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On the influence of the urban heat island on the cooling load of a school building in Athens, Greece

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ABSTRACT

The present study investigates the effect of the urban heat island (UHI) phenomenon, measured in the Greater Athens Area (GAA), on the energy consumption of a typical modern school building. The energy performance of the selected building has been calculated using an accurate, extensively validated, transient simulation model for 17 different sites of the GAA, for the summer period. Calculations showed that the urban heat island phenomenon affects remarkably the thermal behavior of the school building, as suburban areas presented much lower cooling loads. The cooling load values fluctuated between 3304.3 kWh for the rural stations and 14,585.1 kWh for the central stations (for the year 2011) or between 3206.5 kWh and 14,208.3 kWh (for the year 2012), respectively. Moreover, the mean monthly cooling load values varied between 0.4–2 kWh/m^2 for the rural stations and 4–6.9 kWh/m^2 for the central stations, for the selected time period.

Furthermore, a neural network model was designed and developed in order to quantify the contribution of various meteorological parameters (such as the mean daily air temperature values, the mean daily solar radiation values, the average wind speed and the urban heat island intensity) to the energy consumption of the building and it was found that the urban heat island intensity is the predominant parameter, influencing remarkably the energy consumption of the typical school building.

1. Introduction

The “urban heat island phenomenon” is characterized by recording air temperature measurements over cities which are remarkably higher than those that had been observed over the surrounding areas. The intensity of the aforementioned phenomenon depends on the special characteristics of each urban area, perceived by wind tunnel effects and irregular turbulence (Santamouris, 2001; Tan and Li, 2015). Beside the rise of the temperature, the urban heat island phenomenon is accompanied by a remarkable time hysteresis at the cooling of the air over cities, compared to the cooling of the air over the surrounding rural areas (Escourrou, 1991; Eliasson, 1996; Kaloustian and Diab, 2015; Tam et al., 2015). According to many well-known scientists (Park, 1986; Oke et al., 1991; Santamouris, 2007), the heat island effect is due to the differences in the thermal properties of the urban environments compared to those of the surrounding areas, caused by the differences in the atmospheric components, the existence of anthropogenic heat sources, the differences in shapes, geometry or materials, the differences in short and long-term meteorological characteristics and the topography of the area. Urban heat island effect is present 24 h a day, presenting a maximum at calm and cloudless nights.

For the “quantification” of the UHI phenomenon, the maximum differences between the “urban” air temperatures and the “rural” ones are used. These differences also depend on the geometric, meteorological and geographic characteristics of the areas (Dhalluin and Bozonnet, 2015). UHI effect results on a remarkable increase of the cooling loads of buildings, especially in lower latitudes, such as countries near Mediterranean Sea (Hassid et al., 2000; Cartalis et al., 2001; Assimakopoulos et al., 2007).

Athens is the target city in this article, because a severe UHI effect has been recorded, due to the high industrialization and urbanization of the greater area. UHI phenomenon in GAA has been risen during the last years, presenting peak values in July and January (Kassomenos et al., 1998; Mihalakakou et al., 2002). Santamouris et al. (1999) and Livada et al. (2002) demonstrated that the temperature differences between the air temperature of the densely built neighborhoods of the GAA and this of the surrounding areas fluctuate between 6 and 12 °C.

The main objectives of the present paper are, primarily, to investigate the influence of the heat island intensity on the energy consumption of a representative public building-in this paper a typical school building has been chosen-during the summer

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period. The strategy to achieve this purpose is as follows: Primarily, the thermal behavior of the aforementioned building is extensively examined by the use of a proper simulation tool at different locations of the GAA, in order to export results about the energy consumption of the building (or the cooling loads) and these results are used as a reference level. Secondarily, the energy consumption of the selected building is investigated again, by the use of an appropriate neural network model, which allows to investigate the contribution of each parameter that influence the thermal behavior of the school building, each time. Comparing the latest results with the reference basis, we come to conclusions about the contribution of some significant factors (as the urban heat island intensity) on the thermal behavior of the selected building.

The present study describes the influence of several meteorological parameters to the energy consumption of a school building, using a neural network model and it offers quantitative results, as regards the above mentioned influence. Obviously, the same methodology could be implemented for other parameters or other category of buildings throughout the world.

