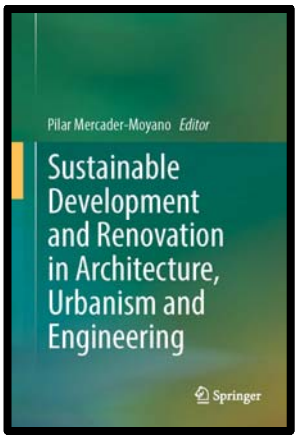

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Urban heat island of Madrid and its influence over urban thermal comfort

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Abstract. This work is part of the activities MODIFICA Project: Predictive model of the energy performance of residential buildings under conditions of urban heat island (BIA2013-41732-R). This project is funded by the Ministry of Economy and Competitiveness through the R + D + i, 2013 program, and the authors are involved in their development, together with the research group Bioclimatic Architecture in a Sustainable Environment - ABIO (UPM). The hypothesis of the project is the fact that the transformation of land for urban growth in the city of Madrid potentiates the effect of the urban heat island (UHI), which modifies substantially in the urban microclimate. The UHI is the result of the gradual replacement of natural surface by the urban area, whose surfaces absorb more solar radiation. This, coupled with other anthropogenic factors, increase the air temperature and cause an increase in local temperature. The consequence is a modification of the urban microclimate that affects to the comfort conditions in urban space and to the energy performance of buildings and, therefore, to the quality of life of the inhabitants.

Keywords Urban climate; heat island; climate change; comfort; public space

1 Introduction

This communication is part of the MODIFICA Project: Predictive model of the energy performance of residential buildings under conditions of urban heat island. BIA2013-41732-R, financed by the Ministry of Economy and Competitiveness through R & D + i 2013 program.

This part of the research aims to quantify the evolution of urban heat island in Madrid in the last 30 years. Urban heat island is a phenomenon by which the built-

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up areas have a higher temperature than less urbanized surrounding areas due to the progressive replacement of natural and vegetal surface by the urban area. Thus, the surfaces absorb more solar radiation and this, coupled with other anthropogenic factors, increase the air temperature and cause therefore a rise in the local temperature.

The result is a modification of the urban microclimate that affects to the comfort conditions in urban space and to the energy performance of buildings and therefore, to the quality of life of the inhabitants. The growth of the city and features of the new urban area determine the evolution of the heat island and the change in comfort conditions in different areas of the city.

2 Method

In this phase of the research we have started from the temperature data obtained during field work MODIFICA project in the period 2015-2016 for results and conclusions. Data collection was performed using urban, corresponding to three directions crossing Madrid and the towns of the surroundings, with different densities and types transects (**Fig. 1**). The measurements were performed simultaneously on the three routes. In addition to obtaining current values, the intention was to make a comparison with the data obtained in 1985 (López Gómez et al., 1988) on the same routes, as there are areas that remain in the same state edified and others that have changed over this period. In addition, measurements were carried out in similar summer conditions (11 July 1985 and 15 July 2015), at the same hours (from 21:00 to 23:00 solar time) and time stable in both cases. It should be noted that the temperatures recorded in July 2015 were higher than the average of the historical record of the weather station Barajas (about 4 more) due to a heat wave that happened during those days in the center of the peninsula. Along with this we have to consider the general trend of rising temperatures caused by climate change.

The ability to relate measurements at each point chosen routes with the building density and dominant type in the nearby area let see if variations in the temperatures are guidelines based on the urban area studied.

