Case studies on discomfort levels in different regions in Athens, Greece

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ABSTRACT

It is well known that meteorological parameters like air temperature and relative humidity, affect public health concerning the human discomfort. The impact of these parameters can be of a small or regional scale, as a result of the oncoming climatic change. A relative climatological index, discomfort index, is developed to evaluate interregional variations in human discomfort.

In the current work an extensive and thorough analysis is carried out concerning the discomfort levels during a three-month period. Besides this analysis an attempt is made to reveal the influence of different parameters (e.g. sparse urban green) in the formation of discomfort levels in two different sites (#1 and #2) located in the western part of Athens, which is densely built-up and includes residential and industrial regions.

The hourly discomfort index values calculated for the two measuring sites were examined in order to study both the temporal and the diurnal variation. According to this analysis, the temporal as well as the diurnal variation at the remote station #1 is considerably larger than at the remote station #2. This may be attributable to the different site characteristics influencing the corresponding meteorological parameters. During the examined period the discomfort index levels remain lower than 24^0C, when more than 50% of the total population feels discomfort, in both rural measuring sites.

Keywords: discomfort index, urban green areas, Athens, Greece

INTRODUCTION

The influence of environmental conditions on public health was thoroughly investigated by the ancient physicians, whose observations are summarised in the works of Hippocrates. In one of these texts entitled “On the Atmosphere, Water, and Space” we learn the importance of the orientation of a town in relation to the predominant wind direction. Wind direction from the South was identified with unwholesome conditions. Although the idea of an environmental influence on public health was always widespread, quantitative studies on this effect have always come to very poor conclusions. To make research on the subject easier and more comprehensive a lot of bio-climatological indices have been proposed. Buttner (1938) recognised that in order to assess the thermal influence of the environment on the human body, the integrated effects of all the thermal parameters had to be taken into account. Since then a lot of researches on indoor and outdoor human thermal comfort have been carried out by many researchers some of whom have put forward bioclimatologic indices such as Thom (1959), Lally and Watson (1960), Givoni (1963), Fagner (1970), Masterson and Richardson (1979), Winterling (1979), Jendritzky and Nübler (1981), Kalkstein (1982), Weiss (1983) and Steadman (1984).

In the last 20 years, several studies concerning the influence of environmental factors on humans in Greece have been published (Katsouyanni et al., 1988; Giles and Balafoutis, 1990; Matzarakis and Mayer, 1991; Tselepidaki et al., 1995; Paliatsos and Nastos, 1999; Bartzokas et al., 2004; Panagiotakos et al., 2004; Nastos et al., 2006). Theoretical or empirical formulae have attempted to compare the rate of heat loss to surroundings with the rate of heat production by work and metabolism. Recent empirical relations, based on relative comfort expressed by human subjects under differing atmospheric combinations, have attempted to indicate the temperature at which air at some standard humidity, air motion and radiation load would be equally uncomfortable or comfortable (Tanaka et al., 1987; Hoppe, 1999).

Athens is a European capital of about 4,000,000 inhabitants, which faces as most of the other big cities in the world, air pollution problems. The rapid increase of population since 1950, caused by the accumulation of industrial and commercial activities around the city, resulted in high pollution levels during the last four decades. This growth causes a rise of both air and thermal pollution. The western part of Athens is densely built-up and includes residential and industrial regions. This, in relation to narrow roads and heavy traffic burden has resulted in discomfort due to environmental conditions for the city residents. Over this area, an intense urban heat island is observed. This phenomenon is mitigated by the sparse urban green of this area (Chronopoulou et al., 2004).

This study is focused on two areas in the thermally polluted area of the western part of Athens. In order to evaluate the qualitative and quantitative influence of those green areas, the hourly discomfort index values calculated and analyzed for the two measuring sites in order to study the differences for both the temporal and the diurnal variation.

DATA AND METHOD

In the present study, the bioclimatic index most commonly used in urban climate studies to describe the level of thermal sensation that a person experiences due to the modified climatic conditions of an urban area, is the discomfort index (DI) of Thom (1959). This index reflects the proportionate contribution of air temperature (T_a) and relative humidity (RH) on the human thermal comfort. For estimating discomfort index (DI) in degrees Celsius the following equation by Giles et al. (1990), has been applied:

$$DI = T_a - 0.55\,(1 - 0.01\,RH)\,(T_a - 14.5)$$

where T_a is the hourly value of the mean air temperature in degrees Celsius and RH (%) is the corresponding hourly value of the relative humidity. Discomfort increases as DI increases.

Table 1. Classification of the DI values (Giles et al., 1990).