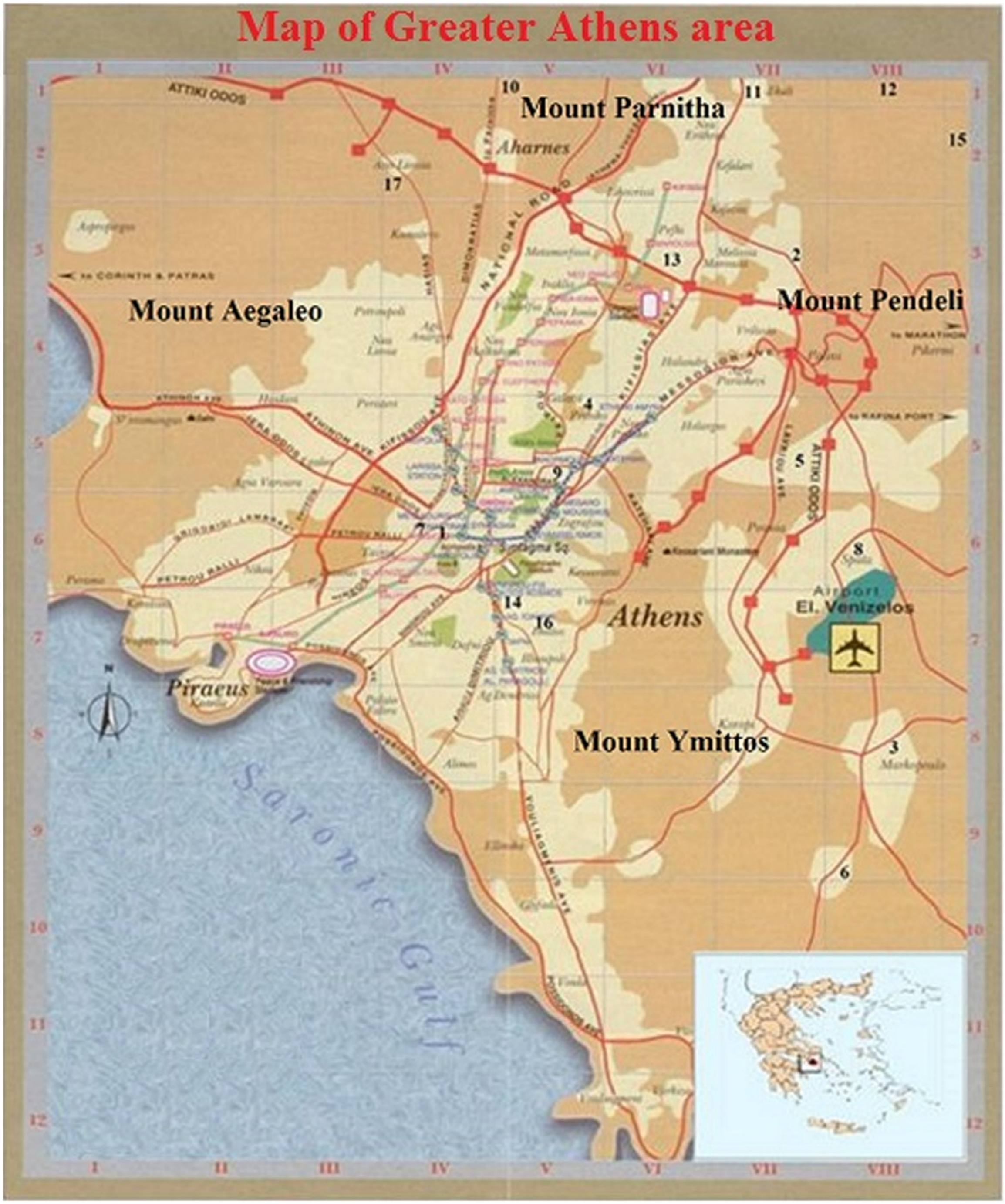

Fig. 1. Map of Athens with the seventeen experimental sites (1: Thisseio, 2: Pendeli, 3: Markopoulo, 4: Psyhiko, 5: Kantza, 6: Kalyvia, 7: Gazi, 8: Spata, 9: Ambelokipi, 10: Parnitha, 11: Ekali, 12: Dionysos, 13: Maroussi, 14: Neos Kosmos, 15: Nea Makri, 16: Ymittos, 17: Ano Liossia).