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Mobile Meteorological Survey Station: Applying Measurement Tools on a bike to create the Meteobike

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Abstract

This paper presents a logistic proposal for the research project related to thermal comfort in Rio de Janeiro's open spaces. Part of the investigation consists of collecting weather data and applying a thermal sensation survey to pedestrians in Rio de Janeiro city's centre. The weather station used is a Davis-Pro2, composed by a cylindrical module body moulded on plastic and sustained by a central tube attached to a tripod, both in galvanized iron. The fieldwork dynamics requires data collection in different points, therefore, involving the constant transportation of the equipment throughout the city. Carrying the equipment in a big town generally implies travelling long distances with a heavy and bulky cargo by using public transport or a car, creating pollution, facing traffic problems and dealing with lack of adequate parking spaces. The idea of attaching the station to a bicycle came naturally to the two researchers. The system, as idealized, has proven to be efficient, providing practicality, lightness and mobility in data collection, coupled with the advantage of being a non-polluting transportation. The bike name 'Meteobike' was suggested by many respondents.

Keywords: Meteorological Station, Urban Microclimate, Meteobike, Measurements Facilities

1 Introduction

The growing concern about the environmental phenomena has promoted an increase of studies related to the urban heat island (UHI) formation in several research areas that correlate the human being with the climate. These heat islands can be defined as urban areas with higher temperatures than in neighboring regions and their formation is a result of the interaction of various factors, and for its study it becomes important to have a broader view of the problem. There are many variables involved in the UHI generation process and it is important to take into account the largest possible number of them.

Large concentrations of buildings in cities mean a very large amount of solar radiation absorbing surfaces, facilitating the emergence of (along with pollution) heat islands, particularly noticeable at night, when the material of the buildings dissipates the heat stored during the day.

UHI has negative effects ranging from environmental discomfort until the energy consumption increase, which represents a high financial and environmental cost. This increase is due to the need of use of refrigeration and air conditioning equipment, to provide users of the built environment in these regions the proper comfort level. Thermal energy poured into the outer space by apparatus feeds back the phenomenon, producing in turn a higher consumption of electricity.

The theoretical and practical interest in this subject comes from the need to establish the best relation between ventilation intensity and solar radiation for a specific region, according to the climate conditions, not inducing urban heat islands formation. When determining the parameters such as wind velocity and air temperature to define these areas it is possible to use some simulation tools seeking at least some degree of prediction of trends for each study area. Initial studies from Drach et al. and Carneiro et al. (Drach et al, 2013; Carneiro et al, 2012) indicate the ability to interfere with air circulation, for example, by changing the location or shape of obstacles, the urban cover materials and introducing greenery.

Thus, through simple changes in some cases it may be possible to mitigate the effects of UHI. For example, the introduction of green areas, both for production and for aesthetic uses, can also improve and minimize the negative effects of heat islands, and contribute positively to the urban landscape. The effectiveness of any recommendations to minimize or sometimes resolve the problem seems to be proportional to the support found in society, administration and local governments.

Experimental and computational studies to evaluate alterations in ventilation from changes in urban morphology were developed in Wind Tunnel at the Faculty of Architecture and Urbanism of the Federal University of Rio de Janeiro (Drach et al, 2013; Carneiro et al, 2012) and also using the software ENVI-Met (Bruse, 2009), software developed for climate simulations in urban areas (Barbosa et al, 2010a; Barbosa et al, 2010b), respectively. These studies showed the ability to increase ventilation and reduce the temperature from the introduction of greenery and changes in urban morphology. This work, however, focuses mainly on studies of thermal comfort in open spaces in the city of Rio de Janeiro and complements the computational and experimental studies, previously developed. It also presents the possibility of making systematic data collection through the use of weather station and survey about thermal sensation applied to users of open spaces. The production of this database will allow the analysis of data collected for the city of Rio de Janeiro, also allowing further comparisons with the responses previously obtained using the same methodology, to the cities of Curitiba and Glasgow (Krüger et al, 2012a; Krüger et al, 2012b; Krüger et al, 2011), both with climate, in terms of urban areas, and quite distinct local population.