DI (^{o}C)	Discomfort conditions
DI<21	No discomfort
21≤DI<24	Less than 50% of the total population feels discomfort
24≤DI<27	More than 50% of the total population feels discomfort
27≤DI<29	Most of the population suffers discomfort
29≤DI<32	The discomfort is very strong and dangerous
DI≥32	State of medical emergency

Starting in September 2006, relative humidity and air temperature measurements are taken by the Laboratory of Environmental Technology (LET, #1), of the Electronic Computer Systems Engineering using an automatic meteorological station located on a building at the TEI of Piraeus campus (longitude: 23^0 40' E, latitude: 37^0 58' N). The TEI campus, part of the Ancient Olive Orchard of Athens, is situated in the midst of the greater Athens area (GAA).

The objective of this work is to analyze the data measured by the LET, a 3-month period (10-12/2006) and to compare these measurements with the corresponding ones recorded by neighboring measuring station of the Ministry of Environment, Physical Planning and Public Works that is located in the campus of Agricultural University of Athens (AUA, #2) (longitude: 23^0 42' E, latitude: 37^0 59' N).

RESULTS AND DISCUSSION

The hourly discomfort index values calculated for the two measuring sites, during the 3-month common operating period, 10-12/2006. Hourly averages of discomfort index values per month at the abovementioned two measuring sites are shown in Figure 1. As it appears from this figure the diurnal variation of discomfort index values has a single peak structure. This peak is observed between 10:00 - 17:00 LST in the LET and 11:00 - 17:00 in the AUA measuring site.

Figure 1 illustrates that no discomfort appears, in both measuring sites, during the examined period, for all days that the discomfort index levels remain lower than 21 °C.

The amplitude of the diurnal variation ranges from 2.5 to 4.1 °C and from 2.3 to 5 °C, in the LET and the AUA measuring sites, respectively. The higher amplitude of DI diurnal variation, in AUA, is probably due to the more dense urban green in this measuring site. This result emphasizes the qualitative and quantitative influence of the major green areas on the local climate. Similar patterns of diurnal variation have also been observed in other rural sites in GAA (Paliatsos and Nastos, 1999).

