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STUDY OF HEAT ISLAND PHENOMENON IN ANDEAN COLOMBIAN TROPICAL CITY, CASE OF STUDY: MANIZALES-CALDAS COLOMBIA

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Abstract

The Colombian cities, due to their topography, geographic ubication and anthropogenic activities can be affected for urban heat island, making necessary and appropriate to develop studies of environmental urban temperature, to know the climatic dynamic and establish if exists or not the phenomenon . The study was developed in Manizales Caldas-Colombia, using the method of night thermal transects in 13 mobile stations, located on characteristic points of the city. The environmental temperature and wind speed data took at each point, making an altitude correction of sampled temperatures to develop thermal and win speed maps. The thermal maps, evidence that, environmental temperature of the city is concentrated in downtown of Manizales. This indicates, the structural shape to the city of Manizales influence on the temperature rise in downtown, due to, the influence in the high population density that goes around their daily and exerts a pressure on urban environmental factors, causing urban environmental problems.

Key words: UHI, downtown, Temperature, environmental, urban.

1. *Introduction*

Towns and cities are the most densely populated areas on Earth and will continue to be the artificial landscapes most widely used by the greater part of the Earth's population in the future. Changes in urban conditions have often caused deterioration in environmental quality and may result in damage to the health of city-dwellers (Kuttler, 2008).

Urbanization initiates one of humanity's most dramatic land use changes: a natural landscape, often containing transpiring vegetation and a pervious surface, is converted to a built, largely impervious landscape made-up of rigid, sharp edged roughness elements. Exchanges of heat, water vapour and momentum between the new urban "surface" and the atmosphere are modified by the different radiative, thermal, aerodynamic and moisture properties of the urban landscape (Cleugh, 1995).

The Urban Heat Island is a climatic phenomenon that develops in cities, which produces an intense heat accumulation, because the materials which were built, absorb and radiate heat. Furthermore, the way the cities were built and their shapes, has effects on the incidence of solar radiation, remaining and heating the entire surface. Therefore, it can be considerated as an indicator of anthropogenic phenomenon of urban environmental degradation of a city, taking into account that, first, the lack of vegetation (parks, trees, gardens, etc.) incentives the phenomenon, and second, the presence of vegetation and their density attenuates it.

In many cities in Latin America, its development occurred from the center and expanded toward the periphery, following the developments of railway and present routes, under a continuous an apparent lack of planning (Jiménez, 2002 viewed in Ángel *et al*, 2010). No exception has been in Colombian cities like Bogotá, in which was found that the temperature has been increasing. Pabón *et al.* (1998) refer the presence of a heat island that has been forming since 1970 in downtown and expands northward. For that, and the continuous population growth of Colombian cities, is necessary to study this climatic phenomenon in other cities like Manizales, to know if in this city exists the presence of heat island, or if instead, the influence of their geomorphological characteristics, dissipate the accumulation of environmental temperature and therefore, we would find the absence of the urban heat island.

2. Site of study

Manizales spreads on the western slopes of the Central Mountain Range, from the top to the banks of the Cauca River. It has an altitude of 2.126 meters above sea level and an area of 508 Km2 (DANE, 2005 saw in Martínez, 2007 in Hermelin; et al, 2007). It presents a wide variation of climates, from the warm moist transitional to dry warm transitional in the western part of the municipality on the banks of rivers Chinchiná and Cauca, with temperatures into 24°C and 16°C, precipitations between 2011 and 2600 mm/year and potential evapotranspiration of 1400 and 1340 (mm/year); in the eastern sector of the municipality, exists a cold wet and very humid climate, in the upper Rio Blanco basin, having temperatures between 4 and 10°C, and average annual rainfall of 1600-2000 mm with a bi-modal rainfall regime (Martínez, 2007 in Hermelin; et al., 2007).