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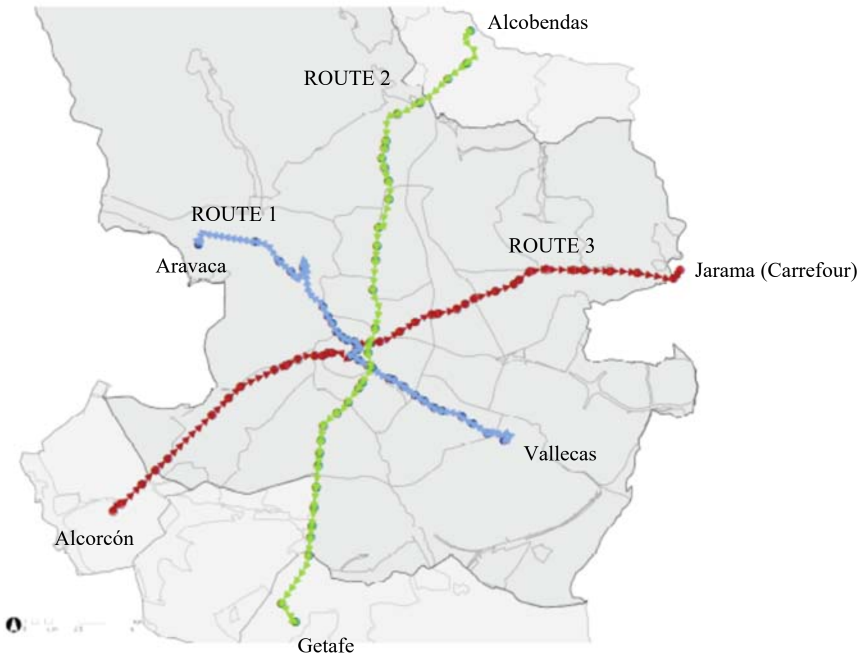

Fig. 1 Routes conducted in 1985 and 2015 to obtain data direct thermal island of Madrid. Source: Elaboration by the authors from Núñez, 2016

For the preparation of corresponding to the urban heat island in Madrid in July 1985 and 2015 have, in addition to the data obtained in fieldwork, used Map provided by the Stations of Quality Municipal Air (ECA) and by the stations of the State Meteorological Agency (AEMET). All data have been incorporated into a Geographic Information System (GIS).

3 Evolution of land use and heat island in Madrid during the period 1985-2015

It has been a continuous increase in per capita land use and housing in recent decades in the region of Madrid. The evolution and expansion of the heat island in Madrid has not occurred evenly throughout the territory. Measurements taken in 1985 allowed obtaining first information about setting it in the study area. The data collected during the years 2015-2016 show a direct link between recent urban developments, driven mainly in the first decade of s. XXI, and temperature variations

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observed in different parts of the city, compared to the base year (1985). The question that arises is to define urban factors that have had the greatest influence in this modification of the urban climate of Madrid during this period.

3.1 Land use in the region of Madrid between 1985 and 2015

According to data from Naredo and Garcia, land use rose from 112 m^2 / inhabitant in 1956, to 196 m^2 / inhabitant in 1980 and 269 m^2 / inhabitant in 2005. In other words, during the period considered land use increased 140% compared to the initial state considered, implying a major transformation of the territory and a high consumption of natural resources (Gomez, 2014). In addition, housing occupancy went from 448 m^2 / dwelling in 1956, to 551 m^2 / dwelling in 1980 and to 580 m^2 / dwelling in 2005 (Naredo and Garcia, 2008). One of the consequences of this great transformation that has suffered this territory in just 50 years, is the modification of the urban climate, particularly by increasing the heat island effect, which joins rising temperatures from climate change in the region , as numerous studies have pointed out (Tapia et al, 2015). In the last twenty years (1990-2010) the area devoted to urban uses in the metropolitan area of Madrid has increased by 45%, approximately 80,000 Ha (Nuñez, 2015)

3.1 Evolution of the urban heat island from 1985 to 2015

The measurement of the urban heat island in Madrid in July 1985 (Lopez et al, 1988) allowed to observe a decreasing temperature gradient that ran from the city center (records temperatures 28.6°C) to the peripheral areas (temperature records 24.6°C), with differences in temperature to 4°C between the area during data collection. The cause is the thermal inertia of the city, generated in part by the transformation of natural and permeable soils to urban land, paved mostly and therefore more waterproof and with a lower coefficient of albedo (more capacity to capture energy as heat). This fact is also produced by the presence of buildings and human activities, such as vehicular traffic, which increase the effect described.

