Warm-Humid Climate: Methodology to Study the Distribution of Air Temperature

Angelina D. L. Costa[1], Lucila C. Labaki[1] and Virgínia Maria D. de Araújo[2]

[1]School of Civil Engineering, Architecture and Urban Planning – UNICAMP, Campinas, Brazil
Caixa Postal 6021 Cep 13083 970 Campinas/ SP – Brasil - Tel. 55 19 37882384
E-mail:angelina@fec.unicamp.br; lucila@fec.unicamp.br
[2] Federal University of Rio Grande do Norte- UFRN - Brazil
Institution, University, City, Country

ABSTRACT: This paper presents partial results of a research about urban space in a warm-humid climate at the Northeast region of Brazil. The objective is to verify the air temperature distribution in the city through fixed measurements of environmental variables. Results of measurements for a summer period, in February 2006, are presented. The fixed points were defined using 20 mobile phones base stations in the city of Natal, RN, distributed along the four administrative zones. Measurements were carried out for 07 days, registering air temperature and relative humidity at intervals of 30 minutes. Statistical analysis with previous experiments shows that the mobile phone equipment, that emits microwaves and waves in radiofrequency do not interfere in the measurements. Results show a temperature variation among the fixed points from 24,8^{0}C to 37,4^{0}C (average 28,8^{0}C), and from 39% to 94% relative humidity (average 71%). Obtained data were associated to satellite images to define the land use at each point, so correlating the density of occupation with the results of measurements. In fact, in some dense areas the highest temperatures and the lesser humidity values were found. The proposed methodology of measurements in fixed points using mobile phones base stations is original, provides safety to equipment and exposure standardization.

Keywords: temperature distribution, urban spaces, mobile phone base stations, satellite images.

1. INTRODUCTION

This paper describes results of a research about urban space in a warm-humid climate at the Northeast region of Brazil. The objective is to verify the air temperature distribution in the city through fixed measurements of environmental variables. Satellite images with high resolution allow identifying how the horizontal surfaces can influence microclimatic alterations.

The city of Natal is located at the Eastern coast of the Rio Grande do Norte State, at an 5^0 South latitude and 45^0 West longitude, bordered by the Atlantic Ocean, in the northeast of Brazil.. The topography is almost plane with an altitude of about 18m. The climate is hot and humid, standing out for the high humidity, intense radiation, small daily and seasonal thermal amplitude, air temperatures always under that of human skin and with variable wind speed predominantly in southeast direction. The city is the capital of the State of Rio Grande do Norte, in the oriental coast of Brazil (Figure 1).

Due to the proximity with the Equator line the horizontal surfaces are mainly responsible for solar heat gain; roof and pavement materials in the open external spaces therefore play a decisive role in the process of heat transfer to the environment. Like many other medium size cities, Natal is undergoing an accelerated urban development, characterized by an intense process of vertical and horizontal growth, with denser occupation and the use of more impermeable materials, like asphalt.

Figure 1: The map of Brazil with the localization of Natal

Natal presents two "different characteristic periods", in agreement with Araújo; Martins; Araújo (1998) [1], with a little climatic variation among them. The first period, from April to September will be called here winter period. It is the rainy period, with lower temperatures, higher relative humidity, prevailing winds from the Southeast quadrant, with variations South - Southwest, mainly in the first hours of the day. The second one, from October to March is considered the summer period, with higher temperatures, lower relative humidity and predominant wind direction also from Southeast, but with variations East - Northeast.

2. METHODOLOGY

All the geographical extension of the city was considered in the study, an area of 170km^2 of a complex urban reality, with different use configurations and land occupation.

The first stage of the study was, by combining data from cartographic base, aerial pictures, satellite images and *in loco* visits, to identify the different patterns of urban occupation in the study area, with location of vegetation and water. Then the points to collect climatic data were chosen. The measurements are programmed to be carried out in the two climatic summer and winter periods: in February and July 2006, respectively.