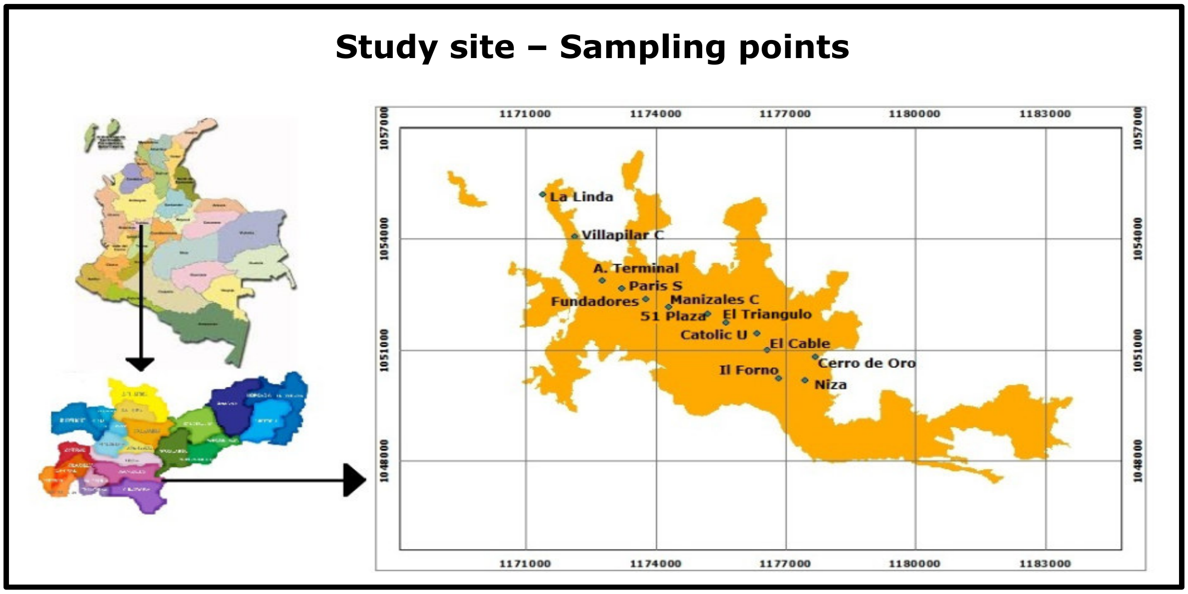

Figure1. Study site and nocturnal sampling points

Methodological development

For this study, the methodology chosen is known as thermal transects (Oke, 1973; Oke & Maxwell, 1975; Stewart, 1998; Blankenstein, S. Kutter, 2004; Kuttler et al., 2007; Schwarz et al., 2012) where a line transect by the city was taken, having as reference 13 important points of the city. Which are characteristic and referenced for the urban population of the city, because they concentrate most of the traffic, people and commercial sector of the city. (Table 1, Figure 1).

For sampling temperatures and wind speed data, a pickup truck was used, which on the back, automatic mobile weather station Davis Instruments® was installed, belonging to the Environmental Studies Institute IDEA from headquarters National University of Colombia in Manizales. The station was located at a height of 10 meters from the ground (approximately), thus to avoid any interference with the vehicle exhaust. Studio tours were conducted between February and March 2013 and temperature data were taken between 19 and 21 hours. They were in total 16 trips (round trip) in order to get data from one of the dried or low rainy seasons that the region presents (Jaramillo, 2005).

For statistical analysis, we performed a correction for altitude using a lineal regression (Jaramillo, 2005; Stewart, 2011), matching the lower and higher altitudes at constant altitude range of mobile stations, in order to achieve uniformity in the temperature data and thus a better analysis (Franco, 2013). Also the UHI intensity was calculated these values, were correlated with the temperature and wind speed values, obtained from the network of stations. All statistical analysis were calculated with a 95% confidence level.

