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A "Trojan" in Climatic Change: The Urban Effect

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Abstract: This paper sets out the preliminary results of an experimental research plan aimed at analysing the thermal processes inherent to the urbanisation effect. Although this effect is undeniable, the extent of its impact is a matter of controversy. The results obtained in this study show both the nature of the phenomenon and its considerable magnitude. Failure to take this process into account might seriously bias any analysis of thermal evolution, the cornerstone of the climate change hypothesis.

Key words: Temperatures, urban heat island effect (UHI), homogeneity, climatic change.

1. Introduction

Much research has been devoted in the past three decades to climate change and mankind's influence on the climate. This intense research activity is justified by the current hypotheses regarding the future of the climate. However, despite the great striving to control data quality, many uncertainties still persist in this domain, in which middle-degree, or perhaps larger, oscillations should be examined with circumspection, since they could be caused by a simple change of shelter or relocation of the observatories.

Thus, the evolution of temperature through the historical series available at the world's main laboratories cannot be readily analysed, because certain non-climatic processes need to be taken into account. Of these processes, the subtlest and most important is undoubtedly the urban thermal effect. Though this effect is undeniable, its importance is a matter of controversy. Cities have become cells or bubbles with very different climate conditions from those of the surrounding atmospheric or rural environment. This process is known as the urban heat island effect (UHI).

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The existence of the UHI effect is undeniable. The more buildings, pavement, inhabitants and activities accumulated in an area, the stronger the changes observed in the temperature trends, and even in the precipitation records. Cities have become nuclei or bubbles with specific climate conditions, quite different from the atmospheric rural environments that surround them. Therefore, during the day the urban temperature records are only a little higher than the rural ones, as much in summer as in winter. But during the nighttime urban temperatures are warmer than those on the outskirts, with differences in readings that can exceed 5 or 6 ºC.

Some of the energetic processes that lead to the generation of UHI are: the heat capacity and conductivity of building and paving materials, increased absorption of short-wave radiation due to canyon geometry, increased long-wave radiation loss because of the reduction of the sky view factor, anthropogenic heat sources, increased sensible heat storage and decreased evapotranspiration due to construction materials, decreased total turbulent heat transport due to wind reduction caused by canyon geometry, and lastly, the atmospheric pollution of the air covering the cities, which is capable of containing long-wave radiation, thereby increasing the latent heat. That effect may be a true Achilles heel when it comes to analysing temperature evolution.

The phenomenon was first investigated and described by Luke Howard in the 1810s [1]. The urban heat island (UHI) is a metropolitan area which is significantly warmer than its surrounding rural areas. The question being asked is, have urban areas contributed to the observed trend of warming temperature and influenced our knowledge of global warming? A view often held by sceptics of global warming is that much of the temperature increase seen in land based thermometers could be due to an increase in urbanization and the sitting of measurement stations in urban areas. In such a way it can be concluded that about half of the observed warming trend could be accounted for by the residual UHI effects in the corrected temperature data set they studied [2], so the rapid warming measured over the last century could be just a record of the urbanisation [3]. Consequently, researchers must remove heath island effects from temperature records to accurately estimate climate change.

Thus, whilst some climatologists now think that the warming in the temperature record from some small urban area is partly the result of UHI, other prominent scientific and the IPCC have concluded that the impact of the urban heath island on the temperature records is real but local and has only a negligible effect on regional or global trends. However while the "heat island" warming is an important local effect, there is no evidence that biases trends in historical temperature record [4, 5]. Studies that have looked at hemispheric and global scales conclude that any urban-related trend is an order of magnitude smaller than decadal and longer time-scale trends evident in the series [6, 7]. Parker [8] noted that warming trends in night minimum tperatures over the period 1950 to 2000 were not enhanced on calm nights, which would be the time most likely to be affected by urban warming. The infrared AVHRR imagery shows the relevance of that phenomenon. This effect is visible in all the seasons during the nigth but it differs during the day in the maximum temperature records [3]. Thus, the global land warming trend discussed is very unlikely to be influenced significantly by increasing urbanisation [8, 9].