Through seven consecutive days from 02nd to 10th February air temperature and relative humidity data were registered at intervals of 30min in 20 different points spread along the city. The days of measurements presented compatible characteristics with the typical climatic summer day. instruments are 03 Testostor175, 11 Testo175-177, 03 Hobo H8, and 03 meteorological stations, protected from direct solar radiation through a plastic protection developed especially for the research, based on the model of standard meteorological shelter (Figure 2). The protections were fixed in the stairs of mobile phones base stations at 1,5m-2m height from the floor.

Wind speed and direction were registered at intervals of 10 minutes in three points, strategically positioned in function of the safety for the equipment and space distribution, in relation to the others. They are called EST03, EST027 and EST REF. Figure 03 shows the map with the localization of all points of data collection separated in administrative zones.

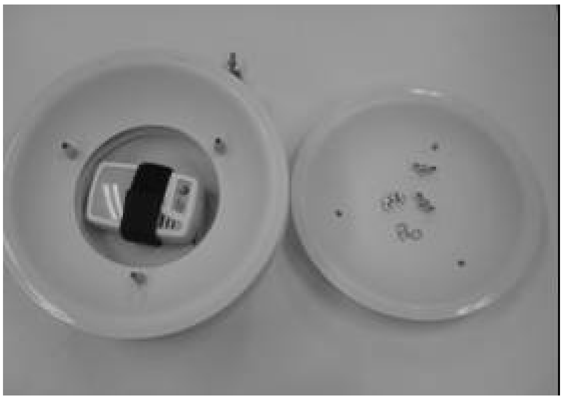

Figure 2: Detail to protect the equipment

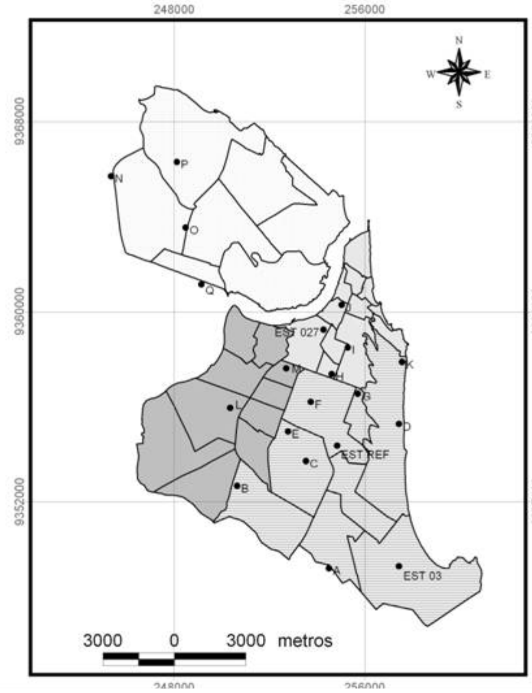

Figure 3: Location of the 20 measurement points

From these 20 points, 19 are sites of mobile phones base stations. That choice is due to some positive factors:

- The stations assure safety to the equipments, since the sites are closed, with restricted access to the company employees - BSE CLARO.
- This standardization in the equipments exposure, since all the base stations have the same physical structure - surrounded by a wall 2,5m height, covered floor with stone gravel, shelter for equipments and metallic tower
- their strategic distribution - they are dispersed through the whole city
- the diversity of typologies found around them
- the facilities of access because it depends only on a company,
- the non interference of the human activity in the measurement schedules, as well as in the equipments, and the certainty that the measurement points will not have their physical structures altered (for the second stage of the research)
- the possibility of methodology repetition in areas with similar climate, because of the presence of this building site type in most cities nowadays.

However, some aspects that were observed for the choice of such points, to be sure that they were appropriated for research. These aspects were related to three main factors: urban ventilation, lot, and the height of implantation of the base stations in relation to the soil. The first aspect is important to consider because of the wall around the site, which can be an obstacle for free flow of predominant ventilation. The equipments were installed to 1,5m-2m height. So some points were discarded - if the walls were higher than 2,60m with lots smaller than 200m^2. In relation to lot size it was considered as ideal the standard lot admitted in the established law for the urban plan of the city, which is 200m^2 (Art.46 of PDN, 1994) [2]. Sites whose lots present larger area or equal to 200m^2 were considered appropriate for the research. Lots with areas smaller than 100m^2 were discarded and those ones with area between 100 and 200m^2 were selected carefully.

