CLIMATIC OR NON-CLIMATIC WARMING IN THE SPANISH MEDITERRANEAN?

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Abstract

The present study validates the conclusions drawn in the Spanish National Plan on Climate Change (1996) on the thermal evolution of the Mediterranean region over the period 1950–1996, rigorously treated by the SNHT (Standard Normal Homogeneity Test). In this context, it was considered judicious to verify twenty years later, in 2016, the validity of the trends obtained and conclusions drawn at the end of the 20th century (1996) regarding the regional climate. In this study, two analytical techniques were used: analysis of the regional temperature trend (1950–2016) and localised experimental verification (2001–2016). The territorial delimitation was intended to provide the thermal series used with greater spatial cohesion. The cohesion was further heightened by two factors. The first was the greater proximity to the experimentally investigated area (2001–2016) of the thermal processes inherent to the urbanisation effect. The second factor was that it included the coastal area facing the Columbretes Islands (28 miles off the coast of Castellón). The island climate series, analysed for the first time, entail a profound revision of the conclusions drawn to date. The conclusions entail, as noted, a profound revision of the trends indicated in our previous studies on the processes inherent to the region's thermal evolution.

***Key words**: Temperatures, urban effect, heat island, homogeneity, SNHT, climate change*.

1. Introduction

The last three decades have witnessed extensive research into climate change and into human influence on the climate. The starting point may be deemed the creation of The Intergovernmental Panel on Climate Change (IPCC). However, despite the formidable efforts made to control data quality, numerous uncertainties persist in this vibrant domain, in which swings of half a degree, or perhaps more, must be carefully examined as they could stem from a simple change of shelter or relocation of the observatories.

Analysis of temperature data records is consequently no simple task, as non-climatic processes such as the effect of cities encroaching upon observatories and the relocation of most observatories also need to be accounted for. Any analysis of regional or global temperature evolution thus bristles with difficulties and uncertainties. The subtlest and most important of these is undoubtedly the urban heat effect. Cities have become cells or bubbles of very different climate conditions from those of the atmospheric or rural surroundings in which they are located. This process, known as the urban heat island (UHI), appears to have been deliberately ignored, as it could otherwise constitute a real Achilles heel in temperature evolution analyses. In this regard, regional temperature analysis, with spatial cohesion, could contribute to eliminating such "noise" from temperature records and possibly allow detection of a climate warming trend.

The answers put forward by the scientific community show that, though the UHI effect seems undeniable, its importance is subject to controversy. The IPCC scientific protocols themselves, while recognising the city microclimate effect, indicate that this effect is only local and practically negligible in the regional or global trend. Thus, under the influence of the ocean, the overall UHI of the trend, would tend to zero (IPCC, 2007). In short, while it may be accepted that urban heating is of local importance, there is no evidence that it alters the global temperature trend (IPCC, 2007; Trenberth *et al*, 2007).

However, the IPCC Fifth Assessment Report (IPCC, 2013) has begun to profoundly review those scientific considerations and bases regarding the UHI. Analyses of the process in China and in other industrialised areas have drawn further attention to these issues. Thus, on comparing the temperature of urban areas and rural areas, various researchers have concluded that the urban effect could account for between 40% and 80% of the observed thermal trend in the last few decades (Ren *et al*, 2007; Yan *et al*, 2010. At the same time, in the USA, McKitrick and Michaels (2007) concluded that half the warming trend observed between 1980 and 2002 could stem from changes in the uses of surfaces. It has been attempted to weight or reduce these magnitudes by satellite radiation and reanalysis measurements (Parker, 2011; Jones *et al*, 2012; Vose *et al,* 2012). However, these reductions have not precluded a profound revision of the statements of the IPCC's fourth report (IPCC, 2007). Thus, Efthymiadis and Jones (2010) concluded that the urban influence, would currently only be 0.02 ºC per decade and up to 15% of the global warming trend recorded between 1951 and 2009.

These difficulties justify the ongoing quest for comparative techniques of homogenisation algorithms (Mitchell *et al,* 1966; Sneyers, 1975; Easterling and Peterson, 1992; Lamarque and Jourdain, 1994; Easterling *et al,* 1997; Moberg and Alexandersson, 1997; Venema *et al,* 2013). Indeed, as the validity of any conclusion on climate evolution depends on data quality, all the series used need to undergo a certain number of control operations. Thus, together with the internal homogeneity tests, relative homogeneity tests have enabled acceptable homogeneity control and correction of heterogeneities. The method used in the present study is based on the methodology SNHT (Standard Normal Homogeneity Test) set out by Alexandersson (1986) and Moberg and Alexandersson (1997).