It is observed in the temperature record and in the graphical representation of the heat island that the influence of the presence of a large mass of vegetation appears in **Fig. 2**, in the northwest of the city of Madrid (Monte de El Pardo), whose effects are channeled through the valley of the Manzanares. It also should be noted the presence of El Retiro park, located in the city center, and whose cooling effects conducive to a temperature difference with the neighboring districts of more than 3 ° C.

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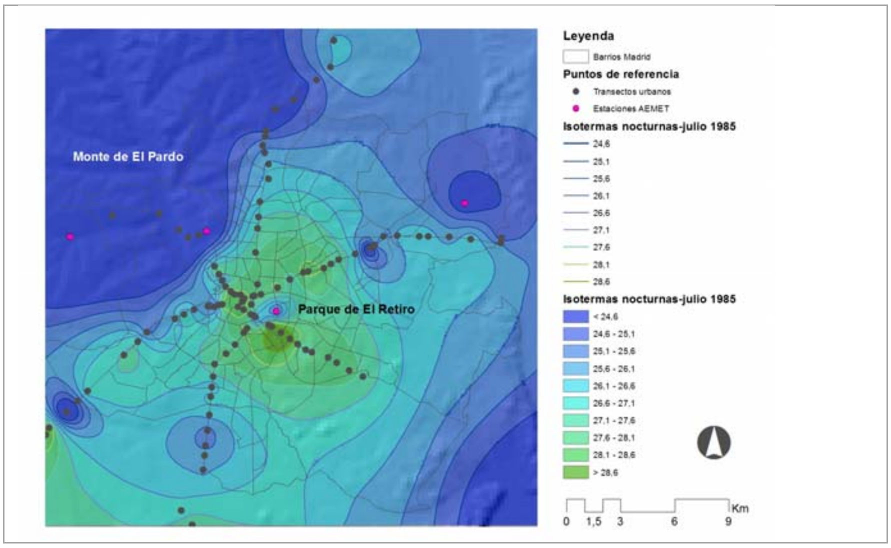

Fig. 2 Night isotherms in Madrid, July 11, 1985 (ºC). Source: Elaboration by the authors from López Gómez et al. (1988)

In the records taken 30 years later it shows how the heat island thermally accentuates and extends to areas where urban growth has been developed with more intensity, particularly in the northeast suburbs, southwest and southeast of Madrid (**Fig. 3**). In urban temperatures is also evident the influence of the intervention for "Madrid Rio", with the burial of the M-30 highway and the creation of a linear park that runs parallel to the Manzanares river and extending from El Pardo to Getafe . This action has led to a drop in temperatures and increases in extent, for 1985, the effect brought about by the Monte de El Pardo.

Notably, in the city center they have increased heat sources in intensity and surface relative to the reference year, although the influence of El Retiro Park as a thermal regulator great importance for this area is maintained.

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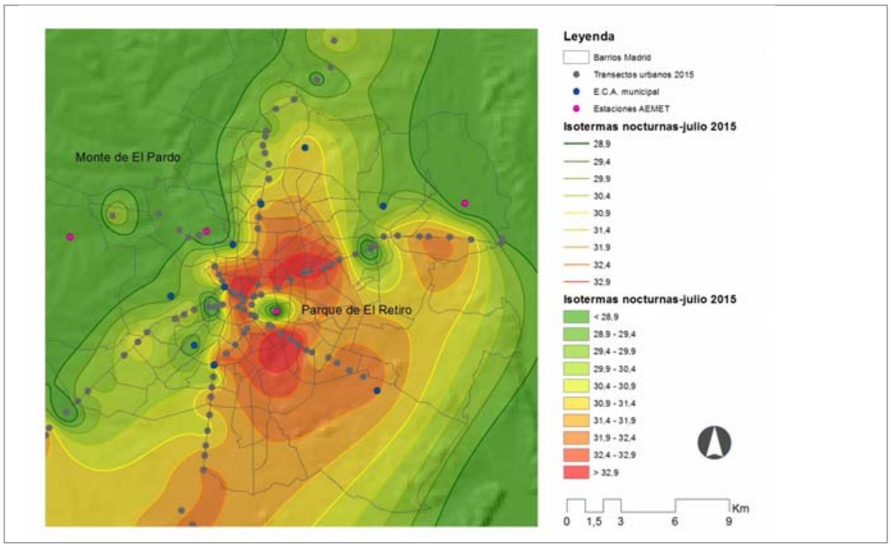