Currently fieldwork campaigns are being implemented for collecting meteorological data and information about thermal sensation. The research is being conducted in pedestrian streets in the city centre area of Rio de Janeiro. Seven stop points were defined according to the differences observed in urban form, for example, height and proximity of buildings, presence of vegetation, squares etc. Here these differences are represented by the sky view factor - FVC. For the determination of the SVF, fisheye images at each monitoring point were taken using a fisheye lens Sigma 4.5mm f 2.8 EX. From the fisheye images, the SVF and 'solar path' were calculated using the computational tool, Rayman-pro (Matzarakis, 2013). The relationship between the sky view factor in urban canyons and the air temperature was noted in previous studies (Taha, 1988).

This paper presents a logistic proposal for the research project related to thermal comfort in Rio de Janeiro's open spaces. Part of the investigation consists of collecting weather data and applying a thermal sensation survey to pedestrians in Rio de Janeiro city's centre. The weather station used is a Davis Pro2, equipped with temperature and humidity sensors, cup anemometer with wind vane, silicon pyranometer and globe thermometer. This station is composed by a cylindrical module body moulded on plastic and sustained by a central tube attached to a tripod, both in galvanized iron.

The fieldwork dynamics comprises data collection in different stop points of the city centre, therefore, involving the constant transportation of the equipment throughout the city. Carrying the equipment in a big town generally implies travelling long distances with a heavy and bulky cargo by using public transport or a car, creating pollution, facing traffic problems and dealing with lack of adequate parking spaces. Being cyclists, the idea of attaching the station to a bicycle came naturally to the two researchers. The bicycle used is a Tandem Recumbent Zöhrer model, previously owned.

From observations of the behaviour of thermal sensation survey associated to microclimatic conditions it could be possible to devise strategies such as, shading, proper use of vegetation or other urban elements, in order to improve the qualities of the pathways studied as a way to try to minimize the external discomfort. So, the main objective of this proposal is to study the general human response of local people to climate particularities of Rio de Janeiro City and determine some intervention strategies in urban morphology that could lead to improvement of environmental comfort.

2 'Meteobike'

The system, as idealized, has proven to be efficient, providing practicality, lightness and mobility in data collection, coupled with the advantage of being a non-polluting transportation. The bike name was suggested by many respondents that referred to a 'meteorological bike', which was shortened to 'Meteobike' (Figure 1).

Figure 1. The 'Meteobike' in Copacabana Beach, Rio de Janeiro, Brazil.

When biking to the collection point, the station can be positioned at the lower end of the tube, leaning over the trunk and wrapped in absorbent material to avoid impacts. As a precaution against possible accidents, currently a Styrofoam kit is used, but it is planned to build one in fiberglass. Thus, it was possible to improve the system, giving lightness (to get rid of heavy galvanized iron tripod) and mobility at the same time.

The problem of providing stability to the weather station set over the bike, once parked at the collection point, was solved by the making of a 'centre stand' in aluminium (not to add more weight to the set, since the models found in bike stores are usually made of cast iron) similar to those used in motorcycles. Thus, in Figure 2 it can be seen the 'centre stand' on aluminium, designed and built by the researchers. Part of the twisting force on the bike frame is relieved by supporting the rear wheel on the centre stand (Figure 2a). There were still the two tasks, namely, to deal with the usual possibility of uneven floors and to give lateral stability to the whole set. The first was solved by a system allowing the adjustment and longitudinal displacement of the rack to which the tube (shaft station) is set, as well as the transverse displacement of the same tube. Thus the station can be positioned plumb, which is its ideal working position. The second was solved by setting up across a long aluminium tube at the centre stand.

(a) (b)

Figure 2. Centre stand (a) support for station (b) aluminium designed and built by the researchers.

The 'Meteobike' has been tested during the 16 campaigns in Rio de Janeiro city, Brazil, and along the 39 campaigns in Glasgow city, UK. In all of these campaigns the 'aluminium stand centre', similar to those used in motorcycles, proved to be able to withstand the cycling set and the weather station giving firmness and stability to the assembly. When standing at a stop point, the 'Meteobike' performs as the tripod supporting the meteorological station and its correct position is adjusted using a spirit level.

3 Area of Study

The region of the city of Rio de Janeiro is located in the administrative center of Region 2 and belongs to City Centre Council covering the districts of Catumbi, Cidade Nova, Estácio, Gamboa, Glória, Praça da Bandeira, Santo Cristo, Saúde. The occupation of this region occurred with the beginning of the city of Rio de Janeiro and, despite the constant changes imposed on the area, it still has an important historical and cultural heritage of the city.