2. Thermal evolution in the Western Mediterranean

2.1. The regional network of observatories and series quality control

The basic scientific objective in this study was to establish, with the greater possible rigor, the trends displayed by the regional climatology between 1950 and 2016, in order to verify whether they matched the forecasts of the climate change models. This verification required taking into account the thermal series recorded at the regional observatories. The AEMET (State Meteorology Agency) regional network, after the quality control processes, consisted of 10 observatories that, with series over 67 years long, covered the period 1950–2016.

The analysis performed focused on the Mediterranean region of Valencia (23,255 km²). This territorial delimitation was intended to provide the thermal series used with greater spatial cohesion, avoiding any possible bias from the incorporation of the Murcia Region (11,313 km²) observatories (Quereda Sala *et al,* 2016). These observatories, initially included in the spatial unit of the National Climate Plan, tripled, in the rural observatories category, those of the Valencia network (Quereda Sala *et al,* 2000; Quereda Sala *et al,* 2004). Moreover, the ten Valencia observatories provide a more consistent climatic framework for the experimental processes recorded in the Castellón area (2001–2016), Castellón having one of the three coastal first-order observatories forming the core of the present study, weighted on a similar number of urban and rural observatories.

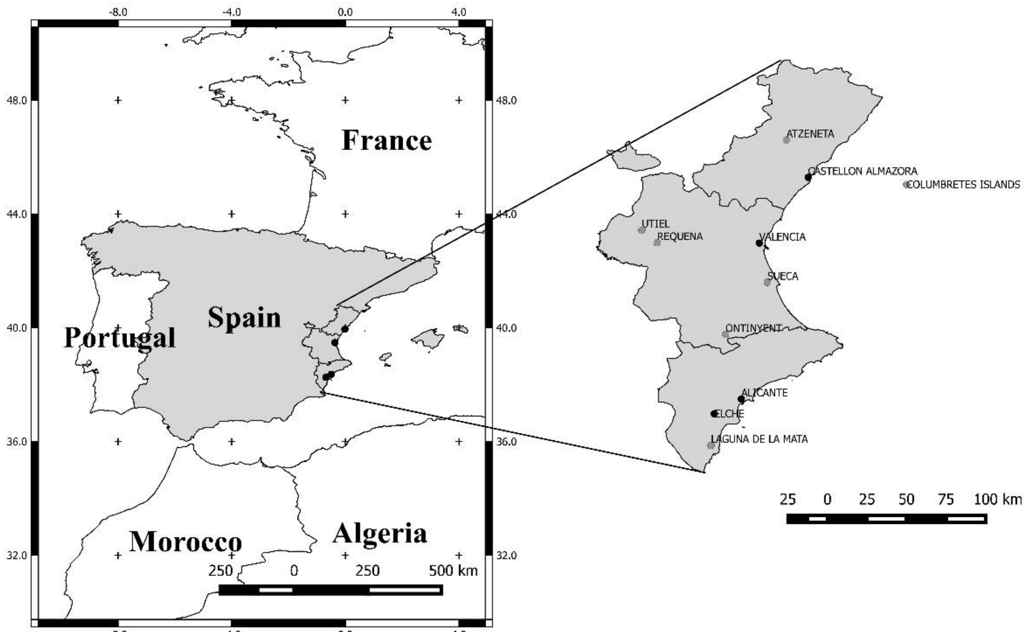

Figure 1. Map of the regional network of observatories with complete temperature series over the period 1950–2016. The observatories in bold type correspond to urban centres with more than 200,000 inhabitants. Of these, Alicante, Valencia, and Castellón are first-order observatories in the AEMET (State Meteorological Agency) regional network.

2.2. Results of the regional temperature evolution

The analysis results evidenced a climate warming trend in the temperature evolution of the Spanish Mediterranean region. The secular mean value of this trend, in the first-order observatories (Alicante, Valencia, and Castellón), was notable: 2.4 ºC, equivalent to 1.6 ºC for the period 1950–2016. This value even acquired a “dramatic” warming magnitude, as it only began to be detected from 1980 on, after a relatively cool preceding decade (Figure 2).