The option for installing the equipment in the stair comes from the fact that there are three tower types with different structures: tubular, triangular and square, and all of them have a vertical stair, which allows for the standardization. (Figure 4)

Figure 4: Installed equipment (a testor with plastic protection).

After the measurements, the next step is the statistical analysis in search of a thermal characterization for the city. In addition to that, satellite images have been used in other recent works (FARIA, 2005) [3]; trying to establish dynamic relationships between occupation and thermal fields to subsidy urban planning.

Two tests preceded the summer measurements. The first one with the aim to verify if the of the equipments sensor need a better ventilation and a new protection was proposed for the equipment.

The second one occurred in Natal,RN in February 2006 to verify the behavior of the four types of equipments involved in the research. All the equipments were put side by side with the protections registering temperature and humidity during 24 hours, at intervals of 30min. It was observed that the differences in the records were not significant (Figure 5).

Figure 5: The equipments in test

3. ANALYSES

The land use around each measured point was analyzed: close to seashore (points D and K), areas with very small lots (points P and Q), not so high dense areas (points EST03 and N), areas close to natural barriers to predominant wind – *Parque das Dunas* (point G) and artificial ventilation (point H).

It was still adopted one point as reference (INPE), located at the University Campus, which is free from occupation interferences, and is situated at 10m height from the floor (Figure 6) .

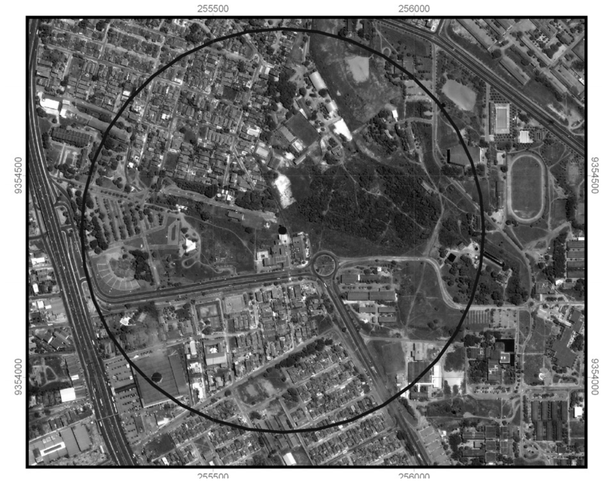

Figure 6: Image of EST REF point - meteorological station of the Campus UFRN

The statistical analysis showed that the transmission equipments and existent reception of mobile telephony in the base stations, that emits microwaves and radiofrequency radiation did not interfere in the results of the test, since the results are compatible, when compared to the reference

It is interesting to observe that the humidity was high in the point closer to water of Atlantic Ocean (point D - 80,6%) and the point EST03 (27,8 ^{0}C) presented to smallest average temperature, in an area with small density and without barriers to ventilation.

The measurements occurred in days that can be considered as typical for the area, without the occurrence of rains. Average values are presented for each point - temperature (Figure 7), and humidity (Figure 8). It can be observed that temperature values varied from 27,08^{0}C to 30,01^{0}C and relative humidity from 80,6% to 65,5%. If we isolate the point of reference, it is obtained 27,14^{0}C average temperature and 72,1% for the humidity.

The points E, K and M are the hottest ones and the points EST-03 and the point of reference in INPE are those with lowest temperatures. In relation to humidity, it can be said that the points A, Q and EST-27 present the smallest values.

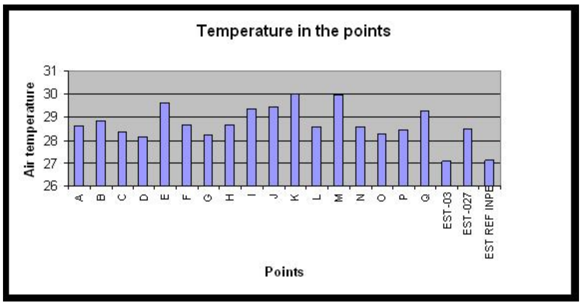

Figure 7: Mean temperature for all points (temperature in °C)