3.1 Construction for thermal maps

Using ArcGis 10.1 software a climate modeling was performed, with which we obtained a map of isotherms; in this way we constructed a heat map that describes the behavior of nocturnal temperature in the city, comparing the sampled temperature data in field (corrected by altitude regression) with the temperature and wind speed of network stations from Environmental Studies Institute IDEA from National University of Colombia Manizales headquarters.

These temperatures were processed taking ancient existing data, the same months, days and hours, which were developed in the tour to compare among both temperatures to also have a statistical reliability analysis. In addition, it was constructed a wind map to contrast temperatures sampling with wind speed to know, if exists a relationship between the two variables and their behavior.

Point No	Name	Ubication	Altitude	T°C corrected Average	Latitude	Longitude
1	La Linda	Rural	2017	20,05	5°05'37"N	75°31'56"O
2	Villapilar Clinic	Urban	2128	20,38	5°04'60"N	75°31'32"O
3	Antique Terminal	Urban	2149	20,52	5°04'21"N	75°31'11"O
4	Paris Store	Urban	2122	20,5	5°04'14"N	75°30'56"O
5	Fundadores Theater	Urban	2156	20,34	5°04'05"N	75°30'38"O
6	Manizales Clinic	Urban	2148	20,17	5°03'58"N	75°30'21"O
7	Plaza 51	Urban	2180	20,02	5°03'52"N	75°29'52"O
8	El Triangulo	Urban	2173	19,88	5°03'44"N	75°29'38"O
9	Catolic University	Urban	2192	19,55	5°03'35"N	75°29'15"O
10	Architecture Faculty (El Cable)	Urban	2203	19,22	5°03'20"N	75°29'07"O
11	Il Forno Restaurant	Urban	2244	19,1	5°02'53"N	75°28'39"O
12	Niza	Urban	2232	18,95	5°02'53"N	75°28'39"O
13	Cerro de Oro	Rural	2306	18,84	5°03'14"N	75°28'31"O

Table 1 Nocturnal sampling points and Temperature corrected by altitude regression in °C through the city of Manizales

3. Results

In the hours that nocturnal sampling was developed (19-21 h), we observed a constant flow of vehicular traffic. These are commonly called "peak" hours because they are offset hours of general population coming back to their homes, also shopping and visiting entertainment sites such as restaurants and bars.

Also, during the tour sectors like 51 Plaza to El Cable, we observed the presence of strong winds but at the time the measurement, was not influenced in making temperature in the days when sampling data. The behavior of the average nocturnal temperature data sampled during the study is observer in Figure 1 - A

Regarding to correction of the altitude to 2100 m, the regression with r^2 de 0,753 was

$$Altitude_{2100\text{ m}} = 3434{,}9 - 63{,}411 \text{ x } T\,°C$$

On the opposite the linear regression for the temperature corrected by altitude to 2100 meters (Table 6) with r^2 de 0,753 was

$$T°C_{2100\text{ m}} = 45{,}77 - 0{,}012 \text{ x } Atitude\ m$$

The UHI intensity, was a difference of environmental temperature of 1,498 °C average, the maximum day intensity was 3,52 °c and the minimum 1,56. The relationship between temperature sampled and wind speed fixed stations was 0.114, which indicates that there is no influence of winds on UHI intensity (-1 <-0.114 <0).

4.1 Thermal maps

From the data supplied by the IDEA, we obtained the thermal maps of the city of Manizales. Figure 1-B shows the change in temperature of the city between the sampled points, observing warmer temperatures in the center of the city between the points, Manizales Clinic and La Linda, with temperatures between 19.7°C and 20.5 °C degrees.

The relationship coefficient between the sampled temperature and permanent stations temperature (Figure 1 A - B) was -0.16; these values indicate that there is not strong influence among the variables due to that their relationship is negative (-1 < - 0.16 < 0); the sampled temperature and wind speed relation coefficient was -0.119. (-1< -0.119<0), is also negative.

