The impact of wind on air temperature distribution in Athens and in Santorini

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ABSTRACT

Research studies of thermal comfort in buildings aim mostly at maintaining air temperature, especially during summer period, within the acceptable comfort conditions and with the minimum energy consumption. The contribution of wind is known to be an important parameter for natural ventilation and passive cooling of buildings. In the present work the correlation between the variation of wind and air temperature is studied for two different meteorological stations in major Athens area, where the heat island effect exists. The same study is also performed for another station in Santorini island and a comparison analysis between the two regions is made, since Santorini is not exposed at the urban environment and furthermore it is directly affected by the etesian winds and the vicinity of the sea.

1. INTRODUCTION

The increase of living standards in buildings and the persistence of high ambient temperature values during summer especially in big cities have increased the installation of air-conditioning systems and consequently the energy requirements for cooling. Analysis of summer air temperatures and wind velocities is thus necessary in order to provide appropriate information to building designers. Calculation of cooling load, appropriate sizing of AC systems and interaction of passive and hybrid cooling techniques and components within the building are directly related with the availability of local climatic conditions, of which ambient temperature and wind velocity are the most important parameters.

Tselepidaki and Santamouris (1991) reported that the frequency of high summer air temperature values exceeding 25^{o}C in Athens during June to September ranges from 0.32 to 0.65. Besides the persistence of existing consecutive days with high air temperatures was found statistically significant during this period. Especially for July and August it was estimated that cooling is necessary for more than five hours per day. Balaras et al. (1992, 1993) estimated the cooling power index for Athens, which was proposed by Vinje. This index is based on air temperature and wind speed values and corresponds to human sensation. It was found that the occurrence of hot conditions over a day is statistically significant during summer period. The prevailing high air temperatures together with low wind speeds assist the persistence of hot conditions of a high number of consecutive hours. Tzikopoulos et al. (2004) attempted to model the energy efficiency of bioclimatic buildings based on the estimated degree days of Greece and other Mediterranean areas and the rest of Europe.

The purpose of the present study is twofold. The cooling degree hours, DH(26), are estimated for two stations in the extended Athens area and for an insular station in Santorini island. Besides the impact of wind on the observed air temperature distribution is analyzed during June to September for a five year period (2000-2004).

2. METEOROLOGICAL DATA

The study of hourly air temperature and wind speed values is of concern not only on a tempo-

ral but also on a spatial basis. Tselepidaki et al. (1992, 1994) observed important differentiations in neighbor regions in major Athens area. However, a comparison analysis between summer conditions in Athens and in islands is also very interesting. Livada et al. (1998) found that the mean return period of daily maximum air temperatures, exceeding 26°C is about two days in Cyclades for the period May to September.

In the present work the hourly air temperature and wind speed data were used for the period from June to September 2000-2004 of the National Observatoty of Athens (NOA), as well as, of Ellinikon station that it is located in a rural area near Saronikos gulf. Also another island station is studied which is placed in Santorini, in the southern part of Cyclades (Fig. 1), where strong winds and the absence of heat island effect are the most predominant characteristics. The selection of the examined period, 2000-2004, is based on the fact that in all studied stations the mean monthly air temperatures were 0.5°C to 3.5°C greater than the corresponding average climatological values (Tselepidaki et al., 1993).

3. ANALYSIS OF DEGREE HOURS

The number of cooling degree hours with reference 26°C, DH(26), is given in Table 1 where it is shown that NOA is characterized by greater values from 20% up to 62% in comparison with Ellinikon station that is placed in an open area adjacent to the sea at a distance of 20Km from NOA. In spite of the fact that NOA is placed in an area with relative vegetation, on the top of a 417 meter high hill, its position near the centre of Athens, makes it exposed to the heat island effect (Livada et al., 2002). The estimated DH(26) values for NOA station and for the period 2000-2004 are 1.9 to 2.7 greater than the corresponding values for the period 1977-1986 (Tselepidaki et al., 1993). This can be explained by the higher air temperatures and the increase of the heat island effect. In addition, comparing the DH(26) in Ellinikon station with the corresponding values in Izmir, in Turkey (Satman and Yalcinkaya, 2000), which is placed in bay of Aegean sea at almost the same latitude with Ellinikon, it was found that the DH (26) are of the same order for the two stations. The observed small number of DH(26) values in Santorini shows that the absence of the heat island effect favors the predominance of lower air temperatures during summer. Moreover the vicinity to the sea, where the surface temperatures range between 22°C and 25°C (Theoharatos and Tsepidaki-Livada, 1990) results in lower ambient temperature values in the whole region.

