WARM-HUMID CLIMATE: METHODOLOGY TO STUDY AIR TEMPERATURE DISTRIBUTION: MOBILE PHONES BASE STATIONS AS VIABLE ALTERNATIVE FOR FIXED POINTS

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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. Satellite images with high resolution allow identifying how the horizontal surfaces can influence microclimatic alterations. Results of measurements for a summer period, in February 2006, are presented. The fixed points were defined using 20 mobile phone base stations in the city of Natal/RN, distributed along the four administrative zones. Measurements were carried out for seven 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 Ikonos 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 lowest humidity levels were found. The proposed methodology of measurements in fixed points using mobile phone base stations is original, provides safety to equipment and exposure standardization. Another advantage is their strategic location and distribution, which could facilitate the repetition of this kind of experiment in others cities and regions.

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. some authors have already prove it for different situations, like Katzschner (1997), Mizuno et al (1990), Luxmoore, Jayasinghe & Mahendran (2005) and Oke (2004).

The city of Natal is located at the Eastern coast of the Rio Grande do Norte State, at 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 01).

Figure 01 – Natal localization in Brazil

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.

The city presents two "different characteristic times", according to Araújo, Martins and Araújo (1998), with small climatic variation among them: the first one consists of the period from April to September (called here the winter period), and the second one from October to March (considered the summer period). The winter period is rainy, with mild temperatures, high relative humidity and the highest wind speed with predominance in the southeast quadrant. In the first hours of the day, mainly, the wind direction varies south – southwest. The summer period, from October to March is characterized by higher temperatures, lower relative humidity and relatively low wind speeds with southeast predominance, presenting small variations in the direction east - northeast.

2 METHODOLOGY

For the accomplishment of this work the whole geographical extension of the city was considered, an area about $170km^2$ of a quite complex urban reality, with different land use and urban configuration.

The first stage of the field work was the analysis of the cartographic basis complemented by *in loco* visits. By combining data of the cartographic basis, aerial photography, high resolution satellite images and field research, the different patterns of urban occupation in the study area were identified. A survey of vegetation and water bodies was also carried out. With these data, the points were chosen for collecting the climatic data.

The environmental sensors were programmed for two series of measurements, to characterize the climatic periods of summer and winter: the months of February and July of 2006. The first one has been already accomplished.

For seven consecutive days, from 02nd to 10th February, 2006, air temperature and relative humidity data were registered each 30 minutes. It is worth to point out that the measurement period presented compatible characteristics with the typical climatic summer day.

Air speed and direction were registered every 10 minutes at three locations, strategically positioned in function of the safety for the equipment and space distribution regarding the other points. They were called est03, est027 and estref (reference station).

The collection of data for the fixed measurement points was accomplished by continuous registrations through loggers: 03 testostor175, 11 testo175-177, 03 hobo H8, and 03 Davis meteorological stations. The protection for direct and diffuse solar radiation was a plastic protection developed especially for the research, based on the model of standard meteorological shelter (Figure 02). The protections were fastened in the safety stairs of mobile phones base stations, at 1,5m height above the floor, on average. This is the height considered appropriate in researches about human thermal comfort.

Figure 02 – Protection to the equipment

Figure 03 shows the map with the location of all field measurement points separated through administrative areas. The following criteria were considered in making these selections:

- in first place was the safety for the equipment (since they are terrestrial enclosed with restricted access to the company grantee's employees - VSE-Claro)

- the standardization possibility in the exhibition of the equipments, since all the towers present basically the same physical structure (one wall up to 2,5m of height, surrounds the area, the floor is in stone gravel, shelter for equipment can be provided)
- the location and strategic distribution of the points (dispersed for the whole city),
- the diversity of typologies found in the their surroundings.
- the facility of access (due to the fact that the research team works with a single company),
- the lack of interference of the human activity in the measurement schedules, as well as of equipments, the certainty that the measurement points won't have altered their physical structures (for the second stage of the research)
- the possibility of repetition of the methodology in areas of similar climate, given the presence of the same building site type and of technology, in most of the cities nowadays.

