Léa C. L. de Souza

Among Winds, Water Bodies and Urban Elements

Érico Masiero[1], Léa Cristina Lucas de Souza[2],
[1] *Federal University of São Carlos, Post Graduate Program of Urban Engineering, Address: Washington Luis Road Km 235 CEP 13565-905, São Carlos, São Paulo, Brazil*
ericomasiero@yahoo.com.br
[2] *Federal University of São Carlos, Post Graduate Program of Urban Engineering, Address: Washington Luis Road Km 235 CEP 13565-905, São Carlos, São Paulo, Brazil*
leacrist@ufscar.br

dated : 15 May 2015

1. Introduction

The effect of adiabatic direct evaporative cooling related to water bodies can contribute to decreasing the air temperature and increasing the humidity index, efficiently taking advantage of wind flows. In other words, extreme ranges of temperature and the possibility of heat island occurrence may be minimized by inserting water vapor into an urban environment that is under tropical climate conditions.

Arnfield (2003) reports that the complete estimation of circulating water volumes - from natural and anthropogenic origins - in urban areas requires further investigation. The physical environment may alter the natural regime of evapotranspiration, therefore elucidating the interaction between the water surface and the urban canopy layer, which is an important step in urban studies. This interaction affects heat transmission through the horizontal movement of air masses.

In addition, few studies have quantified the extent of the influence on the microclimate, caused by urban parks in dense built-up areas. Thus, guidance for the establishment of urban blocks, streets, urban canyons and urban density in relation to the distribution of vegetation and water bodies should be most considered in urban planning.

The combination among the wind potential of a given location with moisture provided by water bodies, soil and vegetation may be optimized by the physical characteristics of the terrain and especially the choices of certain patterns of occupation of the built environment. Coutts et. al. (2013) claim, for example, that storm water has the capacity to increase soil moisture, increase water availability for urban vegetation and, along with green infrastructure, may provide a mechanism for improving urban climates in Australia.

Heat exchanges, wind flows, evapotranspiration and physical phenomena which are generally related to the urban environment, are influenced by the features of urban areas, creating microclimates. The microclimatic phenomenon is a result of the interactions among urban buildings and the natural elements of the macro and mesoclimatic scale.

Associated with the performance of water bodies on the microclimate, the knowledge of prevailing characteristics of wind speed and direction on a particular site is of fundamental importance for the zoning of its surroundings, helping to prevent unwanted effects caused by urbanization itself. The action of prevailing winds may provide necessary energy to facilitate the evaporative cooling process. As long as the wind makes contact with the water surface, water droplets may spread throughout the urban environment and may contribute to reducing the temperature and increasing the absolute humidity in their neighborhoods.

Taking this into account, this analysis consists of evaluating the variation of air temperature and absolute humidity on the surroundings of two margins of an urban water reservoir. To reach this aim, this paper analyses the joint action of local winds and water body on the microclimate of the surroundings of a water reservoir located in São José do Rio Preto, SP, Brazil.

2. Method

The adopted method for this research consisted of monitoring two urban fractions in São José do Rio Preto, which are on opposite water body banks and under different conditions of wind influence. For this purpose, a methodology was developed to describe the physical characterization of studied areas regarding the macroclimate, the microclimate and the urban morphology. The collection data from the field was carried out to support the computing simulation with ENVI-Met, in order to understand how humidity behaves in an urban residential area.

The site is characterized by a slightly wavy topography with a broad ridges and a modest altitude - 500m on average, with the distribution of the urban fabric in 117.43 km². Two highways - the BR-153, in the NE-SW and in the E - W direction, have influenced the direction of city growth, which has about 420,000 inhabitants. The urban area is cut by two rivers, the Black River and the Macacos River which together form two areas of 9 km² of artificial water reservoirs close to the central urban area. Since the damming of the rivers began to be promoted in the 1970s, many residential areas emerged along their banks without any occupation criteria. This occupation has generated different patterns in urban areas, sometimes damaging the natural surroundings and polluting the water, but never taking advantage of the microclimatic potential.

According to Monteiro, (1973), the São Paulo State territory, in which São Jose do Rio Preto is located, is vulnerable to the occurrence of the main atmospheric masses South America. The Atlantic Tropical, the Atlantic

Polar and the Continental Equatorial air masses, combined together with the geographical factors of positioning, contribute to defining the characteristics of the tropical climate, alternately humid and dry.

The city areas correspond to an Aw climate, according to Koppen's climate classification updated by Peels et. al. (2007), representing a Tropical Altitude Climate with dry winters and warm summers, mild and rainy, with an average winter temperature close to 18℃ and 30℃ in the summer. The annual average of relative humidity stands at around 70% approximately, reaching ranges below 20% in the driest months.

