

# THE URBAN HEAT ISLAND IN THE CITY OF LLORET DE MAR

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## I. INTRODUCTION

The Urban Heat Island (UHI), derived from urban climate change, is a well known phenomenon that has been widely studied by different experts, especially in North America and Asia. It is a thermal phenomenon that is developed in urban areas and is caused due to the different temperature levels that exist in center of a city and in its suburbs. Three main factors explain this thermal difference: the heat generated from combustion; the slowing the cooling rates of urban areas due to thermal prosperities of buildings materials; and the part solar radiation that is returned to earth's surface by the atmospheric impurities and absorbed by urban surface (Domínguez, 2002).

There are two types of UHI: the *atmospheric urban heat island* is the thermal air difference between urban areas and rural areas; the *surface urban heat island* represents the existing thermal differences of urban materials and urban pavements (roadway, roofs sidewalk, etc.). Differences between both types can be observed due to the mechanism of generation, the technique used to identify them and the mitigating measures (Fernández, 2009).

The study analyses the influence of urbanization on the temperature in the small-sized city, describing its UHI configuration and its location inside the city. The main objectives are:

- a) Extending the research about urban climate, which has been developed since 1980 in Spain, based on the thermal trends of Spanish cities (López et al, 1993; Fernández et al, 1998; Brunet, 1992; Dorta, Marzol y Rodriguez, 1992; Cuadrat, De La Riva y López, 1993; Ezpeleta, 1993; Moreno, 1993; Bello, 1994 y 1995; Ortigosa, Sobrón y Gómez et al, 1998; Montávez, Rodríguez y Jiménez, 2000; Alonso, Labajo y Fidalgo 2003; Vicente, Cuadrat, Sanz, 2005; Castillo, 2006; Ramiro, 2006; Ruíz, Romero, Mayer y Hernández, 2008; De la Morena, 2010; Acero *et al.*, 2013; Martínez 2014).

- b) Continuing with the study on UHI in tourist cities based on the thermal comparison between the season of more activity (summer) and the season of less activity (winter), analysing if the tourist activity introduces some modification into main trends of the phenomenon (Serra, 2007).

## **II. STUDY AREA**

The city of Lloret de Mar is situated in the Northeastern side of Iberian Peninsula, It belongs to the region of Catalonia, being part of Girona's province and of the south of the so-called Costa Brava area. The municipality has 48,7km<sup>2</sup> and 40.803 inhabitants (Padron 2013). It borders with Blanes (south-east), Tossa de Mar (north-east), Vidreres, Maçanet de la Selva (north) and Tordera (north-western).

Lloret de Mar was pioneer in Europe on the tourism in the 50s, turning into one of the most popular destinations in Spain. The urbanisation of the city was developed under the influence of the tourism activity. Therefore, free spaces of the urban area were consumed while new spaces were build (neighbourhoods, etc.), according to the "city garden" thesis. Consequently, tourism activity had an important impact on the urban morphology of Lloret de Mar.

This impact has generated a high urban growth and Lloret de Mar has evolved from a small tourist town to a big tourist city. The rapid population growth, caused by national immigration (south and south-western of Spain), made necessary to built new peripheral neighbourhoods and suburbs in order. These new areas were built without previous planning and lacking in many cases of proper urban infrastructures and/or services.

## **III. METHODOLOGY**

Methodology used is based on the mobile surveys. A portable thermo-hygrometer was installed in a car. This instrument, which shows air temperature and relative humidity, allows to obtain meteorological measures in diverse points throughout an itinerary. The research only analysed air temperature data.

Three mobile surveys were designed (18,9 km long). The surveys allowed to record 71 thermal values throughout the 47 observation points that were distributed around the city. Some points were shared by surveys to allow corrections about thermal values and so they are able to consider as simultaneous.

The most important survey is the third one, which is the longest. It crosses the city center and shows more points shared with the other two surveys. Besides it was last survey that was done, 2/3h after the sunset, when the UHI effect should have high intensity. Therefore, this survey is used to check that the thermal values are simultaneous.

## **IV. RESULTS**

The measurement campaigns were carried out from July 2010 to March 2014, in summers and winters seasons. Thus the data have been obtained during four summer seasons and four winter seasons. In total, measurement has been done in 160 days (80 in summer and 80 in winter), recording 11.360 thermals values and doing 3.024 km throughout three paths.

The highest summer intensity is recorded during the first measurement campaign in July 15<sup>th</sup> of 2010 with 6,6°C. The summer average of UHI intensity is 3,5°C. The summer spatial configuration of UHI shows a little core situated in Agustí i Font which is defined by isotherm of 25°C. Around this thermal core, the isotherm of 24°C covers the maritime area and the major part of Nucli Antic and Riera neighborhoods.