This all requires awareness of the enormous difficulties involved in verifying the climate warming hypothesis, because of the great heterogeneity in temporal thermal series. Indeed, despite rigorous use of the most sophisticated statistical analytical techniques, this uncertainty in detecting significant trends remains present in all conclusions concerning the magnitude of the observed warming [10-15]. A major process in this uncertainty is the urbanisation effect [16-19].

2. Experiment

The temperature evolution in the Spanish Mediterranean region displays a significant climate warming trend. The value of this trend for the century would be appreciable, 1.6 ºC, equivalent to 1 ºC for the period 1950-2010. However, this value becomes even more striking if one considers that it only began to be detected after 1980, following a relatively cool decade (Fig. 1).

However, both the sharp post-1980 increase and the different magnitude of the warming recorded between these observatories, which lie quite close to each other, namely + 0.03 ºC/year in Castellón, + 0.02 ºC/year in Valencia, + 0.016 ºC/year in Alicante and a mere 0.014 ºC/year in Murcia, together with the varying behaviour of the maximum and minimum temperatures, have cast doubts on the anthropogenic or natural nature of the change, as well as on its actual existence [20] (Fig. 2).

Data used in the analysis belong to the network of meteorological stations for the Murcia Region and the Province of Alicante (Spain). That zone has an extensive weather station network with long-term series of more than 50 years. This network consists of four first order stations and thirty second order stations (Fig. 3). The analysis was done over the monthly mean minimum and maximum temperatures from the Instituto Nacional de Meteorología (INM).

Given that the validity of all conclusions on the evolution of the climate depend on the quality of the data, all the temperature series have undergone a rigorous process of quality control consisting of three steps. In the first step, a continuity and spatial coherence test has been applied to the data. If the data were loss or missing, they were reformed. Within this step, the records that have not reached a confidence level of 99% were rejected. The second step was the application of the homogeneity test. Firstly, an internal homogeneity test (sequence and Helmert methods) was applied and afterwards a relative homogeneity test.

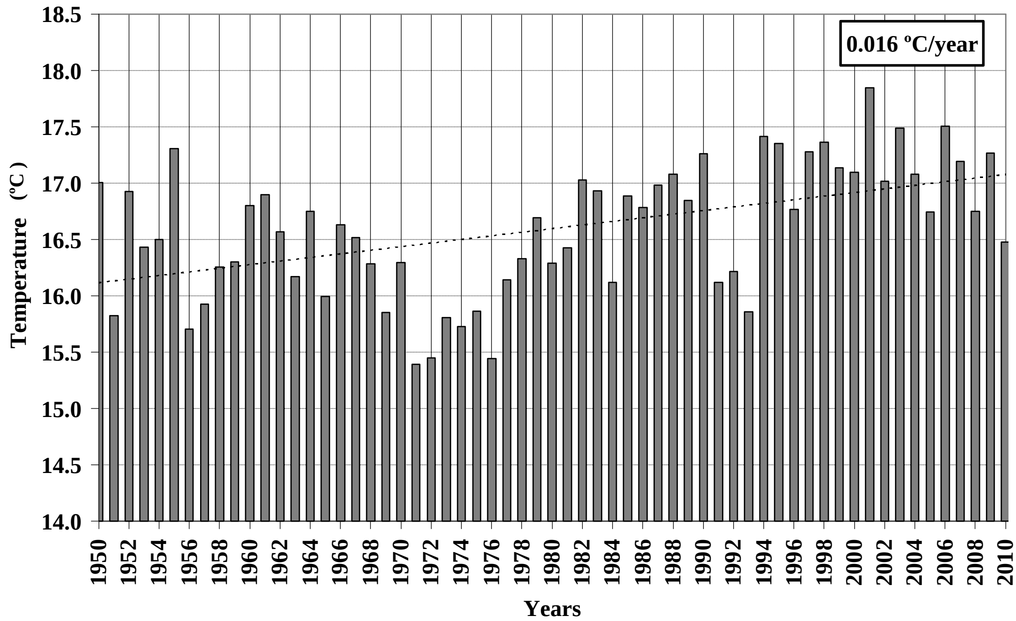

Fig. 1 Evolution of the homogenised mean annual temperatures in the Murcia and Valencia Region, INM [21].

