SPATIAL PATTERNS ESTIMATION OF URBAN HEAT ISLAND OF ZARAGOZA (SPAIN) USING GIS

Miguel A. Saz Sánchez, S.M. Vicente Serrano, J.M. Cuadrat Prats
Departamento de Geografía y Ordenación del Territorio. Universidad de Zaragoza. 50009, Zaragoza, Spain.
masaz@posta.unizar.es

Abstract

29 daily sample maps of urban spatial distribution of temperatures, obtained by means of urban thermal transects, were used to generate mean and temporal variability maps of urban heat island in Zaragoza (Northeast of Spain). Both maps were obtained using GIS. Each daily map was generated from 217 records of temperature. Three car-transects were used to obtain this thermal data. Time duration of transects was about 1 hour, beginning 3 hours after nightfall. Negative trends are identified along duration time of transects because of the surface night cooling. Trends were eliminated by means of linear adjustments and residual analysis. Each daily-corrected data was standardized in order to obtain homogeneous spatial series. The standardized daily values were mapped in a GIS using semivariogram adjustment and ordinary kriging. The result was a set of 29 daily grid standardized maps of spatial thermal distribution in the city, at 30 m of spatial resolution. Using GIS analysis and daily grid temperature maps, we generate two thermal maps: the first one represents the average thermal characteristics; the second one indicates the temporal variability of temperature distribution within the city. The grid values of these digital maps can be incorporated in a GIS, and allow us to integrate thermal information with other spatial variables for monitoring the urban environment.

Key words: Urban Heat Island, Urban Transects, Kriging, Zaragoza, Spain

1. INTRODUCTION

Urban areas are spaces where the human transformations of environment are the greatest. Human action has changed land uses and vegetation cover, among other environmental parameters, introducing new elements and materials that are able to change locally the surface-atmosphere energetic fluxes. This fact may disturb climatic regional patterns in urban areas. One of the effects more studied is the temperature increment in the city (Böhm, 1998) and the development of urban heat islands, a general characteristic of medium and large urban areas (Landsberg, 1981).

Nowadays, when a high percentage of world population live in urban areas (45%), with a much higher fraction (75%) in developed countries (Population Reference Bureau, 2001), it is especially interesting to know the magnitude of these changes which can modify the life quality of citizens. In this work, we present the general spatial patterns of urban heat island (UHI) in Zaragoza, a medium size city (600.000 Hab.) located in a flat area in the centre of the Ebro valley (Northeast of Spain). The study area is described in detail in Cuadrat et al. (1993). We present a digital mapping of the UHI in Zaragoza that shows its shape and intensity. The digital information allows us to integrate UHI in a GIS with other environmental and structural parameters of the city, in order to have a better knowledge from the spatial characteristics and the causes that create the UHI.

2. METHODOLOGY

2.1. Data base creation

Data used in this work were obtained from urban transects (i.e. Unger et al, 2001) with three cars equipped with temperature sensors (±0,1°C of accuracy) and a data-logger. Every measuring day (29) the air temperature measurement from 217 different points of the city was recorded (figure 1). Time duration of transects was about 1 hour, beginning 3 hours after nightfall, since it is at night when UHI intensity is the greatest (Tereshchenko and Filonov, 2001).

Daily air temperature data series show a significant negative lineal trend, related to the surface night cooling. Winkler et al (1981) explained the importance of correcting data in correctly defining the magnitude of the UHI. Daily data series were detrended using linear adjustment and residual analysis. Therefore, data corrected is considered simultaneous in time. Moreover, for comparing the different daily measurements, they must be standardized, since the contrasted thermal gradients observed in the different days could introduce bias in the general spatial patterns of UHI. Subsequently, each detrended daily air temperature data series was standardized for obtaining spatial and temporal homogeneous series. Mean and standard deviation were used to standardize
the data. These standardized data series were integrated in a Geographical Information system (ArcView 3.2) in UTM-30N coordinates.

2.2. Mapping standardized air temperature conditions

From the standardized daily database we created a set of 29 maps. Each one represents the standardized air temperature in the measuring days. However, these maps are created from punctual information, and this fact is an important shortcoming in the identification of thermal spatial patterns within the city. Grid surfaces are more adequate to spatial representation of temperature, which is continuous in the space. For this reason, spatial interpolation techniques are needed to transform thermal information in grid maps, which represent more really the thermal distribution, and allow us more efficient spatial analysis in a GIS.