Fig. 3 Night isotherms in Madrid, July 15, 2015 (ºC). Source: Elaboration by the authors from temperature data obtained in the MODIFICA project

4 Relationship between urban grid and local evolution of heat island: two case studies

From these general data evolution of the urban heat island in Madrid, they have identified several areas where there has been greater urban transformation over the last 30 years and therefore would be expected to have also produced more local modification of the heat island when comparing 1985 data with 2015.

For the selection of these case studies have used the comparison of temperature profiles obtained for the different transects the two dates of measurements (summer of 1985 and 2015), since the effect of transforming the microclimate effect and urban heat island climate change, can have a major impact on the health of people (Tapia, 2015). In addition, we considered the maps generated by GIS, corresponding to the heat island in both periods (exposed in previous points) technology. With this information has made a selection of two areas where temperatures have increased considerably compared to 1985 measurements (> 5 ° C) (**Fig. 4**) for the local study of the evolution of urban heat island in Madrid:

- **Barrio de las Rejas**, in the district of San Blas. Increased temperatures between 5 to 6°C compared to 1985 (from 26.1ºC to 26.6°C isotherm night in 1985 to 31.9 to 32.4 ° C isotherm night in 2015)

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- **Ensanche de Vallecas**, in the district of Villa de Vallecas. Variation in temperature between 5-6 ° C compared to 1985 (from 26.6 to 27.1 ° C isotherm night in 1985 to 31.9 to 32.4 ° C isotherm night in 2015)

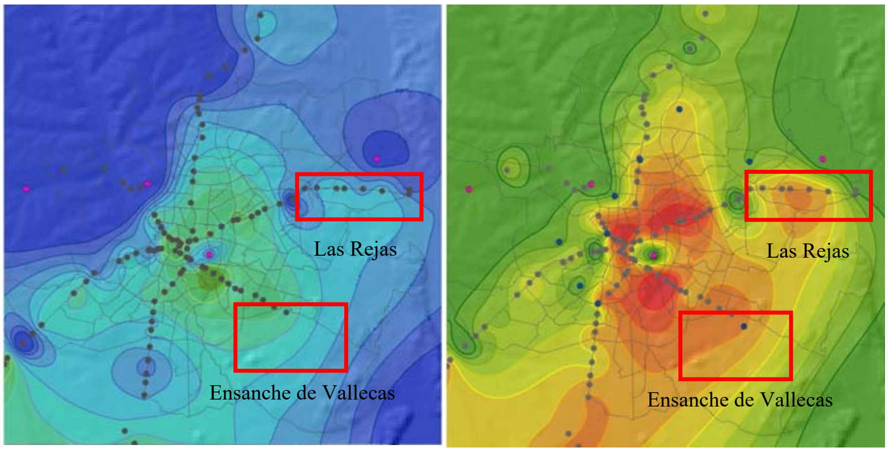

Fig. 4 Selection of case studies from the comparison of temperatures in the two periods considered, 1985 and 2015, respectively. Source: Elaboration by the authors

4.1 Case Study 1. Barrio de las Rejas

This suburb is located in the district of San Blas, northeast of Madrid. Its geographical location, south of the airport of Barajas, between the A-2, M-40 and M-21 railways, as well as the abundance of industrial estates, industrial and give it an isolated character. Historically the residential population is concentrated in the western part of the neighborhood, specifically in Ciudad Pegaso. Urban development considered by the Urban Plan of 1997 led to the construction of over 1,600 homes, greatly increased its population and occupation in recent years[1].

