Influence of a Waterbody in the Urban Microclimate

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ABSTRACT: This research analyses the waterbody influences in lowering the warmth in the São José do Rio Preto SP city, Brazil, due the evaporative cooling effects that it roles locally. Three collect points of temperature and humidity were placed in an urban area close to the municipal dam, which the first one was placed on the dam margin, the second one, 50m distant of the margin and, the third one, 100m distant, over the quarter interior with low built density. The field information was taken during December 2010 and compared so to the climate data of the Climate Station of CILAGRO – Integrated Center of Agro Meteorological. After that, the collected field results were compared with a simulation process using the software Envi-met 3.1 which was configured according to the same climatic conditions. The results were, due the abundant local water, the measured variation of temperature increases as it goes into the quarter. The humidity rates verified at the closest point of the waterbody indicate values higher than those ones collected at the most distant point. With the simulation process, it was possible to prepare a microclimate urban map which indicated similar behavior of urban temperature and humidity and presented the results graphically over the urban area. So, the conclusions are, firstly, that the Municipal dam represents an important element in the urban space to increase the stability of the temperature in the nearest. Secondly, the Envi-met 3.1 software demonstrates to be an able tool to estimate quite precisely the effects in the microclimate of possible urban interventions.

Keywords: Waterbody, human comfort, urban evaporative cooling, Envi-met 3.1.

INTRODUCTION

The high urbanization rate of Brazilian medium sizes cities have increasingly demanded the development of planning strategies that minimize the harmful effects of uncontrolled urban growth. The occurrence of heat island and air pollution in midsize cities in the interior of Brazil are some of the facts that have influence the conditions of comfort and health of residents.

A research conducted by Patz et. al. demonstrate the close relationship between climate and health and reports that climate change due local occupations in urban areas is one of the causes for the loss of 150,000 lives in the last 30 years that have passed due respiratory and cardiovascular diseases caused by heat waves [1].

According to Castilho, in a survey conducted at São Jose de Rio Preto, Brazil, found a direct relationship between the spatial distribution of diseases with unfavorable weather conditions, and the most arid and dense neighborhood had higher number of respiratory cardiopulmonary diseases, especially in winter when the action of dry and cold weather system become more frequent [2].

The process of evaporation related to waterbodies can contribute to decrease the air temperature and increase the humidity of the surroundings and distribute wind flows efficiently, so that both the temperature range as the possibility of heat islands may be minimized.

For the study of urban microclimates, Bruse & Fleer have developed a computational program named ENVI-met, which consists of a numerical modeling and spatial analysis that aims to simulate the thermal behavior and energy exchange in urban environments [3].

Huttner et. al., in an experiment conducted in the city of Freiburg, Germany, applies ENVI-met to estimate urban areas with higher levels of thermal stress and to support a proposed afforestation and interventions for neighborhoods in studies. So that any intervention to have their expected effects on urban thermal environmental with sufficient accuracy of results [4].

Han et. al. applying the same computational program, investigated the changes in microclimate and the reduction of thermal load on the urban scale resulting from environment restoration of Cheonggye stream in Seoul, Korea. A field study evaluated the variation of temperature and humidity before and after the restoration and compared with actual data produced by ENVI-met simulation. The study concluded that the stream of Cheonggye helps in reducing the daily temperature average of 0.31 °C and increase in average 0.89% the relative humidity in their vicinity, however the cooling effect of the stream diminished as the distance goes further from the stream. This study proposed a method to forecast the changes in the microclimate arising from the exchanges of urban surfaces to green surfaces and consequently promoting the reduction of energy load of buildings, that suggests a remarkably reduction of electricity in summer [5].

Nakata et. al. evaluated the influence of thermal environment on the behavior of pedestrian in the city of Bauru, Brazil. They found that the urban setting, the
presence of accumulated heat by the vegetation and cover materials affect the thermal sensation of walking in their paths. The data obtained from interviews with pedestrian were compared with measurements of temperature, humidity, wind direction and speed on-site and computer simulation of pedestrian routes. The research also shows that, for the city studied, the more accurate simulated results with Envi-met were obtained after the sixth iteration of the algorithm and for morning hours, showing differences lesser than 1°C. So, there is a need for adjusting the simulation process to fit the specific local situation which is being applied for [6].