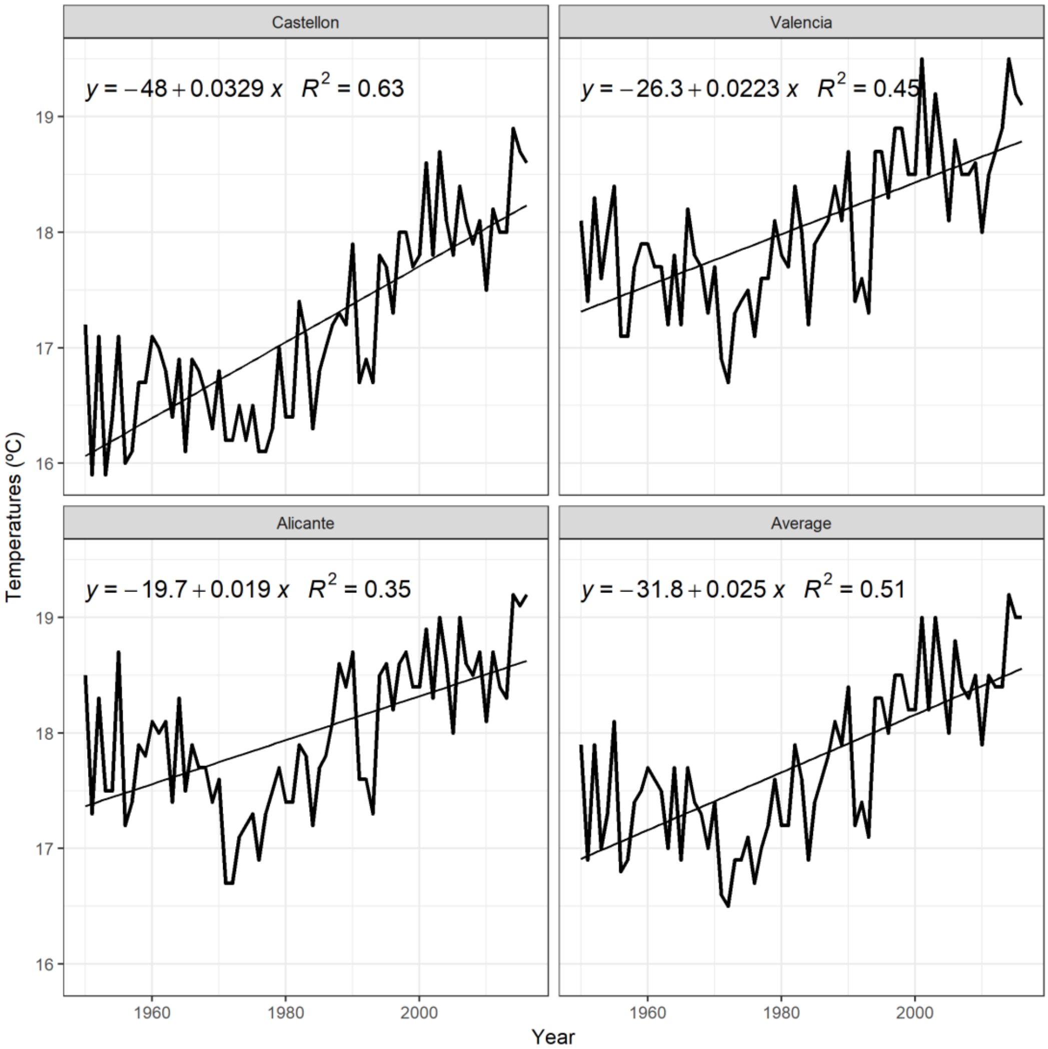

Figure 2. Evolution of mean annual temperatures (1950–2016) in the Valencia Region on averaging the three first-order observatories (Alicante, Valencia, and Castellón), of the regional network (AEMET).

However, both the “abrupt” rise from 1980 on and the different warming magnitudes recorded between very close-lying observatories: + 0.033 ºC/year in Castellón, + 0.022 ºC/year in Valencia, and only + 0.019 ºC/year in Alicante, as well as the different behaviour of the maximum and minimum temperatures, raised doubts with regard to the nature and magnitude of the (anthropogenic or natural) change (Figure 3).