In winter seasons, the maximum value of UHI intensity is 5,5°C and it is gotten in January 28<sup>th</sup> of 2013. It is worth noting that in winter campaigns, it is the only day that the intensity gets a value lower than 1°C. The winter average intensity is 3,1°C. The UHI configuration shows an isotherm of 10°C, which marks the UHI's core, that it includes the major part of Nucli Antic and part of Riera neighborhoods. It is necessary to stress that the major part of tourism activities are in these neighborhoods.

The UHI of Lloret de Mar shows an intensity average of 3,3°C. The summer intensity is higher than winter intensity. The highest intensity of UHI is recorded in the first summer campaign (6,6°C) and it is 1,1°C higher than the maximum value of winter intensity which is acquired in the third campaign (5,5°C). The lowest intensity is in the first winter campaign (0,9°C) and it is 0,8°C lower than the minimum value of summer intensity (1,7°C), which is recorded in the second campaign.

During 160 days of measurements, the moderate intensities (2°C to 4°C) are the most common because they take place in the 56% of cases. Also it is important the rate of days (31%) that the intensity is high (4°C to 6°C).

The spatial configuration of UHI in Lloret de Mar shows a thermal core along maritime area. Isotherm of 17°C defines the scope of the thermal core, which covers the major part of Nucli Antic neighborhood and the part of Riera neighborhood, which is close to the sea. Therefore, it can be noted that the thermal core of UHI is localized, in summer as well as in winter, on the coast area. Around the UHI's core appears the isothermal of 16°C which includes the major of urban area, where the residential neighborhoods as well as Fenals are. These neighborhoods are around the old city and tourist neighborhood. Thus, these neighborhoods have the same temperature trends. It is curious that the extension of thermal core is different. Generally, the core is longer in summer than winter and it enters towards the old city and tourist areas. However, in winter, the core is situated in a small part of maritime area and it is focused on Jacint Verdaguer sidewalk. Therefore, Nucli Antic shows different thermal trends than other neighborhoods and the UHI's core is usually located in this neighborhood. Surely, the tourism might cause that the core shows a longer extension in summer because this season is when there are tourists and the economic activities achieve its peak, while in winter many parts of the city do not have any activity (hotels, souvenir's shops, pubs and the major part of bars and restaurants are closed).

Moreover, it should be noted that the thermal profiles have two issues to be underlined:

- There are cooling areas into the city. The analysis of thermal profiles shows some urban areas where the temperature decreases compared with its surrounding area. These areas show vegetation and a low density.
- The difference of maximum temperature trends between winter and summer. The summer campaigns show that the maximum temperatures are situated close to Just i Marlès avenue (tourist area). However, in winter campaigns, the maximum tempera-

tures are in Camprodom sidewalk. Moreover, in summer, the maritime area has stable thermal trends, while in winter trends show a slight fall in temperature. These different thermal trends might be caused by tourism because it produces a higher human activity along Just i Marlès avenue and the maritime area close to it.

## V. CONCLUSION

The measurements shows that there is a clear thermal contrast between the urban and rural areas of Lloret de Mar. Accordingly, it is demonstrated that the UHI phenomenon exists in the city. The average of UHI intensity is 3,3°C and the highest intensity is 6,6°C. The spatial configuration shows how of the old city (Nucli Antic) has a thermal trend warmer compared to the residential neighborhoods close it. The coldest areas of Lloret de Mar are in the suburbs in the north of the city. Besides, cool points inside the city can be observed. These points are displayed from close isotherms, which are colder than the territory where they are. Cold points are characterized by a low density building.

The core of UHI is located in the maritime area of Lloret de Mar, extending its influence through the sidewalks along Lloret beach and penetrating into Nucli Antic.

Finally, the comparison of measurement season shows that there are some differences on UHI trends between winter and summer. Thus, the summer average intensity (3,5°C) was higher than winter average (3,1°C). The UHI core is larger in summer than in winter and the thermal profiles show that the maximum of temperatures is moved towards tourist area of Just i Marlès in summer.

Tourism might be the cause of these differences, especially in the spatial configuration. The research carried out by Abtualeb *et al.* (2014) in Alexandria shows that the urban areas where are crammed with people show a hotter intensity than another urban areas. It is worth noting that the meteorological conditions is a decisive factor of UHI phenomenon, as Oke (1982) points out, the highest intensities of UHI occur in summer, when there are a rise in anthropogenic. The rise in anthropogenic heat is caused by the seasonal growth of population due to the arrival of tourists. This growth should be associated with the opening buildings (hotels, hostels and seconds residencies) or some part of buildings (bars, pubs, shops, restaurants...) which are closed in winter, and the higher traffic due to: the buses have more lines working and high frequency, the presence of tourist coaches, the incrementing in the number of private vehicles and delivery trucks. Lastly, it should be noted that researches have linked the UHI magnitude with the city's size, for example Oke (1973), suggesting that the rise in temperature of cities could be a function of the growth of population. In summer, the growth in Lloret de Mar is above 32.500 inhabitants, so the city goes from 40.800 inhabitants to 73.000 inhabitants or more. This growth might have influence on the highest summer intensity.