All selected points for measurements and surveys are located in the pedestrian streets in the city centre of Rio de Janeiro. The streets have vehicle access allowed only for services (deliveries and withdrawals of goods and other related maintenance activities of trade, offices, businesses, etc.), thus not having a steady stream of cars or traffic. In Table 1, the population numbers of the study area are presented according to the IBGE Census 2010, and these values are interesting for understanding the population dynamics of the region.

Table 1. Population - City and central area of Rio de Janeiro.

	Total
Rio de Janeiro city	6.323.037
Central area	41.142

IBGE censo 2010 - http://www.ibge.gov.br/home/estatistica/populacao/censo2010/tabelas_pdf/total_populacao_rio_de_janeiro.pdf

From these data it can be seen that this is a region with a very low local population, and the flux of people during the day is related to a mass of floating population.

The evaluation of comfort in public open spaces is a complex issue, since many factors interfere with pedestrian feel. Their perception includes answers to a range of stimuli to which they are exposed, not only physiological and physical, but also social and psychological. The points are located mostly close to the emblematic areas of Rio de Janeiro Centre, which have historical or cultural attributes. They also have a nice landscape around and the regions have not been shown a visual pre-disposition to discomfort. In this subject they have some similarities.

External activities in the region can be classified as predominantly ‘necessary’ (Gehl, 2001), since they do not depend on the conditions of the environment, being related to daily life. These spaces are used as binding path for the development of numerous activities, including work, school, trade, among other interrelated and providing support to the activities developed.

As mentioned earlier the determination of measuring points was to evaluate differences in spaces with urban morphology. At first the points were selected on a map, and prioritized being a point of pedestrians. Following, these points were visited and pictures of the surroundings, using the Fisheye lens, were taken. With these photos the sky view factor (SVF) and ‘solar path’ were calculated using the computational tool, Rayman-pro (Matzarakis, 2013). From the analysis of this documentation and impressions about the place visited, the seven points evaluated in this study were selected, taking into account the variations in height and proximity of buildings, existing vegetation, squares and confined spaces. The idea is to make possible the representation of the area using different configurations of urban morphology.

4 Development of the research

4.1 Defining the stop point locations

For identification around each measurement point, pictures were taken in the North, East, South and West views - identified with the use of a compass. Exhibitions geared toward heaven were also made for the determination of sky view factor (SVF). For each point, three images (bracketing) were taken to obtain an optimal point of exposure - thus allowing the subsequent selection of the most suitable for calculating the sky view factor image. Beyond the compass, a measuring tape and a spirit level were used for precise adjustment of the equipment.

From images on Table 2 is possible to observe the seven stop points determined for Rio de Janeiro city centre. The images and the SVF values allow noticing the variation in urban morphology with the representation of a greenery area, an open square, a narrow canyon etc.

Table 2: Seven stop points defined for Rio de Janeiro city centre.

Stop point	1	2	3	4	5	6	7
Fisheye image							
Black / White Image							
SVF	0.272	0.030	0.269	0.454	0.111	0.252	0.038

4.2 Campaigns and equipment

The campaigns take five hours and begin at 9 a.m. and finish at 3 p.m. As told previously, a Davis Vantage Pro2 weather station was used for measurements, as it can be seen in Figure 1. The weather station comprises an air temperature and humidity sensors at 1.1 m above ground, a three cup anemometer (at approximately 1.5 m above ground) and a silicon pyranometer at 1.4 m. In addition, as in Krüger et al (Krüger et al, 2012a-b), a globe thermometer was organized for evaluating the Mean Radiant Temperature (T_{mrt}), which consisted of a gray sphere with an enclosed temperature data logger (Tinytag:TGP-4500), attached to the tripod at 1.1 m above ground.

Data from all sensors were registered by a logger and recorded every five seconds, and averaged over one minute. T_{mrt} was calculated according to (ISO 7726, 1998) for forced convection from the measured globe temperature (Tg), wind speed (Va), air temperature (Ta), and globe's emissivity (εg) and diameter (D) as in Krüger et al (Krüger et al, 2012a-b).

4.3 The survey

As in Krüger et al (Krüger et al, 2012a-b), a comfort questionnaire was personalised according to the recommendations of ISO 10551, 1995. The first trial had two pages and questions related to the wind, shade and other specific preferences, but it did not work because it was big enough to make people not agree to answer so many questions.