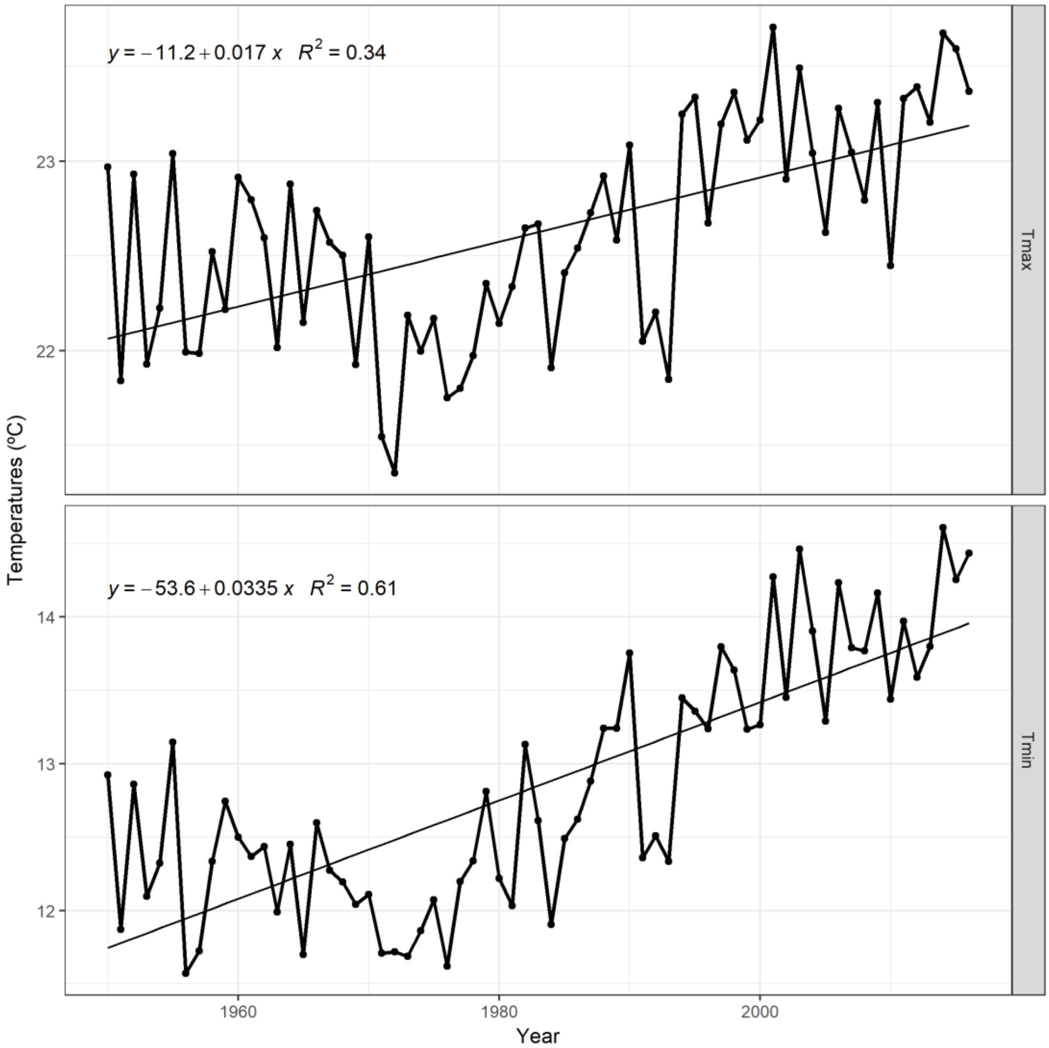

Figure 3. Evolution and trend of mean annual maximum and minimum temperatures in the network of first-order observatories (Alicante, Valencia, and Castellón) (1950–2016).

Consequently, the arising doubts regarding the true warming trends urge trend analysis, in particular because part of the temperature rise could stem from the urbanisation effect. As noted above, this effect has been evidenced progressively and cumulatively, as the observatories have been gradually enveloped by the cities in their expansion. The result of this process may be reflected by the fact that most of the regional thermal rise occurred in the minimum temperatures, with a value of 0.033 ºC over the period 1950–2016. The evolution of the maximum temperatures by 0.017 ºC, during the same period, would hardly have contributed half the warming in the maximum temperatures. Consequently, the urban heat generation process persists as one of the main uncertainties in identifying the nature and magnitude of the regional climate warming trend.

