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ScienceDirect
Solar Energy 83 (2009) 1871–1883
Solar Energy
www.elsevier.com/locate/solener

Urban heat island in southern Europe: The case study of Hania, Crete

D. Kolokotsa *, A. Psomas, E. Karapidakis

Technological Educational Institute of Crete, Department of Natural Resources and Environment, 3 Romanou Str., 73133 Hania, Crete, Greece

Received 31 March 2009; received in revised form 24 June 2009; accepted 25 June 2009
Available online 23 July 2009

Communicated by: Associate Editor Matheos Santamouris

Abstract

The aim of the present paper is to analyze the results of the urban heat island research for a coastal densely built small Mediterranean town namely Hania, Crete, Greece. The specific research targets to verify the existence, the intensity, the size and the form of the urban heat island phenomenon in the specific region as well as to understand its correlation with the local weather conditions. Nine urban and three rural meteorological stations are used for this study. Temperature and relative humidity measurements are collected from May 26, 2007 until October 24, 2007. In parallel, meteorological data including wind speed and direction, barometric pressure, sunlight and precipitation for the specific region are collected and elaborated for cross-correlation with the appearance of the urban heat island (UHI) phenomenon. During summer period, where the temperature is high, the UHI takes its maximum intensity, of about 8 °C. Also, the form of the UHI is strongly influenced from the wind speed and direction. The northern winds expand the UHI front, while the western winds contribute to the UHI reduction. Finally the Discomfort Index (DI) is calculated for the 2007 summer period to indicate the outdoor living conditions.

Keywords: Urban heat island; Urban discomfort; Heat stress; Coastal area

1. Introduction

Urban settlements are the most important human habitat. Approximately 50–60% of the world population lives in cities and towns. The second half of the last century was a period of the more intensive urbanisation that earth has never experienced. In fact, urban population has increased from 160 millions to about 3 billions in just 100 years, and it is expected to increase to about 5 billion by 2025. The quality of urban agglomerations is mainly defined by the type and the strength of the anthropogenic activities, the existing infrastructures and the used resources, the generated wastes and emissions and the corresponding environmental impact (Hardy et al., 2001).

Cities are often warmer than their unbuilt surroundings (Landsberg, 1981; Oke, 1982). This phenomenon which is governed by significant differences between the energy budgets of cities and the countryside is called the urban heat island phenomenon (Crutzen, 2004). Significant research efforts have been performed to evaluate the urban heat island phenomenon's impact on the urban environment (Akbari et al., 1999; Mihalakakou et al., 2000; Santamouris, 2001; Santamouris et al., 2007a; Alcoforado and Andrade, 2006; Kolokotroni et al., 2006; Kolokotroni and Giridharan, 2008). The heat island studies on European level during the last 15 years are summarised by Santamouris, 2007. Based on this study, the quantification of urban heat island phenomenon in Europe is analysed using the following tools:

Statistics of temperature differences between pairs or groups of urban and rural stations.
Results obtained by networks of fixed stations in a city.
Mobile stations across urban areas.

* Corresponding author. Fax: +30 2821023003.
E-mail address: Kolokotsa@chania.teicrete.gr (D. Kolokotsa).

0038-092X/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.solener.2009.06.018

The increased urban temperatures created by the UHI are extensively studied (Livada et al., 2002; Mihalakakou et al., 2004; Livada et al., 2007). The impact of the wind, cloud cover and generally of cyclonic or anticyclonic conditions on UHI intensity is also reported (Papanikolaou et al., 2008; Stathopoulou et al., 2008, 2009). In addition, the diurnal and seasonal variations are discussed by many researchers (Santamouris et al., 2007a; Alcoforado and Andrade, 2006; Kolokotroni et al., 2006; Kolokotroni and Giridharan, 2008).

The urban heat island's impact on the cooling load of buildings, the peak electricity demand for cooling and the efficiency of air conditioners and passive cooling techniques is of a major importance (Cartalis et al., 2001; Santamouris et al., 2007b; Santamouris et al., 2001; Hassid et al., 2000; Geros et al., 2005).