So the survey consists of items related to: gender; age; height; weight; clothing insulation adopting a look-up table with typical clothing garments (ISO 9920, 2007); time of residency in Rio de Janeiro or surroundings (to take into account the acclimatisation factor) and time spent outdoors before completing the survey. The second part of the questionnaire consisted of two symmetrical 7-point two-pole scales ranging from -3='cold` over 0='neutral` to +3='hot`, used for assessing the respondent's thermal perception and preference. The time of residency and time spent outdoors were adopted as exclusion criterion of the answer, when less than 6 months and/or less than 15 minutes outdoors, respectively (Krüger et al, 2012a-b).

4.4 Temperature field simulations

The first computational simulations were done by using the ENVI-Met software, developed for climate simulations in urban areas (Bruse, 2009). This research is trying to find some answers for questions such as: how can we minimize the creation and the effects of heat islands? So, urban morphology and greenery could be helpful. An example using vegetation was done for the area close to Points 1 and 2.

The first image (Figure 3a) presents the current situation, in other words, with some greenery and the proposed change, without vegetation, is shown in Figure 3b. Even being the first tests using computational simulation, the results are able to show a qualitative response, similar to that was observed in loco. The presence of the greenery represents an increase in comfort quality.

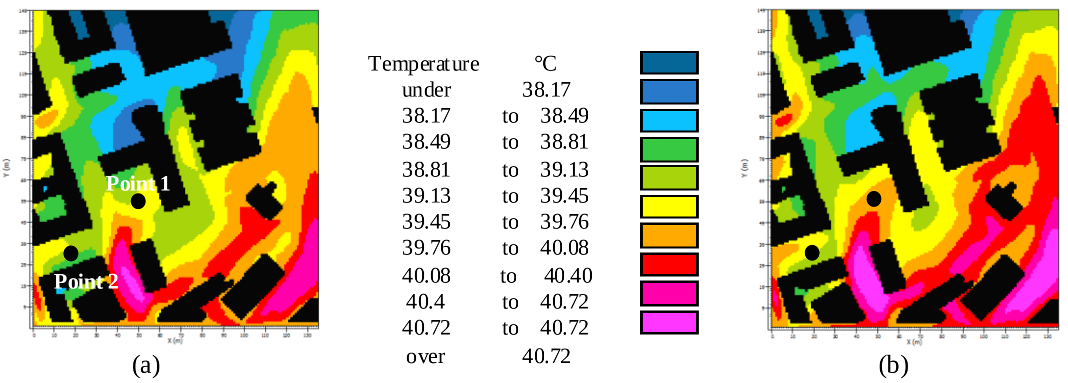


Figure 3. Area close to Points 1 and 2: (a) current scenario and (b) an imposed scenario, without vegetation.

An observer was located in a specific point (Figure 4) inside the model area, where processes in the atmosphere and the soil can be monitored in detail. It was chosen to allow comparative analysis.

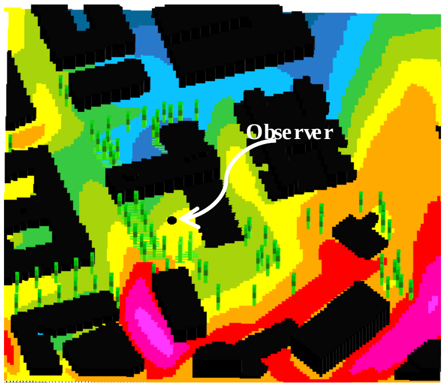
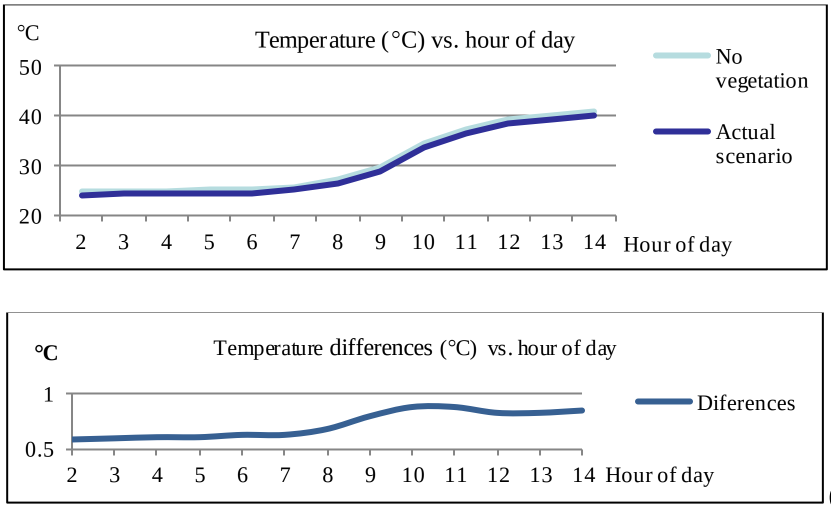