However, the regional temperature records show an undeniable warming throughout the 20th century. This climate warming is validated by the mean recorded temperature on the Columbretes Islands in the period 1905–1926 (Wrobel, 1940) and the mean value of the recent period 1992–2016

(AEMET). The records at the beginning of the century correspond to the observations of the lighthouse keeper who lived, with his family, on the islands at that time. The current records correspond to the automated AEMET observations since 1992. Those records indicate that the mean temperature rose by 1.4 ºC from the 1906–1925 mean value, 17.1 ºC, to the 1992–2016 mean value, 18.5 ºC. This island warming was not influenced by any urban effect but, if such an influence did occur, by the rise in sea surface temperature (SST).

This weather station is located next to the automated lighthouse on the Columbretes islands, which comprise four small volcanic islands 28 miles off the coast of Castellón. The archipelago, of a volcanic nature, is uninhabited and has an area above sea level of just 19 Hm^2, 14 of which correspond to Columbretes Gran, which rises 67 metres above sea level. The automated lighthouse and the weather station are located at this height, and their records were subjected to systematic control of time correlations with the records from the sea platform and the Castellón harbour lighthouse (Figure 4).

Figure 4. The Columbretes islands are about 28 nautical miles off the coast of Castellón. (39°55′00″N 0°40′00″E).

3. The "experimental" analysis of the urban thermal effect (UHI)

The above justifies rigorous investigation of a process that could be seriously biasing the study of thermal evolution, the veritable axis of the climate change hypothesis (Lee, 1992; Quereda Sala *et al,* 2000). Indeed, in its introduction, the recent PNACC (National Plan on Climate Change in Spain, OECC, 2006) notes: "to plan an adaptation for a warming horizon of 2 ºC is not the same as to plan one for a warming horizon of 4 ºC".

3.1. The observation arrangement

The urban thermal effect might therefore be a true Trojan in the analysis of thermal evolution. That is, the true "natural rise" of the temperature, corrected for the urbanisation effect, might be much smaller than that suggested by current studies and models, hence justifying rigorous investigation of this process (Quereda Sala *et al,* 2015). The investigation conducted was based on the records of five observation stations located in the Castellón city area, a city that has witnessed notable demographic growth in recent years: in 1970 the city had 93,000 inhabitants, whereas in 2016 it had close to 200,000 inhabitants.

Of those five observation stations, four (Casino Antiguo, UJI, Port, and Platform) belong to the Universitat Jaume I (UJI) network of automatic weather stations, while the fifth belongs to the first-order Castellón-Almassora observatory (AEMET, State Meteorological Agency). The observatories, shown in Figure 5, were selected to record the temperature in the urban centre of Castellón de la Plana (Casino Antiguo) and, at the same time, on the city outskirts (AEMET, UJI, Port, and Platform observatories). Every station was rigorously calibrated with two instruments (CASELLA-DAVIS). With a view to having the freest aerological conditions, at the Casino central observatory, the station located 5 metres above the terrace was used; at the UJI, the outside on-campus station was used, while the data of the port station and of the marine station on the BP Oil Platform, the station farthest removed from urban influence, were averaged. The experimental study also included the exceptional observatory on the Columbretes islands.