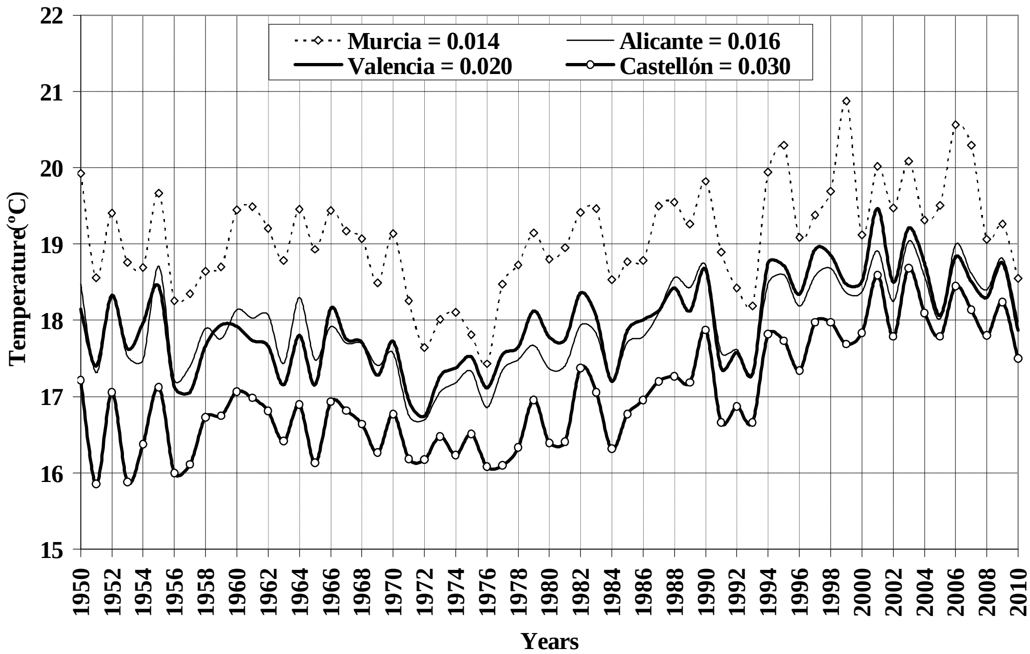

Fig. 2 Evolution of mean annual temperatures at the Murcia, Alicante, Valencia, and Castellón observatories.

