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The influence of air temperature and humidity on human thermal comfort over the greater Athens area

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ABSTRACT

Meteorological data collected from 26 fixed stations placed in the greater Athens area, have been used to investigate the human thermal comfort during the period of June–August of 2009. The two main parameters used in this analysis are the air temperature and the relative humidity. The city has been divided in five geographical zones (center of the city, northern, eastern, southern and western section) presenting different thermal balances, showing that the five areas of this analysis had definitely different temperature and discomfort conditions.

The highest air temperature values were observed in the western section of the Greater area of Athens and the western parts of the southern section, while the lowest ones were detected in the northern section and the northern parts of the eastern section. The highest relative humidity values were observed in June and July in the southern section, while in August higher values occurred in the city's center. In this study, statistical methods have been used to calculate the distribution of Humidex (H) values, the spatial distribution of the probabilities of discomfort conditions ($H > 30$ and $H > 40$) and the persistence of hours with great or more discomfort conditions.

1. Introduction

Human thermal comfort, as it is widely known, depends on air temperature, wind speed, solar radiation, humidity, clothing and human activity (Givoni, 1963). The average atmospheric conditions, below which humans feel comfortably, are between 21 °C and 27.5 °C concerning air temperature; from 30 to 65%, for relative humidity; and wind speed values greater than 5 m/s (Olgyay, 1973).

However, individual's age should not be waved aside, along with human's adaption ability in high air temperature, as well, which is inversely proportional to latitude (Kalkstein & Davis, 1989; Kalkstein & Greene, 1997). Studies have shown that in regard to ages between 60 and 65 years, during summertime, high values of air temperature and relative humidity coupled with calm weather are linked to increased mortality (Applegate et al., 1981; Ballester, Corella, Perez-Hoyos, Sáez, & Hervás, 1997; Mc Farlane, 1978; Sáez, Sunyer, Castellsague, Mourillo, & Antó, 1995). As far as it concerns even higher ages, over 75 years old, it has been found (Katsouyanni et al., 1993) that during heat waves in the summer months an abrupt increase of mortality is observed. Additionally, if the heat waves persist of a long time period and connected with increased atmospheric pollutants, the mortality augmentation extends to younger ages (Mc Farlane, 1978; Katsouyanni et al., 1993; Bridger, Ellis, & Taylor, 1976; Faunt et al., 1995; Kunst, Looman, & Mackenbach, 1991; Mackenbach, Borst, & Schols, 1997; MMWR, 1995).

A heat wave phenomenon can be conceived as an extreme weather phenomenon which is practically a rare stochastic event. Considering, though, the global air temperature augmentation in the past years, as a result of the greenhouse effect which according to the existent scenarios will be sustained, suppose no environmental protection measures will be taken, those rare events will be increased (Meehl et al., 2000; NRCROGTC, 2000; Yoganathan & Rom, 2001).

The weather heat waves in question provoke certain problems, mainly in urban areas, on the score of occurring heat absorption on buildings and asphalt, resulting thus in the emergence of high temperatures during night-time. This observed high temperature persistence distresses human organism. Other factors affecting urban microclimate are the anthropogenic heat production (artificial lighting, A/C function in households and workplaces, traffic load) (Hardy, Mitlin, & Satterthwaite, 2001) in conjunction with wind speed reduction, in virtue of high residential density and

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building height (Papanikolaou, Livada, Santamouris, & Niachou, 2008).

High air temperature persistence can also occur over rural areas, suppose the relief, together with wind creates katabatic winds (Yannas, 2001).

Considering, therefore, that a percentage of 50–60% of the world population lives in urban areas, with certain increasing tendency (until 2025 the city residents is expecting to reach 5 billion), the studies considering thermal comfort in cities become quite interesting.

This paper aims to present an investigation on human thermal comfort in the Greater Athens area, during the period of June–August of 2009, with regard to the combination of air temperature and relative humidity.

2. Data analysis of air temperature and relative humidity

In the present study an analysis of the summer (June, July and August of 2009) air temperatures collected from 26 meteorological stations (Fig. 2) installed in various municipalities over the Greater Athens area is presented. Every measuring station consists of one meteorological cage of size 23 cm × 23 × 23 cm placed on a base with height 1.70 m. Inside the meteorological cage we have placed a temperature and relative humidity data logger (TinyTag 4500). This logger records temperature and humidity using self-contained sensors. It can record temperatures between −25 and +85 °C and relative humidity between 0 and 100%. The logger is rugged and waterproof, so it can be used outside or harsh environments indoor (Fig. 1).