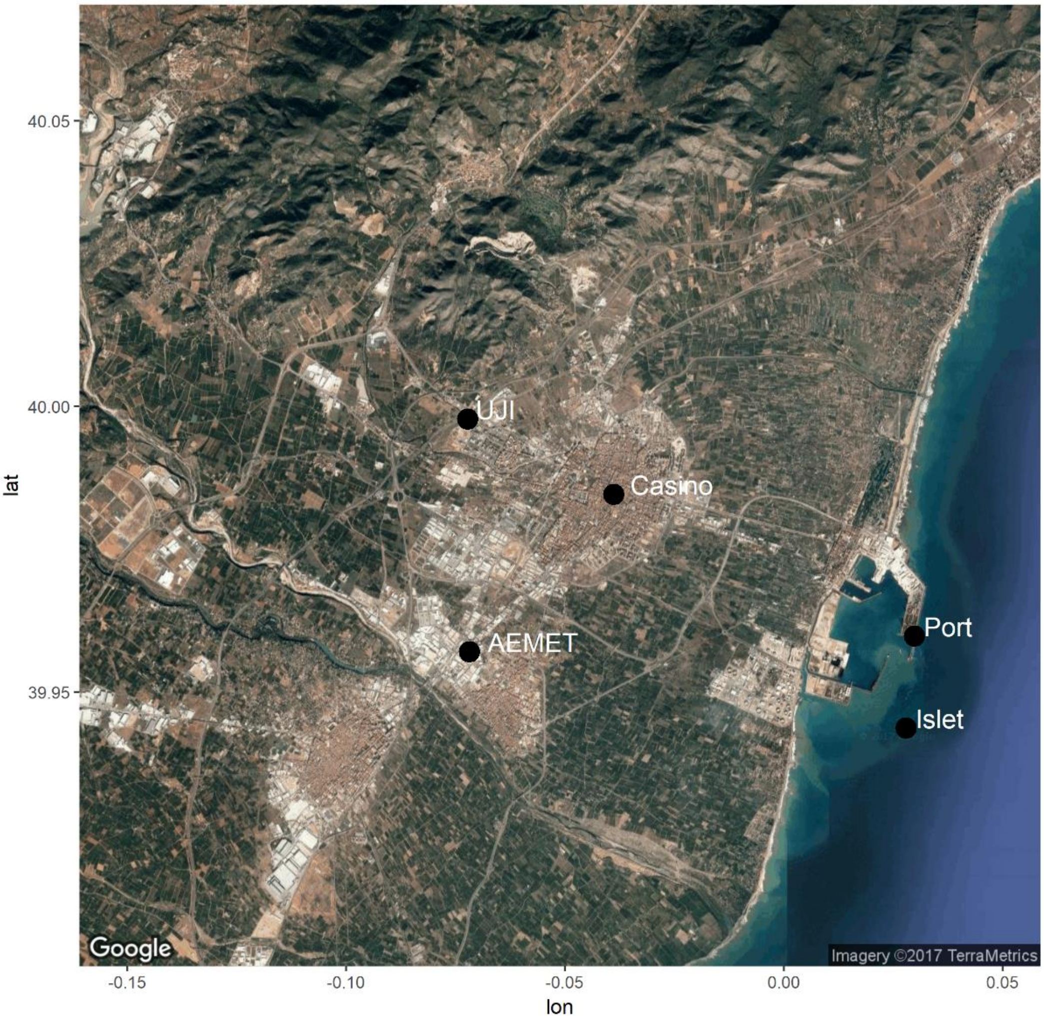

Figure 5. Network of stations used in this study: university marine station on the BP Oil Platform (Isleta), Universidad Jaume I stations (UJI, Casino, Port), and Castellón-Almassora observatory (AEMET).

3.2. Results of the experimental analysis

The meteorological records analysed here cover the first sixteen years of the 21st century, the period 2001–2016. In this period, together with the operation of the AEMET observatory, the four automatic weather stations of the university network were constantly controlled and calibrated. The resulting analysis, in a period of acceptable length, was thus extremely rigorous in all records and the experiment may be deemed of high value with regard to the UHI (Urban Heat Island) effect.

A great difference can be observed between the mean annual temperature (Figure 6) of the Casino Antiguo station in the city centre, 19.3 ºC, and that of the other three meteorological stations located on the urban outskirts (AEMET, UJI, and Port), with mean records of 18.1 ºC (UJI, outside on-campus), 18.7 ºC (AEMET), and 18.5 ºC (Port). The mean value of the Port station was almost identical to that recorded at the BP Oil Platform station (18.3 ºC), at 14 m above sea level and in the air–sea interface, with a SST (Sea Surface Temperature) of 19 ºC. The mean annual temperature on the Columbretes islands was 18.5ºC, very close to that of the Port and the Platform.

