Changes of summer air temperature during the last 28 years in Athens

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ABSTRACT

The increase of living standards in buildings and high summer maximum air-temperature values during the last years have increased the installation of A/C in buildings. Analysis of the summer ambient temperatures is thus necessary to investigate the important impact on energy consumption. Ambient temperature data from the National Observatory of Athens station for the period 1977 - 2004 are presented. The number of hours with air temperature above 30°C, as well as the degree hour values (DH) in base of 30°C are statistically analysed in order to evaluate passive, hybrid and conventional cooling systems and techniques.

The general conclusion of this study is that during the last 15 years a dramatic increase of the number of hours with high air temperatures in combination with an increasing persistence is observed. However, this corresponds to the rising part of a cyclic change and therefore, a significant increasing tendency can not be established.

1. INTRODUCTION

The increase in living standards has promoted the use of A/C. For the period 1976 – 1985 an increase of 300% in the total market has been registered (Predicasts, 1987). In Greece this increase is very important and the purchase of A/C during 1987 – 1990 has increased by 800% (Santamouris, 1990).

This study presents a statistical analysis of high hourly air temperature values for Athens, Greece. The paper aims to offer a procedure on the necessary calculation methodology for statistical treatment of summer air temperature data used for cooling purposes.

In earlier years a first approach has been made to study high temperatures for cooling purposes not only for Athens (Tselepidaki and Santamouris, 1991; Tselepidaki et al., 1992; Tselepidaki et al., 1993; Tselepidaki and Santamouris, 1993; Tselepidaki et al., 1994; Tselepidaki et al., 1995) but for other regions of Greece as well (Livada et al., 1998; Kyriakopoulos et al., 1996; Niachou et al., 1998). These studies refer mainly to the period before 1989, where the observed air temperature values were lower than those of the recent years.

2. THE DATA USED

Athens is characterised by a warm Mediterranean climate with mild and relatively wet winters and warm dry summers. Mean monthly maximum ambient temperatures for the hot period June to September are between 25.6 – 35.8°C. High hourly temperatures occur mainly during the period June to September. Therefore, this period of the year will be examined.

Hourly temperature data for the period 1977 – 2004 and maximum daily values for the period 1950 – 2004 are taken into account from the National Observatory of Athens (latitude = 37°58´N, longitude = 23°43´E and altitude = 107 m). The station is located on a hill at the centre of Athens characterized by thick vegetation of trees.

3. STATISTICAL ANALYSIS OF THE DATA

For the designers of cooling systems the time period with high air temperature values during a

day is required. Therefore the frequency distribution of hours with air temperature above 30°C during a day as well as the corresponding degree hours (DH) are necessary inputs.

In Figures 1a, b for the months June, July, August and September the mean days per month (n) for each hour of a day to present air temperature higher than 30°C and the corresponding degree hours (DH) are given. The analysis of the data shows that the probability of an hour being very hot (above 30°C) is between P = 0.063 for September and P = 0.305 for July.

From the examination of daily distribution of the mean number of hours with air temperature above 30°C it is obvious that the maximum is focused between 14.00 and 15.00 when the maximum daily temperature occurs. For July and August high mean monthly values are calculated especially for the period 09.00 to 20.00.

Almost the same distribution for July and August was recorded for the variation of the mean DH values. For June and September it should be pointed out that these values (n and DH) are observed for the shorter time length 10.00 to 18.00. The mean monthly values of DH for June, July, August and September are 239, 593, 469 and 80 respectively. It is important to mention that these values are very much lower from those that have been measured in the centre of Athens, where the heat island effect is intense (Santamouris et al., 2001).

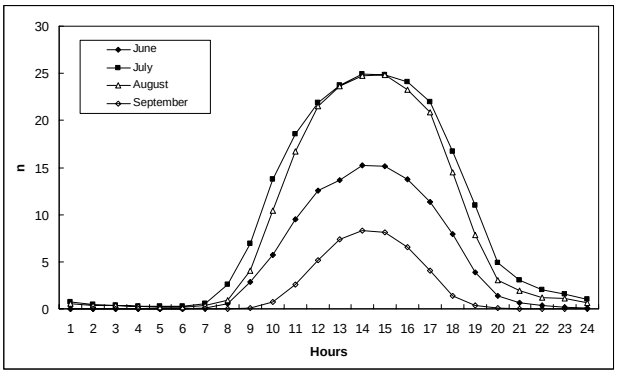

Figure 1a: Mean days per month (n) for each hour of a day with T>30°C.

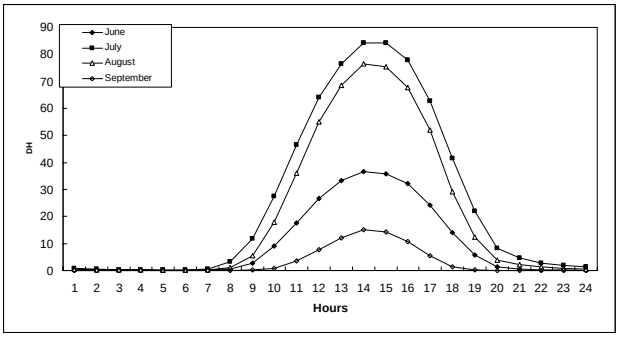

Figure 1b. Mean degree hours per month (DH) on the base of T = 30°C.