According to Bruse, for the specific case ENVI-met 3.1 considers waterbodies as a special kind of soil for simulations in the urban environment in, which include 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 waterbody and the urban environment so that the software is able to simulate only as still water and does not reproduce the effects caused by turbulent water spray sources, nor effects of sea breezes [7].

In this study, the influence of a waterbody on the surroundings microclimate of a Brazilian city named Sao Jose do Rio Preto - SP is analyzed, taking into account the possibility of applying Envi-met to develop maps of the thermal environment.

**METHODOLOGY**

Sao Jose do Rio Preto is located on the north area of Sao Paulo State, at coordinates 20° 49'11" South Latitude and 49° 22' 46" West Longitude. The urban area corresponds to 117.43 km² and it is cut by two streams. The Black River, along with the creek of the Apes, form the two artificial water reservoirs in the urban area. Figure 1 shows the margin of the dam and on Figure 2 it is shown a panoramic of the vicinity area.

Nimer reports that factors of static and dynamic nature combine to define the climatological processes in the Southeast region of Brazil, where Sao Jose do Rio Preto is situated. It receives influences of typical climatic disturbances of this region. Brazil Southeast is located under the preferred trajectory of the polar fronts. The anticyclone system of circulation and the polar latitudes circulation system of the South Atlantic’s and the anticyclones of the low latitudes are often combined in a dynamic equilibrium, characterizing the diversification of the regional climate - typically tropical with alternately wet and dry conditions [8].

Sao Jose do Rio Preto climate corresponds to a Tropical altitude climate with dry winter and hot summer and mild and rainy, with average winter temperature close to 18°C and summer temperature around 30°C. The annual average of relative humidity stands at around 70% approximately, reaching ranges below 20% in the driest months.

The site is characterized for a slightly wavy topography with broad ridges and modest altitude - 500m on average. Two highways - BR-153, in the NE-SW, in the E - W direction, have influenced the direction of city growth, which has about 420.000 inhabitants. The studied area is located between two dams near the city center and is characterized by a mixed zone of occupation, with services and residential buildings of low-density (Figure 3).

The area is characterized by a predominant occupation of buildings with one and two floors and an occupancy rate per batch of approximately 70%. Some commercial buildings are about 6 meters high and a few buildings have up to 8 floors. Overall, the neighborhood, despite already being practically consolidated, has few vacant batches. There are also many open public areas, especially along the river that flows into the municipal dam. In a radius of 250m is possible to see approximately 20% of the area covered by low vegetation, by 5.5 % of arboreal vegetation, 30% of built area, 10% of surface covered by water and 34.5% area paved with asphalt or concrete.

At the northern margin of the dam, three points were assigned for data collection of temperature and humidity. They were all fixed on a height of 3 meters. Point A was positioned on the edge of the water surface of the dam, Point B was set at 50 meters from the shore of the dam, and Point C was fixed in a distance of 100 meters from the edge of the dam, within a low-density neighborhood.

In this research the basic distance assigned to measure the influence of the waterbody was 50 m, in order to evaluate the prevailing winds that penetrate into urban fabric from southeast. A HOBO Pro V2 U23-001 sensor was applied and placed inside a ventilated shell of PVC, as recommended by the manufacturer. The data of temperature and humidity were collected hourly between days 08th and 16th December 2010. The observed results in the field were compared with data obtained from the Meteorological Station of the Integrated Agro Meteorological Information CIIAGRO.
which is located about 7 km southward from the studied area [9].

![Figure 3 – Cutout of the urban area in São Jose do Rio Preto](image)

After collecting field data, a digital model of the area was developed with the help of the ENVI-met 3.1 software, in order to simulate the thermodynamic phenomena that occurred in the urban area and compare so to the obtained results with the measured results on site.

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

### Table 1: Input data to the Envi-met digital urban area model

<table>
<thead>
<tr>
<th>Contents</th>
<th>Input values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Speed in 10 m Ground</td>
<td>2 m/s</td>
</tr>
<tr>
<td>Wind Direction Southeast</td>
<td>178°</td>
</tr>
<tr>
<td>Initial Temperature Atmosphere</td>
<td>299.99 K</td>
</tr>
<tr>
<td>Specific Humidity in 2500m</td>
<td>10 g Water/kg air</td>
</tr>
<tr>
<td>Relative Humidity in 2m</td>
<td>65%</td>
</tr>
<tr>
<td>Model size</td>
<td>180x180x20m</td>
</tr>
<tr>
<td>Height of buildings</td>
<td>Z = between 5 e 10m</td>
</tr>
<tr>
<td>Mesh</td>
<td>2 x 2m</td>
</tr>
<tr>
<td>Latitude</td>
<td>0°49’11” South</td>
</tr>
<tr>
<td>Longitude</td>
<td>49°22’46” West</td>
</tr>
</tbody>
</table>