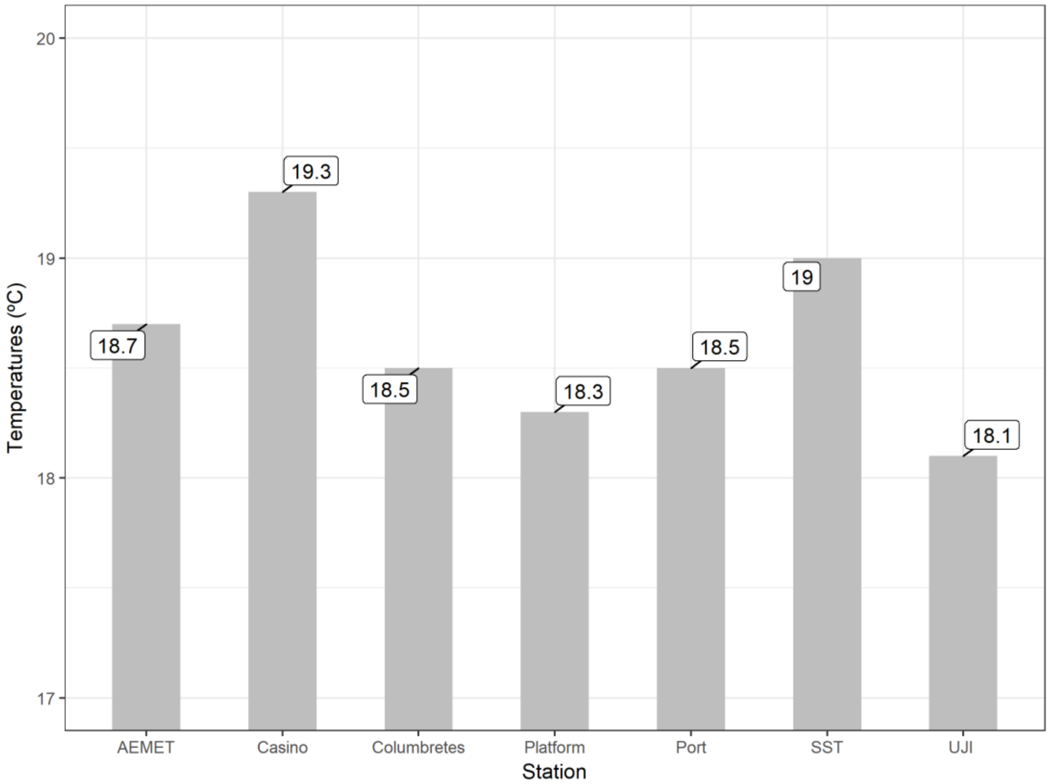

Figure 6. Mean annual temperatures at the different observatories (2001–2016).

These results allowed the great magnitude that the UHI may be acquiring at observatories currently recording their data within urban areas to be evaluated. Thus, assuming that the observatories on the Castellón city outskirts were unaffected by the influence of urban heat, the value of the UHI with respect to the urban centre (Casino) would swing between 0.6 ºC at the AEMET observatory (only 2 km from the Castellón city centre) and 1.2 ºC, 0.8 ºC, and 0.8 ºC at the UJI outside on-campus, Port station and Columbretes, respectively.

This urban influence constituted the true nature of the process, evidenced by the differentiated thermal gradient found between the mean maximum temperatures and the mean minimum temperatures (Figure 7) at the urban centre and on the outskirts. Indeed, the mean minimum temperatures exhibited a difference of 2.4 ºC between the university station (UJI) and the Casino, and a difference of 1.8 ºC between the Casino and the AEMET observatories. However, in this order of mean minimum temperatures, there appears to be an anomaly in the difference recorded between the Casino (15.8 ºC) and the Port (15.6 ºC) station, which was only 0.2 ºC. This further highlights the great influence that variations in the surroundings have on thermal records. Thus, the Port station, located at the end of the harbour dyke of the lighthouse, acted as an annual atmosphere–sea interface governed by a mean annual SST of 19 ºC and 15.6 ºC in the mean minimum temperatures. The sea's thermostatic role was shown to be determinant, as evidenced by the mean minimum temperature, 16.1 ºC, and the mean maximum temperature, 20.8 ºC, on the Columbretes islands.

