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A PCA ANALYSIS OF THE UHI FORM OF MADRID

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Abstract

In this work a study of the relation of the Madrid's UHI and the structure of the city is presented. The data used are a set of more than 100 transects performed during the period 1992-1993, and have been obtained in all seasons of the year and in different meteorological conditions. For extracting the main thermal patterns a Principal Component Analysis has been performed. On the other hand some index of urbanization have been created from two data bases of the building and green areas distribution. The indices and Empirical Orthogonal Functions show very good correlations, indicating that the spatial structure of UHI can be easily derived from this kind of data.

Keywords: Urban Heat Island, Madrid, urbanization index, PCA

1. INTRODUCTION

The problem of the climate perturbation due to the inclusion of cities has been broadly studied (Landsberg, 1981, Oke, 1987). The most important and studied phenomenon has been the well-known Urban Heat Island (UHI). It has been studied from the theoretical point of view by means of hadware and software models (Montavez, 2000b) and experimentally.

Several experimental methods have been applied to study this phenomenon from the experimental point of view: by comparing urban and rural stations (Figueroa and Mazzeo, 1998), analyzing long temperature series (Karaca et al. 1995), by the method of transects (Montavez, 2000a), and by satellite and aircraft observations (Lee, 1998). By the method of the transects it is possible to obtain a detailed structure of temperature field but usually one cannot have a good temporal distribution of the phenomena. Additionally some authors have tried to relate UHI intensity to several factors such as the city size (Oke, 1973) and the canyon structure in the warmer sites (Oke, 1981), but this information is just a number related to the full city not capaple to give information of its thermal structure.

In this work we investigate as a first approach the relationship between the urban temperature profiles obtained by the transect method and urbanization indices built from a data base obtained from a GIS. Therefore the goal of this study is to have a tool for obtaining the thermal structure of the city. In section 2 the data used in this work are described as well as the area for which the study has been performed. In section 3 a (Principal Component Analisys) PCA is performed in order to obtain the main patterns that characterize the temperature field. In section 4 some indices of urbanization are created and the relation to the EOF's obtained in the before section studied. Finally, some conclusion and comments are exposed.

2. DATA BASE DESCRIPTION

Madrid and surroundings are the largest crowded area in Spain with a population of more than 4 million people living in area within a radius of 15 km. It is located at the center of Iberian Peninsula and its climate can be classified as Mediterranean with a large number of clear ski days. All this promotes the formation of an intense UHI with important nuances related to the urban morphology.

Transect	***N***	***NP***
NS	41	46
WE	32	88
RI	41	36

Table 1. Number of transects (N) and points of recording data (NP) for each group of transects.

The urban climate studies on Madrid started in 1984 (López G. y Fernández, F.) focusing mainly in the UHI dynamics. This work tries to contribute the previous works relating the UHI form to the structure of the city. For this purpose we use two different sources of data, temperature records from several trancsects done during the years 1992 and 1993, and building and green areas information extracted from a GIS. During the recording time three different kind of transects were preformed: the first one tries to get some information about the North-South (NS) section temperature profile, the second one West-East (WE), and the third connects the previous transects following the River Manzanares (RI). In Figure 1a, a map of the urban area and the point of transects where the temperature records were taken is