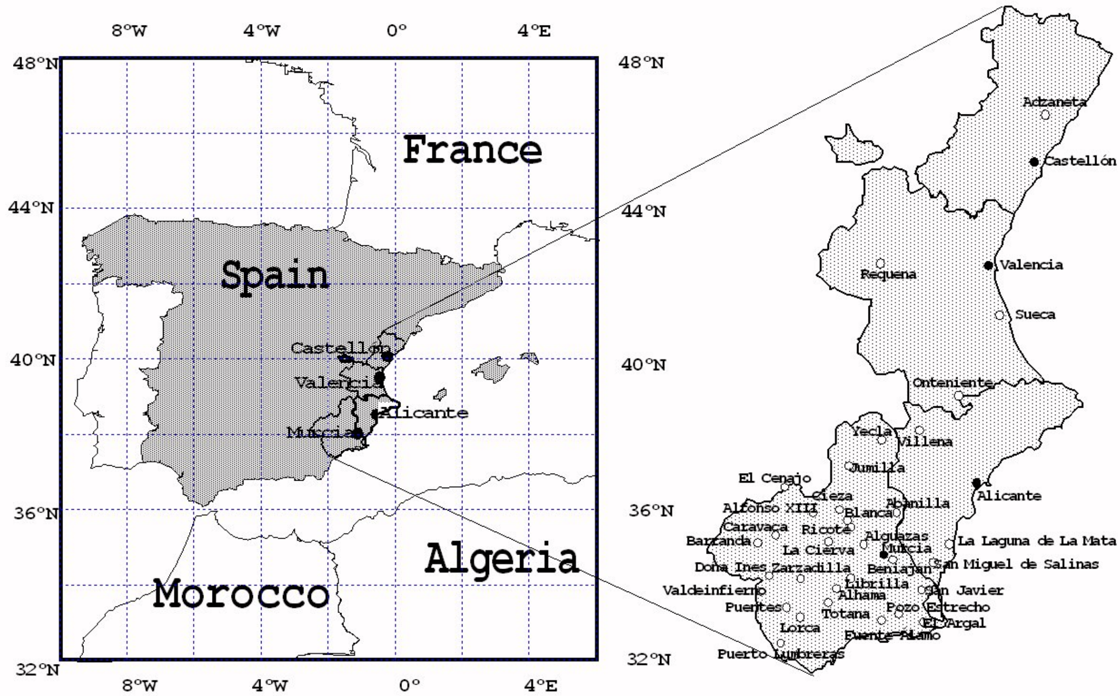

Fig. 3 Map of the major Spanish Mediterranean observatories used in this study (1950-2010).

That second step was used to ensure that most of the long-term series were not contingent. Consequently, a certain number of homogeneity tests and heterogeneity correction were applied to all the used records. The techniques used have been described exhaustively [22]. The third and last step consisted of a heterogeneity correction, which established the difference between the mean of the period of the series to be corrected and the mean of the period of the homogeneous series. That difference has been added to the difference of the values of the series to be corrected. Correlation coefficients between both series must be higher than 0.7 to be considered.

In this respect, after performance of the complex and laborious homogenisation process to correct the heterogeneities [13, 20, 22, 23], the assumption may be made that part of this temperature increase, 1 ºC in the period 1950-2010, is due to the urbanisation effect. An effect that has materialised progressively and cumulatively as the observatories has been gradually engulfed by city growth.

The result of this process may be reflected in the fact that most of the thermal increase has occurred in the minimum temperatures, with a value of 1.4 ºC in the period 1950-2010. The evolution of the maximum temperatures, with an increase of 0.4 ºC in the same period, would have been responsible for barely a third of this rise in temperature (Fig. 4).

As a result, the urban heat generation process continues to be one of the major uncertainties in the climate change hypothesis. And with good reason, since this scientific hypothesis is based on the records of historical observatories which, in the case of the Mediterranean observatories, were established at the end of the 19th century on town outskirts, and which have been progressively swallowed up by urban growth, with effects that need to be determined because they could be disguising real climate trends. Failure to take these effects into account might seriously bias the results and lead to errors in verifying the magnitude and nature of climate warming. This is evinced by the great difference in the trend value between the observatories located in large cities and those in smaller towns (Fig. 5).