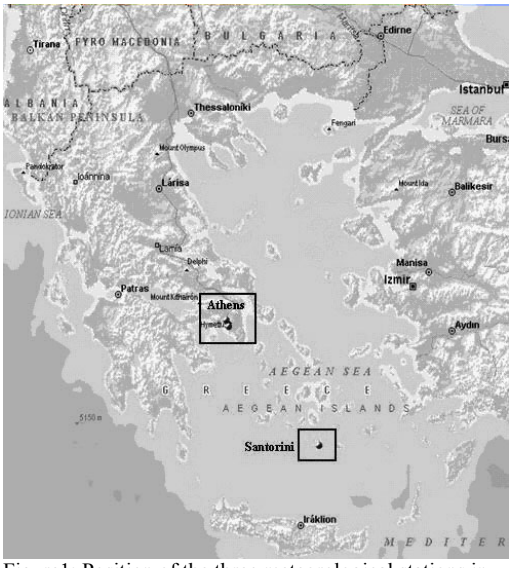

Figure1: Position of the three meteorological stations in Athens and in Santorini island.

Seeing that during summer the local Etesian winds (daily strong winds) are predominant in Cyclades, it is raised a question whether these winds favor the maintenance of lower air temperatures. Thus, the relation between the ambient temperatures and wind velocities is analyzed in the following paragraphs.

4. IMPACT OF WIND ON AIR TEMPERATURE DISTRIBUTION

The relation between wind speed and air temperature was studied for the total data set and thereinafter for each wind direction. Namely, in Athens existing data were classified in three different data sets based on wind direction relative to the real North (293°-45°, 46°-135° and 136°-292°), while calms (wind speed lower than 0.3m/s) were analyzed separately. The purpose was to study the impact of a) northern winds (293°-45°) which correspond to local Etesian winds during summer, b) SSE-WNW (136°-292°) winds which blow from the sea, c) ENE-

Table 1: Number of Dh(26) for NOA, Ellinikon and Santorini stations during the period 2000-2004.

	NOA					ELLINIKON					SANTORINI				
	J	J	A	S	Sum	J	J	A	S	Sum	J	J	A	S	Sum
2000	1786	3458	2565	838	8647	1338	2219	2287	543	6387	308	1275	395	290	2268
2001	1304	3302	3050	930	8586	814	2478	2532	645	6469	131	1400	995	419	2945
2002	1555	2898	1684	198	6355	1219	2132	1863	280	5494	187	1325	1201	111	2824
2003	2164	2742	3089	621	8616	1051	1763	1953	279	5046	380	959	728	233	2300
2004	1270	2548	2043	600	6461	580	1797	1829	418	4624	216	548	808	90	1662
Mean	1616	2990	2486	637	7729	1000	2078	2093	433	5604	244	1101	825	229	2400

Table 2: Slopes of the linear correlation between wind and air temperature values for NOA, Ellinikon and Santorini stations during day and night (values in parenthesis) period.

Stations	Wind Direction	June	July	August	September
NOA	136-292^o	0.26(*-0.08*)	0.05(*-0.001*)	0.62(*0.20*)	0.60(*0.41*)
	293-45^o	0.42(*0.17*)	0.42(*0.17*)	0.53(*0.26*)	0.29(*-0.13*)
	46-135^o	0.71(*0.49*)	0.94(*0.21*)	0.57(*0.59*)	0.33(*-0.07*)
Ellinikon	136-292^o	-0.37(*-1.19*)	-0.49(*-0.32*)	-0.09(*0.94*)	0.06(*0.25*)
	293-45^o	0.12(*0.37*)	0.36(*0.26*)	0.42(*0.35*)	0.09(*0.32*)
	46-135^o	0.56(*0.09*)	1.03(*0.14*)	0.74(*0.04*)	-0.08(*-0.45*)
Santorini	0-179^o	-0.22(*-0.03*)	-0.14(*-0.28*)	-0.16(*-0.15*)	-0.26(*-0.27*)
	180-360^o	-0.19(*0.001*)	-0.15(*0.07*)	-0.12(*-0.02*)	-0.22(*0.02*)