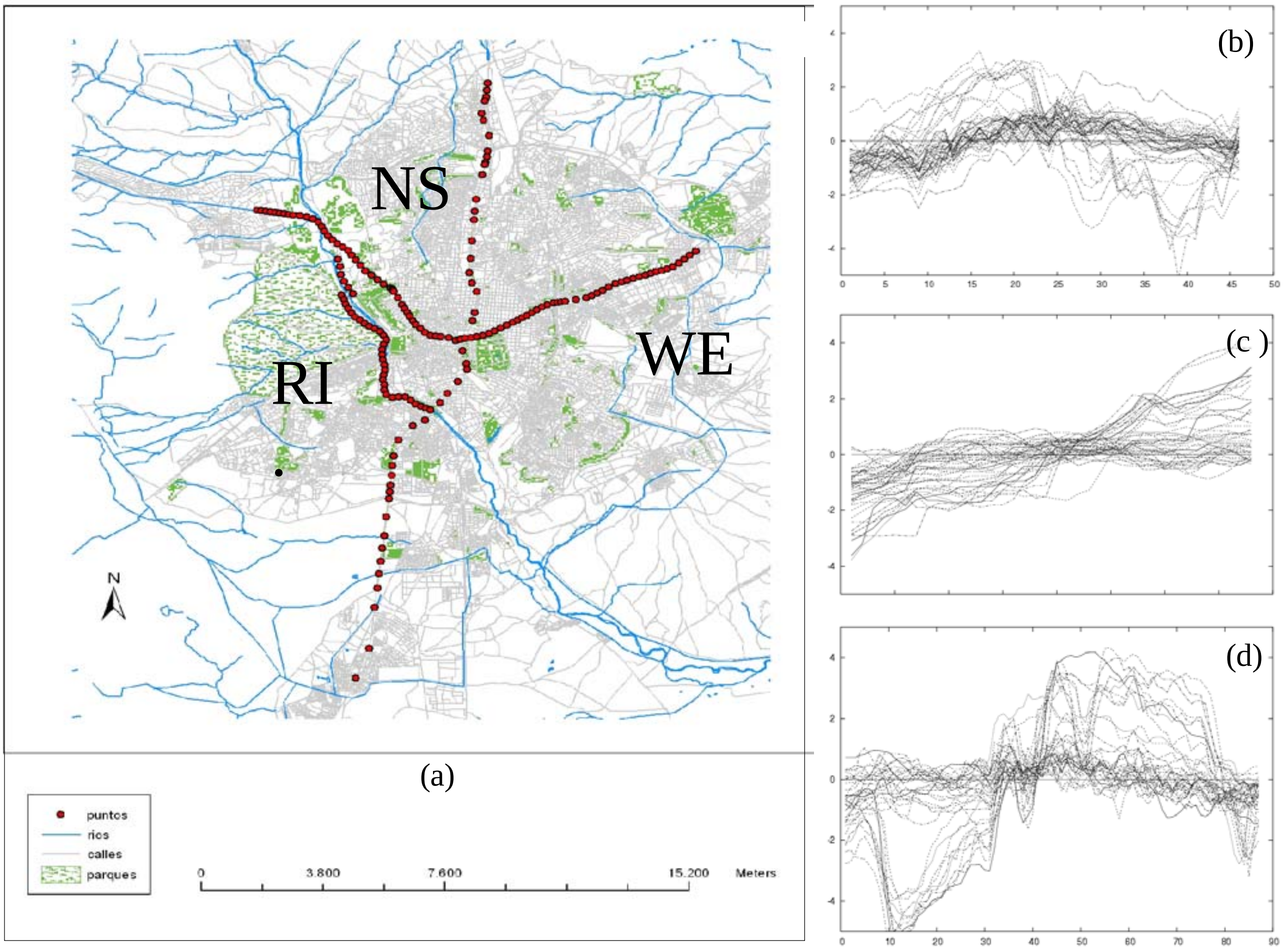

Figure 1. (a) Morphology and transects. The measure points are marked with circles. (b) (c) and (d) show the temperature profiles recorded in transects NS RI and WE for all the experiences.

shown. The transects were done throught the year at several times (07,09,13 and 22 Z) and under different weather conditions. In Table 1 the number of measuring points (NP) and the number of experiences (N) for each transect are shown and in Figures 1b,1c and 1d the recorded temperature profile (anomalies respect the mean temperature of the experience) in each experience are plotted.

Additionally, a data base derived from a GIS consisting in two logical matrices, one for buildings and other for green areas covering the zone represented in Figure 1a with a spatial resolution of 10x10m is used. In the matrix of buildings (green areas) the value 1 is given to pixels covert by buildings (green areas) and 0 where there are no buildings (no green areas).

3. A PCA ANALISYS OF THE THERMAL PROFILES

For extracting the thermal structure which explains more variance in the transects exposed in the previous section a Principal Component (PCA) Analysis has been performed (Storch and Zwiers 2000). Three different analysis have been carried out for each group of transects (NS, RI and WE) using the anomalies of temperature respect the mean temperature of every transect.

As can be seen in Table 2, in all cases the percentage of explained variance is larger than 90%. This means that the larger thermal variations have a clear structure. The first EOF's of each transect are represented in Figure 2b, 2c and 2d.

transect	***EOF1***	***EOF2***	***I1***	***I2***	***I3***
NS	57.16%	29.52%	0.76	-0.18	0.80
RI	87.94%	6.01%	0.93	-0.81	0.94
WE	87.90%	4.48%	0.84	-0.62	0.91

Table 2. Explained variance of the main EOFs obtained for every set of transects and the correlation between the EOF1 and the index of urbanization.