4. THE USE OF KENDALL-MANN TEST TO INVESTIGATE TENDENCIES

Increased emission of pollutants as well as the expansion of the green house effect in Athens are the sources of important climatic changes. In order to investigate the existence of tendency concerning the number of hours above the temperature base of 30°C for the period of June to September and the corresponding degree hours (DH) the sensitive non-parametric test of Kendall-Mann for tendency is used (Sneyers, 1975).

As it is shown from the u(t) values in Figures 2a and 2b in the base of mean values for the June to September period, there is a statistically significant positive tendency regarding the number of hours (n) above 30°C as well as the corresponding values of DH.

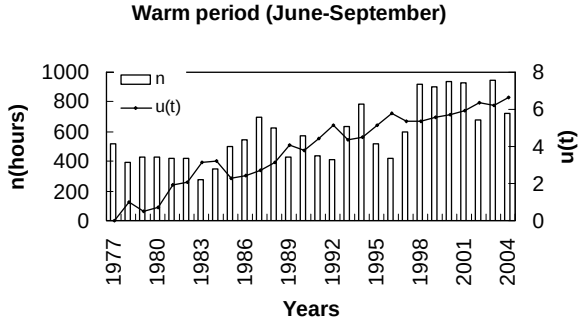

Figure 2a: Time series of the warm period (June to September) for mean number of hours with T>30°C and the corresponding u(t) values of the Kendall-Mann test of tendency.

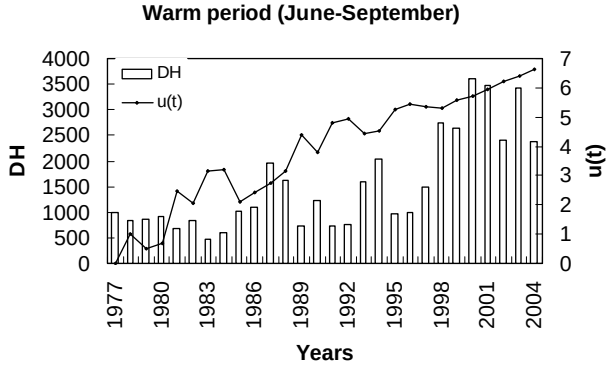

Figure 2b: Time series of the warm period (June to September) for mean number of degree hours (DH) on the base of 30°C and the corresponding u(t) values of the Kendall-Mann test.

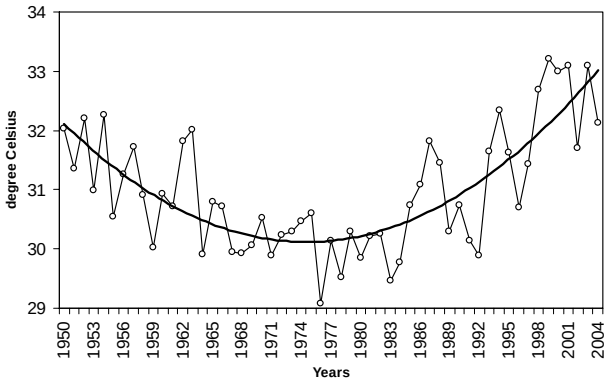

Figure 3: Time series of the warm period (June to September) mean maximum air temperatures for the period 1950 – 2004 and the corresponding polynomial curve of best fit.

However, from Figure 3, where the time series (1950 - 2004) of the mean maximum temperature values for the period June to September are shown, it is obvious that a cyclic change of the mean maximum temperature exists. This fact leads to the belief that the observed tendency probably will not continue in the future.

5. MEAN DAILY DISTRIBUTION OF N AND DH VALUES

Considering the mean number of days (n) with air temperature values above 30°C for the time period 1977 – 1989 and 1990 – 2004 (table 1) it can be observed that, especially in June, the increase in the n values for the period 1990 – 2004 in comparison to the n values for the period 1977 – 1989 are obvious.

The differences are significant, principally during the period 09:00 – 19:00.

The differences, observed between the mean degree hours (DH) for the two examined subperiods (Table 1) for the four months, are more important. A detailed study showed that the number of degree hours (DH) has increased and the duration of their appearance has expanded resulting to the appearance of persistence of high air temperature values.

Table 1: Mean hours per month (n) with T> 30° C and the corresponding DH values for the two examined periods.

	n		DH	
	1977-1989	1990-2004	1977-1989	1990-2004
June	77.3	147.5	141.1	327.4
July	189.2	259	453.4	801.9
August	160.8	240.5	342.3	730.4
September	36.3	52.9	57.2	99.5

6. CONCLUSION

The investigation of the hours (n) with air temperatures values above 30°C and the corresponding degree hours (DH) for the warm period of the year (June – September) lead to some important comments, summarized as follows:

a. The probability of hourly air temperatures during the time period June to September being higher than 30°C is between 0.063 for September and 0.305 for July.
b. The mean monthly values of degree hours (DH) are 239 for June, 593 for July, 469 for August and 80 for September, but from the period 1990 – 2004 these values are statistically higher (327.4, 801.9, 730.4 and 99.5 respectively).
c. It is evident from the Kendall – Mann test of tendency that the values n and DH present a statistically significant increase for the period 1977 – 2004. However, it is not possible to investigate whether this increase is not part of a long cyclic change.
d. For the period 1990 – 2004 an increase of the values n and DH was observed as well as an expansion of the interval during the day that higher air temperatures are observed. This fact shows a persistence of the phenomenon which can be connected to the heat island effects.

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