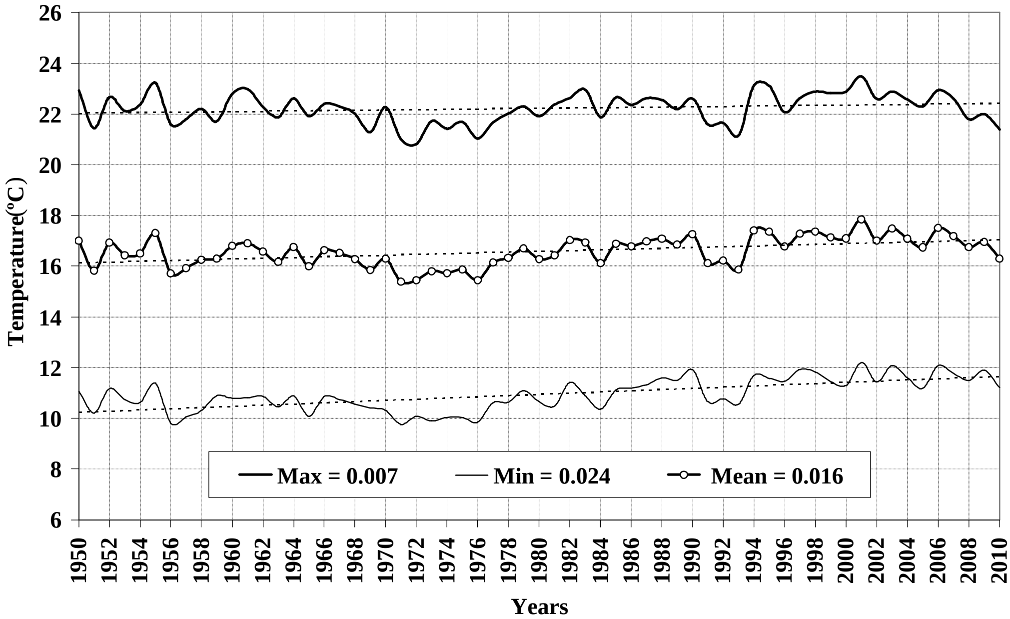

Fig. 4 Evolution and trend of the mean annual, maximum, and minimum temperatures at 34 major observatories in the Murcia and Valencia Region, INM [21].

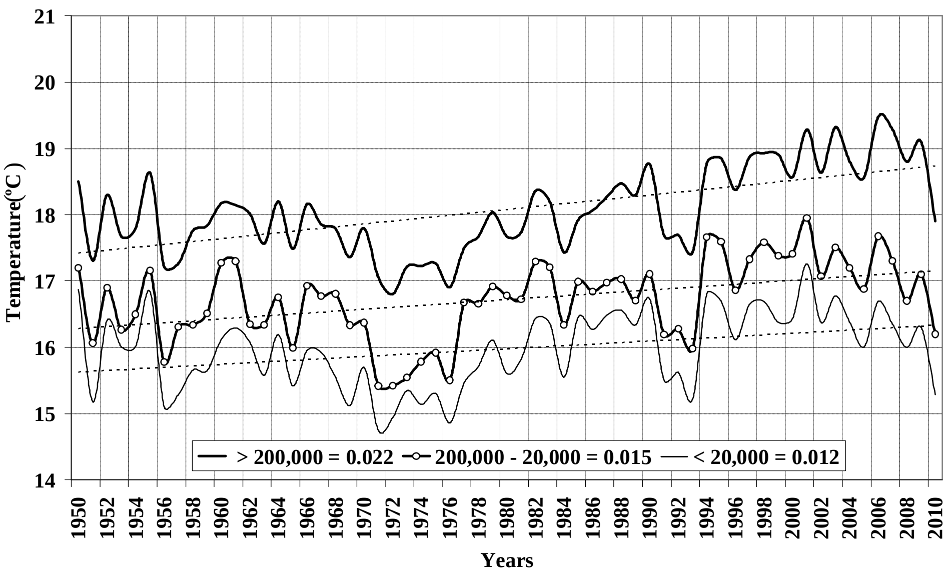

Fig. 5 Evolution and trend of the mean annual temperatures at the observatories in the cities of Murcia, Elche, Alicante, Valencia and Castellón and at the more rural observatories (towns with more than 200,000 inhabitants, and with fewer than 200,000 inhabitants and with fewer than 20,000 inhabitants), INM [21] and self generated.

3. Results and Discussion

The foregoing analyses suggest that the true "natural increase" in temperature, corrected for the urbanisation effect, could be much smaller than that posited by current studies and models, or possibly non-significant. In addition, the analyses justify further research into a process that could be seriously biasing the study of thermal evolution, the cornerstone of the climate change hypothesis [8, 17, 20].

3.1 The Observational Arrangement

In the present study, the urban thermal effect has been examined by installing three duly calibrated, automatic meteorological stations (Davis-Casella). These three stations have been located in the Castellón city area, a city that has undergone marked demographic growth in recent years (from 53,000 inhabitants in 1950 to 190,000 inhabitants in 2010) (Figs. 6 and 7).