Additionally, the urban heat island phenomenon in coastal cities is analysed by various researchers. Pinho and Manso Orgaz, 2000 studied the heat island phenomenon in the coastal city of Aveiro, Portugal. It was found that the heat island intensity is almost 7.5 °C. Moreover Saaron et al., 2000 measured the urban heat island in Tel-Aviv. Air temperature differences of up to 6 °C at the street level and of 2 °C at the roof level were identified between the city centre and the south-eastern margins of Tel-Aviv.

Based on the above analysis, it is expected that urban heat island phenomenon occurs in highly populated urban areas. Moreover the majority of the urban heat island studies are performed in areas with population higher than 120.000–150.000 inhabitants (Santamouris, 2007). The aim of the present work is to analyse the existence, the intensity and the form of the urban heat island phenomenon in a coastal densely built small Mediterranean town namely Hania, Crete, Greece.

The present paper is structured in three more sections. Section 2 provides the description of the region and the prevailing climatic conditions. Section 3 analyses the experimental procedure while Section 4 includes the experimental results and discussion. Finally, Section 5 summarises the conclusions and discusses issues for future consideration, research and development.

2. Description of the area and prevailing climatic conditions

Hania is a north oriented coastal town whose northern border is defined by the Aegean Sea. The city of Hania is inhabited by 53,000 residents and is located in a plain, at the base of a large circular shaped peninsula named Akrotiri. The southern part of the plain is constricted by the White Mountains with more than 2000 m altitude (see Fig. 1). The most interesting characteristic of the specific region is the fact that Hania is the third most densely populated area in Greece following Athens and Thessaloniki metropolitan regions having 4444.1 inhabitants/km^2.

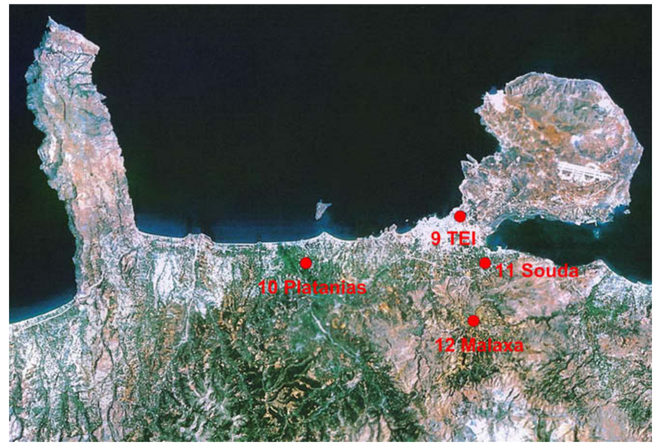

Fig. 1. The three rural measurements' locations.

The synoptic conditions occurring over southern Greece and consequently over Hania, Crete during summer is classified by Kassomenos, 2003 into four categories or clusters:

- Cluster 1: The synoptic conditions are characterised by low solar radiation and temperature and high humidity levels. This synoptic situation favours the establishment of local circulations as a sea breeze.
- Cluster 2 is frequent during July and August. Days characterised as cluster 2 present the highest solar radiation and air temperatures, while the humidity levels are low.
- Cluster 3 is typical of summertime. It presents its highest frequency during July and August. During the days classified in this cluster, the pressure gradient over Greece is very weak and the humidity is high. This situation favours the formation of local circulation systems i.e., sea breezes.
- Cluster 4 is similar to cluster 2. The main difference between them is the higher pressure and the weaker pressure gradient over the Aegean Sea in cluster 4, leading to a significant weaker NE flow over the Aegean Sea.

The prevailing anticyclonic conditions contribute to the development of the heat island during summer. On the other hand the predominant high pressure systems combined with low pressure ones over the Aegean Sea result to increased wind regimes that may decrease the persistence of the UHI subject to suitable cities' orientation and form.

3. Experimental procedure

The experimental procedure includes the following steps:

1. Formulation of a measurements' grid including urban and rural stations.
2. Collection of measurements for a whole summer period.
3. Collection of weather data.
4. Initial elaboration of data.
5. Analysis of experimental results.