SE (46^o-135^o) winds that are affected by Ymittos, a 1027m high mountain placed east of Athens and d) calms on the ambient temperatures. In Santorini the classification of wind directions was made in two sectors (0^o-179^o and 180^o-359^o) depending on whether or not the station is affected directly by the sea. Figure 2 shows that in Santorini, air temperature is reduced when wind speed is increased, independently of wind direction and especially for wind speeds greater than 5m/s, either during day or night period for the whole summer period. Not to mention that the reduction of ambient temperature was greater when the wind was blowing from 0^o to 179^o, from the seaside, rather than when it was blowing from 180^o to 359^o, where the air stream followed a continental route (Table 2).

In Ellinikon station (Fig. 3), it is observed that in all cases (except for the day period during September) air temperature is increased with wind speed, independently of wind direction. On a first sight this seems paradox, however, when the same analysis was performed for winds blowing from the sea (SSE-WNW directions) then the ambient temperatures were reduced for increasing wind speeds during the 24 hour period (except for September). On the contrary, when the wind was from ENE to SE directions where the effect of topography was existing then higher ambient temperature corresponded to higher wind speeds (Table 2). Finally, the existing northern wind speeds caused higher ambient temperatures, although this was not expected. This may be attributed to the fact the northern airstream is mixed with the hot air from the urban canopy layer and thus high air temperatures are observed independently of wind speed.

In case of NOA station (Fig. 4), it was found that for all wind directions and during the 24-hour period, the ambient temperature is proportional to the logarithm of wind speed (except for the night period during September). The increase of air temperature is greater when the wind speed is from ENE to SE directions when the catabatic winds from Ymittos mountain become warmer. During the night period the increase is smaller whereas, for winds from SSE to WNW a positive correlation is found for August-September (Table 2). During September when the sea is characterized by higher surface temperatures then the air mass is heated underneath and this is strengthen by the heat island effect and thus higher air temperatures are observed at NOA station for high wind speeds either during the day or night period.

On the contrary during the night period for northern or eastern wind directions, lower air temperatures correspond to higher wind speeds. In general, it has been found that for lower wind speeds there is an abrupt increase of air temperature, while when the wind speed is in-

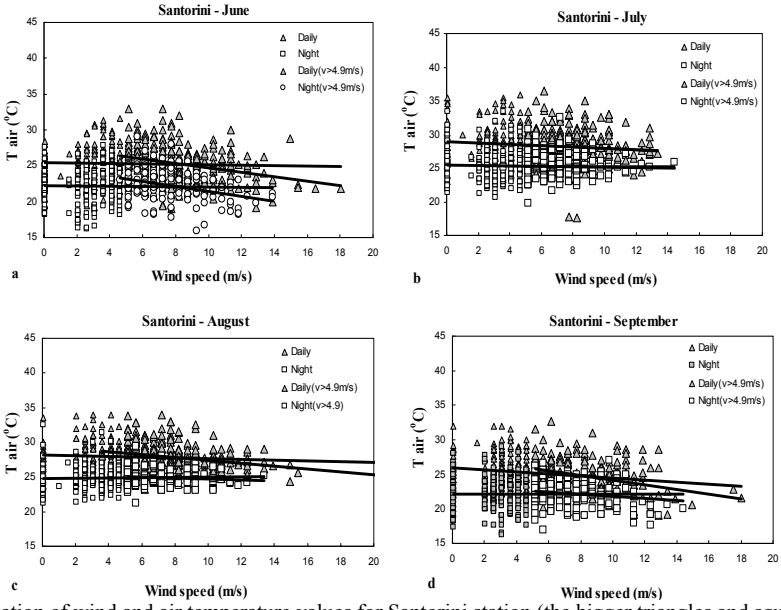

Figure 2: Correlation of wind and air temperature values for Santorini station (the bigger triangles and squares correspond to V>4.9m/s).