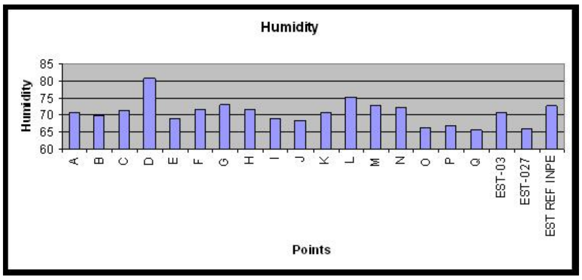

Figure 8: Mean humidity for all points (humidity in %)

In relation to wind speed, results show very big differences, which was expected. The following table shows minimum and maximum values obtained at the three stations. These data show the role of wind for climatic attenuation it provides the city.

Table 1: Wind speed values (values in m/s)

Point	Min. Velocity	Max. Velocity
EST REF	1,3	9,4
EST 03	0,5	2,2
EST 027	0,3	3,6

4. CONCLUSIONS

The experiment is still in process but even in this stage it allows some initial considerations. Analyzing the distribution of the air temperature it could be verified its relationship with land use, buildings geometric characteristics, properties of construction materials, density and effects of parks and green areas; this fact confirms those obtained by other studies as Givoni (1989) [4], Mizuno Et Al (1990) [5], Katzschner (1997) [6], Duarte (2000) [7], Barbirato (1998) [8], and Luxmoore, Jayasinghe & Mahendran (2005)[9]. It was observed that the points in areas with high building density presented higher temperatures as compared to areas with vegetation in the proximity.

Besides that, the option for locating the measurement points in mobile phones base stations proved to be correct and opens this possibility for other researches in different cities. The equipments were safe and the diversity of soil use found allowed to accomplish the objective of the research, that is, to study areas with different occupation types.

The next phase will be the elaboration of the maps in the software ArcView to make possible the comparison of the thermal behavior in administrative areas, by using the technique of supervised digital classifiers.

ACKNOWLEDGEMENT

The authors thanks CAPES and CNPq for financing the research and BSE-CLARO - Natal,RN

REFERENCES

[1] ARAÚJO, Eduardo H. S., MARTINS, Themis L. F. & ARAÚJO, Virgínia M. D. (1998). Dias típicos para o projeto térmico de edificações em Natal - RN. EDUFRN. Natal

[2] PREFEITURA MUNICIPAL DO NATAL. Plano Diretor de Natal: Lei Complementar nº 07 de 05 de agosto de 1994. Natal, 1994.

[3] FARIA, João Roberto Gomes de. (2005) O uso de imagens de satélite em estimativas de temperaturas do ar na camada intra-urbana. Anais do VIII Encontro Nacional sobre Conforto no Ambiente Construído e IV Encontro Latino-Americano sobre Conforto no Ambiente Construído. ENCAC-ENLACAC. Maceió, 2005

[4] GIVONI, Baruch. Urban design in different climates. Geneve: WCAP-10, World Meteorological Organisation - WMO/TD n. 346, 1989.

[5] MIZUNO, M. et al. Effects of land use on urban horizontal atmospheric temperature distributions. Energy and Buildings, n. 15-16, 1990/91, p.165-176.

[6] KATZSCHNER, Lutz. Urban climate studies as tools for urban planning and architecture. In: Encontro Nacional de Conforto no Ambiente Construído, 4, Salvador, 1997. Anais... Salvador: FAUFBA, ANTAC, 1997. p. 49-58.

[7] DUARTE, Denise Silva. Padrões de ocupação do solo e microclimas urbanos na região de clima tropical continental. São Paulo: 2000 (Tese de doutorado) – Faculdade de Arquitetura e Urbanismo da Universidade de São Paulo.

[8] BARBIRATO, Gianna Melo. Aplicação do modelo de balanço de energia na análise do ambiente térmico urbano de Maceió, AL. São Carlos: 1998 (Tese de doutorado) – Escola de Engenharia de São Carlos da Universidade de São Paulo.

[9] LUXMOORE, D.A., JAYASINGHE, M.T.R. & MAHENDRAN, M. Mitigating temperature increases in high lot density sub-tropical residential developments. In: Energy and Buildings, 2005, v. 37, p.1212–1224