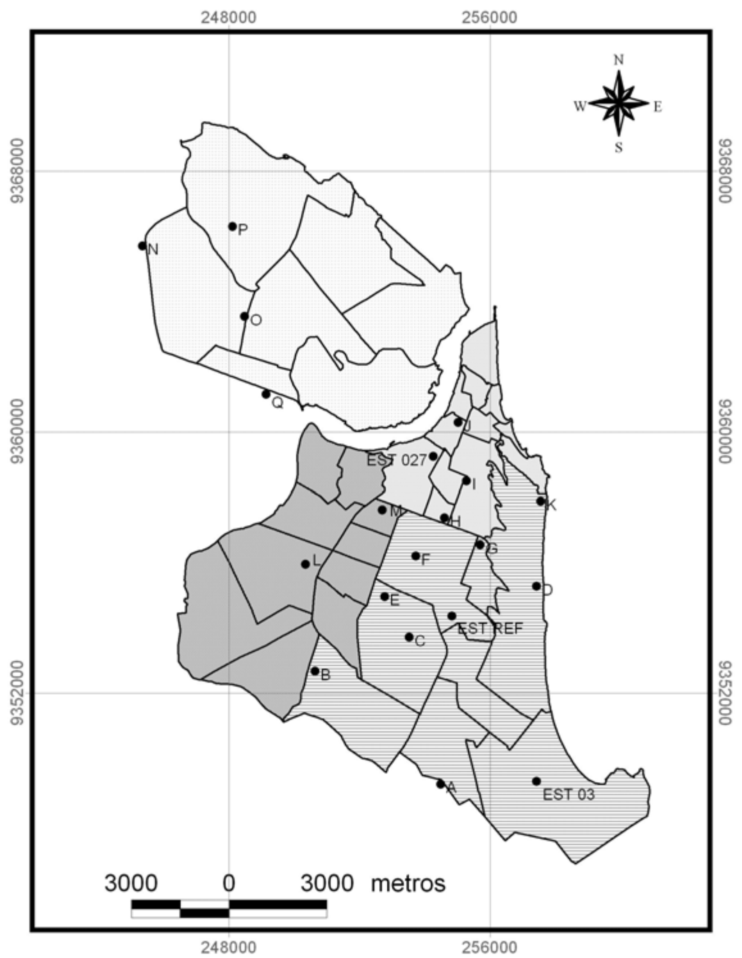

Figure 03 - Points of measurement in the city

There are, however, some aspects that were observed for the choice of the most appropriate measurement points for the research in the existent sites. They are related to three main aspects: urban ventilation, the size of the available land, and the height of the mobile base phone station in relation to the soil. When treating the first aspect it is important to consider the environment close to the area and the limits of the terrain (walls or grids) present in the site, so that there should be no barriers for the free flow of the predominant ventilation. For this research, the equipments were installed at 1,5m height, so locations that had wall heights higher than 2,60 meters and lots smaller than $200m^2$ were not considered in the study To define what would be considered as the ideal lot size, it was verified that the standard lot admitted in the established division in law for the master plan of the city is $200m^2$ (art. 46 of PDN, 1994). Having this fact in mind, the sites whose areas were equal to or larger than $200m^2$ were considered appropriate for the research; while sites with areas smaller than $100m^2$, were discarded. Sites with areas between 100 and $200m^2$ were studied individually.

The option for installing the equipment in the stairway comes from the fact that there were three basic tower types with different structures: tubular, triangular and square. All the base stations possess this access stairway, which allowed the standardization.

After the field measurement, the next step was the statistical analysis of the data, which is still in process, which aims to find a thermal characterization of the city. At the same time, satellite images have been used obtained through remote sensoring (Faria, 2005); this resource allows establishing dynamic relationships on soil occupation and the thermal field, serving as subsidy and tool for the urban planning.

It is worth to emphasize that two test types preceded summer measurements, to validate the method. The first one showed the need to better ventilation of the temperature sensor, so a new kind of protection was proposed for the equipment.

The second one was carried out in Natal/RN in February of 2006. It consisted of a study of the behavior of the four types of equipments involved in the research. All of the protected sensor units were mounted above a flagstone surface (Figure 04). Temperature and humidity were then measured over a 24 hour period at 30 minutes intervals; no meaningful statistical differences were observed among the data.

Figure 04 – View of the test

3 Analysis of the results

The surroundings of each measured point were studied through image of the satellite Ikonos 2003, since its resolution allows for the detailing of the occupation types. There were points very close to the seashore (points D and K), areas with very small lots (points P and Q), others in less dense areas (points Est03 and N), or areas close to barriers to predominant wind, either a natural barrier - Parque das Dunas (point G), or an artificial one (point H).

It was necessary also to adopt a point as reference, and this one is located at INPE - National Institute for Space Research, at the campus of the University. It could be observed that the transmission equipments and existent reception of cellular telephony in the towers, which emit radiation of the kind of microwaves and radiofrequency, it didn't interfere in the results of the test, since those, when compared to the reference are statistically compatible.

From the analysis, it is interesting to observe that the humidity was highest at the point close to the Atlantic Ocean (point d - 80,6%) and that the point Est-03 (27,80ºC), with the lowest average temperature, is in a low density area and without barriers to ventilation.

Results show meaningful differences between the measurements points. The average values for temperature and humidity at each point in summer are presented in Figure 5 and Figure 6 respectively. Temperatures varied from 27,08^{0}C to 30,01^{0}C and relative humidities varied from 80,6% to 65,5%. The reference site had an average temperature of 27,14^{0}C and average relative humidity of 72,1%.