The locations, shown in Fig. 8, were chosen to record the temperature at the city centre (Casino Antiguo station, 51 m), at the Mediterranean Sea surface (marine station on the BP Oil Platform, 12 m), on the western outskirts of the city (Universitat Jaume I, UJI station, 79 m), and at the INM observatory, (Instituto Nacional de Meteorología, 42 m) which is located on the southwestern outskirts of the city, around 4 Km of the Casino Antiguo station. The four stations are located on an E-W diagonal of just 10 km on the coastal plain. The marine station records two temperatures: air and the sea surface temperature (Fig. 9).

3.2 Results of the Analysis

The meteorological records analysed here cover the first ten years of the 21th century, from 2001 to 2010. During this period the three automatic meteorological stations (Casino Antiguo, UJI and marine station) have been constantly controlled and have functioned perfectly. Thus, though the observational period has been short, data recording and processing have been rigorous, making this a valuable experiment in regard to the process being studied.

3.2.1 Mean Annual Temperature

The mean annual temperature (Fig. 10) shows the great difference between the values of the meteorological station installed on the terrace of the Casino Antiguo in the centre of Castellón and the values at the marine station (BP Oil Platform), the university station (UJI) and the INM observatory located outside the built-up area. The mean annual temperature for the (2001-2010) period was 20.1 ºC in the city centre, while it was only 17.8 ºC at the sea surface air (18.9 ºC, SST) and 18.1/18.2 ºC on the outskirts of town (UJI and INM respectively). These values suggest that the mean temperature at the Casino station exhibits the considerable magnitude of the urbanisation effect.

3.2.2 Maximum and Minimum Temperatures

The difference between the mean annual maximum

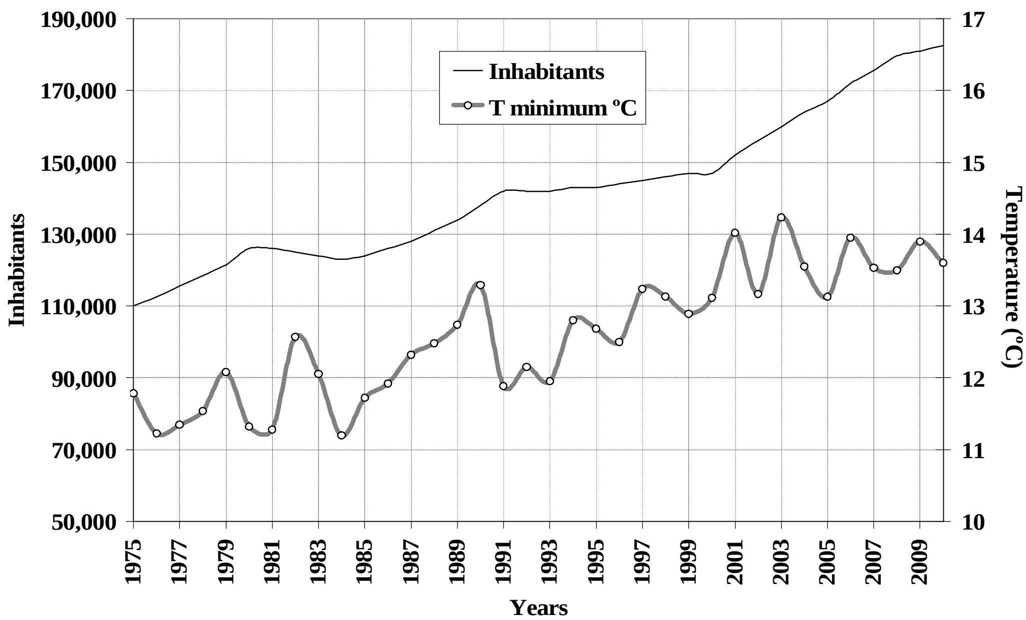

Fig. 6 Evolution of the inhabitants and the minimum temperature in the Castellón city area (1975-2010).

Fig. 7 Castellón city centre in 1950 and in 2010, with the Casino Antiguo building on the left.

temperatures is significant. Thus, a mean maximum value of 24.3 ºC was recorded at the city centre, while this was 22.4 ºC at the UJI station and 22.8 ºC at the INM observatory. The sea temperatures presented a value of 20.8 ºC, reflecting the thermal air regime in the surface waters of the sea (Fig. 11).

