The influence of the wind speed on the heat island phenomenon in Athens, Greece

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ABSTRACT

In the present study the relation between the wind speed and the air temperature during the summer period over the greater area of Athens is examined. Specifically, the hourly data of the air temperatures, recorded by 27 stations, were studied for the months of June, July, August and September during the period from 1996 until 1998, in relation to the corresponding mean hourly values of the wind speed which were measured by the National Observatory of Athens. As a result, a low increasing rate of air temperature in correlation to the wind speed exists during the day and night, time period. This correlation is approached by statistically significant regressions of hyperbolic or exponential function.

1. INTRODUCTION

In a previous study (Papanikolaou 2007) the effect of the wind on the air temperature for 4 stations was examined, for specific wind directions during the day for the summer period. The stations were selected in such a way that the flow of wind for these directions was not prevented by the urban geometry. The aim of the study was to examine how the winds from certain directions influence the configuration of the air temperature distribution in the greater area of Athens. In the present study, the effect of wind speed for the summer period in the air temperature, that was measured in 27 stations (Fig1), which were placed in the wider region of the city of Athens, is examined.

In Athens during the summer period N-NE winds ("etesian" winds), strong during the daytime, are prevailed. Furthermore, during the day the sea breeze that is developed strengthens the winds of southern direction. The study examines separately the time period between 09:00 – 19:00 and 20:00-08:00, because of the powerful effect of solar radiation in the configuration of the air temperatures and the wind speed. From the data analysis, a tendency of the appearance of higher air temperatures for higher wind speeds has been observed. This tendency is higher during the day in June and September, and during the night in July and August.

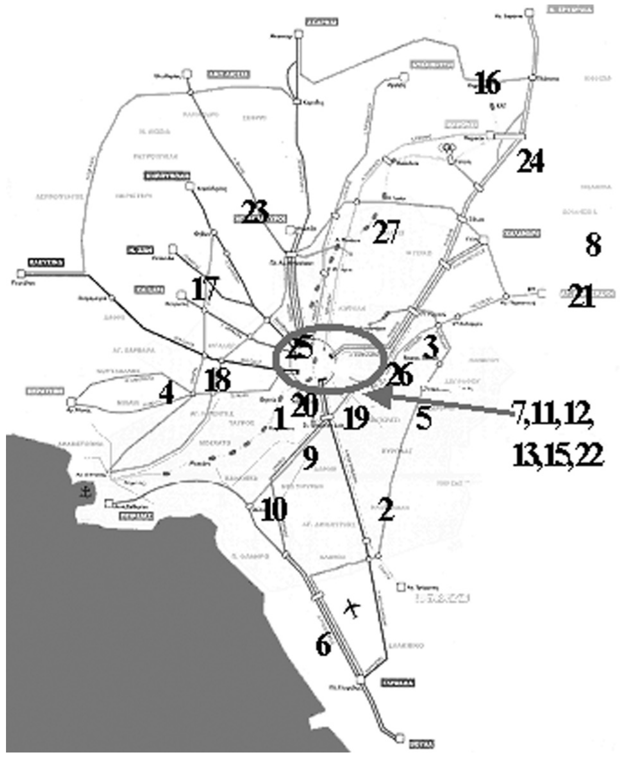


Figure1: The 27 stations in Athens basin.

2. DATA ANALYSIS

In this study the hourly air temperatures, recorded by 27 stations, which were installed in the wider region of Athens, related to the mean hourly wind measurements, which were emanating from the National Observatory of Athens (Station 1) for the summer period (June to September) are examined.

The study also examines the day period (09:00-19:00) and the night period (20:00-08:00) for each month (June to September) separately.

The wind data were categorized in orders of 0,5m/s intervals and for each interval the mean air temperature was calculated. Then, the correlation between the mean air temperatures and the mean wind speeds values that corresponds to each interval was examined. As a result of the analysis it is clear that in almost all the cases, a statistically significant correlation coefficient exists, in the significant of 0,05 by a fitting to exponential or hyperbolic function.

The correlation coefficient for the most of stations is positive. Exception constitute the stations No 21 and No 23 which are found in regions of low urban density with important presence of vegetation and with NE orientation. The orientation in combination with the low urban density results in the development of high air temperatures early in the morning, where there are generally observed low wind speeds. Due to this reason a negative correlation during the day is observed.

The fit to hyperbolic function was observed during the day for June and September and during the night period for August. This form of curve shows a tendency of stabilization of the air temperature for high wind speeds. The higher gradient of change of air the temperature in relation to wind speed is observed in low wind speeds. The highest values of these rates were observed in stations situated in the centre of the city in areas were there is no circulatory pressure (Station 11,19,20) in which heat transfer from neighboring urban places with the absence of green and intense circulatory pressure is observed. In the other cases (June-night, August-day and night and September night) the change of the air temperature associated with the wind speed follows an exponential function. Consequently, the air temperature increases constantly along with the increase of the wind speed. Nevertheless, the rate of change of the air temperature in relation to the wind speed does not exceed the 1°C / ms^{-1}.