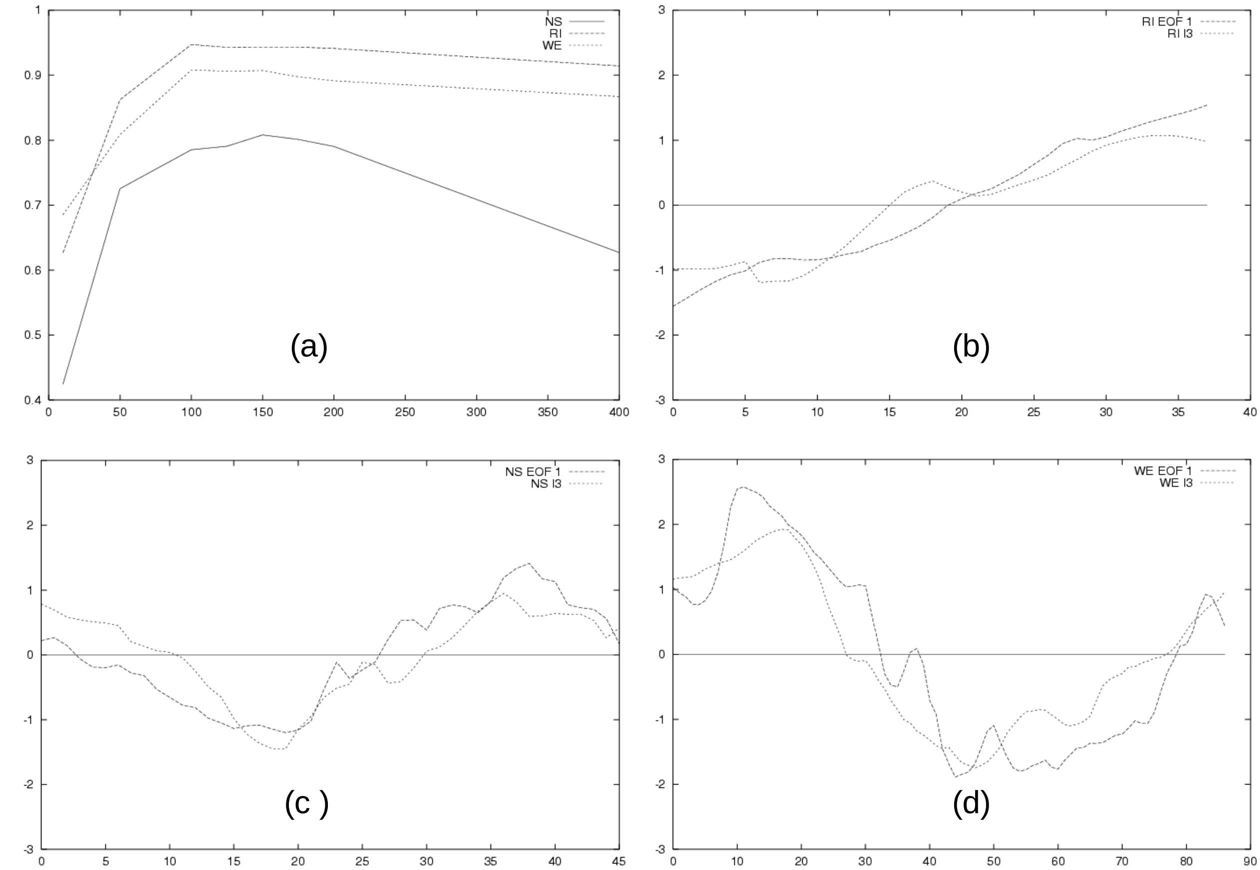

Figure 1 (a) Correlation index between the EOF1 and I3 as a function of the radius of influence. In (b) (c) and (d) the index I3 and the EOF1 is represented for the transect RI, WE and NS.

On the other hand, although the analysis of the Principal Components (loadings) is not shown here, it should be mentioned that they are related to the hour and meteorological conditions given in each particular transect, obtaining the larger values for fair weather conditions and night time.

4. RELATION OF THERMAL STRUCTURE WITH URBANIZATION INDICES

In this section we study the relationship between the first EOF of each group of transects presented in section 3 and the structure of the city. For this purpose three indices have been set up to identify the structure of the city. The first one (I1) only takes into account the density of buildings, the second one (I2) only considers the density of green areas inside the city and the third one (I3) is a linear combination of I1 and I2 .

The indices are created for each point of the transects and then compared with the thermal structure of the city. Therefore, each point is associated with three indices. As mentioned before, the GIS information we have is a data matrix. To form an index for a given point we just select a ratio of influence and calculate it as a combination of all points included within the ratio weighted with the distance to the central point. In Figure 2a is shown how the correlation between the EOFs and I3 depends on the ratio selected. It seems that the optimal ratio is located around 100 points, i.e, 1km. In Table 2 the correlation indices between the EOFs and the urbanization indices are listed. The results show that the indices I1 and I3 correlates very well with the EOFs being I3 always the best option.

5. CONCLUSIONS AND COMMENTS

This work shows a relationship between the urban structure and the thermal profile of the city has been shown. The thermal profile of each group of transects has been obtained by means of a EOF analysis. The results reveal a clear relation between the urbanization indices and the thermal structure of the Madrid's UHI. The indices constructed using a radius of influence of 1km seem to be the best option for the explanation of large spatial variations of temperature. This could be explained because of air temperature perturbation in a point is due not only to the very near morphology but also due to advection of air masses coming from surrounding areas (Montavez 2000a, Eliasson 1996). However, when a more detailed structure of the thermal profile is required, then a smaller radius of influence (not shown here) is also needed, and a better relationship can be obtained by combination of several indices constructed using different radius of influence.

This is a first approach to the problem and more work has to be devoted to this task. Some future applications of these indices could be the setting-up of models for forecasting the urban thermal structure, as it is Madrid in our case, for a given meteorological situation. Even, another potential use could be determining temperature changes associated to urban planning.

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