The behaviour of the minimum temperatures is even more significant. The annual minimum temperature regime exhibits an even greater difference between the urban values (16.5 ºC) and those recorded to the west of the city, on the university campus (13.7 ºC) and 13.6 ºC at the INM observatory (Fig. 12). The marine temperature (air) presented a value of 14.8 ºC.

4. Conclusions

Though the records obtained in the experimental

Fig. 8 Network of stations used in this study: Casino Antiguo, marine station on the BP Oil Platform (Islet), University Jaume I station (UJI) and at the INM observatory on the western outskirts of the city.

Fig. 9 Marine station on the BP Oil Platform (Islet) in the left side of the photograph. The geographic co-ordinates are: 39º56´42´´N and 00º01´36´´E.

meteorological network only cover the first ten years of the 21th century, from 2001 to 2010, they allow some very interesting conclusions to be drawn regarding the effect of urban growth on temperature. The analysis performed has allowed assessment of the magnitude of this heat effect in Castellón, a city of 190,000 inhabitants. Urban heat generation has been shown in both the maximum and minimum temperatures. However, the minimum temperatures have exhibited the greatest effect. Thus, the differences between the city centre temperatures (Casino Antiguo) and those at the periphery (university campus) are quite high: 2 ºC in the maximum temperatures, and 3 ºC in the minimum temperatures. Such differences entail a strong bias in the determination of the mean temperatures.

These results pose an important question. What would be the real current temperature obtained in the historical data if the urban effect was eliminated? This paper highlights the nature and significance of this process in the Spanish Mediterranean region. The heat island effect is undeniable and of great magnitude. The notable differences in temperature between the city centre and the outskirts demonstrate the need for further analysis of the process. This should commence with a careful examination of the thermal evolution recorded at observatories far from human activity, as set out in the current regulations on atmospheric

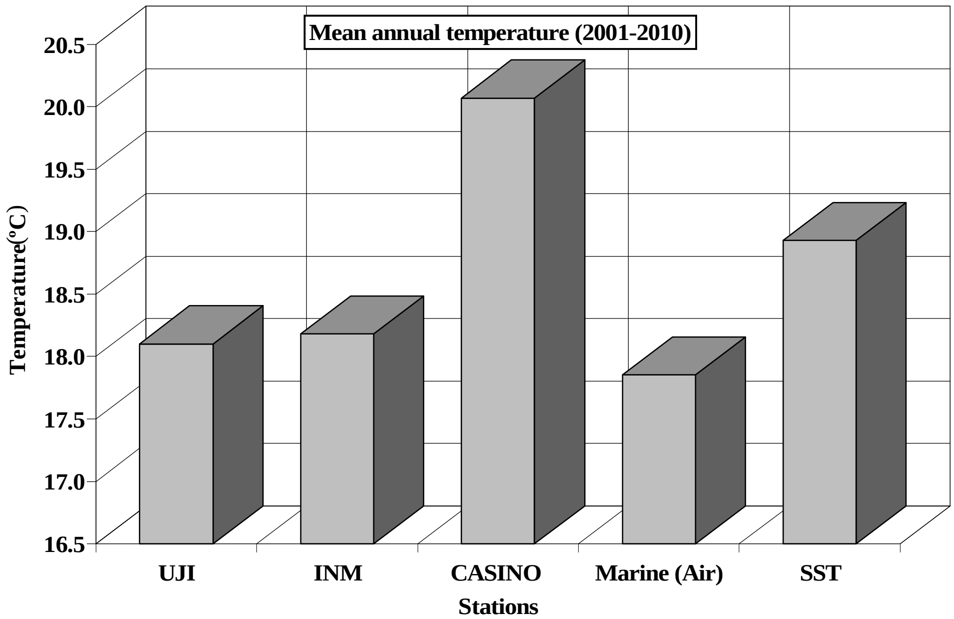

Fig. 10 Mean annual temperatures at the city centre and peripheral stations (2001-2010).