The figures 2a,b – 3a,b – 4a,b and 5a,b that follow are reported in 4 stations which have been installed in 4 different categories of areas of the wider region of Athens (Livada 2002). In these figures the scatter diagrams are given for each month and for the day and night periods. The higher rates of change appear in July, while the differentiation between the day and night rates in the months of June, July and August are obvious.

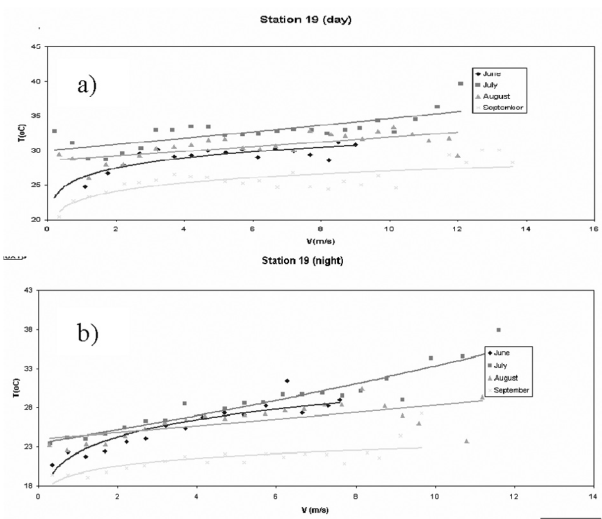


Figure 2: Data analysis during day (a) and night (b), for the reference station, which was placed in the National Garden of Athens.

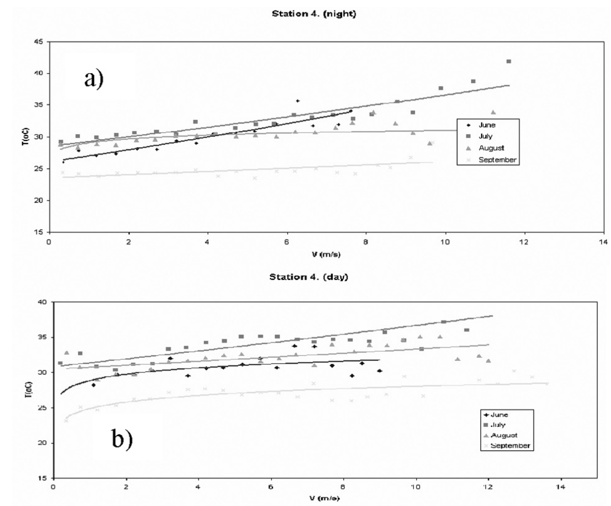


Figure 3: Data analysis during day (a) and night (b) for a station in the west area of Athens with high temperatures during evening.

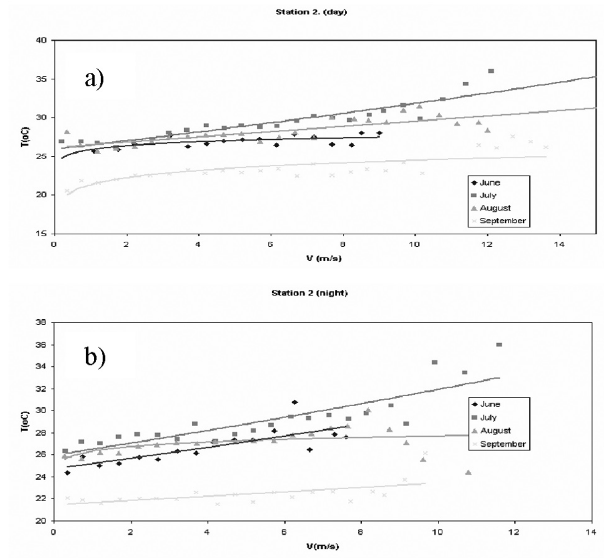


Figure 4: Data analysis during day (a) and night (b) for a station in the east area of Athens with lower temperatures during day.

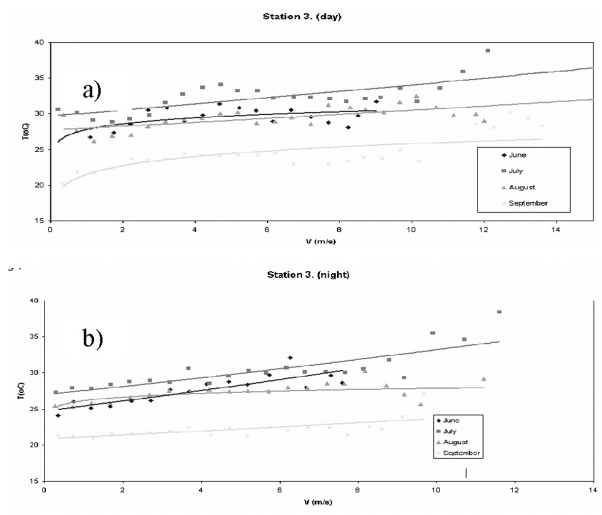


Figure 5: Data analysis during day (a) and night (b) for a station in the centre area of Athens.