The isotherm map (Figure 1-C) demonstrated that the behavior of the temperature in downtown have a little variation, in contrast, the area from 51 Plaza to Il Forno Restaurant with considerable variation. Comparing this variable with wind speeds the last zone, shows a variability of large airstream.

4. *Discussion*

The urban structure of the city, explains much of the reason for the heat buildup in downtown, from the Fundadores Theater to the Ancient Terminal. There, the few winds that exist in the area are channeled into the canopy of the city (Oke. T.R, 1982) failing to dissipate accumulated heat during the day. This is consistent with decreasing wind speed by friction and the front obstacle that suppose buildings screen, which may be an amount of 10 to 20% between the maximum winds, also observed in an increased number of calm (Moreno, 1999).

The Manizales downtown 6.23% is the commercial area, that coincide with the historical center, the political center (Caldas Office Governor and Mayor of Manizales), religious (Cathedral of Manizales) and Financial District. This formation of Manizales is established from a dominant centrality; which influence in the high population density that goes around there daily and exerts a pressure on urban environmental factors, causing climatic environmental problems such as the heat island phenomenon.

The change in the perception of temperature is explained because the city responds to the adaptation of a very broken topography and abrupt, given its geographical location in the middle of the central mountains Andean which makes it possess very unique characteristic. Is located on the edge of the hill, allowing permanent opening to the landscape throughout your route (García, 2008).

These characteristics influence the taking of temperature which is evident in the relation temperature - wind being one neutral connection (1 <0.119 <0). Although this is an area of confluence of winds for being located in a mountain range, close to the equator and being affected by the Intertropical Confluence Zone, is an ideal place where interactions occur between topography and weather elements.

In Manizales, orographic winds are influenced mainly in the north by the presence of the Olivares-Minitas stream, which is close to the city (Franco, 2010). In Figure 1 –D these orographic winds were evidenced, which shows that in the area from El Triangulo to El Cable strong air flows confluence, particularly the Catholic University area to El Cable, recognized for strong air flows. This area is conformed mainly of wingspan and height buildings which divert to the ground, faster wind flows, canalizing them through the streets, with the funnel resulting effect, producing an acceleration of the speed (Moreno. G. M., 1999).

The higher intensity of UHI demonstrated, corresponded to warm days and starry clear nights with calm or no wind, which can be attributed to the fact that the study, was conducted in one of the dry season or low rainfall in the region (Jaramillo, 2005), which agrees with Roth (2007), finding in tropical and sub-tropical cities, that UHI studies are seasonally very marked, and performed mostly in low rainfall season.

UHI intensities are clearly associated with these times, although some cities with tropical highland climates show either a very pronounced seasonality like Mexico City and Guadalajara and or little variation like Bogota. Although Jauregui (1986 view in Roth) suggested that the small amplitude in the case of cities located near the equator such as Bogota, could be due to the dry/wet seasonal rhythm which is less differentiated.

5. *Conclusions*

In this study, there was evidence that the conformation of Manizales city, due to their topography, influences in the generation of heat island, downtown, this, combined with the presence of few winds, makes the intensity of the phenomenon even greater in cloudless nights with calm winds.

