planners to reach their fundamental aim: creating and safeguarding of healthy environmental conditions for residence and work. The global warming problem additionally increases the urgent need for adaptation.

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