Moreover, the analysis shows that powerful winds lead to a more homogeneous distribution of air temperatures in the basin of Athens. This happens mainly due to the fact that in places which due to their peculiarity (parks, pedestrian roads, archaeological sites etc.) have lower temperatures, the powerful wind contributes to the transport of hot air masses from the areas of high temperatures in neighboring places and thus air temperatures increase with a rate higher than that in stations which have been placed in a typical urban environment.

The observation mentioned above is distinctly shown in the mean air temperature differences, of each station in relation to the reference station (station 19), which was placed in the National Garden of Athens. For wind speeds higher than 5m/s, the mean air temperature differences concerning the reference station are clearly lower than the corresponding differences for wind speeds less than 2m/s. This phenomenon is much more intense during the night. During the day the phenomenon becomes weaker, due to the effect of solar radiation, while it has been observed that quite often the air temperatures of the stations are lower in comparison to the reference station for wind speed higher than 5m/s. Consequently, the increase of wind speed strengthens the cool island phenomenon during day in Athens. (Figures 6a-b, 7a-b, 8a-b, 9a-b).

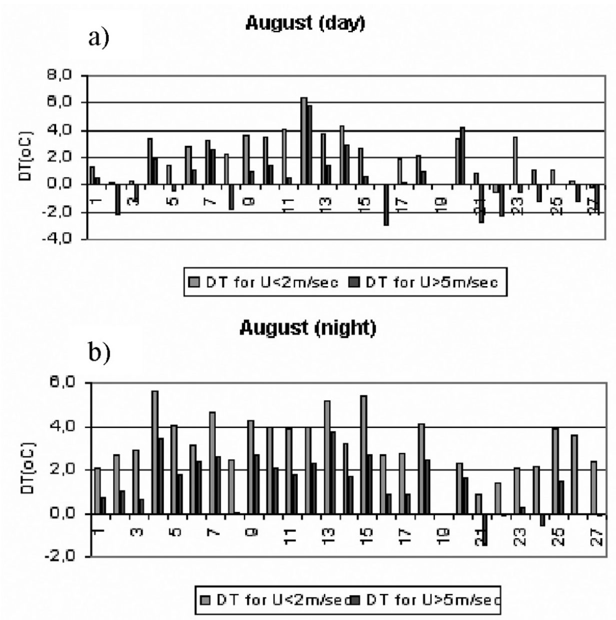


Figure 6: Mean DT(°C) for U<2m/sec and U>5m/sec during day (a) and night (b) for August.

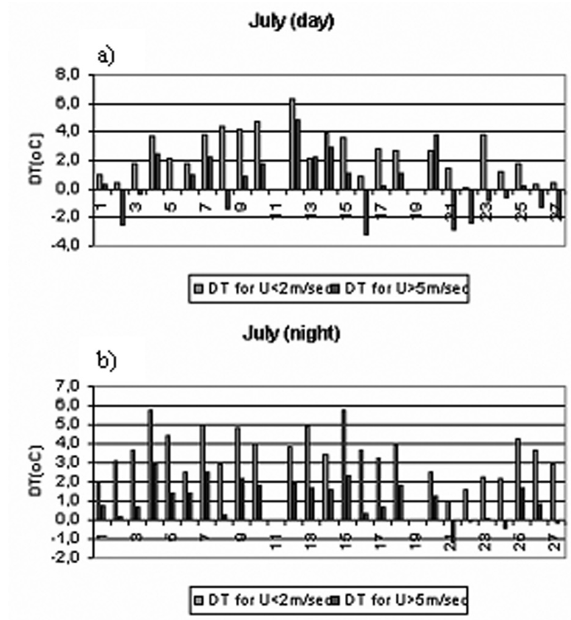


Figure 7: Mean DT(°C) for U<2m/sec and U>5m/sec during day (a) and night (b) for July.