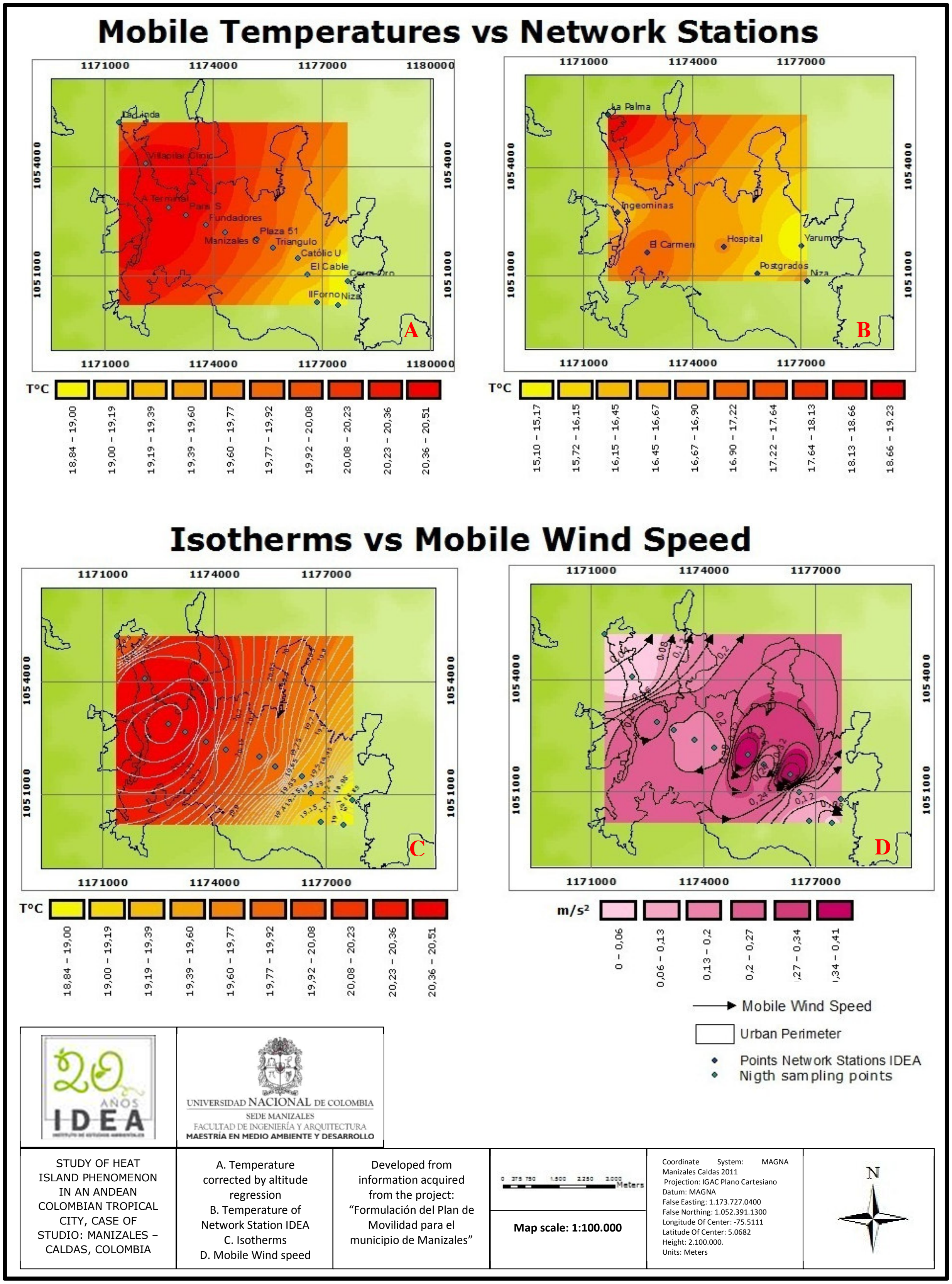

Figure1. A. Temperature corrected by altitude regression. B. Temperature of Network Station IDEA C. Isotherms. D. |Mobile Wind speed maps

The UHI problem generates a possibility to see the city with new eyes, especially downtown, because their mobility plan should be changed as important cities of the world have done, they transformed downtown areas in pedestrian zones and environmentally clean; using ways of transport more environmental, friendly as the bicycle or placing urban tolls for the movement of vehicles in these zones, this with the purpose to take care of historic centers and urban landscapes, in addition to contribute to the decline air pollution in the city.

6. Acknowledgement

The Environmental Studies Institute IDEA group and the National University of Colombia Manizales headquarters, for the cooperation provided, to Professors Freddy Leonardo Franco and Ian Stewart, for the guidance and the advice that offer me during this research.

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