Maps were created by means of ordinary kriging (Borrough and McDonell, 1998) using ArcView GIS 3.2 extension Kriging Interpolator for Spatial Analyst. The result was a set of 29 daily grid standardized at 30 m of spatial resolution. Two examples of these maps are showed in figure 2. The excellent adjustments of semivariograms (figure 3) guarantee the mapping quality.
2.3. Average map and temporal variability map of urban heat island

From this set of maps we create two thermal maps using GIS: the first one represents the average thermal characteristics, and the second one indicates the temporal variability of thermal distribution in the city. Both maps were carried out in ArcView GIS 3.2.

In the average map, the value of every pixel was obtained from the average of the standardized values in the same pixel in the 29 daily grid maps. This map shows the general UHI patterns in Zaragoza. For the second map, the value of every pixel was obtained from the standard deviation, and it really shows the temporal variability of temperature within the city.

3. RESULTS

3.1. Spatial patterns of urban heat island in Zaragoza

The average thermal map (figure 4 left) indicates that central and eastern-central areas are the hottest of the city. These areas, in which are dense building and have a poor vegetation cover (Vicente et al., 2003), positive thermal anomalies recorded in the urban transects usually oscillate between 3º-4ºC, reaching 6ºC in persistent anticyclonic conditions. In the South and Southeast (located in the high terraces of the Ebro River) and in the North, temperatures are cooler than the previous ones. Both zones are less built-up and the elevation is higher than in the central areas.

The analysis shows us that UHI of Zaragoza as two main characteristics. The first one is that the highest UHI intensity appears in the Right Bank of the Ebro River. In the left bank the urbanization process is more recent and there is less building density. The second one is that the centre-periphery gradient of UHI is not equal in all directions. This gradient is usual in the cities where UHI has been analyzed. However, in Zaragoza, this gradient is more intense to the South and Southwest, towards the high terraces of the Ebro river, showing the topographic influence (Vicente et al., 2003). On the other hand, this gradient is less intense to the Northeast and Southeast, towards the industrial areas, located in the low terraces of the Ebro River.

3.2. Temporal variability of UHI in Zaragoza

Temporal variability map of temperature (figure 4, right) displays the hottest areas located in the centre of the city have the lowest standard deviation values. This fact indicates that these areas show a minor temporal variability of thermal conditions and, consequently, a major persistence of UHI.

The coldest and more vegetated areas located in the south of the central area, show low standard deviations, related to the presence of vegetation. Nevertheless, in the North, the coldest spaces show a great temporal variability. On the other hand, hot areas from the eastern-central part of the city have higher standard deviation values than the central areas.

4. CONCLUSIONS

In this work we have shown the main spatial patterns of UHI in Zaragoza (Northeast of Spain) and the spatial distribution of temporal variability of temperature. Both maps were obtained using GIS. The thermal map indicates that the central and eastern-central parts of the city are hotter than the rest. The temperature shows a peripheral negative gradient, most important to the South and Southwest, where the terraces of Ebro River have the highest elevations. Temporal variability map of thermal conditions indicates that the hottest areas of the city show a minor temporal variability.
Thermal information of this digital maps can be incorporated in a GIS, allowing us to integrate thermal information and other spatial variables for the management of cities (vegetation cover, traffic, urban density, topography or building materials) in order to determine the influence of human, physical and environmental factors on UHI, and to improve life-quality of citizens.

Figure 4: General urban heat island map (left) and temporal variability map of thermal conditions (right) in Zaragoza

ACKNOWLEDGEMENTS

This paper was supported by the following projects: “Caracterización espacio-temporal de las sequías en el valle medio del Ebro e identificación de sus impactos” (BSO2002-02743) financed by the CICYT, “Clima y calidad ambiental en la ciudad de Zaragoza” financed by the Zaragoza Council, and the “Programa de grupos de investigación consolidados” financed by the Aragon Government.

References

Vicente, S.M., Cuadrat, J.M., Saz, M.A., 2003, Topography and vegetation cover influence on urban heat island of Zaragoza (Spain). Fifth International Conference on Urban Climate. Lodz. In this volume.