The data of evapotranspiration and shading vegetation were obtained by ENVI-met library called Plants.dat and which provides the generic behavior of vegetation. According to [6] ENVI-met 3.1 requires long time interval to perform the iteration of the model input data, so that the software stabilizes and finds the results more consistent with the reality. As mentioned before, the authors also indicated that the morning of the sixth iteration provided the most accurate results. This matter was also verified in the present study, therefore, six days were simulated from a hypothetical 03th December 2010 with automatic saving of data on temperature, humidity, wind speed and wind direction every 60 minutes on the same receptors A (on the edge of the waterbody), B (50 meters from the waterbody) and C (100 meters from the waterbody), into the quarter.

![Figure 4 – Urban area model produced on ENVI-met 3.1](image)

From the data generation, software ENVI-met 3.1 has also an interface called Leonardo 3.75 that allows it to generate the graphical representation of behavior maps of temperature, humidity, wind speed, and direction at the same positions of the sampling points on the scaled site. Thus, it is possible to evaluate the results of computer simulation with the data actually collected and complete accuracy of the obtained information.

### RESULTS AND DISCUSSIONS

To analyze the effects caused by the waterbody in the urban environment, the 09th day was selected, for being the driest and stable one of all the studied period. The data of temperature and moisture of the three points of collection were compared with the Meteorological Station of CIIAGRO in the rural area [9]. In Figure 05, it is observed that the temperature variation registered by the Meteorological CIIAGRO station is higher than the three collecting points. The lowest thermal amplitude was recorded near the water surface of the dam. The highest temperature range was found at Point C, which is 100 meters far from the waterbody. This means that, the more the point moves away from the dam, the higher the thermal amplitude is. This occurs due the influence of moisture provided by the waterbody, and due to the density and paved surface of the built environment within the neighborhood.
It was observed that the most accurate results of simulation in relation to reality corresponded to the early morning hours, with an error of about 1°C. While the afternoon approached, the model lost precision, gradually. Therefore, still an improvement is necessary in order to simulate this specific period.

Differences on values of measured and simulated relative humidity were also observed, as shown in on Figure 6.

It is possible to verify by Figure 07 that the interaction between the prevailing winds simulated in a southeasterly direction, vegetation and moisture provided by the dam creates areas with milder temperatures, represented by yellow and green hues. The waterbody area represents a low barrier to the wind penetration into the urban fabric through the valley of the stream and as there are gaps between the buildings, the ventilation is efficiently distributed. The warmer areas, represented by red and magenta tones refer mostly to the heat gain of paved floors in concrete and asphalt.

The map shows the distribution of moisture drier areas near the paved floors and wetter areas along the bank of the dam. The vertical distribution, showed in the section, allows to observe the penetration of moisture into the urban fabric. The convection process provided by the humidified wind moves over the built area in layers up to 5 meters high.
The open area of the dam has minimal roughness and provides small barrier to entry into the southeast wind. It is possible to notice the highest velocities of wind near the bank and along the valley of the stream. It is important to reinforce, that the face of the buildings are shaded south. North façades are getting intense sunlight at this time and at this period of the year. So, they tend to store more heat, because they interact with the wind from southeast, by being under leeward. This situation makes the north side more prone to excessive accumulation of heat having higher temperatures ranges, poor ventilation and low humidity levels than the other sides.

CONCLUSION
The precision of ENVI-met data depends on the accuracy of input data and on careful shaping of the components of the space. Therefore, its application should not be indiscriminately performed, because it does not completely replaces the surveying field. Even with the limitations of modeling and simplification of the complex physical phenomena arising from the interaction between atmosphere and built environment, ENVI-met 3.1 is able to allow the assessment of negative impacts on the urban microclimate of possible interventions. Thus, the maps generated by the simulation process can assist in positioning of points measurements to generate a more precise idea of the microclimate of a particular area. The production of these kinds of maps can induce positive microclimatic design of the city in order to discipline its occupation with a lower possibility of negative impacts and better environmental quality to the inhabitants.

REFERENCES