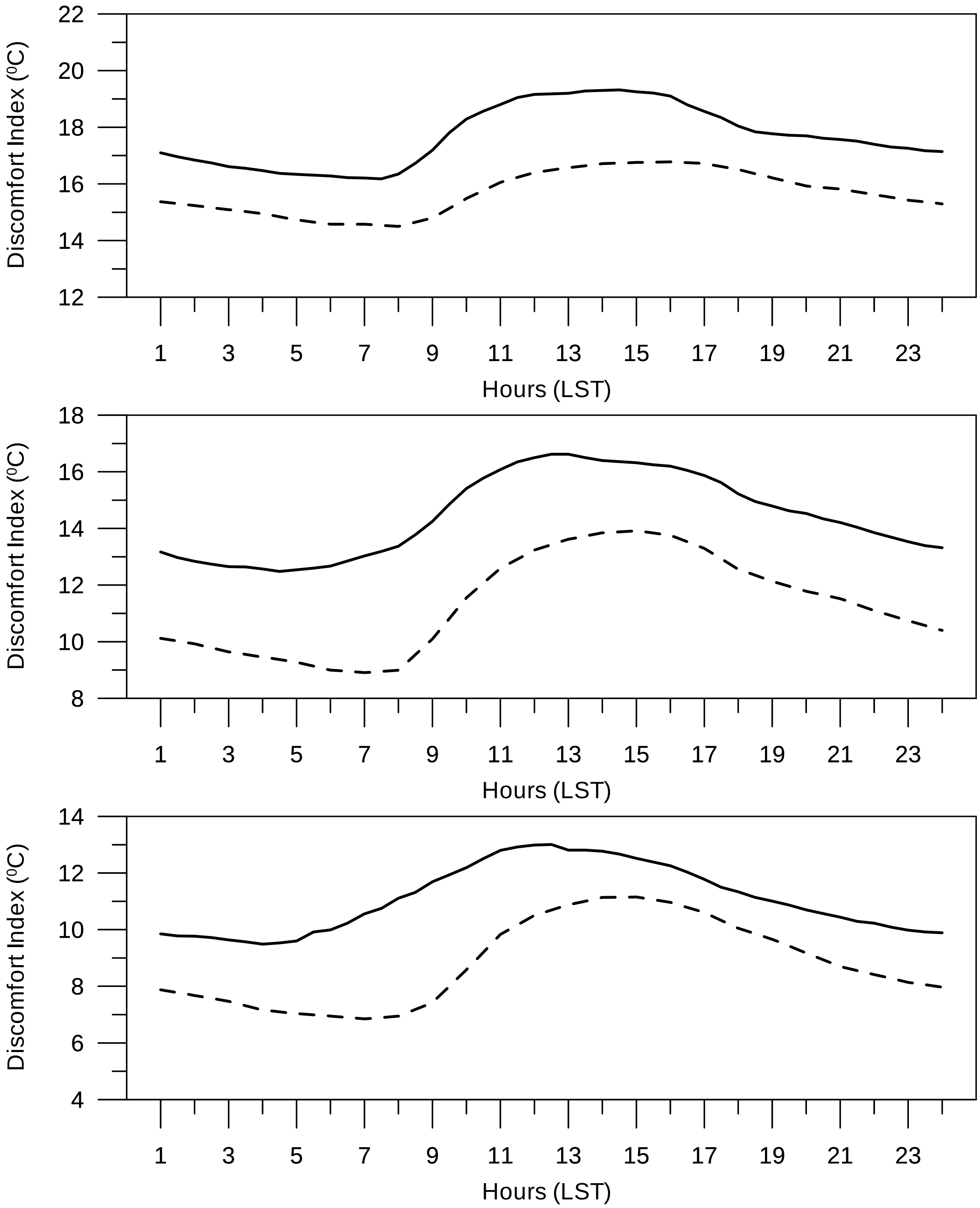

Figure 1. Mean diurnal variation of DI values on measuring sites: LET (heavy solid line) and AUA (dashed line) for October (*upper panel*), November (*intermediate panel*) and December (*lower panel*).

Figure 2 (heavy solid line) illustrates the temporal evolution of the average daily DI (in ^{0}C) values in the LET, for the period 10-12/2006. Similar pattern appears from Figure 2 (dashed line) that illustrates the average daily DI values in the AUA, for the same period. From this figure it appears that DI values in the AUA measuring site are obviously lower as compared with the LET's ones.

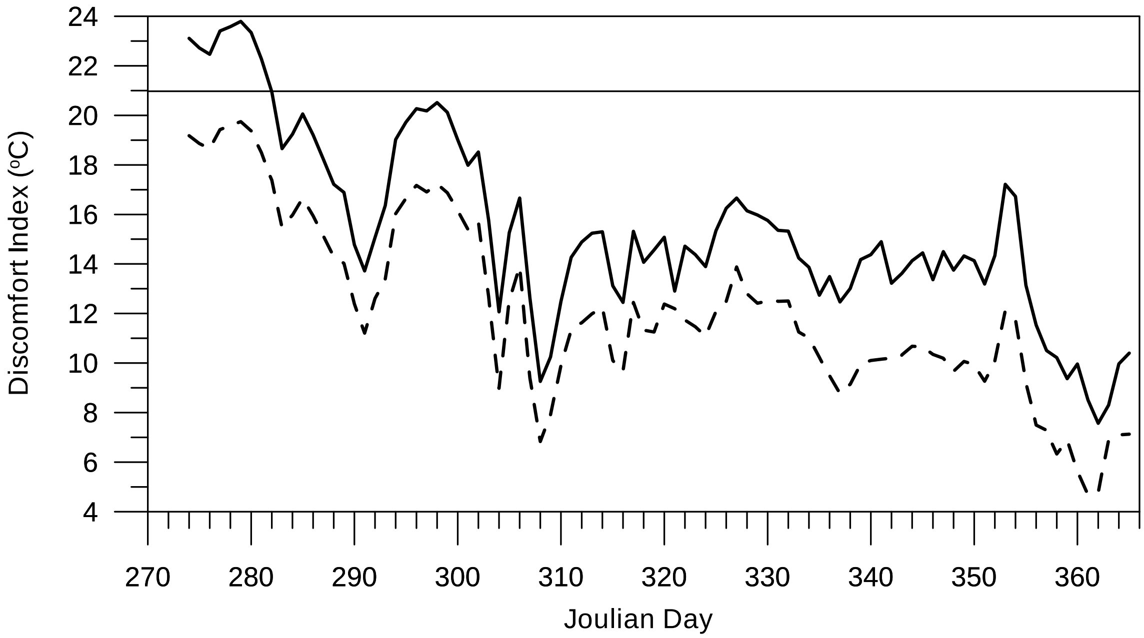

Figure 2. Temporal evolution of mean DI daily values on measuring sites: LET (heavy solid line) and AUA (dashed line).

Table 2 shows the main statistical parameters of the average daily DI (in ^{0}C) values for the two measuring sites under study. From this data, clear differences in discomfort conditions in the two measuring sites become apparent. This also means that even the average values of DI are not particularly high, while, on the other hand, the maximum values recorded at LET exceeded the standard, which, in fact, justifies acceptance of the potentiality for discomfort problems in the area. Comparing the main statistical parameters of the studied measuring sites, it is obvious that urban green areas have not only an important role on nocturnal cooling processes (Landsberg, 1981) but also they seem to have a strong influence on local climate.

Table 2. The main statistical parameters of the average daily DI (in ^{0}C) values for the two measuring sites, for the period 10-12/2006.