Fig. 1: São José do Rio Preto city and experiment location
Source: adapted from Google Earth (2015) and PMSRP (2010)

This study was carried out during August, as it is the month which presents the lowest annual humidity rates. This fact allows for a more accurate recording of the influence of the water reservoir on the microclimate, with no excessive interference from humid and cold air masses. The data were compared to the local registered data made available by the meteorological station from the CIIAGRO Weather Station – Integrated Center of Agro Meteorological Information, which provided data of wind speed and direction. The latter is located in a rural zone 6.5 Km southeastward from the studied area, exactly in the same direction of the prevailing winds of the region.

At this stage, the temperature, humidity, wind speed and direction data were collected during three consecutive days. Thermohigrometer sensors were located at opposite margins, east and west and positioned at pedestrian level (1.5 meters high) and at 30 meters away from the water surface (Figures 2 and 3).

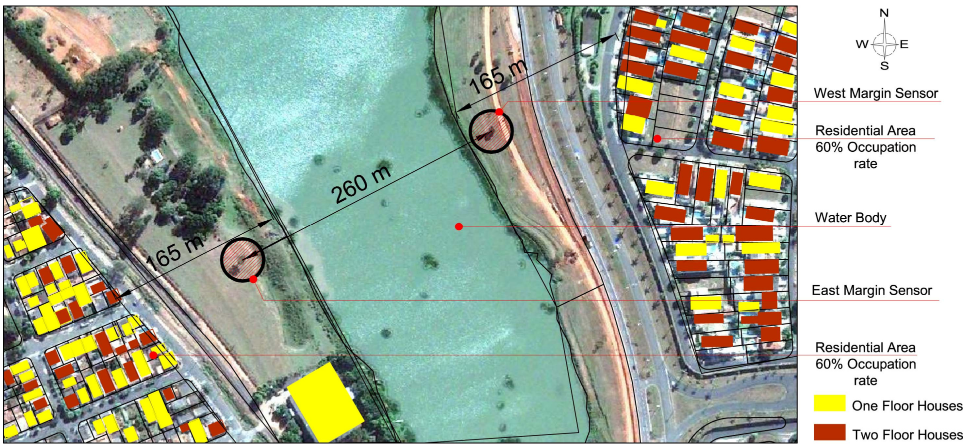

Fig. 2: Area of experiment location and urban section
Source: adapted from Google Earth (2015)

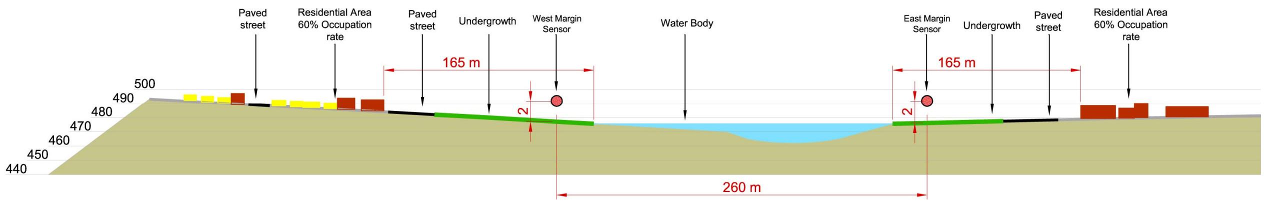

Fig.3: Profile of the water reservoir and its surroundings

After collecting the data from the field, a digital model of the area was developed by applying the ENVI-met 3.1 software. This process was able to simulate the thermodynamic phenomena that occurred in the urban area and served as a basis for the comparison between the simulated and measured data.

The inputs of this computational program are the macroclimate data, the vegetation type, the main features of buildings - such as shape and height - and the roughness of the predominant pavements in the area. The climatic input data, which were related to the predominance of local climate factors and other spatial factors, were applied as follows in Table 1:

Table 1: Input data applied to the ENVI-met model

Contents	**Input values**
Wind Speed at 10 m Ground	2 m/s
Southeast Wind Direction	178°
Initial Temperature Atmosphere	299.99K
Specific Humidity at 2500m	10g Water/kg air
Relative Humidity at 2m	65%
Model size	180x180x20m
Height of buildings	Z = between 5 and 10m
Grid	2 x 2m
Latitude	20°49'11" South
Longitude	49°22'46" West

The evapotranspiration and shading vegetation data were obtained by the ENVI-met library providing the generic features of the vegetation.

