Spatial variations of the urban climate and its influence on thermal comfort and behaviour

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Abstract

The increased number of people living in urban areas emphasises the need for an improved understanding of how the urban climate affects human activity and behaviour. The spatial and temporal variation of climate within cities is an important factor in people's health and well-being. The purpose of the work presented in this thesis is to contribute to a better understanding of the spatial variations of climate and bioclimate in urban areas and to investigate people's usage and perception of the urban outdoor environment based on microclimatological and meteorological conditions. The thesis also includes work on the improvement of measurement techniques and modelling of the mean radiant temperature, one of the most important meteorological parameters governing human energy balance.

An array of different meteorological, behavioural and geoprocessing methods were used in this thesis. Spatial variations of air temperature were examined by mobile measurements in both Göteborg, Sweden (57°N) and Szeged, Hungary (46°N). Surface temperature variations in Göteborg were examined by airborne infrared thermal mapping. The geoprocessing work included in this thesis was mainly based on raster modelling using high resolution Digital Elevation Models (DEM) of building structures and ground topography. In order to study how human behaviour is related to weather and climate, extensive field campaigns of simultaneous micrometeorological and behavioural measurements were carried out in three cities: Göteborg and Luleå in Sweden (65°N) and Tokyo in Japan (36°N). Studies were conducted across seasons and in different urban places such as squares, parks and waterfront plazas.

Urban geometry is commonly represented by the Sky View Factor (SVF) in urban climate studies. The results presented in this thesis show that only a weak relationship exists between SVF at a point source and the average mean of SVFs taken around the same point source. This implies that SVF derived from a single location cannot be used to represent a larger source area of averaged SVFs. Two different methods for deriving continuous images of SVFs (raster and vector-based methods) give very similar values of SVF. However, the raster-based technique is considerably faster than the vector-based method. Areal average SVFs have a much better degree of correlation with intra-urban air temperature variations than SVF values that are taken at a single location. Consequently, areal averages of SVF values should be used in future intra-urban air temperature studies.

Regarding climate and human behaviour, the results confirm that air temperature is the major determinant for the use of urban outdoor places, i.e., the higher the air temperature, the greater usage. The thesis also outlines examples of how good design strategies may increase and prolong the usage of these spaces and outdoor activity throughout the year. Furthermore, it is shown that weather parameters (cloudiness, air temperature and wind speed) have a significant influence on participants' weather assessments and place-related perceptions, emotions and attendance. It is thus clear that cloudiness, air temperature and wind are vital aspects of the functional and psychological components of a place.

A globe thermometer is used to derive the mean radiant temperature (T_{mrt}). The results show good agreement between the values of Tmrt obtained by a 38 mm flat grey globe thermometer and those obtained by integral radiation measurement. The new formula presented in this thesis provides a simple, mobile and cheap method and thus a valuable tool for thermal comfort researchers, urban planners and designers. Concerning the modelling of Tmrt, a new model SOLWEIG, which calculates spatial variations of Tmrt based on simple meteorological data and urban geometry is presented in this thesis. There is good agreement between the values obtained from the model and measured values of T_{mrt}.

Keywords: *Sky view factor, air temperature, surface temperature, GIS, raster modelling, mean radiant temperature, globe temperature, the SOLWIEG-model, human behaviour, outdoor activity*