As can be seen in **Fig. 5**, the increase in land use in 2005 is considerable compared to the year 1980, where practically the only core residential population was concentrated in Ciudad Pegaso and the rest of the area was occupied by developments industrial and undeveloped areas.

[1] Source: http://www.ciudadpegaso.com/cplocalizacionentorno.html [Consulted on: August 24, 2016]

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Fig. 5 Comparison of land use for the area of Las Rejas, 1980-2005. Source: Visor Comparativo-Planea, Dirección General de Urbanismo, Comunidad de Madrid

Nowadays it can be see how the occupation of the territory continued to rise to transform a large percentage of natural soil in artificial soil, mainly asphalt and residential, services and industrial buildings (**Fig. 6**).

Fig. 6 Land use in the area of Las Rejas, 2015. Source: Elaboration by the authors from Google Earth

Housing urban land   Industrial urban land

By analyzing the temperature increase of the area can be seen how the main focus of refractivity heat with the densest area in which there are several shopping centers (Centro Comercial Plenilunio, Makro Barajas, Media Markt, etc.) with large paved parking, which they are impervious areas with a low coefficient of albedo, and with sparsely vegetation (**Fig. 7**). However in the border east and west of the area of higher temperature areas is recorded a decrease of this variable. It could be due to the presence in the west of the Pegaso City, residential blocks consisting of semi-detached houses and detached houses, with wide green spaces and great presence of trees in public space. In the limit of this suburb is appreciated a large vacant lots and green areas.

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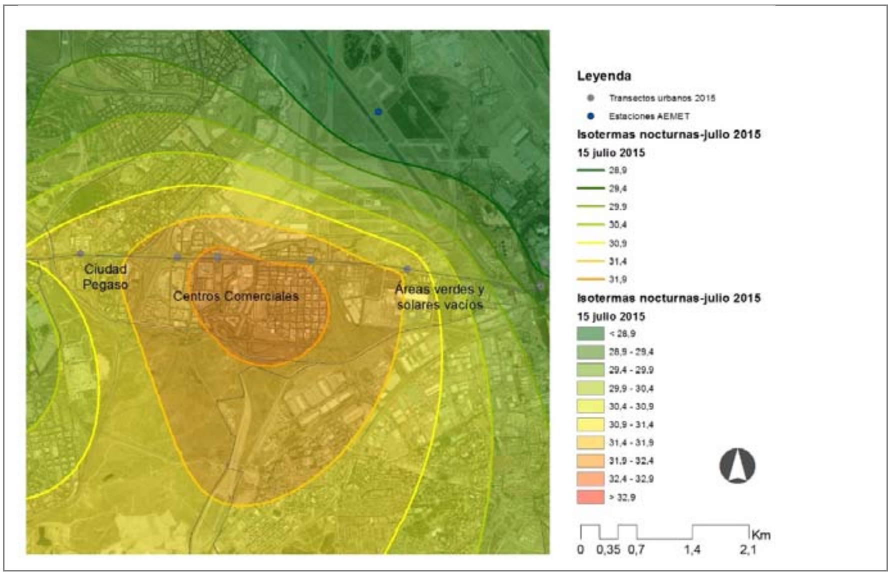

Fig. 7. Night isotherms in the neighborhood of Las Rejas, 2015. Source: Elaboration by the authors

4.2 Case Study 2. Ensanche de Vallecas

Ensanche de Vallecas is located southeast of Madrid, between highways M-40 and M-50. In this area is also seen a considerable land occupation. In 1980, there was the old town of Villa de Vallecas and part of Santa Eugenia, which joined the west industrial estate South Vallecas, as shown in **Fig. 8**. However already in 2005, virtually the industrial areas of western and residential area between Vallecas and Santa Eugenia have silted. It has also begun to develop the Urban Action Plan of Vallecas, designed in the early 90s. This plan has provided for the execution of 28,000 dwellings with services, to an occupation of more than 7 million m^2.