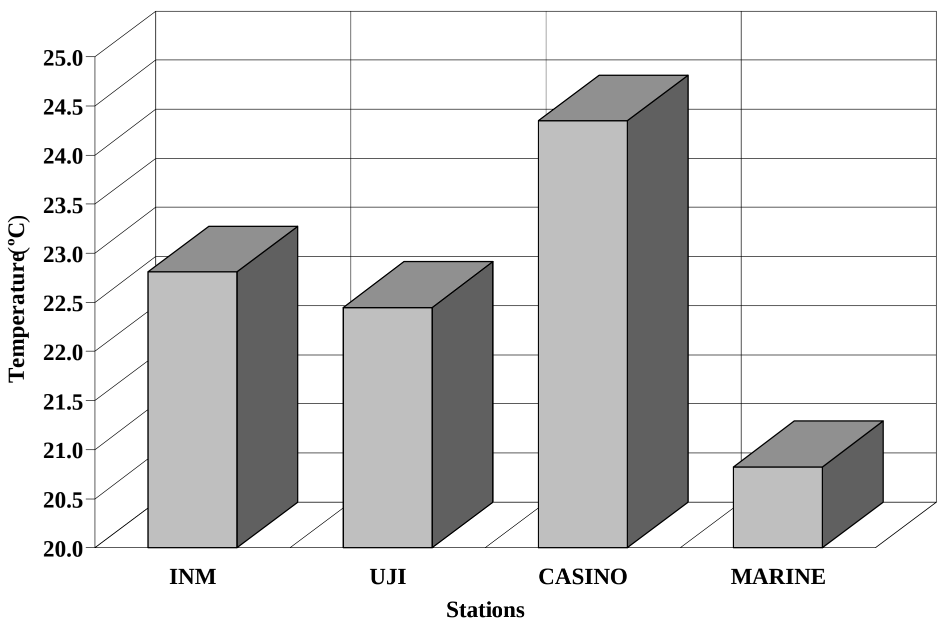

Fig. 11 Differences in the mean annual maximum temperatures between the city centre and peripheral stations.

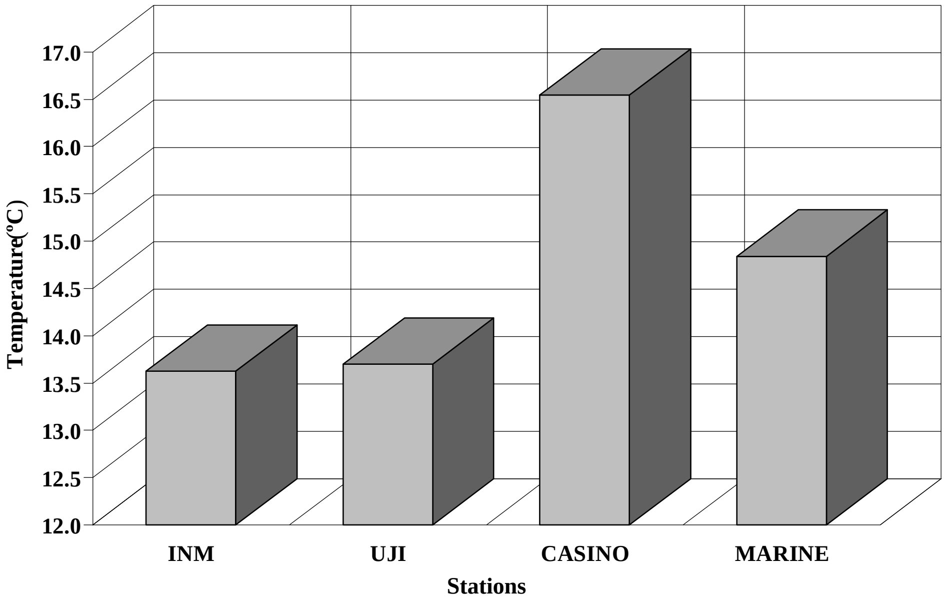

Fig. 12 Thermal differences in the minimum temperatures between the city centre and the peripheral stations.

pollution in special ecosystems.

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