Water bodies in the urban environment are represented mathematically in ENVI-met 3.1 as a special kind of soil, which includes the calculation process of transmission and absorption of short-wave radiation. The process of natural convection is the main factor influencing the heat exchange between the water body and the urban environment. The software treats the water body as still water and does not reproduce the effects caused by turbulent sources, nor effects of sea breezes. (BRUSE, 2012)

According to Nakata et. al. (2011) ENVI-met 3.1 is a model that requires a long period of time to perform the iterations, until the software stabilizes and finds results consistent with the reality. In our case, six iterations were simulated from a hypothetical day of 29th August, 2014. The data of the temperature, humidity, wind speed and wind direction were automatically saved every 60 minutes, for receptors positioned on the east and west margin of the dam.

3. Results

For the spatial conformation of the dam, the point situated on the east bank is more susceptible to winds coming from drier and warmer urban areas. On the other hand, the points situated on the West bank are virtually embraced by the dam and experiences a greater influence from the southeast and northeast winds, which carry moisture obtained from the dynamic interaction with the water body surface. The combination of gusty winds from northern, northeastern and northwestern directions, which occurred during the morning of the 29th and the evening of the 31th, contained enough moisture to reduce the temperature of the west margin by about 1.77℃ more than the eastern one (Figure 4).

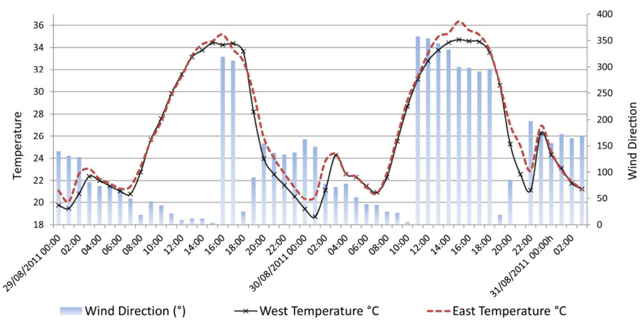

Fig.4: Temperature variation from 29th to 31th August

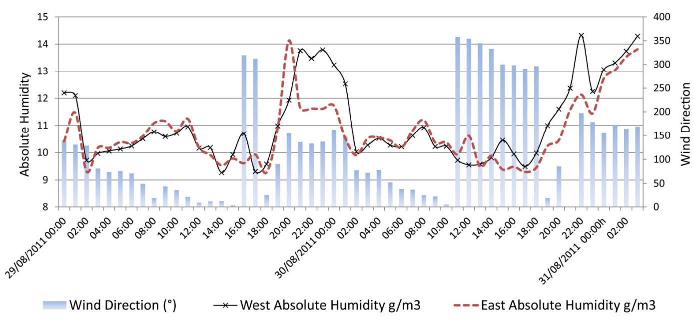

Fig.5: Absolute Humidity variation from 29th to 31th August

In Figure 5, values of the variation of absolute humidity show a higher water concentration in the air during the night of the 30th August, under light wind conditions. Around 10 p.m. of the 30th, the sensor on the west margin registered its maximum absolute humidity of 14.32 g/m³, while the east margin presented 12.13 g/m³.

Figure 6, which was produced by applying the ENVI-Met 3.1 software, represents the interaction between the simulated prevailing winds from a southeastern direction and vegetation, showing that the moisture provided from the water surface created mild temperatures areas on the west margin. The warmest and driest areas are concentrated on the east banks, due to the heat gain from paved floors, mostly in concrete and asphalt, and the most dense built-up environment situated at this side of the city.

The open area of the dam has minimal roughness and provides few barriers to the entry of the southeastern wind. Here, the highest velocities near the bank and through the valley of the dam can be observed. Most importantly, the façades of the buildings are south shaded, while the north side area obtains intense sunlight at this time and this period of the year. Therefore, this region tends to store more heat, because of the weak interaction with the wind from the southeast, caused by the leeward conditions. Therefore, the eastern side is likely to accumulate heat, presenting the highest temperatures ranges and lowest levels of humidity (Figure 7). The winds encounter low barriers when penetrating through the valley into the urban fabric, and along the gaps between the buildings. Thus, humidified ventilation can be distributed with the most efficiency and temperatures decrease in inhabited areas on the western side.