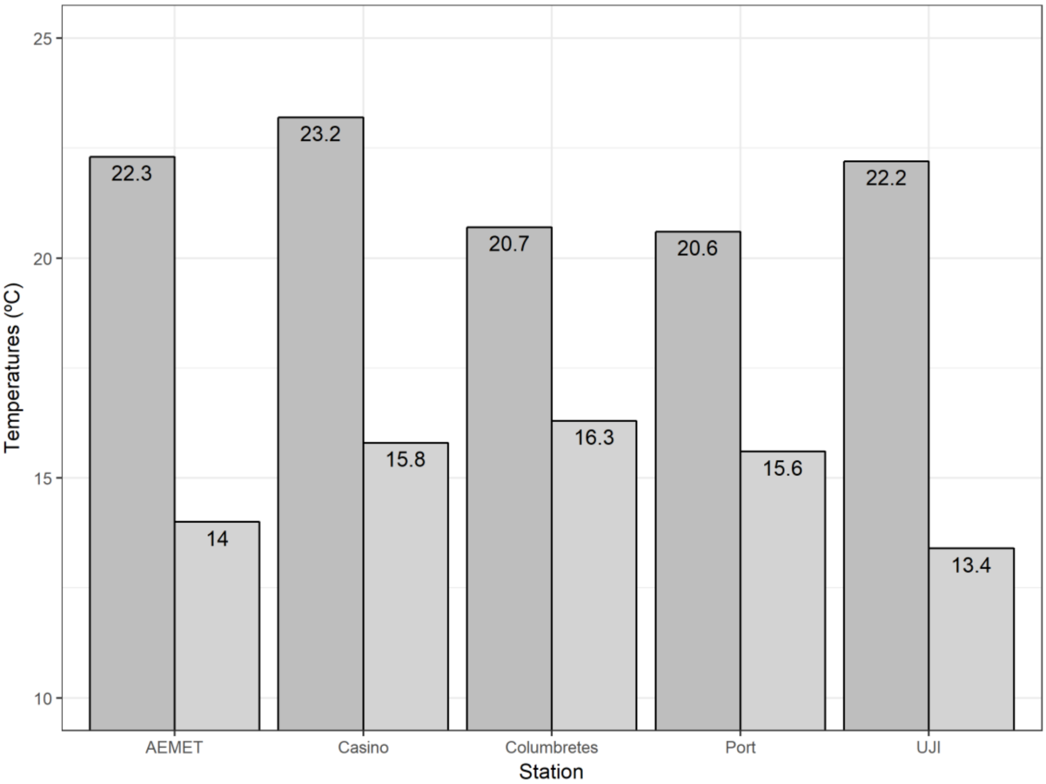

Figure 7. Mean maximum and minimum temperatures.

4. Conclusions

This study completes the line of work on thermal evolution in the Mediterranean region (Murcia and Valencia Regions) in the Spanish National Plan on Climate Change. Twenty years after the conclusions drawn in that framework were published (1996), the present investigation has verified, in 2016, the validity of the thermal trends that the regional climate displayed at the end of the 20th century. The analysis conducted in this study has focused on the Mediterranean region of Valencia (23,255 km²). The territorial delimitation was intended to provide the thermal series used with greater spatial cohesiveness, avoiding any possible bias from the incorporation of the Murcia Region observatories. The ten Valencian observatories provided the experimental processes recorded in the Castellón area (2001–216) with a more climatically consistent framework. The Castellón city area having one of the three coastal first-order observatories that form the core of this study, weighted on a similar number of urban and rural observatories. The validation and experimental study were based on the exceptional records from the insular environment of the Columbretes islands. The observatory on this small, uninhabited volcanic archipelago, 28 miles off the coast of Castellón, allowed estimation of a real warming of 1.4 ºC in the 20th century in the Valencia Region.

The Castellón observatory recorded a thermal increase of 2.4 ºC between 1912 and 2016, while that recorded on the Columbretes Islands was 1.4 ºC in the same period. This raises a vital question in the regional and global rising-temperature process. Are urban areas contributing to the observed warming trend on which climate change is based? The answer to be drawn from our analysis is affirmative. This answer, at least in the Mediterranean region, then leads to the question: What temperature would currently be obtained in the historical series of the Mediterranean region if the urban effect were removed? This question might be answered through the thermal evolution recorded at the historical observatories of Castellón closest to the studied area and, in particular, through the climate records of the Columbretes Islands. These records, unaffected by urban influence, have shown a warming of 1.4 ºC during the 20th century. The present study thus verifies that there is real climate warming in the Mediterranean and that the added value of the UHI could account for 42% of the recorded warming trend.

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