The frequency of the measurements was 15 min and in order to analyze the collected data hourly values were calculated.

The heat island effect that has been widely outlined by several researchers (Crutzen, 2004; Lansberg, 1981; Mihalakakou, Floka, Santamouris, & Helmis, 2000; Mihalakakou, Santamouris, Papanikolaou, Cartalis, & Tsagrassoulis, 2004; Oke, 1982; Santamouris et al., 2001; Santamouris, Paraponiaris, & Mihalakakou, 2007; Santamouris, 2001) is an effect in Athens, appeared since the eighties (Livada, Santamouris, Niachou, Papanikolaou, & Mihalakakou, 2003; Tselepidaki, Santamouris, & Dris, 1995; Tsinonis, Koutsogiannakis, Santamouris, & Tselepidaki, 2003). Likewise this phenomenon has appeared over many European cities as Santamouris (2007) report. To erase heat island effect, various mitigation techniques involving the use of cool materials, intelligent materials, green roofs and extended green spaces have been proposed (Tselepidaki et al., 1995). From the analysis of a former study of Giannopoulou et al. (2011) with regard to air temperature over the Greater Area of Athens, became clear that the heat island effect is mostly detected at the western part of the city.

Fig. 1. One of the 26 meteorological boxes.

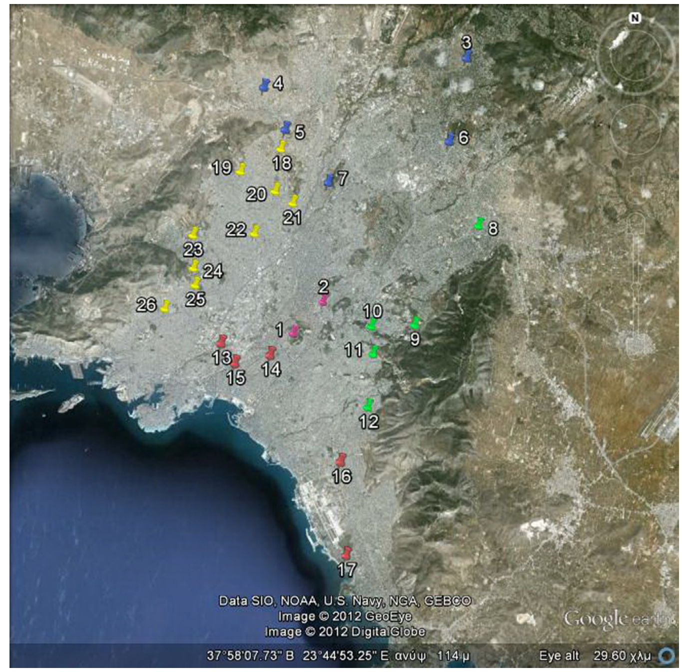

Fig. 2. Spatial distribution of the 26 network stations of great Athens area (the name of each station is referred in Table 6).

2.1. Results

The five regions of the greater Athens area consist of, the city center with a structural density of 29.8% and the North, East, South, and West regions, with structural densities of 46.1%, 44.8%, 44.1% and 49.8% respectively. The structural density of the city center area is not a realistic representation of the whole region due to the positioning of the meteorological cages. The whole area is characterized by its intense structural density, its narrow streets with constant traffic, while at the mean time it is affected by the industrial zone located in the southwest part of the region. The West region with structural density of 49.8% although a bit different from the other regions, it is considered to be the warmer region due to its lack of green areas that cover only a 4.7% of the entire area.

Table 1 shows the mean monthly air temperature values and their standard deviations for the center of Athens along with the, as already defined, four areas around it. Fig. 3 demonstrates the contours of the mean monthly air temperature values during summer 2009.

The highest values of mean air temperature are observed sometimes at the western parts of the city (June, July) and sometimes at the southern ones (August). Considering the whole summer period, the highest values are located in the western section and the western parts of the southern section, as well, with certain values differing from the northern' s section ones up to 3.5 °C. The second parameter in issue is the relative humidity. Table 1 also shows the