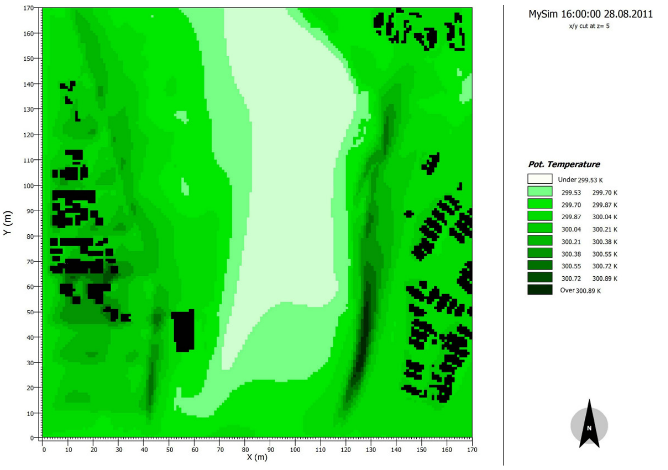

Fig. 6: Temperature map variation at 16:00h

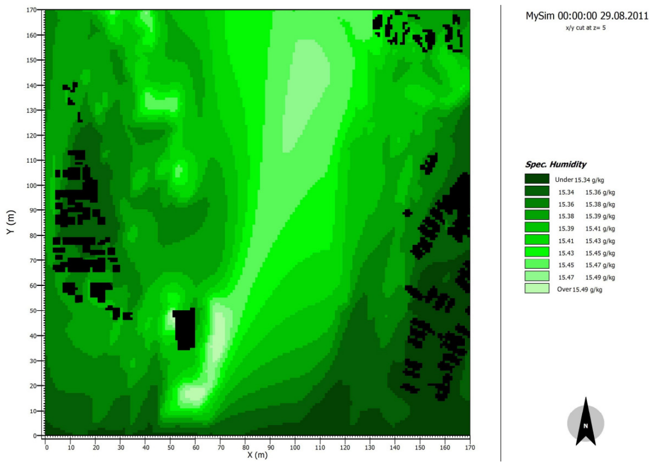

Fig. 7: Absolute Humidity variation at 0:00h

4. Conclusions

It was observed that as the wind blows in a predominantly Southeastern direction, and during Northeastern and Northwestern gusts of wind, the temperatures and absolute humidity on the east bank tend to be higher than the values found on the west bank.. On average, throughout the experiment, it was found that the combination of winds with the water supply in the environment was able to keep the western margin 0.5℃ colder and with absolute humidity 0.4 g / m³ higher than the eastern one.

The extension of this study may indicate, for example, the establishment of areas in the city that contribute to capturing the humidified prevailing winds, allowing the purification of the air through the valleys and distributing them to densely built-up areas. The production of maps to assess this behavior may induce a positive microclimatic design of the city, orienting its occupation with a lower possibility of negative impacts.

There is evidence that the dam is an important element to maintain thermal quality of the urban air increasing humidity levels and having direct influences on its surroundings. Thus, the water bodies may play an important role in mitigating harmful effects of urban heat waves in cities. In addition to other environmental benefits, such as encouraging the development of vegetation, and the contribution to the rainwater runoff, it is a place for contemplation and recreation for the inhabitants. Due to a high rate of evaporation caused by the reservoir, the anthropogenic heat can be dissipated by the principle of evaporative cooling and may reduce the thermal amplitude of the surroundings.

Acknowledgment

The authors would like to thank the Coordination for the Improvement of Higher Education Personnel (CAPES) and the National Counsel of Technological and Scientific Development (CNPq) for their financial support in this research.

References

ARNFIELD, A. J. (2003). Review: Two Decades of Urban Climate research: A Review of Turbulence, Exchanges of energy and water, and the urban heat island. *International Journal of Climatology*. No. **23**, 1–26.

BRUSE, M. (2012) ENVI-Met 3.1 Software [Online], Available: http://www.envi-met.com/ . Accessed 9th April, 2012

COUTTS A., M., TAPPER, N., J., BERINGER, J., LOUGHNAN, M., DEMUZERE, M. Watering our cities: The capacity for Water Sensitive Urban Design to support urban cooling and improve human thermal comfort in the Australian context. *Progress in Physical Geography* **37**(1) 2–28. 2013.

MONTEIRO, C. A. F. A dinâmica climática e as chuvas do estado de São Paulo**:** estudo geográfico sob forma de Atlas. São Paulo: Universidade de São Paulo. *Instituto de Geografia*. 68 p. 1973

NAKATA, Camila; SOUZA, Léa C. L.; FARIA, João R. G.. Simulação da Sensação Térmica do Pedestre. *XI Encontro Nacional de Conforto no Ambiente Construído.* Búzios, Rio de Janeiro, 2011.

PEEL, M. C.; FINLAYSON, B. L.; MCMAHON, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences*. No. **11**, p. 1633-1644, 2007. Available at http://www.hydrol-earth-syst-sci.net/11/1633/2007/hess-11-1633-2007.pdf

PREFEITURA MUNICIPAL DE SÃO JOSÉ DO RIO PRETO SP (2010). Available at: http://www.riopreto.sp.gov.br/PortalGOV/do/subportais_Show?c=5050 Accessed 8TH January, 2010.