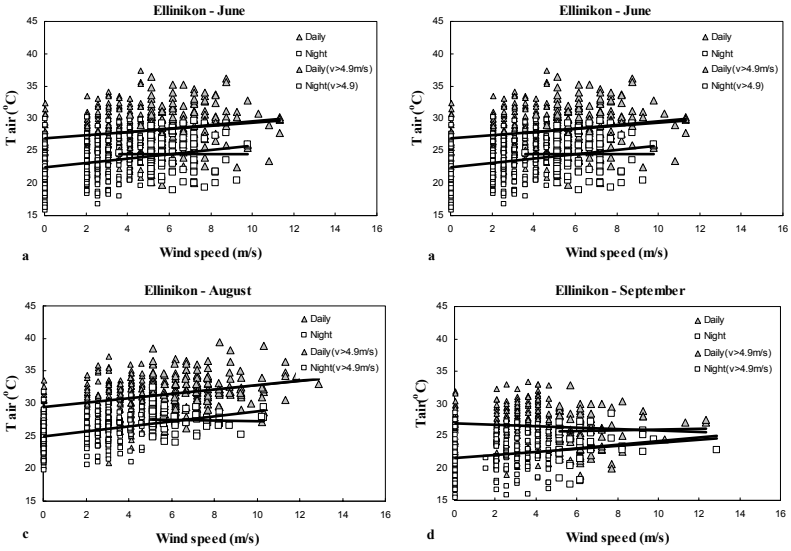

Figure 3: Correlation of wind and air temperature values for Ellinikon station (the bigger triangles and squares correspond to V>4.9m/s).

creased above a threshold values then the air temperature tends to stabilize presenting a tendency to cancel the island effect.

5. CONCLUSIONS

From the study of Dh(26) in three meteorological stations in Athens and in Santorini, the heat island effect is evident in the centre of Athens with the total number of Dh(26) values in NOA ranging from 6355 to 8647 during the cooling

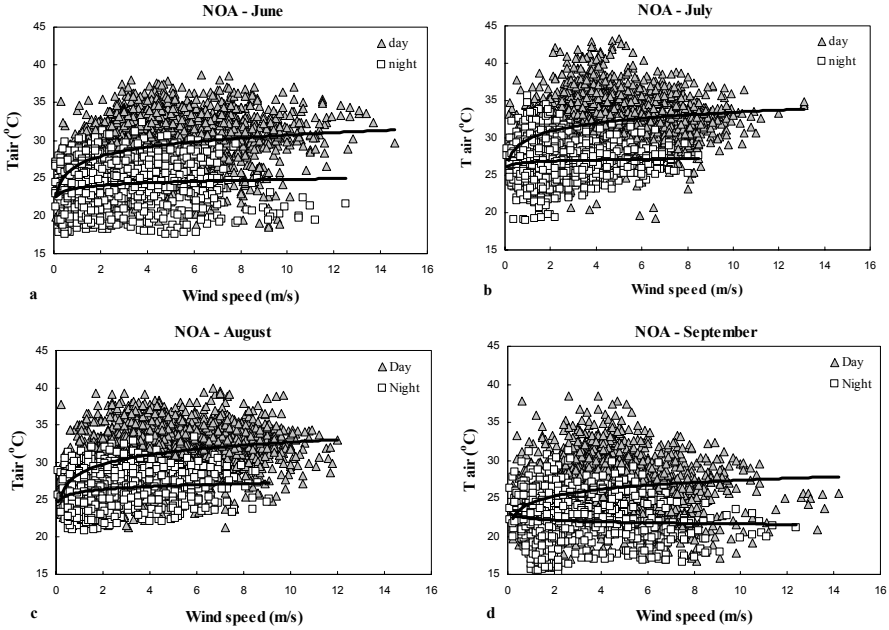

Figure 4: Correlation of wind and air temperature values for NOA station (the bigger triangles and squares correspond to V>4.9m/s).

period of the year. In an open area adjacent to the seaside at a distance of 20Km from the city centre the total number Dh(26) is reduced varying from 4624 up to 6469, however these values are considered relative high when compared with the corresponding values for Santorini (1662-2945). This reveals that the heat island effect is predominant in the extended Athens area, even with a smaller intensity at rural places.

The impact of wind speed on air temperature distribution in Santorini showed that higher wind speed values correspond to lower ambient temperatures, either during the day or night period and especially when winds flow from the seaside. In Ellinikon station a negative correlation is found when the wind blows from the sea and especially during June, July and August. For all other wind directions the air masses are directly affected by the heat island effect, presenting its greater intensity in the centre of Athens and thus resulting in higher air temperatures independently of wind speed. Finally, for NOA station near the centre of Athens, the heat island effect overrides the influence of wind speed during the 24-hour period and this is mostly observed for lower wind speeds, while in no case a negative correlation was observed.

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