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The effects of elevation on thermal bioclimatic conditions in Uludağ (Turkey)

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RESUMEN

Se comparan las condiciones térmicas bioclimáticas registradas en las estaciones meteorológicas de Bursa (100 m) y Uludağ (1878 m) a las 7:00, 14:00 y 21:00 horas de 1975 a 2006. Para ello se utiliza la temperatura fisiológica equivalente (TFE), que se calcula por medio de parámetros meteorológicos. Se analizaron y valoraron los efectos de las condiciones ambientales y atmosféricas dependientes de la altura sobre la percepción térmica (*i.e.*, TFE). El análisis mostró que la diferencia anual media de los valores TFE en Bursa y Uludağ fue de 12 ºC. Esta diferencia fue menor en invierno (9 ºC TFE) y mayor en verano (15 ºC TFE). La mayor diferencia en los valores TFE se registró en la tarde (16 ºC TFE) y la menor en la mañana (9 ºC TFE). Las diferencias se deben a la mayor altitud y al mayor albedo debido a las nevadas. Esto ocasiona valores TFE más bajos y por lo tanto condiciones térmicas menos confortables. Los valores TFE medios para Bursa y Uludağ decrecen 0.67 ºC por cada 100 m.

ABSTRACT

This study compares the thermal bioclimatic conditions recorded at Bursa (100 m) and Uludağ (1878 m) meteorological stations at 7:00, 14:00 and 21:00 LST (local standard time) between 1975 and 2006, by using the physiologically equivalent temperature (PET), which is calculated from meteorological parameters. The effects of elevation-dependent environmental and atmospheric conditions on thermal perception (*i.e.*, PET) values were analyzed and assessed. The analysis showed that the mean annual difference between PET values in Bursa and Uludağ was 12 ºC. The difference was lower in winter (9 ºC PET) and higher in summer (15 ºC PET). The highest difference between PET values occurred in the afternoon (16 ºC PET) and the lowest difference occurred in the morning (8.4 ºC PET). The differences occur as a result of high altitude and higher surface albedo due to snowfall, which leads to lower PET values and thus to less comfortable thermal conditions. The mean PET values of Bursa and Uludağ decrease 0.67 ºC every 100 m.

Keywords: Thermal comfort index, physiologically equivalent temperature, bioclimatic conditions, effect of elevation, environmental and atmospheric changes.

1. Introduction

People's thermal perception depends on air temperature, air humidity, wind speed and radiation fluxes, as well as their personal body energy balance. When the environmental conditions are suitable for human heat balance, they feel comfortable. Any disruption to this balance results in thermal stress (Fanger, 1972; Landsberg, 1972; Auliciems, 2005). There are indices that use various methods to determine the thermal conditions. These indices use meteorological data to reveal the effects of the ambient conditions on people. While there are rather simple comfort indices calculated by including several meteorological parameters (*e.g.*, heat stress, wind-chill, apparent temperature), there are also more complex indices that include physiological thermoregulatory reactions as a variable in the calculation: predicted mean vote (PMV) (Fanger, 1972), effective temperature (ET), standard effective temperature (SET) (Gagge *et al.*, 1986) and Klima-Michel-model (KMM) (Jendritzky and Nübler, 1981). There are some bibliographical studies on the historical development and the types of thermal comfort indices that currently exist (Landsberg, 1972; Driscoll, 1992; Parsons, 2003; Auliciems, 2005). The physiologically equivalent temperature (PET) is a thermal index based on the human energy balance; it includes thermo-physiological variables and yields results in centigrade degrees (Mayer and Höppe, 1987; Höppe, 1999; Matzarakis *et al.*, 1999). Thus, as PET analyzes the bioclimatic conditions for a given setting, it also allows for comparisons as it uses variables stemming from human thermo-physiology in the calculations and yields concrete results.

The study area of this work lies in the Marmara Region, in northwestern Turkey. Data from two meteorological stations, Bursa and Uludağ, were used. Having an altitude of 100 m, the geographical coordinates of Bursa meteorological station are 40º 11' N and 29º 04' E. Uludağ meteorological station has an altitude of 1878 m and its coordinates are 40º 08' N and 29º 05' E. Even though the city centers of Bursa and Uludağ are close (15 km, air distance), the altitude difference creates different geographical and climatic conditions (Fig. 1). According to Köppen's climate classification, Bursa has a moderate climate with temperate winter and hot and dry summers. Uludağ, on the other hand, has severe winters and short and humid summers. This study aims to use PET values to compare the bioclimatic conditions of Bursa and Uludağ, which lie close to each other but at different altitudes, and reveal the changes that occur throughout the years. The information acquired from this study will help to understand the changes in thermal comfort conditions according to elevation. In order to find the vertical changes of PET values, the data obtained from the stations that have different altitudes will be very useful. This paper also analyzes the vertical variations of meteorological parameters that have positive and/or negative impact on thermal bioclimatic conditions. The effects of elevation on outdoor conditions can be used also for economical purposes, because Bursa and Uludağ have great potential for tourism and recreational outdoor activities. Although this is the first study that investigates the vertical changes of thermal perceptions, there are many researches that focus on the bioclimatic conditions in several parts of Turkey (*e.g.*, Çiçek, 2003; Topay and Yılmaz, 2004; Yılmaz *et. al.*, 2007; Toy and Yılmaz, 2010). There are also some studies on the spatiotemporal distribution of the climate and the impacts of some issues (urbanization, climate change, deforestation, etc.) on the meteorological parameters in Turkey (*e.g.*, Türkeş *et. al.*, 1995, 2002; Tayanç *et. al.*, 1997, 2009).