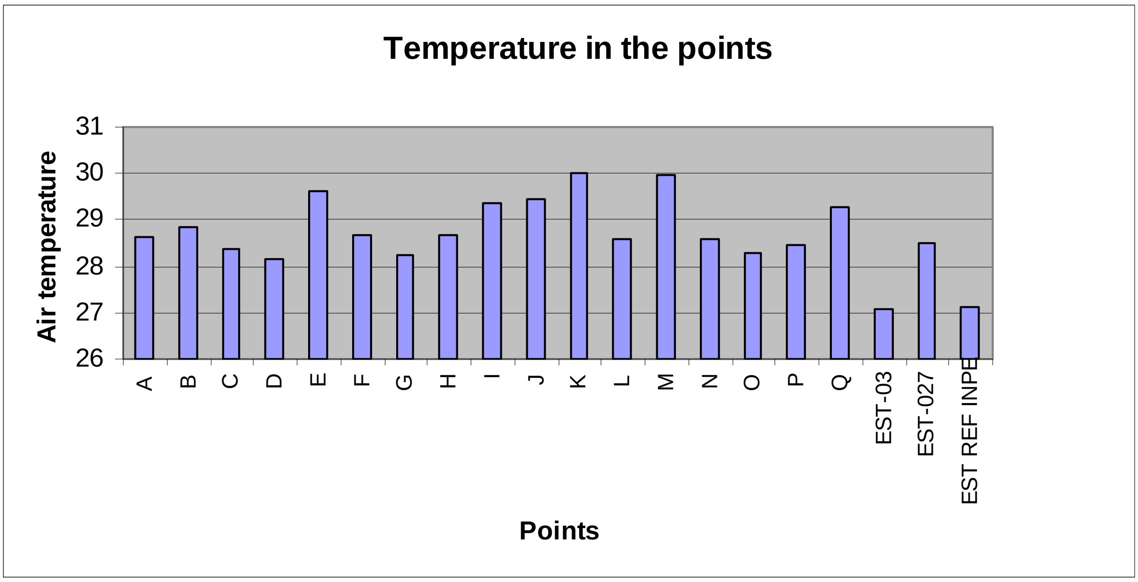

Figure 05 – Mean temperature for all points (temperature in ^oC)

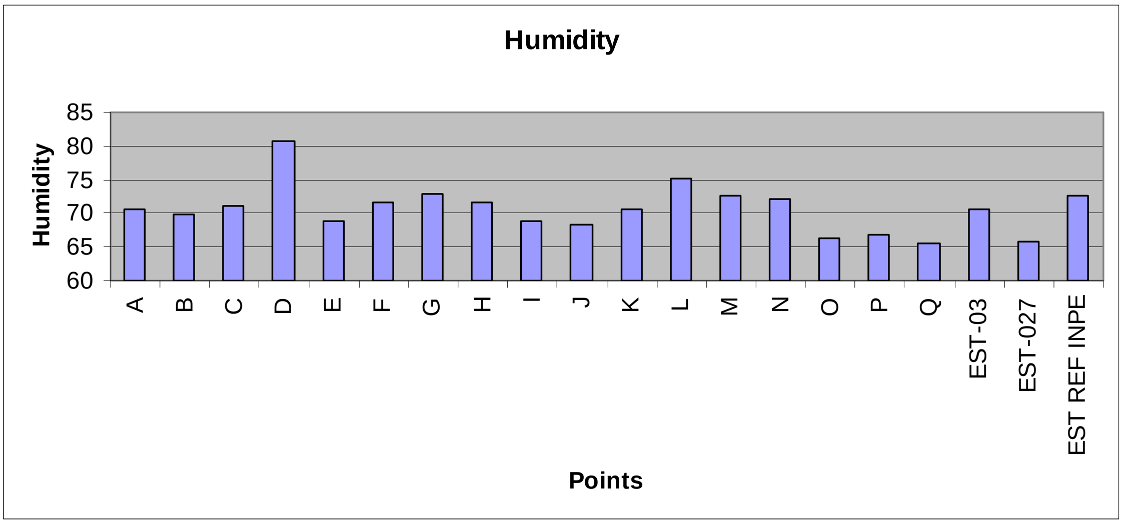

Figure 06 – Mean humidity for all points (humidity in %)

The hottest points were E e K (near big paved areas) and M (in a dense area); the points Est-03 and the point of reference at INPE are those with the lowest temperatures. They are located in areas free from obstacles, with green area and low density. In relation to humidity, points O, Q and Est-27 present the smallest values.

In relation to the values of wind speed (measured in only three points) it was noticed a great variety of data, as expected. Table 1 shows the average maximum and minimum results, but there always had a breeze.

Table 01 –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 SOME CONSIDERATIONS

The work continues in process but it already allows some initial considerations. The air temperature analysis, showed that air temperature is related to the use of the urban soil, geometric characteristics of the buildings, properties of the construction materials, density of the built area, and effects of parks and green areas, facts already confirmed by other studies. It was observed that the points in highly built-up areas had higher average temperatures than areas with vegetation.

In addition, the option of locating the measurement points in areas with mobile phones base stations proved to be correct and it can allow the repetition of that methodology in other areas. The equipments were not put in risk and the found diversity of soil use allowed accomplishing the objective of the research in studied areas with different occupation profiles.

The next phase will be the elaboration of the maps in Arcview to make possible the comparison of the thermal behavior for administrative areas, refining the research through the technique of supervised digital classifiers.

This kind of research is very important because the knowledge of urban climate has to be applied in urban planning, as Oke (2005) defends, developing a new planning strategies with environmental quality, what allows the continuity of the growth of the urban areas.

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