	AUA			LET		
	October	November	December	October	November	December
Average	16.1	11.5	8.9	19.3	14.4	12.6
St. Deviation	2.7	1.6	2.0	3.1	1.7	2.4
Minimum	9.0	6.8	4.7	12.1	9.3	7.6
Maximum	16.1	13.9	12.1	23.8	16.7	17.2

More specifically, in Figure 2 it is evident that early October, in LET (heavy solid line), the recorded average daily DI values for 8 days exceeded the 21^{0}C and remained lower than 24 ^{0}C. The value of

24^0C is critical because below this less than 50% of the population feels discomfort and beyond this more than 50% of the population lives under discomfort conditions (Giles et al., 1990).

As shown in Figure 2, during the examined 3-month common operating period, the DI daily values show an AUA to LET ratio of about 1:1.3. This superiority of DI values in LET may be attributed to the deficiency of the sparse urban green in this measuring site (Chronopoulou et al., 2004).

In order to provide a quantitative relation between the DI mean daily values calculated from LET data and the DI mean daily values calculated from AUA data, a scatter diagram was constructed. Then, the best fitting mathematical relationship was investigated and the best results were obtained with the linear fitting model (LET = a + bAUA).

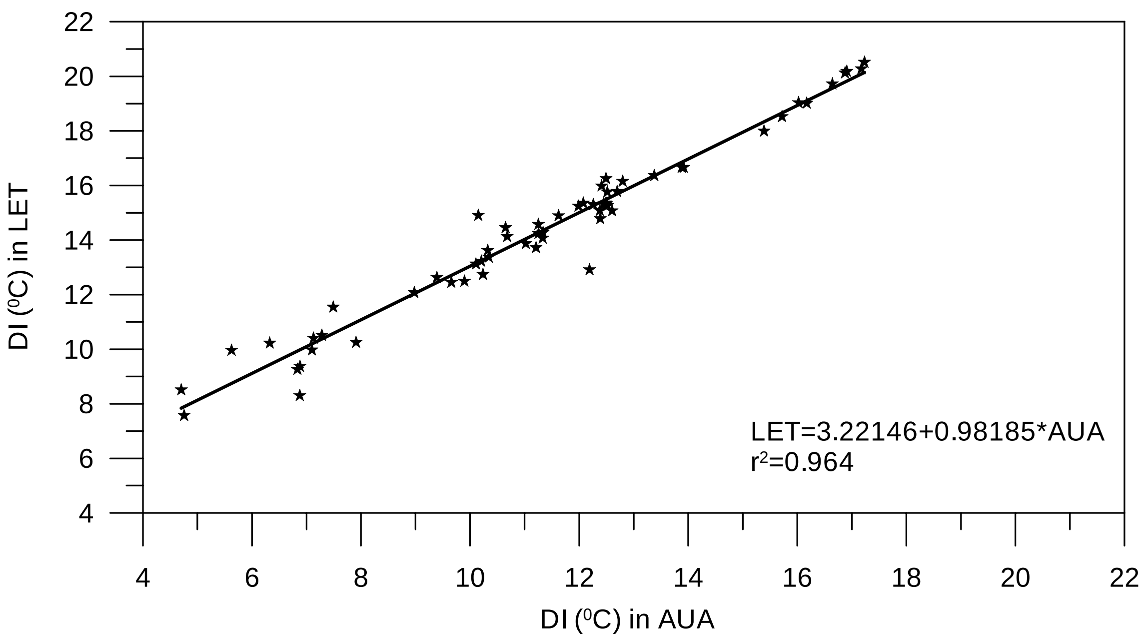

Figure 3. Relations between the DI mean daily values in LET and AUA by using linear fitting model.

In Figure 3 the results from examining the relation between the DI mean daily values in LET and AUA is presented by means of a linear relationship, which is the best-fit line. From this result it appears that by using the linear model, 96.4% of the variance (r^2=0.964) of DI values in LET can be explained by the variations of the DI values in AUA.

CONCLUSIONS

The hourly discomfort index values calculated for the measuring sites LET and AUA were examined in order to study the diurnal variation. From this analysis the following conclusions can be outlined:

The amplitude of the mean diurnal variation at the remote station of AUA is rather larger than at the remote station of LET. This may be attributable to the different site characteristics influencing the discomfort index values, like the more dense urban green.

The main feature observed in the average daily DI values is the general decline of DI levels throughout the examined period of each monitoring site. The analysis shows that the average daily DI values remain lower than 24^{0}C limit, which is the limit when more than 50% of the total population feels discomfort, in both measuring sites, during the examined period.

At the measuring site LET there is a clear superiority of the average daily DI values to the AUA's ones during the studied period, because of different site characteristics (e.g. sparse urban green), an urban heat island could be observed.

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