DETERMINATION OF PLACES IN THE GREAT ATHENS AREA WHERE THE HEAT ISLAND EFFECT IS OBSERVED

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ABSTRACT

The main purpose of the present study is to define places in the major Athens area where the heat island effect occurs. Several important climatic parameters are examined in combination with the application of various statistical tests. From this research it is mainly observed that the central and the west industrialized parts of the city of Athens develop intensely the "urban" heat island effect. Nevertheless, district variations as regards the heat island intensity can be found in some regions, located close to the city centre and eastward of it, characterized by thick vegetation of trees or by "open areas". Moreover, in places near the seaside the air temperatures are higher in the cold period of the year not because of the urbanization but mainly due to the influence of the sea, which favors the maintenance of high air temperatures. Last but not least, the persistence of high air temperatures during the hot period of the year or low air temperatures in the cold period is mostly related to the synoptic weather conditions and reasonably it cannot be considered as an index for the heat island effect development.

KEYWORDS

Heat Island Effect

1. INTRODUCTION

Air temperature values in densely built areas are higher than those of the surrounding rural country. This phenomenon, which is widely known as "urban heat island", is considered to be the most representative and documented manifestation of climatic modification. Heat island is present in every town and city and is the most obvious climatic indication of urbanization, (Landsberg, 1981). This phenomenon is mainly caused by the differences in the thermal structures between the urban and rural environments such as the polluted air of the city, the anthropogenic heat released by the urban pollution, the thermal characteristics of the urban fabric and the urban geometry. The existence of the heat island effect in densely built urban cities has been extensively investigated by many researchers from different locations and all over the world in the last 20 years (Oke, 1981, Oke, 1987).

In the extended area of Athens various attempts have been carried out, to calculate possible air temperature climatic tendencies. Those researches were supported by measurements from a network of three meteorological stations, established many years ago. However, the results of these investigations were not satisfactory as failed to give clear or definite answers. This was mainly caused by the fact that the investigations were established in places where the urbanization was not essentially intense (Balaras et al, 1993; Livada et al, 1994). It is known that the research of the heat island effect demands a lot of detailed and extensive air temperature measurements. These measurements in relation with wind speed measurements can be helpful to the investigation of the horizontal temperature distribution around the center of the city.
The main purpose of the present paper is to classify 20 air temperature measurement stations installed, in the framework of the project "POLIS, " from June 1996 to March 1998 (a period of 22 months), in the great Athens area, and thus to define single places where the heat island effect is predominant.

2. THE URBAN HEAT ISLAND EXPERIMENT IN ATHENS

The great Athens area, GAA, is situated in a small peninsula located in the southeastern edge of the Greek mainland. The urban heat island phenomenon in GAA was examined using hourly measurements of ambient air temperature and humidity from twenty experimental stations, being installed in the Athens urban and suburban region. A brief description of each experimental station is presented in Table 1. The climate of GAA is typical "Mediterranean", with mild winter and dry hot summer.

TABLE 1
Characteristics of the experimental Stations

Station Number	Station Characteristics
1	Placed on a green hill at the centre of Athens (altitude=107m). The area is characterised by low building density and absence of traffic.
2	Placed in the south-eastern area of Athens near a mountain. The area is less populated with low traffic and medium building density.
3	Placed in the eastern area of Athens centre. The area is densely populated with a lot of traffic
4	Placed in the south-western area of Athens. The area is less populated with low traffic while its vegetation is nearly negligible
5	Placed in the eastern area of Athens near a mountain. The area is highly populated with a lot of traffic
6	Placed in the southern coastal area of Athens, very close to the airport. The area is characterised by very low traffic and by very few buildings
7	Placed in the centre of Athens. The area is densely populated with heavy traffic
8	Placed in the north-eastern area of Athens between two mountains. The area is characterised by an increased building's density and by heavy traffic
9	Placed in the southern area of Athens centre in a big avenue. The area is highly populated with heavy traffic
10	Placed in the southern side of the previous avenue very close to the sea. The area is characterised by low building's density and by heavy traffic
11	Placed in the centre of Athens in a pedestrian road. The area is very densely built and populated
12	Placed in the centre of Athens. The area is characterised by a lot of traffic and by very dense population
13	Placed in the centre of Athens. Traffic and buildings' density are very high
14	Placed in the western area of Athens in a university campus characterised by a moderate vegetation
15	Placed in the centre of Athens. The area is very densely populated with a lot of traffic
16	Placed in the northern area of Athens. Traffic is very low and trees are scattered all over the area
17	Placed in the western limits of Athens basin in a foot-ball ground at the edge of a planted area. The area is characterised by very low traffic and buildings' density
18	Placed in the western area of Athens. Traffic is heavy while buildings' density is very high
19	Placed in the city centre inside National Garden of Athens
20	Placed in the Ancient Market of Athens. It is an area covered by bare soil and surrounded by trees