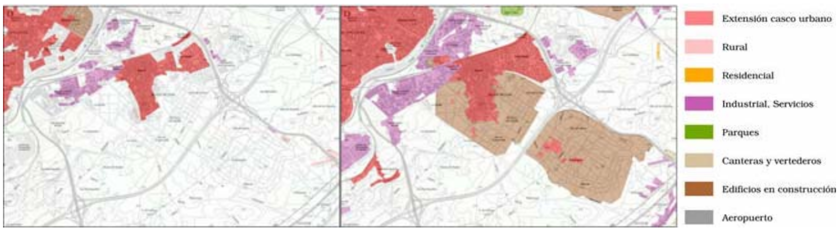

Fig. 8 Comparativa de ocupación del suelo para el Ensanche de Vallecas, años 1980-2005. Fuente: Visor Comparativo-Planea, Dirección General de Urbanismo, Comunidad de Madrid

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In 2015 it shows how the occupation of the territory has continued to increase, by running large number of residential buildings and equipment covered by urban development program (**Fig. 9**). To this the effects of urbanization of much of the area, which has transformed the natural soil in asphalt and impermeable soil are added. Also the extension of these urbanized areas, still unbuilt, south of the industrial estate and southwest of the old town.

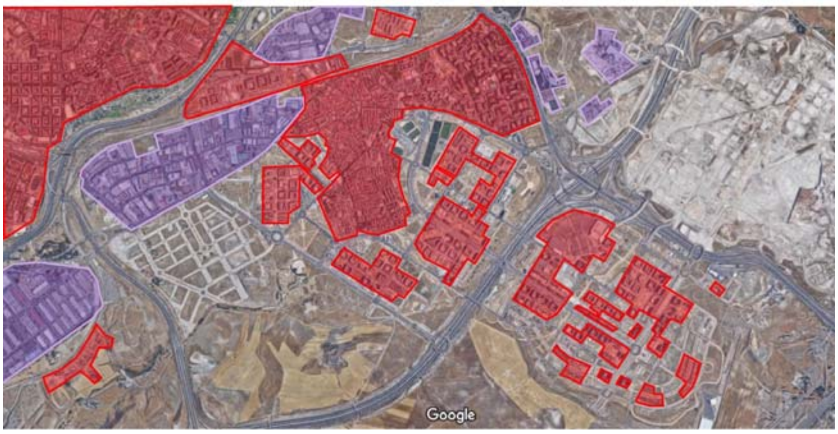

Fig. 9 Land use in the area of Ensanche de Vallecas, 2015. Source: Elaboration by the authors from Google Earth

Housing urban land   Industrial urban land

During data collection in 2015 a significant increase in temperatures over the year 1985 and an increase in the extension of the urban heat island, favored by urban developments that have been mentioned previously observed. The extension of existing heat focus in 1985 in the historical district of Villa de Vallecas increased significantly, an effect brought about by the densification of the corresponding industrial and residential development of this urban area urban fabric.

However, the temperature is reduced according begins to decrease urban density due to voids solar still predominate in the southeast area this area (**Fig. 10**).

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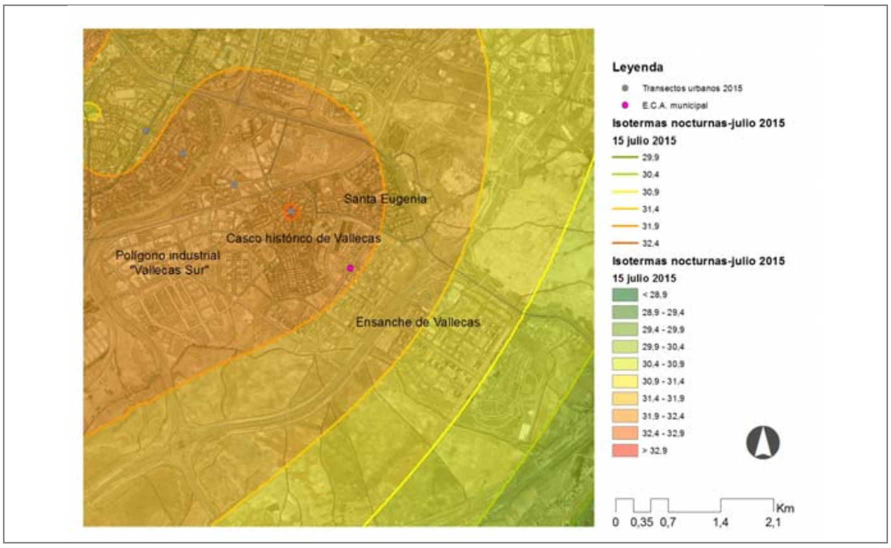