Figure 4. Observer point inside model area.

The graphical results in Figure 5 were read from the viewpoint of this observer. It is possible to notice an increase in temperature when looking the scenario without vegetation (Figure 5a) and also to observe that the difference increases in warmest time (Figure 5b).



(a)

(b)

Figure 5. Graphical results: (a) both scenarios, with and without vegetation and (b) differences between temperatures during the day.

5 First Results and Discussions

The use of the 'Meteobike' does not interfere on the methodology of data collection itself. All the procedure continues to be held by the weather station sensors and processed by several computational methods. The bike only gives more speed and efficiency, in a non-polluting way, for the collection of such data. The convenience and practicality of fieldwork with the support of the 'Meteobike' was tested in several campaigns and represented a major gain since it carries the weather station (which weighs around 5.5 kg), all supporting material (questionnaires, compass, measuring tape and spirit level) and two researchers. Moreover, as previously mentioned, this allows us to leave out the heavy tripod (5.90 kg). If all these materials had to be carried by the researchers, it would mean that they would have to carry nearly 12 kg in each measurement campaign. Apart from that, it is necessary to say that the use of this bike solves the very common problem of parking in urban centres.

On the first summer 328 surveys were according to the exclusion criterion. The first results seem to indicate, as expected, that greenery represents an important ally to improve environmental quality in open areas. Streets, as Pedro Lessa in the city centre, presented, even in warm day, better thermal sensation if compared with other areas without vegetation.

The utilization of the green areas and their cooling effect on urban climate has been explored all over the world in the last years, and indeed the UHI effect is intensified due to the lack of green areas in the urban environment (Wong & Yu, 2005). The use of greenery can be also considered as one of the most important methods to mitigate the UHI effect (Lu et al, 2012; Chen & Wong, 2006; Argiro & Marialena, 2003).

If thinking in the future, researches have pointed that the growth of vegetated areas in urban areas can represent an important way to mitigate and adapt to the negative climatic effects of climate changes expected in the near future (Shimoda, 2003; Oliveira et al, 2011).

In his book Emmanuel (Emmanuel, 2005) indicates some strategies for the tropics, among them the need to act in small spaces aiming to improve the comfort conditions in each block. He proposes the use of natural elements (vegetation and water) as tempering agents and indicates, from studies, the effectiveness of an action on micro scale, i.e., a larger number of small parks influence the microclimate of a larger area to their immediate surroundings. He argued that the major elements of the climate modifiers have little influence if not treated in micro scale.

Emmanuel (Emmanuel, 2005), Oliveira et al (Oliveira et al, 2011) state that even small green areas can contribute to the mitigation of the UHI and global warming effects on the cities, but they alert to the detail that thermal performance of a green area and its influence in the surrounding environment depend on the urban and climatic features of the city. Therefore, Oliveira et al (Oliveira et al, 2011) also admit that

6 Conclusions

Similar researches have even now been done mostly in temperate climates but further studies are needed in order to provide more and more detailed information about this subject taking into consideration the specific features of each city.

In the case of Rio de Janeiro city, which has been suffering a constant enlargement, it is important to evaluate the high-use areas, such as the city centre as it can be observed, where small alterations in the public space sometimes are able to represent substantial gains in quality of space. The intense afforestation, present at Rua Pedro Lessa, allows its users to enjoy a more pleasant environment.

There are many variables and possibilities for urban form and any proposition should consider solutions guided by beliefs or generalizations. In any project or proposal, the study of models for simulation can assist in decision making of architects and planners.

To deal with the differences related to tropical climates, plus the consequences of global warming, it is really necessary more research and persuasion to find ways to convince the community and private institutions to contribute to apply strategies, some of them really simple to put in practice, but efficient to improve life quality.

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