3. AVERAGE AIR TEMPERATURES

At a first stage, the hourly air temperature measurements for each experimental station and for the time period of July 1996 to March 1998 were separated into four subsets, (Table 2). The first one contains the hourly data for the summer months of July and August 1996 and 1997 and it corresponds to the Summer Period, (SP). The second one consists of the hourly measurements for the transitive months of June and September of 1996 and 1997 and it corresponds to the Summer Transitive Period, (STP). The third contains the winter months of December 1996, of January, February and December 1997 and of January and February 1998. The winter subset corresponds to the Winter Period, (WP). Finally, the fourth subset consists of the hourly data of November 1996, of November and March 1997, and of March 1998. The fourth subset corresponds to the Winter Transitive Period (WTP). The mean air temperature values of each station and for each of the above mentioned time periods were primarily estimated and presented in Table 3. It seems that, the separation in "urban" and "suburban" areas cannot be based on the average values of air temperature. During the summer period (SP) and the summer transitive period (STP), the maximum differences of air temperature approached 4.3^{o}C and 4.6^{o}C respectively, with the maximum mean value occurring, for SP period in station 4 located in the industrial zone of the west part of great Athens area and the STP period in station 12 that is located in a central place with intense traffic circulation.

The minimum values were detected in distant regional stations and in station 19 in the National garden of Athens near the city centre. During winter period (WP) the maximum difference was 4.5^{o}C about the same with the summer period (SP) but during winter transitive period (WTP) the difference (3.8^{o}C) was smaller than the summer transitive period (STP). The maximum mean values appeared again in central stations 7, 9. The minimum mean values occurred at station 19.

TABLE 2

Months	Period's specification
July and August	Summer period (**SP**)
June and September	Summer transitive period (**STP**)
December-January-February	Winter period(**WP**)
November and March	Winter transitive period (**WTP**)

TABLE 3

Station	(SP)	(STP)	(WP)	(WTP)	Station	(SP)	(STP)	(WP)	(WTP)
1	26.9	24.2	10.4	11.3	**11**	28.4	25.0	-	-
2	26.4	23.0	11.1	11.6	**12**	29.3	27.6	11.2	12.0
3	27.3	24.2	9.8	10.5	**13**	29.3	26.7	12.7	13.4
4	29.8	26.3	11.1	13.0	**14**	28.7	26.1	10.4	11.8
5	28.4	25.2	12.0	12.3	**15**	29.2	26.3	12.5	13.6
6	27.2	25.3	12.4	13.5	**16**	27.0	23.3	12.1	11.3
7	29.0	26.9	13.5	12.2	**17**	27.3	24.2	10.2	11.0
8	26.2	23.5	12.0	13.4	**18**	28.5	25.3	11.4	12.1
9	28.9	25.6	13.3	13.8	**19**	25.5	23.4	9.0	10.0
10	28.1	25.7	10.5	12.1	**20**	28.2	25.9	9.3	11.2

4. RESULTS AND DISCUSSION

The investigation of the hourly air temperature values, for both cold and warm periods of the year resulted in defining the regions, where the heat island effect was developed in the extended Athens area. The most important critical comments of the present study can be summarized as follows:

a. Based on the cooling degree hours DH(26), considering as reference temperature 26^{o}C for the summer period (SP) and the summer transitive period (STP), and on the heating degree hours DH(15), considering 15^{o}C as critical value for the winter period (WP) and the winter transitive period (WTP), the experimental stations were classified in "urban" and "suburban" categories.
b. The persistence of existing successive hourly air temperature values, higher than 26 ^{o}C in the SP and STP periods or lower than 15^{o}C in the WP and WTP periods, is statistically significant in all stations. This observation is indicative of the fact that weather conditions promote mainly the persistence and not the heat island effect.
c. Considering 26^{o}C and 15^{o}C as temperature thresholds for the warm and cold periods respectively, the heat island effect is more intense in STP period than in WTP and in SP period than the WP.
d. The "suburban" station 2, due to its altitude and to airstreams caused by the bas-relief, is characterized by lower temperatures in the SP and STP periods in comparison with the other "suburban" stations.

e. Station 19 can be classified in “suburban” category, although it is situated in the city centre. Air temperatures are maintained in low levels in all the considered periods as a result of the thick vegetation, consisting mainly of trees surrounding the station.
f. The heat island effect obtained its maximum values in open-surrounded positions in the city centre, where the canyon effect is not favored. In addition, these locations are affected by the presence of asphalt and by the heavy traffic circulation mainly due to the buses.
g. In the majority of the measurement stations, only stations 14 and 20 were not classified in any category, as during SP and STP periods present attributes of “urban” stations, whereas in WP and WTP have characteristics of “suburban” stations. Nevertheless, it is possible to elucidate their behavior due to their position.
h. For all examined periods, it is possible to estimate the number of DH from the corresponding existing frequencies within power functions. Besides, the slopes of the curves are statistically significant but they do not differ significantly between “urban” and “suburban” data sets.

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