Fig. 10 Night isotherms in the neighborhood of Ensanche de Vallecas, 2015 (ºC). Source: Elaboration by the authors

5 Conclusions

This research aims to show the relevance of the local influence of heat island and its relation to the formation of the city. According to data obtained in the two case studies, the most important variables in the temperature increase in these neighborhoods are urban surface finish and building density. A major transformation of natural surface with significant presence of buildings, the greater has been the increase in temperatures in the period studied, finding differences of up to 6 ° C. Despite the presence of a heat wave in 2015, it has been appreciate a systemized as temperatures increase while the natural surface has been replaced by asphalt. The lack of urbanization, the presence of trees and vegetation zones mitigate the heat island effect in these spaces. This conclusion would open the possibilities for improving the urban climate of these areas with cold treatments pavement, revegetation, and buildings with external insulation.

The expansion of these local studies of urban heat island to other areas of Madrid would identify those areas where the worst conditions and the surfaces that have a greater influence on microclimate modification. Thus, it could be established a program to improve the public space in Madrid adapting solutions to the conditions of each neighbourhood to attenuate the heat island effect and improve urban comfort and, by extension, the indoor comfort.

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This data could be applied to other populations with similar geographical conditions, which were not able to carry out specific studies and for future situations arising from changes in urban planning.

6 Citation and References

Comunidad de Madrid. Información cartográfica y territorial. http://www.madrid.org/cartografia/planea/cartografia/html/web/index.htm. [Fecha de consulta 10 de agosto de 2016]

Ciudad Pegaso: http://www.ciudadpegaso.com/cplocalizacionentorno.html [Fecha de consulta: 24 de agosto de 2016]

Fernández García, F. (2002). El clima urbano de Madrid y su influencia sobre el confort térmico. Boletín de La Real Sociedad Geográfica, 137-138, 12.

Gómez Muñoz, G (2014) Método de análisis diacrónico para la intervención en el alojamiento con criterios ecológicos. El caso de Madrid 1940–2100. Tesis Doctoral. Universidad Politécnica de Madrid

López Gómez, A., López Gómez, J., Fernández García, F., & Arroyo Ilera, F. (1988). El Clima urbano de Madrid: La isla de calor. Madrid: CSIC.

López Moreno, H. (2015) Hacia una evaluación energética de la influencia de la isla de calor urbana en la morfológica urbana de Madrid. Tesina final, Master de Medio Ambiente y Arquitectura Bioclimática. Universidad Politécnica de Madrid

Naredo, J. M., García, R. (Coord.) (2008) Estudio sobre la ocupación de suelo por usos urbano-industriales, aplicado a la Comunidad de Madrid. Ministerio de Medio Ambiente. http://habitat.aq.upm.es/oscam/

Núñez Peiró, M (2015) La isla de calor urbana de Madrid. Principios de integración en simulación energética edificatoria. Tesina final, Master de Medio Ambiente y Arquitectura Bioclimática. Universidad Politécnica de Madrid

Santamouris, M. (2007). Heat Island Research in Europe: The State of the Art. Advances in Building Energy Research, 1(1), 123–150. doi:10.1080/17512549.2007.9687272

Tapia, C., Abajo, B., Feliu, E., Fernández, J. G., Padró, A., Castaño, J. (2015) Análisis de vulnerabilidad ante el cambio climático en el municipio de Madrid. Ayuntamiento de Madrid

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