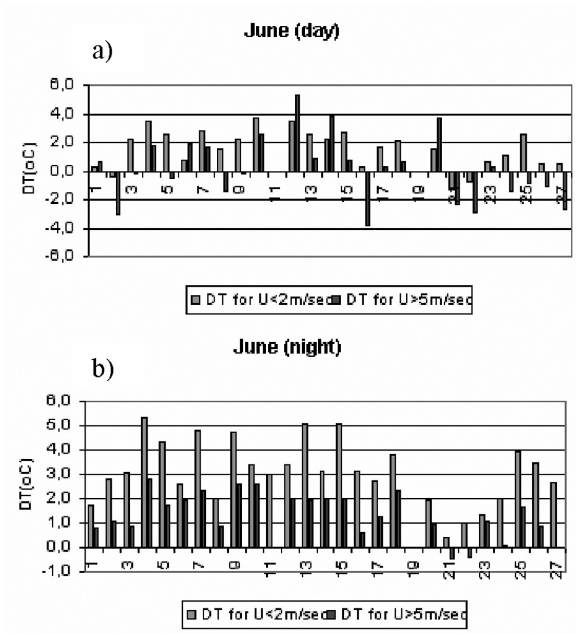
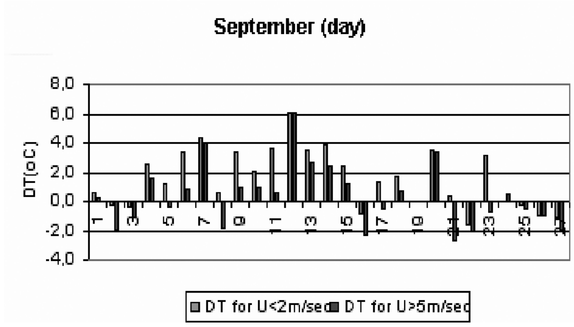


Figure 8: Mean DT(°C) for U<2m/sec and U>5m/sec during day (a) and night (b) for June.



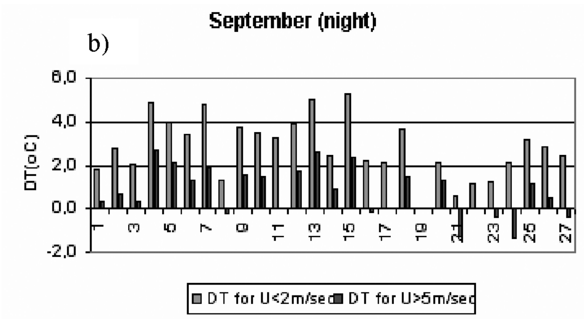


Figure 9: Mean DT(°C) for U<2m/sec and U>5m/sec during day (a) and night (b) for September.

In the table 1 shown below, the mean air temperature differences, as to the total stations, for each month, for the day and night, and for U<2m/s and U>5m/s has been given.

Table 1:

	DT(°C) - night		DT(°C) - day	
	U<2m/s	U>5m/s	U<2m/s	U>5m/s
August	3,3	1,3	1,6	0,4
July	3,5	1,1	1,6	0,1
June	3,1	1,3	2,5	0,3
September	2,9	0,8	2,2	0,3

It becomes obvious that the mean air temperature differences of all the stations from the reference station, for wind speeds higher than 5m/s, is 1,8 to 3,4°C smaller than the corresponding differences, for wind speeds less than 2m/s. The corresponding differences during daytime, range from 1,2 up to 2,2 °C.

Finally in table 2 is recorded the mean heat island intensity for each month.

Table 2:

	Max DT(°C) night		MaxDT(°C) day	
	U<2m/s	U>5m/s	U<2m/s	U>5m/s
August	4,8	5,2	6,9	8,7
July	4,8	4,1	6,2	8,0
June	4,9	3,2	5,1	9,1
September	4,7	4,1	7,7	8,8

It is obvious that the increase of the wind speed during nighttime leads to the reduction of heat island intensity contrary to the daytime where the increase of wind speed leads to the increase of heat island intensity. This is owed mainly to the effect of solar radiation where in combination with the local characteristics of each station (urban layout density, plantation and circulatory pressure) lead to the configuration of areas with low air temperatures in Eastern and North parts of city of Athens.

3. CONCLUSIONS

The conclusions that have been drawn from this study can be summarized as follows:

a) Generally, the high wind speeds correspond to high air temperatures. In June (night) July (day and night), August (day) and September (night), the phenomenon is approached with exponential curves, with low rate of change. In the other cases, the data has been adapted to hyperbolic curves where the highest rates of change, which correspond to low wind speeds never exceed 1°C/ms^{-1}.

b) In July and August the rate of air temperature change during the day is weaker than that at night. This can be attributed to a uniform heating of the wider region of Athens during the day. On the other hand, in June the gradient air temperature change is weaker during the night than that during the day, while in September these can be considered statistically equal.

c) Were found cases where due to special local conditions (NE orientation, low urban density, and urban plantation) the increase of the wind speed is combined with lower air temperatures.

d) Finally, the air temperature differences from the reference station, for wind speeds higher than 5m/s, are considerably decreased. During the night the decrease can be up to 3,4°C, referring to the total of stations. During the day there is a decrease up to 2,2°C.

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